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7 DEMAND, USE, EXPLOITATION AND/OR ALTERATION OF NATURAL RESOURCES

Demand of natural resources makes reference, as its name indicates, to the use of resources for development of activities that require such resources for their execution. It is also associated with the possible interaction with a resource during development of a certain activity that in some way can have an impact on such resource. In this manner, exploitation can occur indirectly when considering use of the resource as a secondary effect of an activity conducted or, directly, where it involves handling of a particular resource for a specific application.

This chapter contains a description of the natural resources to be used, exploited or affected by execution of the Rumichaca – Pasto Divided Highway Project, Segment San Juan – Pedregal. Execution of this project requires exploitation and/or intervention of different natural resources due to the interaction of the layout of the highway project with some natural resources, the needs of supplies and/or building materials and the importance to handle properly liquid and solid wastes that shall be generated by activities of the project. This chapter shows classification of the natural resources that shall be demanded, as well as the permits required to be exploited. The forms for request of permits of surface water catchment and discharge and the program of water efficient use and saving are attached hereto (**Annex 14. Use and Exploitaiton_Catchment_Program of Water Efficient Use and Saving**).

Considering the aspects stated by the community in the participation processes with the communities and authorities of the area of influence, as well as the impacts identified for the project (See Chapter 8. Environmental Impact Assessment), use and management of resources shall observe the provisions of the environmental legislation. They shall have control measures and management plans in order to prevent and mitigate the impacts generated.

As a summary, **Table 7.1** contains the aspects related to the different types of exploitation that shall be developed in this Chapter.

Table 7.1 Demand of Natural Resources Applicable to the Project

<table>
<tr><th>NATURAL RESOURCE REQUIRED</th><th>DESCRIPTION</th><th>DEMAND/EXPLOITATION</th></tr>
<tr><td>SURFACE WATER</td><td>Concesionaria Vial Unión del Sur requests as sources of catchment, concession of Surface water over the water sources listed below. Catchment is proposed in the following points with a mobility of 100 m upstream and 100 m downstream, under the following coordinates.

Catchment Strips Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment.
<table>
<tr><th rowspan="2">ID</th><th rowspan="2">SOURCE</th><th colspan="2">COORDINATES MAGNAS SIRGAS ORIGIN WEST</th><th rowspan="2">MOBILITY RANGE</th></tr>
<tr><th>EAST</th><th>NORTH</th></tr>
<tr><td>1</td><td>Guáitara River</td><td>948503</td><td>590762</td><td rowspan="3">A mobility range of up to 100 meters upstream and downstream of the points</td></tr>
<tr><td>2</td><td>Boquerón River</td><td>948589</td><td>590972</td></tr>
<tr><td>3</td><td>La Humeadora Creek</td><td>955074</td><td>597201</td></tr>
</table>
</td><td>Catchment of Surface water in a maximum estimated flow of 1.95 L/s per camp:
• 0.45 L/s for domestic use.
• 1.5 L/s for industrial use.</td></tr>
</table>

NATURAL RESOURCE REQUIRED	DESCRIPTION	DEMAND/EXPLOITATION

4	Moledores Creek	956019	598991	proposed is requested
5	San Francisco Creek	953962	601557	
6	El Macal Creek	954870	603721	
7	Sapuyes River	954844	605090	
8	Yamurayán Creek	949128	592258	
9	San Francisco Creek	949976	593121	
10	Culantro Creek	950642	594577	
11	El Manzano Creek	951631	595174	

At the same time, Concesionaria Vial Unión del Sur requests, in case of being necessary for domestic use, purchase of water to third parties having permits granted by the competent environmental authority.

GROUNDWATER

No concession of groundwater is requested, given that the water demand for building of the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment. It shall be covered with the sites requested in the surface water sources and with the purchase to authorized companies that provide water with optimal characteristics for human consumption.

DISCHARGES

Concesionaria Vial Unión del Sur requests the alternatives for disposal of industrial and domestic wastes waters presented below:

1. Spraying or infiltration field in areas neighboring camps with surfaces of up to 1000 m^2.
2. Discharge to surface water body in the sites and flows presented in the following table with a mobility rage of up to 100 meters upstream and downstream from the proposed points, in compliance with Resolution 631 of March 17, 2015.

Discharge Strips Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment.

ID	SOURCE	MAGNAS SIRGAS COORDINATES WEST ORIGIN		FLOW (L/s)
		EAST	NORTH	
1	Boquerón River (Camp 1)	948589	590972	0.44
2	La Humeadora Creek (Camp 2)	955074	597201	0.44
3	Guáitara River (Camp 3)	956508	600552	0.44
4	Sapuyes River (Camp 4)	954844	605090	0.44

3. Delivery to an authorized third party having the corresponding permits for management and disposal of waste waters.

Demand/exploitation: The volumes scheduled to be disposed are as follows:

Discharge flow on the soil: 0.44 L/s per camp with periods of up to 4 hours/day

OCCUPATION OF RIVERBEDS

Concesionaria Vial Unión del Sur requests building and fitting of occupation of riverbeds in the intersection sites over surface water bodies for the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment with a mobility range of 50 meters upstream and 50 meters downstream with respect to the point requested, in the coordinates and points listed in the following Table.

Location of Points of Occupation of Watercourse

ID	NAME OF THE WATER BODY	ABSCISSA OF THE PROJECT	MAGNA SIRGAS COORDINATES ORIGIN 3 WEST		PROPOSED WORK
			EAST	NORTH	

NATURAL RESOURCE REQUIRED	DESCRIPTION	DEMAND/EXPLOITATION

OC1	NN1	PK16+120	946811.93	589397.70	Box culvert 2 x 2 m
OC2	NN2	PK16+503	947121.83	589603.72	Box culvert 3 x 2 m
OC3	Yamurayán Creek	PK20+831	949114.02	592065.11	Box culvert 3 x 3 m
OC4	NN3	PK22+428	950054.08	593102.63	Box culvert 3 x 3 m
OC5	Creek Guayarín	PK23+157	950212.94	593774.90	Box culvert 2 x 2 m
OC6	NN4	PK23+370	950321.61	593956.90	Box culvert 1.5 x 1.5 m
OC7	NN5	PK24+136	950636.07	594629.81	Box culvert 3 x 2 m
OC8	NN5	PK24+136	950617.38	594684.56	Box culvert 3 x 2 m
OC9	NN6	PK24+315	950764.62	594725.77	Box culvert 2 x 2 m
OC10	NN7	PK24+525	950967.72	594782.47	Box culvert 2 x 2 m
OC11	NN8	PK25+529	951686.27	595151.47	Culvert 900 mm
OC12	Creek Manzano	PK25+589	951906.14	595274.20	Culvert 1200 mm
OC13	Creek Brigada	PK25+952	952253.56	595420.32	Culvert 1200 mm
OC14	NN9	PK26+440	952669.62	595499.39	Culvert 900 mm
OC15	NN1 Tributary La Humeadora Creek	PK28+516	954206.18	596624.50	Culvert 900 mm
OC16	NN2 Tributary La Humeadora Creek	PK28+516	954290.20	596720.59	Culvert 900 mm
OC17	NN10	PK28+677	954363.00	596797.00	Culvert 900 mm
OC18	Creek Los Arrayanes	PK29+212	954729.44	597199.25	Box culvert 3 x 2 m
OC19	Creek Manzano	PK29+437	954925.68	597342.18	Box culvert 3 x 2 m
OC20	NN11	PK29+593	955050.07	597431.63	Box culvert 3 x 2 m
OC21	Creek Urbano	PK29+756	955178.38	597501.33	Box culvert 3 x 2 m
OC22	NN12	PK30+040	955429.67	597508.01	Culvert 900 mm
OC23	NN13	PK30+880	955776.28	598034.29	Culvert 900 mm
OC24	NN14	PK31+746	955959.13	598715.59	Culvert 1200 mm
OC25	Moledores Creek	PK32+103	955961.93	598913.93	Culvert 900 mm
OC26	Creek El	PK32+729	954964.97	600264.24	Culvert

NATURAL RESOURCE REQUIRED	DESCRIPTION	DEMAND/EXPLOITATION

	Tablón				900 mm
OC27	NN15	PK33+863	954928.86	600362.86	Culvert 1200 mm
OC28	NN16	PK34+018	954892.74	600499.78	Box culvert 1.5 x 1.5 m
OC29	NN17	PK34+107	954867.24	600605.07	Culvert 1200 mm
OC30	NN18	PK34+350	954841.74	600838.89	Box culvert 1.5 x 1.5 m
OC31	NN19	PK35+732	954860.08	601994.55	Box culvert 2 x 2 m
OC32	NN1 Tributary San Francisco Creek	PK35+917	954632.16	602074.88	Culvert 900 mm
OC33	San Francisco Creek	PK36+000	954609.64	602099.98	Box culvert 5 x 3.5 m
OC34	NN20	PK36+751	954134.22	602589.08	Box culvert 2 x 2 m
OC35	NN21	PK36+878	954020.90	602661.87	Culvert 900 mm
OC36	NN22	PK37+959	954012.69	603620.06	Box culvert 2 x 2 m
OC37	NN23	PK39+700	953918.82	604516.47	Box culvert 2 x 2 m
OC38	NN23	PK40+085	953963.00	604813.00	Box culvert 3 x 3 m
OC39	NN24	PK44+013	956818.81	605952.00	Culvert 900 mm
OC40	NN25	PK44+425	956886.56	606301.41	Box culvert 2 x 2 m

The type of designs for occupation of riverbeds is shown in section 7.4 Occupation of Riverbeds of this chapter.

BUILDING MATERIALS

Concesionaria Vial Unión del Sur requests the permit for acquisition of materials in existing sources through third parties in sites of extraction having the corresponding mining-environmental permits and/or licenses granted by the competent entities and authorities.

Likewise, Concesionaria Vial Unión del Sur requests reuse of materials derived from excavation and/or demolition activities as filling material in order to prevent unnecessary earth moving and decrease the volumes of material to be disposed in the ZODME.

FOREST HARVESTING

Concesionaria Vial Unión del Sur requests forest harvesting of **13048.25m^3** in an area of **1629.23 ha** for development of the activities of the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment.

In order to determine the flow, a survey of forest plots was conducted in the natural covers subject to forest harvesting (dense forest, riparian forest and high secondary vegetation). This survey complies with the statistical requirements set forth in the terms of reference. For the anthropogenic-origin covers (mosaic of pastures and crops, mosaic of crops, forest plantation and clean pastures), an inventory (100% of small trees) was made of 47% (662.63ha) of the maximum area to be intervened. Based on this survey, forest harvesting was calculated for these covers. The maximum areas and volumes requested for forest harvesting are shown below:

NATURAL RESOURCE REQUIRED	DESCRIPTION	DEMAND/EXPLOITATION

Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment	TYPE OF COVER		
	Maximum Area to be Intervened (ha)	Average Flow per Hectare (m^3/ha)	Maximum Flow to be Intervened (m^3)
Dense forest in the high orobiome of the Andes	*3.1*	*196.45*	*608.99*
Riparian forest in the high orobiome of the Andes	*50.69*	*61.5*	*3117.43*
Secondary high vegetation in the high orobiome of the Andes	*21.18*	*53.17*	*1126.14*
Secondary high vegetation in the medium orobiome of the Andes	*27.1*	*31.92*	*865.03*
Covers of anthropogenic origin (mosaic of pastures and crops, mosaic of crops, clean pastures and forest plantation)	*1409.37*	*5.20*	*7330.65*
Natural covers not subject to forest harvesting (open rocky grassland and secondary low vegetation)	*117.78*	-	-
TOTAL	***1629.23***	***N.A.***	***13048.25***

Source: GEOCOL CONSULTORES S.A., 2017.

7.1 SURFACE WATER

During development of the activities of the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment, using water for domestic activities that are basically focused on cleaning camps and casinos that are fitted and for industrial activities associated with wetting, concrete plants, washing, cleaning, among others.

As alternatives to satisfy the water needs of the project, four sources of supply are proposed:

- Surface water catchment on catchment strips that can supply the source for the project. Each catchment strip has a central point, from there, 100 m upstream and 100 m downstream, for a total of 200 m of strip.
- Purchase of the resource to a third party available to provide this service. This alternative is an option in case that for an unexpected event or contingency it is not possible to catch the water in the water strips proposed.

7.1.1 Catchment Sources

The proposed water sources for catchment of the water resource are rivers Guáitara, Boquerón, Sapuyes and creeks Humeadora, Moledores, San Francisco, Yamurayán, El Manzano, Culantro and El Macal (See **Photograph 7.1** through **Photograph 7.11**). The sites considered as source of supply are requested during an environmentally feasible time, in accordance with the hydrologic analysis made for the area of influence of the project (See **Table 7.2**).

The variables considered to establish the catchment strips on the surface currents were as follows:

- Hydrological context
- Availability of the resource for different seasons of the year.
- Flow of water required for the project.
- Accessibility to the water current.
- Current and potential conflict for use of water.

Photograph 7.1 Guáitara River in district San Juan (catchment 1)
E: 948503 N: 590762

Source: GEOCOL CONSULTORES S.A., 2017.

Photograph 7.2 Boquerón River in district San Juan (catchment 2)
E: 948589 N: 590972

Source: GEOCOL CONSULTORES S.A., 2017.

Photograph 7.3 Humeadora Creek in district Urbano (catchment 3)
E: 955074 N: 597201

Photograph 7.4 Moledores Creek in district Tablón High (catchment 4)
E: 956019 N: 598991

Source: GEOCOL CONSULTORES S.A., 2017.

Source: GEOCOL CONSULTORES S.A., 2017.

Photograph 7.5 San Francisco Creek in district Tablón High (catchment 5)
E: 953962 N: 601557

Photograph 7.6 El Macal Creek in district El Porvenir (catchment 6)
E: 954870 N: 603721

Source: GEOCOL CONSULTORES S.A., 2017.

Source: GEOCOL CONSULTORES S.A., 2017.

Photograph 7.7 Sapuyes River in district El Porvenir (catchment 7)
E: 954844 N: 605090

Photograph 7.8 Yamurayán Creek in district Aldea de María (catchment 8)
E: 949128 N: 592258

Source: GEOCOL CONSULTORES S.A., 2017.

Source: GEOCOL CONSULTORES S.A., 2017.

Photograph 7.9 San Francisco Creek in district Las Delicias (catchment 9)
E: 949976 N: 593121

Source: GEOCOL CONSULTORES S.A., 2017.

Photograph 7.10 Creek El Culantro in district El Culantro (catchment 10)
E: 950642 N: 594577

Source: GEOCOL CONSULTORES S.A., 2017.

Photograph 7.11 El Manzano Creek in district Las Cuevas (catchment 11) E: 951631 N: 595174

Source: GEOCOL CONSULTORES S.A., 2017.

The water caught in these currents shall be used for development of the activities during the stages of the project with a flow of up to 0.45 L/s for domestic use and 1,5 L/s for industrial use. **Table 7.2** below contains the coordinates of the central points of the catchment strips requested and their spatial location is shown in **Figure 7.1**.

Table 7.2 Catchment Strips Requested for the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment.

CATCHMENT	SOURCE	MAGNAS SIRGAS COORDINATES WEST ORIGIN		TIME	FLOW (L/s)		MOBILITY RANGE
		EAST	NORTH		Domestic use	Industrial use	
1	Guáitara River	948503	590762	Entire year		1.5	A mobility rage of up to 200 meters is requested: 100 m upstream and 100 m downstream from the proposed points.
2	Boquerón River	948589	590972	Entire year	0.45	1.5	
3	La Humeadora Creek	955074	597201	Rainy season (Feb – Aug and Oct – Dec)	0.45	1.5	
4	Moledores Creek	956019	598991	Rainy season (Feb – Aug and Oct – Dec)		1.5	
5	San Francisco Creek 2	953962	601557	Rainy season (Feb – Jul and Oct – Dec)	0.45	1.5	
6	El Macal Creek	954870	603721	Rainy season (Feb – Jul and Oct – Dec)		1.5	
7	Sapuyes River	954844	605090	Entire year	0.45	1.5	

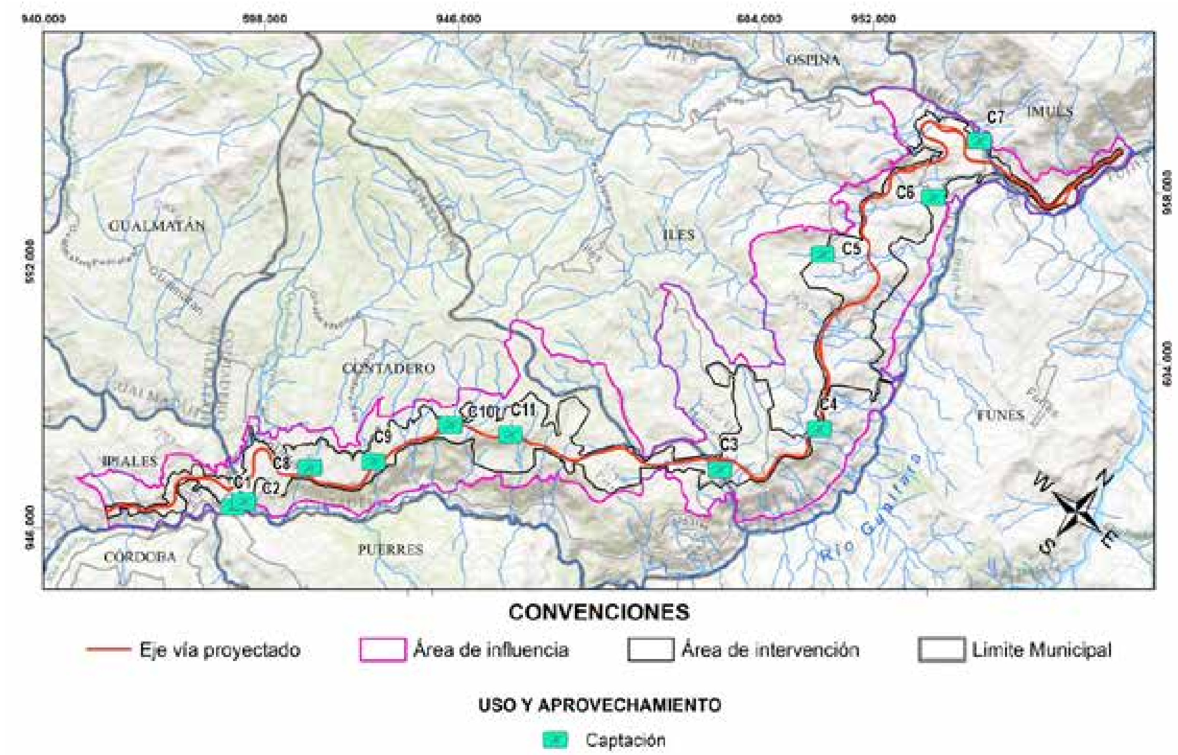
CATCHMENT	SOURCE	MAGNAS SIRGAS COORDINATES WEST ORIGIN		TIME	FLOW (L/s)		MOBILITY RANGE
		EAST	NORTH		Domestic use	Industrial use	
8	Yamurayán Creek	949128	592258	Rainy season (March – Jul, Nov and Dec)		1.5	
9	San Francisco Creek	949976	593121	Rainy season (March – May, Jul, Nov and Dec)		1.5	
10	Culantro Creek	950642	594577	Rainy season (march – May, Jul, Nov and Dec)		1.5	
11	El Manzano Creek	951631	595174	Rainy season (March – May, Nov and Dec)		1.5	

Source: GEOCOL CONSULTORES S.A., 2017.

The description of the general characteristics of the currents subject to exploitation of the water resource is contained in Chapter 5 in the abiotic environment, hydrologic component.

The request of the concession of Surface water in the 11 sites was shared with the municipal administrations, presidents of the community action board, communities attending the meetings of socialization of the workshops of impacts and results of the EIA (See **Annex 13. Social_Minutes of Socialization and Workshops with Municipal Administrations and Communities**).

Figure 7.1 Location of Catchment Sites



Source: GEOCOL CONSULTORES S.A., 2017.

7.1.2 Uses of Water

The uses and/or discharge points in the sources subject to exploitation by the project, which can be influenced directly or indirectly are contained in section **5.1.7 Uses of Water** – Water Demand in the Exploitation Sites of chapter 5 of this study, where it was established that surface water is used in the area mainly for agricultural and farming activities.

This concept is generated based on the community tours and outreach. It is worth highlighting that a tour of 1 km (according to the access possibility) upstream and downstream of the catchment sites defined. Additionally, the uses for this study in the catchment points were identified based on Decree 3930 of 2010, which in Chapter IV, article 9, establishes and defines the uses of the water resource.

7.1.3 Flow of Water Required

The flow required for development of the domestic and industrial activities is conditioned by the supply of water resource in each time of the year and is determined by the specific demand of each activity throughout the different stages of the project. Accordingly, the volumes required for the domestic and industrial activities are shown below.

7.1.3.1 Flow for Domestic Use

In order to determine the water demand for domestic use required for the project, the considerations established in the Technical Regulations of the Sector of Potable Water and Basic Sanitation- RAS – 2000-, adopted by Resolution 1096 of 2000 of the Ministry of Economic Development and adjusted by Resolution 2320 of 2009 of the Ministry for the Environment, Housing and Territorial Development (Currently, the Ministry for the Environment and Sustainable Development – MADS) were used.

· **Complexity Level**

First, it is necessary to determine the level of complexity, which is according to the number of inhabitants and the economic capacity, as set forth in **Table 7.3**.

Table 7.3 Assignment of the Complexity Level

COMPLEXITY LEVEL	PROJECTED POPULATION	ECONOMIC CAPACITY OF USERS
Low	< 2500	Low
Medium	2501 to 12500	Medium
Mid-High	12501 to 60000	Medium
High	60001 onwards	High

Source: Title A. Technical Regulations of the Sector of Potable Water and Basic Sanitation - RAS – 2000.

In accordance with **Table 7.3**, for a population of 250 people per camp, a low complexity level is established.

· **Net Supply**

The foregoing is related to the flow of supply of water per inhabitant according to the complexity level, determining for a low complexity level with cold weather[1], a maximum net supply of **90 L/Inhab.-day**. (See **Table 7.4**).

Table 7.4 Maximum Net Supply According to the Complexity Level Assigned

Complexity Level	Maximum net supply for the populations with cold or temperate climate (L/Inhab.-day)	Maximum net supply for the populations with hot climate (L/Inhab.-day)
Low	90	100
Medium	115	125
Mid-High	125	135
High	140	150

Source: Ministry for the Environment, Housing and Sustainable Development. Resolution 2320 of 2009.

· **Gross Supply**

[1] populations with "*Cold or Temperate Climate*" are those located higher than 1,000 meters above sea level and populations with "*Hot Climate*" are those located lower than or at 1,000 meters above sea level.

Gross supply is determined, in accordance with the following equation:

$$d_{bruta} = \frac{d_{neta}}{1 - \%P}$$

Where %P is the percentage of technical losses and d_{neta} is the net supply. The maximum permissible percentage of losses (25%) which is associated with the complexity level of the system.

$$d_{bruta} = \frac{90}{1 - 0.25}$$

$$\boldsymbol{d_{bruta} = 120\ \mathrm{L/Inhab - day}}$$

· **Average Daily Flow (Qmd)**

Based on the gross supply previously calculated, the average daily flow (Qmd) is determined in the following equation:

$$Qmd = \frac{P * d_{bruta}}{86400}$$

Where p is the population, d_{bruta} is the gross supply and (Qmd) is the average daily flow.

$$Qmd = \frac{250\ hab * 120\ \mathrm{L/Inhab - day}}{86400\ s/day}$$

$$\boldsymbol{Qmd = 0.35\ \mathrm{L}/s}$$

· **Maximum Daily Flow (QMD)**

Then, the Maximum Daily Flow (QMD) is determined with the following expression:

$$\boldsymbol{QMD = Qmd * k_1}$$

where k_1 corresponds to the maximum daily consumption coefficient according to the complexity level of the system, which is obtained from the **Table 7.5**.

Table 7.5 Maximum Daily Consumption Coefficient, k1, according to the Complexity Level of the System

Complexity Level	Maximum Daily Consumption Coefficient - k_1
Low	1.3
Medium	1.3
Medium alto	1.2
High	1.2

Source: Standard RAS – 2000, Title B, page 39.

QMD = 0.35 L/s ∗1.3 = 0,45 L/s

QMD = 0.45 L/s

This latter value corresponds to the requirement of water resource for domestic use per camp.

7.1.3.2 Flow Required for Industrial Use

- In order to determine the flow required for development of the Project, the amount of water to be used for the different industrial activities such as concrete plant, machinery washing and cleaning for the five (5) camps proposed for segment San Juan – Pedregal is considered. See **Table 7.6**.

- Crushing and asphalt plants do not require water for their processes, but it is worth noting that water shall actually be used for cleaning processes of such plants and wetting of crushing. In most of the cases, to the extent possible, the activities shall be carried out with recirculated water observing the measures proposed in the water saving and efficient use program.

- For calculation of the flow of industrial use, the maximum required for development of activities in the work fronts and camps with a loss factor of 25 %. Further, the flow requested for concession is 1.5 L/s which shall be contained in storage tanks in order to supply the flow required for the different processes of the works, to wit, 6 L/s for the aforementioned activities.

Table 7.6 Flow Required for Industrial Use

CAMP / WORK FRONT		ACTIVITY	CONSUMPTION (L/s)	LOSS PERCENTAGE 25%	TOTAL (L/s)	FLOW REQUESTED PER CAMP (L/s)
Name	Abscise					
Camp San Juan	18+800	-Concrete Plant -Cleaning Activities	6	1.5	7.5	1.5
Camp Iles	31+100	-Concrete Plant -Cleaning Activities	6	1.5	7.5	1.5
Camp 35+600	65+600	-Concrete Plant -Cleaning Activities	6	1.5	7.5	1.5
Camp Mikel		-Concrete Plant -Cleaning Activities	6	1.5	7.5	1.5

Source: GEOCOL CONSULTORES S.A., 2017.

In accordance with the previous estimations, the demand of the resource for the domestic and industrial activities at the different stages per camp is summarized in **Table 7.7**.

Table 7.7 Demand of Water Resource

TYPE OF CONSUMPTION	WATER DEMAND PER CAMP (FLOW – L/s)
Domestic	0.45
Industrial	1.5
Total	1.95

Source: GEOCOL CONSULTORES S.A., 2017.

7.1.4 Water Supply

The water quality and characteristic flows of the water sources subject to exploitation of the water resource are indicated below.

7.1.4.1 Water Quality

This aspect was prepared with the purpose of establishing the characteristics of the quality of water bodies that covered the total area of influence of the Rumichaca – Pasto Divided Highway Project, Segment San Juan – Pedregal. The basins and sub-basins of which the area of influence is part were identified defining the points of monitoring in the most representative areas in order to know their current state of quality, as well as the catchment sites. Such analysis is presented in ***Section 5.1.6 Water Quality (Chapter 5_Main Characteristics of the Area of Influence)***. The results shown below correspond to the catchment sites requested.

The points monitored in the catchment sites requested, along with their coordinates and date of sampling, are shown in **Table 7.8**.

Table 7.8 Points of Water Quality Monitoring in the Catchment Sites Requested

CATCHMENT	NUMBER OF MONITORING IN THE BASE LINE	SOURCE	MAGNAS SIRGAS COORDINATES WEST ORIGIN		MONITORING DATE
			EAST	NORTH	
1	2	Guáitara River	948503	590762	February-26-2017
2	4	Boquerón River	948589	590972	February-26-2017
3	26	La Humeadora Creek	955074	597201	March-06- -2017
4	30	Moledores Creek	956019	598991	March-08- -2017
5	35	San Francisco Creek 2	953962	601557	March-13- -2017
6	38	El Macal Creek	954870	603721	March-13- -2017
7	41	Sapuyes River	954977	605045	March-15- -2017
8	5	Yamurayán Creek	949114	592110	February-27-2017
9	7	San Francisco Creek	949980	593156	February-27-2017
10	14	Culantro Creek	950603	594509	March-06- -2017
11	17	El Manzano Creek	951604	595195	March-04- -2017

Source: GEOCOL CONSULTORES S.A., 2017.

Pollution indexes ICOs determined (ICOMI, ICOMO, ICOSUS, e ICOTRO) to assess the conditions of each one of the concerned water sources are presented below considering four types pollution. Nevertheless, **Annex 15. Water Quality_Monitoring** contains the physicochemical and bacteriologic parameters. It initially comprises presentation of the results and the comparison with the quality criteria in conformity with the current regulations. Thereafter, each parameter assessed is described and as a complement of interpretation of the results and in order to determine the quality of the resources in every monitoring point the following is determined: the Water Quality Index (WQI), Water Quality Potential Alteration (IACAL)[2], Langelier Index, Buffer Capacity Index and the Pollution Indexes (ICOs).

7.1.4.1.1 Pollution Indexes (ICOs)

Among the pollution indexes, the following were calculated: mineralization pollution index (ICOMI), organic matter pollution index (ICOMO), suspended solid pollution index (ICOSUS), and the trophic pollution index (ICOTRO). The ICOMI is expressed in the conductivity, hardness and alkalinity variables while the ICOMO considers the values of total coliform, BODs, percentage of oxygen saturation. The ICOSUS involves only concentration of suspended solids that make reference to the organic and inorganic compounds present in water and the ICOTRO is determined with the total concentration of phosphorus. These indexes are very useful to establish the quality of water currents since they identify the intervention degree of water bodies (Ramírez *et al., 1997)*. **Table 7.11** and **Table 7.12** show the values of the concentrations obtained from the physicochemical variables analyzed, required to determine the pollution indexes (ICOs) and, they also show the results for each catchment site requested, in accordance with the methodology presented in chapter 5 and the classification of **Table 7.9** and **Table 7.10**.

[2] IDEAM. 2010. Estudio Nacional del Agua, D. C.

Table 7.9 Rating of the Pollution Indexes (ICOMI, ICOMO e ICOSUS)

ICOs	POLLUTION LEVEL
0- 0.2	None
> 0.2 – 0.4	Low
> 0.4 – 0.6	Medium
> 0.6 – 0.8	High
> 0.8 - 1	Very High

Source: RAMIREZ Y VIÑA, 1998.

Table 7.10 Category Trophic Pollution Index (ICOTRO)

CATEGORY	RANGE
Oligotrophy	<0.01 mg/L)
Mesotrophy	0.01 – 0.02 mg/L
Eutrophy	0.021 – 1.00 mg/L
Hypereutrophy	> 1.00 mg/L

Source: RAMIREZ Y VIÑA, 1998.

Table 7.11 Pollution Rates (ICOs) in Catchment Sites 1 through 6 for the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment.

PARAMETER	UNITS	1. Guáitara River	2. Boquerón River	3. La Humeadora Creek	4. Moledores Creek	5. San Francisco Creek 2	6. El Macal Creek
Conductivity	µS/cm	155	249.5	120	135	125	100
Dissolved Oxygen	mg/L O2	6.5	7.0	5.0	5.2	6.6	6.45
Total Alkalinity	mg/L CaCO3	57	93.8	28.7	31.3	39.8	38.4
Total Suspended Solids	mg/L	46	305	22	22	48	36
DBO_5	mg/L O 2	< 5	< 5	< 5	< 5	15	13
Total hardness	mg/L	56.4	50.0	38.4	28.4	48.4	35.2
Total Coliforms	NMP /100mL	2890	3690	2160	2450	2890	2200
Total Phosphorus	mg/L	<0.1	<0.1	<0.1	<0.1	0.127	0.1065
ICOMI		0.183	0.380	0.114	0.131	0.125	0.089
		None	Low	None	None	None	None
ICOMO		0.334	0.355	0.394	0.390	0.437	0.431
		Low	Low	Low	Low	Medium	Medium
ICOSUS		0.118	0.895	0.046	0.046	0.124	0.088
		None	Very High	None	None	None	None
ICOTRO		**Eutrophic**	**Eutrophic**	**Eutrophic**	**Eutrophic**	**Eutrophic**	**Eutrophic**

Source: MCS Consultoría and Monitoreo Ambiental, 2017.

Table 7.12 Pollution Indexes (ICOs) in sites of catchment 7 to 11 for the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment.

PARAMETER	UNITS	7. Sapuyes River	8. Yamurayán Creek	9. San Francisco Creek	10. Culantro Creek	11. El Manzano Creek
Conductivity	µS/cm	180	190	180	95	80
Dissolved Oxygen	mg/L O2	6.5	1.01	1.20	5.2	5.0
Total Alkalinity	mg/L CaCO3	31.5	42.8	43.2	22.6	22.3
Total Suspended Solids	mg/L	478	34	69	16	53
DBO_5	mg/L O 2	20	< 5	< 5	< 5	< 5
Total hardness	mg/L	45.2	62.8	54.8	33.2	19.2
Total Coliforms	NMP /100mL	2200	1300	1480	1260	1600
Total Phosphorus	mg/L	3.3	0.286	0.222	<0.1	<0.1
ICOMI		0.198	0.229	0.205	0.083	0.065
		None	Low	Low	None	None
ICOMO		0.478	0.535	0.536	0.337	0.352
		Medium	Medium	Medium	Low	Low
ICOSUS		1.00	0.082	0.187	0.028	0.139
		Very High	None	None	None	None
ICOTRO		**Hypereutrophic**	**Eutrophic**	**Eutrophic**	**Eutrophic**	**Eutrophic**

Source: MCS Consultoría and Monitoreo Ambiental, 2017.

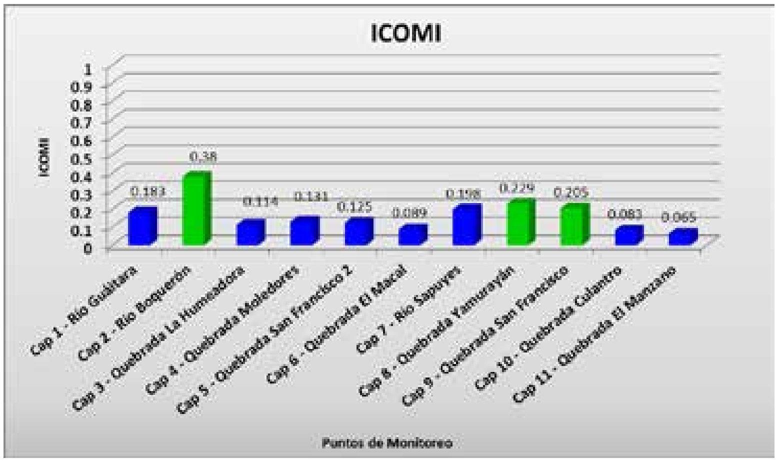
The results of the different pollution indexes for each of the water bodies subject to exploitation and their analysis are presented below.

- **ICOMI**

This index measures the mineralization degree in water. Its purpose is to encompass in few variables the expression of multiple ions dissolved in water. The ICOMI is composed by the electric conductivity values, as a reflection of the set of dissolved solids; hardness since it gathers cations; iron, calcium and magnesium; and total alkalinity because it gathers the anions of carbonates and bicarbonates.

Figure 7.2 shows the results of the pollution index per minerals (ICOMI). It can be evidenced that water sources do not have mineralization pollution problems, except for Boquerón River and creeks Yamurayán and San Francisco which obtained a “lo” classification mainly for the higher concentrations of electric conductivity and total alkalinity with values of ICOMI between 0.21 and 0.38.

Figure 7.2 Results of the ICOMI Pollution Index

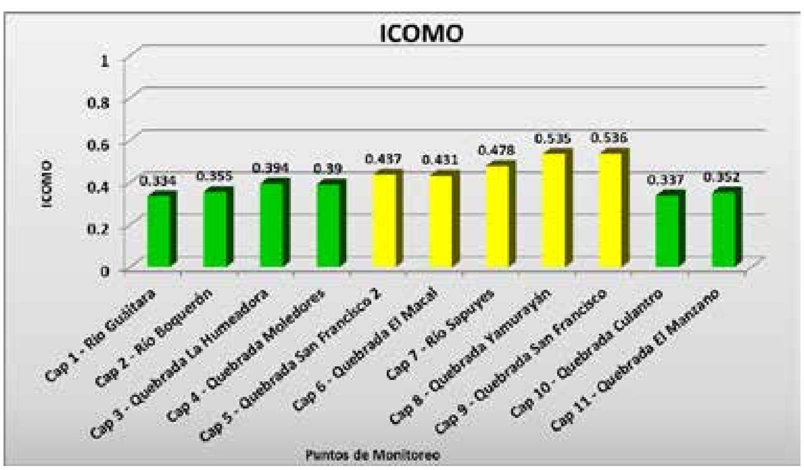


Source: GEOCOL CONSULTORES S.A., 2017.

- **ICOMO**

It measures pollution for organic matter. It is determined through three variables: Biochemical Oxygen Demand, total coliforms and oxygen percentage. For the water bodies analyzed a “medium” pollution level is obtained for organic matter with values between 0.334 and 0.394, for catchment points 5 to 9, mainly due to the high values of DBO_5 (between 13 and 20 mg/L) in points 5, 6 and 7 and for low dissolved oxygen concentrations (1.01 and 1.20 mg/L) in points 8 and 9, respectively, unlike the other sites analyzed in which these parameters have better conditions. This involves that the ICOMO is in a “low” pollution level. (**Figure 7.3**).

Figure 7.3 Results of the ICOMO Pollution Level



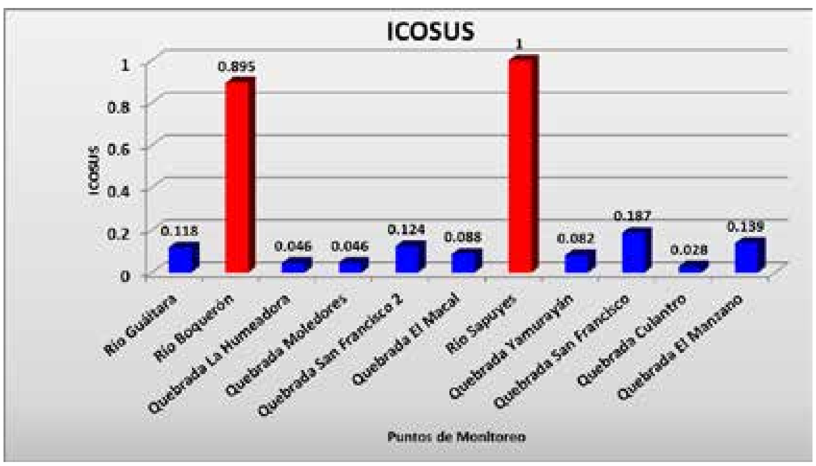
Source: GEOCOL CONSULTORES S.A., 2017.

· **ICOSUS**

This index measures the level of pollution for presence of suspended solids.

For the water bodies assessed, in accordance with the suspended solid concentrations, there is a value of ICOSUS equal to 0.895 and 1 for the samples taken in rivers Boquerón and Sapuyes, respectively, this being one of the main limiting factors of the water quality of these currents. The value presented in these points is due to dragging of material from the bed throughout its entire course. Given the greater flow with respect to other water bodies and the slope of the course, where pollution levels correspond to the category "none" with values between 0.028 and 0.187. (**Figure 7.4**).

Figure 7.4 Results of the ICOSUS Pollution Index.



Source: GEOCOL CONSULTORES S.A., 2017.

· **ICOTRO.**

It is calculated based on the total phosphorus concentration, determined if the water has oligotrophic, mesotrophic, eutrophic or hypereutrophic characteristics.

It is important to clarify that due to the limit of detection of the method used to determine phosphorus, (0.1 mg/L), the sources in the oligotrophic (< 0.01 mg/L) and mesotrophic (entre 0.01 and 0.02 mg/L) categories cannot be established. As for points 5 to 9 that correspond to the latter categories where the ICOMO is in the medium category, they had higher values of ICOTRO. Sources 5, 6, 8 and 10 are thus classified as eutrophic and point 7 corresponding to Sapuyes River has the highest concentration (3.3), being classified as hypereutrophic, which indicates high value of inorganic nutrients consistent with the biologic indexes defined using the hydrological monitoring of water sources showing an excess of nutrients in the water as far as the total phosphorus is concerned.

7.1.4.2 Flows of the Catchment Sources

In order to determine the flow regime in the current to be intervened, the catchment sites were defined with the purpose of knowing availability of the water resource for its exploitation.

Table 7.2 and **Figure 7.1** show the central points of the strips proposed for catchment and/or exploitation of the surface water resource, which are located in rivers Guáitara, Boquerón, Sapuyes and creeks Humeadora, Moledores, San Francisco, Yamurayán, El Manzano, Culantro and El Macal, which were chosen and verified in field.

Estimation of the characteristic flows (total water supply) of the main currents of the Area of Influence is contained in ***Section 5.1.5 Hydrology – Characteristic Flows (Chapter 5_Main Characteristics of the Area of Influence)***. The flows presented below correspond only to the water bodies requested for catchment, considering that in order to obtain the net water supply available, the calculation was made in compliance with the provisions of Resolution 865 of 2004 of the Ministry for the Environment, Housing and Territorial Development (MAVDT), currently MADS, which regulates the methodology developed by the IDEAM in the document "Methodology for Calculation of the Scarcity Rate for Surface water, (IES)" and in the "National Water Study"; therefore, the total estimated water supply is reduce; that is, reduce the total water supply by the minimum ecologic flow and the water quality, including the water demand made and identified in each source, in accordance with the uses determined in section **¡Error! No se encuentra el origen de la referencia. ¡Error! No se encuentra el origen de la referencia.**.

- **Reduction by the Ecologic Flow**

The minimum ecologic flow or minimum remaining flow is the flow required for the ecosystem, flora and fauna of a water current to be sustained.

Calculation of the ecologic flow was made considering the provisions of Resolution 865 de 2004, which ratifies the discount percentage adopted by the IDEAM as minimum ecologic flow, to wit, an approximated value of 25% of the lowest multiannual monthly average flow, important for proper planning of the water resource.

- **Reduction by Water Quality**

The water quality is a factor that limits availability of the water resource and restricts its possible uses. Therefore, by monitoring systematically the water quality indicators, such as the ICOs, determined by laboratory MCS Consultoría and Monitoreo Ambiental between February 26 and March 21 2017, the environmental quality levels of the water resource of the water bodies requested for exploitation were more known.

Based on the foregoing, the addition of reduction by ecologic flow (25%) plus the reduction by water quality (25%) equals to the reduction that must be made to the total water supply calculated in order to determine the net water supply as follows.

- **Estimation of flows for Guáitara River - Catchment 1**

Table 7.13 shows the net supply flows estimated with an analysis range of 1990-2014, from the station PILCUAN (52057050).

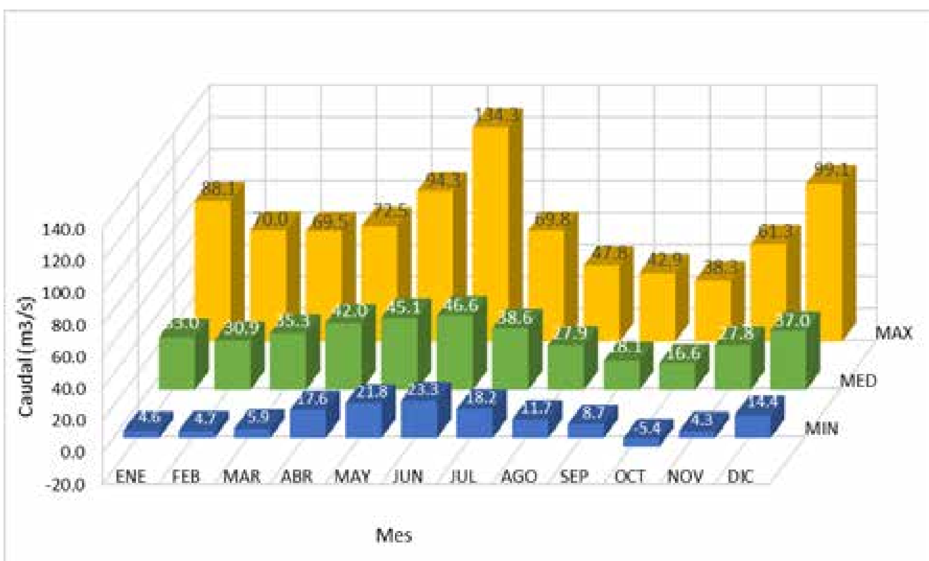
Table 7.13 Multiannual Monthly Flows (1990-2014) Estimated for the Net Supply in Guáitara River – Catchment 1.

FLOWS (m^3/s). CATCHMENT POINT 1 - GUÁITARA RIVER													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
Mean	33.0	30.9	35.3	42.0	45.1	46.6	38.6	27.9	18.1	16.6	27.8	37.0	33.2
MAX	88.1	70.0	69.5	72.5	94.3	134.3	69.8	47.8	42.9	38.3	61.3	99.1	134.3
MIN	4.6	4.7	5.9	17.6	21.8	23.3	18.2	11.7	8.7	-5.4	4.3	14.4	-5.4

Source: GEOCOL CONSULTORES S.A, 2017.

The Guáitara has a permanent hydrologic regime since due to its extension and the high number of tributaries throughout its course; it is not strongly influenced by zone precipitation unlike the basins of the other creeks identified in the field. **Figure 7.5** shows the histogram of minimum, mean and maximum monthly flows of the net water supply where it is evidenced that the highest flows are between December and July with a peak in June. Considering the average values obtained of 38.6 m^3/s, it is also evidenced that the lowest flows are between August and November with a minimum in the month of October, when by making the discounts for ecologic flow and water quality, the water body would not have available flow, but with the analysis made of frequencies of minimum flows for different return periods, it is likely that not even for a period of 100 years there is such a flow in Guáitara River, showing the capacity of the water body during the project.

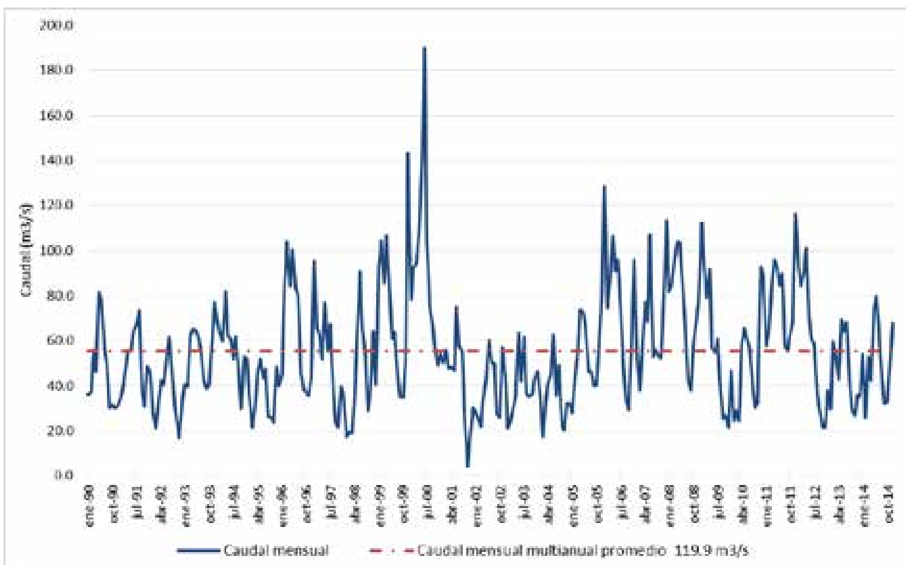
Figure 7.5 Histogram of the Multiannual Minimum, Mean and Maximum Net (1990 – 2014) for Guáitara River - Catchment 1



Source: GEOCOL CONSULTORES S.A, 2017.

By analyzing the annual histogram of flows of the Total Water Supply of Guáitara River (**Figure 7.6**), estimated from the station PILCUAN, it is evidenced that the flows have an everlasting regime or continuous flow characteristic of basins that are permanent with an average flow of 55.4 m^3/s.

Figure 7.6 Annual Hystograph of Flows for Guáitara River

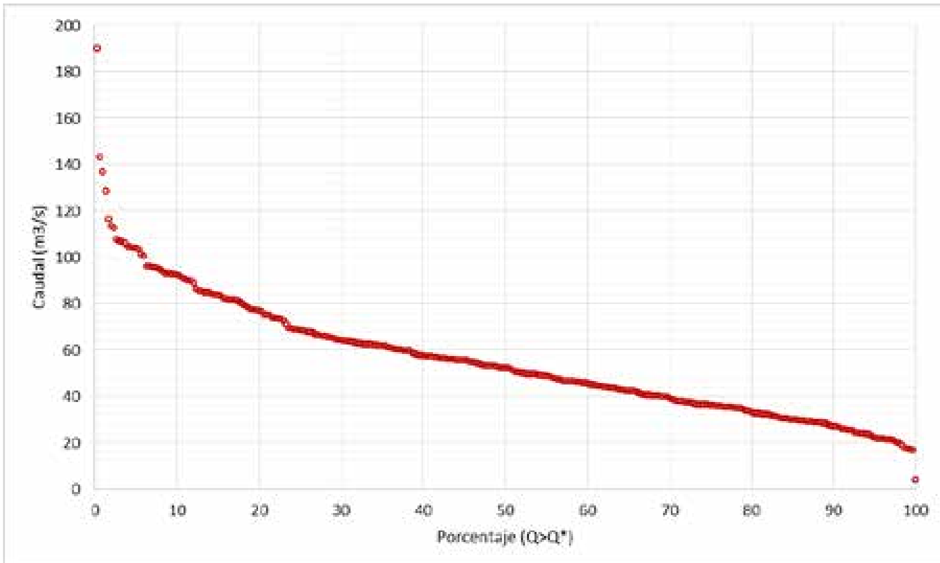


Source: GEOCOL CONSULTORES, 2017.

Figure 7.7 shows the behavior of the curve of duration of flows, which basically indicates the period in terms of percentage of the time in which a certain flow is exceeded or equaled in size, which allows establishing a general knowledge of the regulation of the water source to the point analyzed. In this manner, the curve of duration shows clearly persistence of the estimated flows. The flow 190.1 m^3/s is a flow that on few occasions occurs and the flow of 3.9 m^3/s is the base flow, which means that at some of the moments assessed there have been values lower than the latter. In average, it is expected to have a flow of 52 m^3/s.

The foregoing is stated indicating that Guáitara River shall have enough flow of supply for the entire year since the river keeps its sheet of water 100% of the time.

Figure 7.7 Curve of duration of Flows of the Total Average Monthly Flows Estimated for Guáitara River - Catchment 1.



Source: GEOCOL CONSULTORES S.A, 2017.

· **Estimation of Flows for the Point of Catchment 2 - Boquerón River**

Table 7.14 shows the estimated flows of net supply based on the precipitation – runoff modeling made for the Boquerón River.

Table 7.14 Multiannual Monthly Flows (1990-2014) Estimated for the net Supply in Boquerón River – Catchment 2

FLOWS (m^3/s). CATCHMENT 2 POINT - BOQUERÓN RIVER													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
Mean	1.45	1.70	2.47	2.20	2.13	1.22	0.98	0.56	0.91	1.86	2.31	2.27	1.67
MAX	3.69	4.60	5.20	4.12	7.31	3.38	2.68	1.41	5.14	3.16	4.46	6.85	7.31
MIN	0.07	0.16	0.70	0.97	0.58	0.25	0.26	0.04	0.07	0.12	1.03	0.90	0.04

Source: GEOCOL CONSULTORES S.A, 2017.

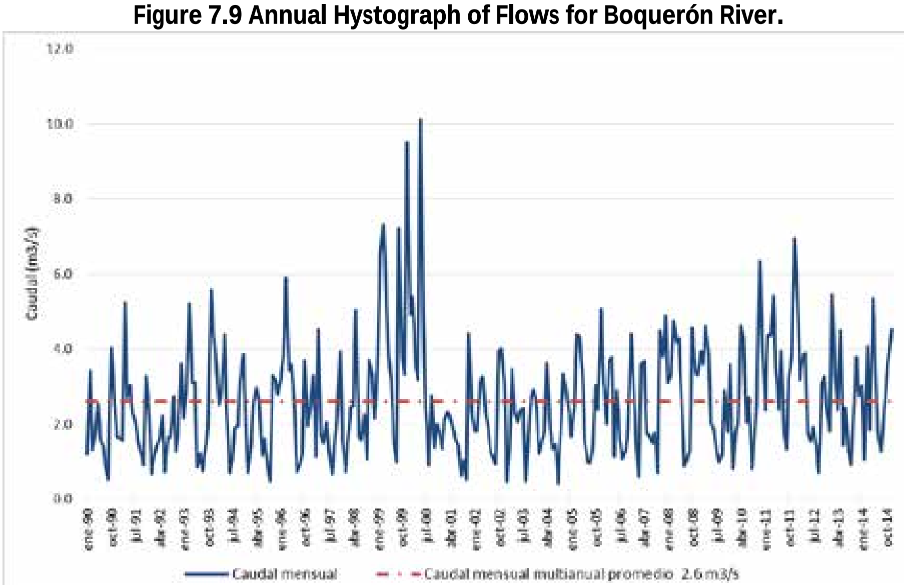
Boquerón River has permanent hydrological regime since due to its extension and high number of tributaries throughout its course; it is not strongly influenced by zone precipitation unlike the basins of the other creeks identified in the field. **Figure 7.8** shows the histogram of minimum, mean and maximum monthly flows of the net water supply where it is evidenced that the highest flows are between October and June with a peak in March. Considering the average values obtained of 1.96 m^3/s, it is also evidenced that the lowest flows are between July and September with a minimum value in the month of August, when by making the discounts for ecologic flow and water quality, the water body would have available flow for the entire year.

Figure 7.8 Histogram of the Multiannual Monthly Minimum, Mean and Maximum Net Supply (1990 – 2014) for Boquerón River - Catchment 2

Source: GEOCOL CONSULTORES S.A, 2017.

By analyzing the annual hystograph of the Total Water Supply of Boquerón River (**Figure 7.9**), estimated based on the precipitation – runoff modeling, it is evidenced that the flows have an everlasting regime or continuous flow characteristic of basins which are permanent with an average flow of 2.6 m^3/s.

Figure 7.9 Annual Hystograph of Flows for Boquerón River.

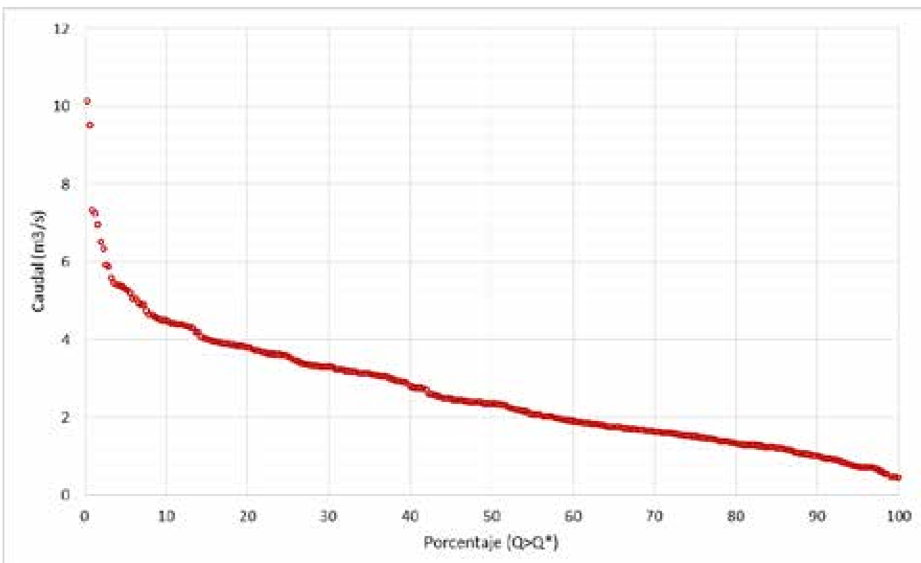


Source: GEOCOL CONSULTORES, 2017.

Figure 7.10 shows the behavior of the curve of duration of flows, which basically indicates the period in terms of percentage of the time in which certain flow is exceeded or equaled in size, which allows establishing a general knowledge about regulation of the water source to the point analyzed. In this manner, the curve of duration shows clearly persistence of the estimated flows. The flow of 10.12 m^3/s is a flow that appears on few occasions and the flow of 0.43 m^3/s is the base flow, which means that never at the times analyzed there have been values lower than such base flow. In average, it is expected to find a flow of 2.33 m^3/s.

The foregoing statement is made indicating that Boquerón River shall have enough supply flow during the entire year since the river keeps its sheet of water 100% of the time.

Figure 7.10 Curve of Duration of Monthly Mean Flows of Total Supply Estimated for Boquerón River - Catchment 2



Source: GEOCOL CONSULTORES S.A, 2017.

- **Estimation of flows for the catchment point 3 - Humeadora Creek.**

En la **Table 7.15** shows the estimated flows of net supply with an analysis range of 1990-2014 based on the precipitation-runoff modeling made for Humeadora Creek.

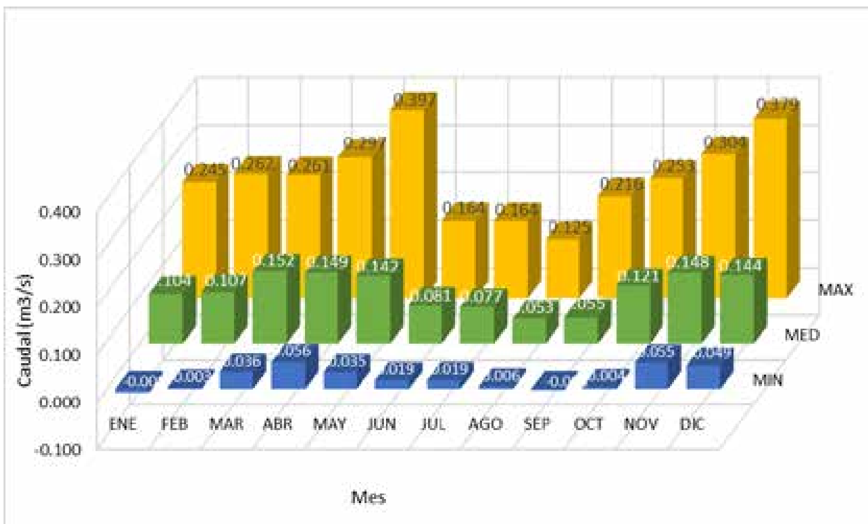
Table 7.15 Multiannual Monthly Flows (1990-2014) Estimated for the Net Supply in the Humeadora Creek – Catchment 3.

FLOWS (m^3/s). CATCHMENT POINT 3 - HUMEADORA CREEK													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
Mean	0.104	0.107	0.152	0.149	0.142	0.081	0.077	0.053	0.055	0.121	0.148	0.144	0.111
MAX	0.245	0.262	0.261	0.297	0.397	0.164	0.164	0.125	0.216	0.253	0.304	0.379	0.397
MIN	-0.008	0.003	0.036	0.056	0.035	0.019	0.019	0.006	-0.003	0.004	0.055	0.049	-0.008

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 7.11 shows the histogram of minimum, mean and maximum monthly net supply flows, where it is evidenced that the highest flows appear between the months of October and May and there is a slight peak in the month of March obtaining values between 0.104 m^3/s for January and 0.152 m^3/s for the month of March. It can also be evidenced that the maximum values registered are about 0.397 m^3/s for the month of May. Nevertheless, it can be observed that in accordance with the minimum values during the months of January and September, the creek can dry and thus it does not have the condition of enough water supply during such months.

Figure 7.11 Histogram of Multiannual Monthly Minimum, Mean and Maximum Net Supply (1990-2014) for Humeadora Creek - Catchment 3.



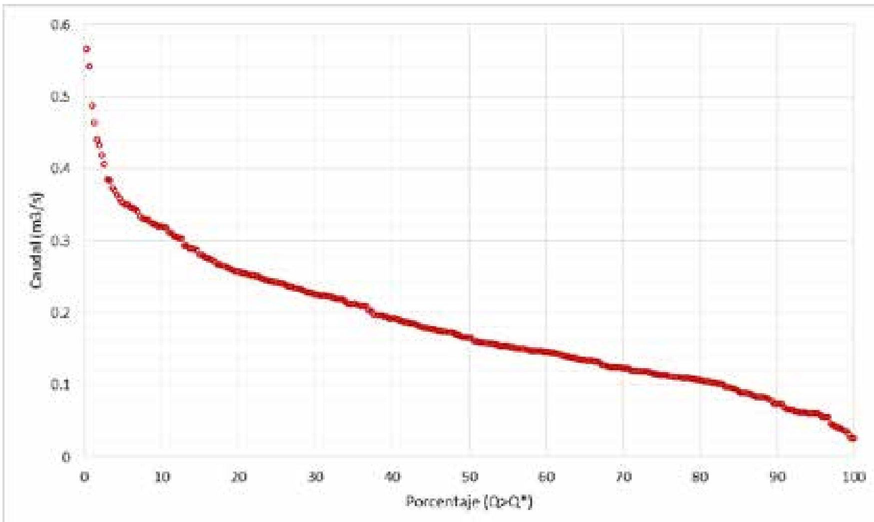
Source: GEOCOL CONSULTORES S.A, 2017.

Figure 7.12 shows the behavior of the curve of duration of flows for Humeadora Creek, where there can be values of up to 0.57 m^3/s and minimum values of 0.024 m^3/s. In average, in accordance with the precipitation records of the area, a flow of 0.16 m^3/s can be generated.

Based on the foregoing, it is evidenced that the basin of Humeadora Creek in catchment point 3 shall have enough flow of supply only during the rainy season (February to August and October to December); given that during the dry season, specifically the months of January and September the source could dry for its intermittent character.

During the rainy season, the estimated value of minimum supply is 0.003 m^3/s (3.34 L/s) for the month of February, if the flow of minimum supply is compared to the flow requested in this creek (1.95 L/s), it is evidenced that the demand requested would be equal to 58.3 % of the net supply under the most critical conditions. Nonetheless, as there may be fluctuations where availability is lower; that is, where in the rainy season there is no sheet of water, catchment in the permanent sources of water as rivers Guáitara, Boquerón and Sapuyes or purchase to authorized third parties shall be considered an alternative.

Figure 7.12 Curve of Duration of Estimated Monthly Mean Flows of Total Supply for Humeadora Creek - Catchment 3



Source: GEOCOL CONSULTORES S.A, 2017.

· **Estimation of flows for the catchment point 4 - Moledores Creek.**

Table 7.16 shows the estimated flows of net supply with an analysis range of 1990-2014 based on the precipitation-runoff modeling made for Humeadora Creek.

Table 7.16 Multiannual Monthly Flows (1990-2014) Estimated for the Net Supply in the Moledores Creek – Catchment 4

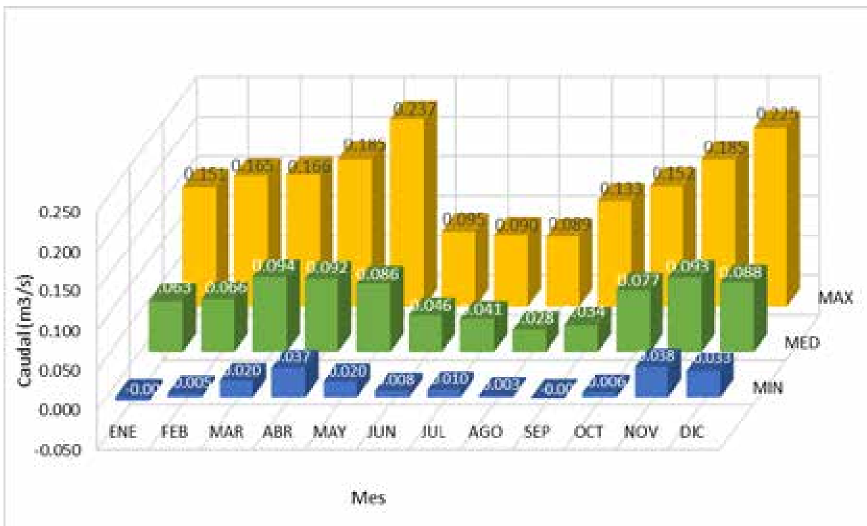
FLOWS (m^3/s). CATCHMENT POINT 4 MOLEDORES CREEK													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
Mean	0.063	0.066	0.094	0.092	0.086	0.046	0.041	0.028	0.034	0.077	0.093	0.088	0.067
MAX	0.151	0.165	0.166	0.185	0.237	0.095	0.090	0.089	0.133	0.152	0.185	0.225	0.237
MIN	-0.004	0.005	0.020	0.037	0.020	0.008	0.010	0.003	-0.001	0.006	0.038	0.033	-0.004

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 7.13 shows the histogram of minimum, mean and maximum monthly net supply flows, where it is evidenced that the highest flows appear between the months of October to May and there is a slight peak in the month of March obtaining values between 0.063 m^3/s para January and 0.094 m^3/s for the month of March. It can also be evidenced that the maximum values registered are about 0.237 m^3/s for the month of May. Nevertheless, it can be observed that in accordance with the minimum values during the months of

January and September, the creek can dry and thus it does not have the condition of enough water supply during such months.

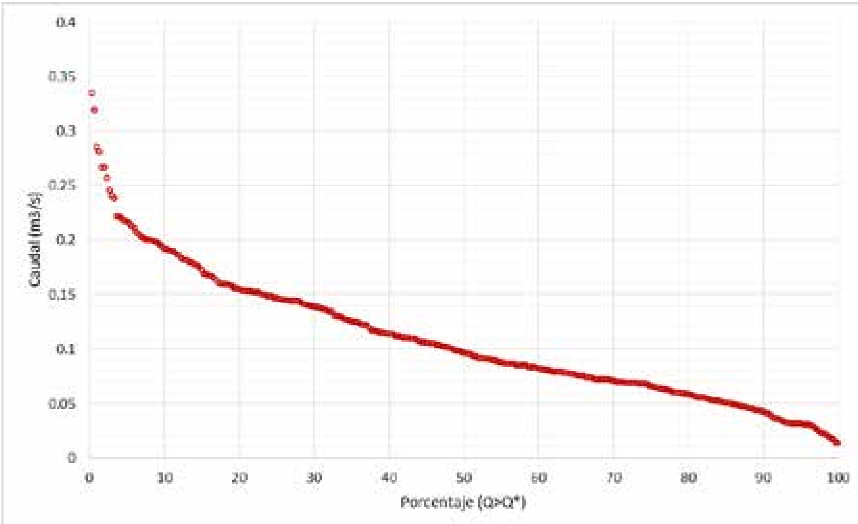
Figure 7.13 Histogram of Multiannual Monthly Minimum, Mean and Maximum Net Supply (1990-2014) for Moledores Creek - Catchment 4



Source: GEOCOL CONSULTORES S.A, 2017.

Figure 7.14 shows the behavior of the curve of duration of flows for Moledores Creek, where there can be values of up to 0.33 m^3/s and minimum values of 0.013 m^3/s, in average, in accordance with the records of precipitation of the area, a flow of 0.09 m^3/s can be generated.

Figure 7.14 Curve of Duration of Estimated Monthly Mean Flows of Total Supply for Moledores Creek - Catchment 4



Source: GEOCOL CONSULTORES S.A, 2017.

Based on the foregoing, it is evidenced that the basin of Moledores Creek in catchment point 4 shall have enough flow of supply only during the rainy season (February to August and October to December); given that during the dry season, specifically the months of January and September the source could dry for its intermittent character.

During the rainy season, the estimated value of minimum supply is 0.0028 m^3/s (2.80 L/s) for the month of August, if the flow of minimum supply is compared to the flow requested in this creek (1. 5 L/s), it is evidenced that the demand requested would be equal to 53.6 % of the net supply under the most critical conditions. Nonetheless, as there may be fluctuations where availability is lower; that is, where in the rainy season there is no sheet of water, catchment in the permanent sources of water as rivers Guáitara, Boquerón and Sapuyes or purchase to authorized third parties shall be considered an alternative.

- **Estimation of flows for the catchment point 5 - San Francisco Creek 2**

Table 7.17 shows the estimated flows of net supply with an analysis range of 1990-2014 based on the precipitation-runoff modeling made for San Francisco Creek 2.

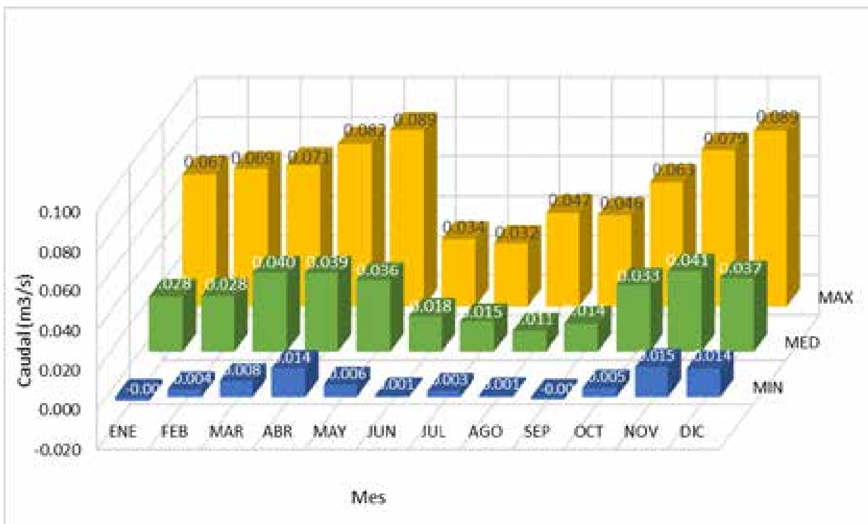
Table 7.17 Multiannual Monthly Flows (1990-2014) Estimated for the Net Supply in the San Francisco Creek 2 – Catchment 5

FLOWS (m^3/s). CATCHMENT POINT 5 SAN FRANCISCO CREEK 2													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
Mean	0.028	0.028	0.040	0.039	0.036	0.018	0.015	0.011	0.014	0.033	0.041	0.037	0.028
MAX	0.067	0.069	0.071	0.082	0.089	0.034	0.032	0.047	0.046	0.063	0.079	0.089	0.089
MIN	-0.002	0.004	0.008	0.014	0.006	0.001	0.003	0.001	-0.001	0.005	0.015	0.014	-0.002

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 7.15 shows the histogram of minimum, mean and maximum monthly net supply flows, where it is evidenced that the highest flows appear between the months of October a May and there is a slight peak in the month of November obtaining values between 0.028 m^3/s para January and 0.041 m^3/s for the month of November. It can also be evidenced that the maximum values registered are about 0.089 m^3/s for the month of May. Nevertheless, it can be observed that in accordance with the minimum values during the months of January, August and September, the creek can dry and thus it does not have the condition of enough water supply during such months.

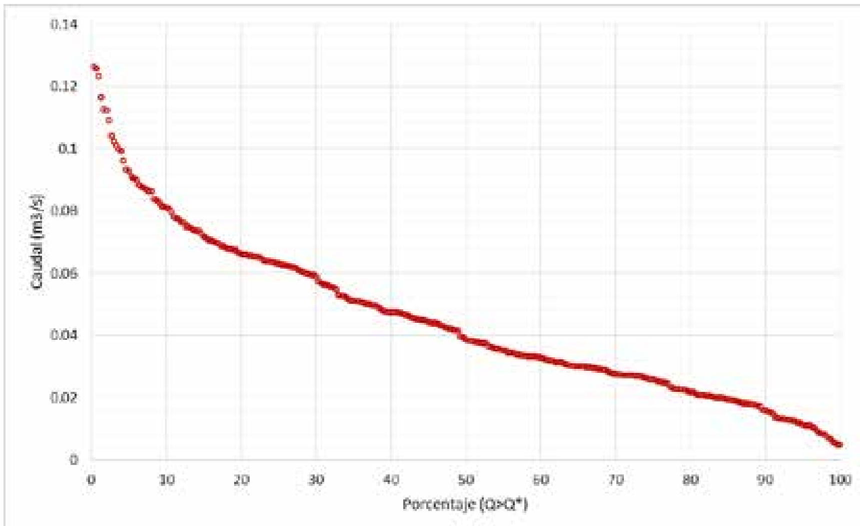
Figure 7.15 Histogram of Multiannual Monthly Minimum, Mean and Maximum Net Supply (1990-2014) for San Francisco Creek 2 in catchment point 5



Source: GEOCOL CONSULTORES S.A, 2017.

Figure 7.16 shows the behavior of the curve of duration of flows for San Francisco Creek 2, where there can be values of up to 0.126 m^3/s and minimum values of 0.004 m^3/s, in average, in accordance with the records of precipitation of the area, a flow of 0.038 m^3/s can be generated.

Figure 7.16 Curve of Duration of Estimated Monthly Mean Flows of Total Supply for San Francisco Creek 2 - Catchment 5



Source: GEOCOL CONSULTORES S.A, 2017.

Based on the foregoing, it is evidenced that the basin of San Francisco Creek 2 in catchment point 5 shall have enough flow of supply only during the rainy season (February to July and October to December), given that during the dry season, specifically the months of January, August and September the source could dry for its intermittent character.

During the rainy season, the estimated value of minimum supply is 0.003 m^3/s (3.08 L/s) for the month of June, if the flow of minimum supply is compared to the flow requested in this creek (1.95 L/s), it is evidenced that the demand requested would be equal to 63.1 % of the net supply under the most critical conditions. Nonetheless, as there may be fluctuations where availability is lower; that is, where in the rainy season there is no sheet of water, catchment in the permanent sources of water as rivers Guáitara, Boquerón and Sapuyes or purchase to authorized third parties shall be considered an alternative.

· **Estimation of flows for the catchment point 6 - Macal Creek**

Table 7.18 shows the estimated flows of net supply with an analysis range of 1990-2014 based on the precipitation-runoff modeling made for Macal Creek.

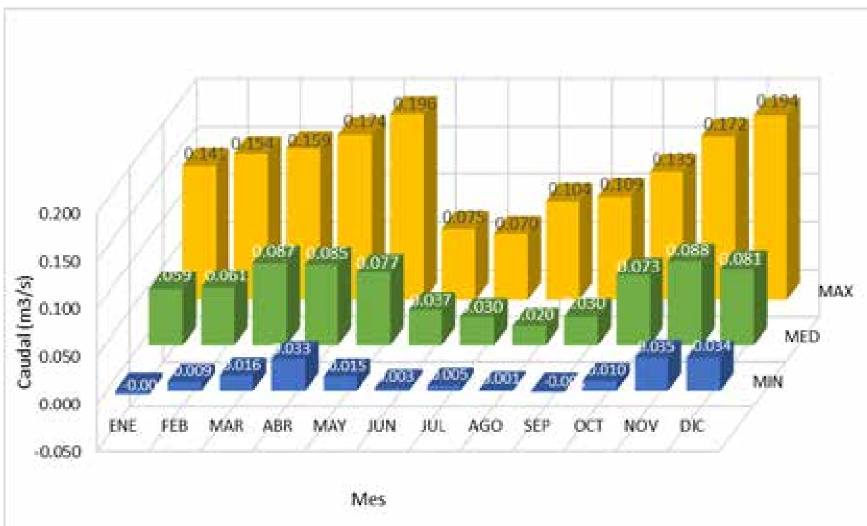
Table 7.18 Multiannual Monthly Flows (1990-2014) Estimated for the Net Supply in the Macal Creek – Catchment 6

FLOWS (m^3/s). CATCHMENT POINT 6 - MACAL CREEK													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
Mean	0.059	0.061	0.087	0.085	0.077	0.037	0.030	0.020	0.030	0.073	0.088	0.081	0.061
MAX	0.141	0.154	0.159	0.174	0.196	0.075	0.070	0.104	0.109	0.135	0.172	0.194	0.196
MIN	-0.004	0.009	0.016	0.033	0.015	0.003	0.005	0.001	-0.001	0.010	0.035	0.034	-0.004

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 7.17, shows the histogram of minimum, mean and maximum monthly net supply flows, where it is evidenced that the highest flows appear between the months of October a May and there is a slight peak in the month of November obtaining values between 0.059 m^3/s para January and 0.088 m^3/s for the month of November. It can also be evidenced that the maximum values registered are about 0.196 m^3/s for the month of May. Nevertheless, it can be observed that in accordance with the minimum values during the months of January, August and September, the creek can dry and thus it does not have the condition of enough water supply during such months.

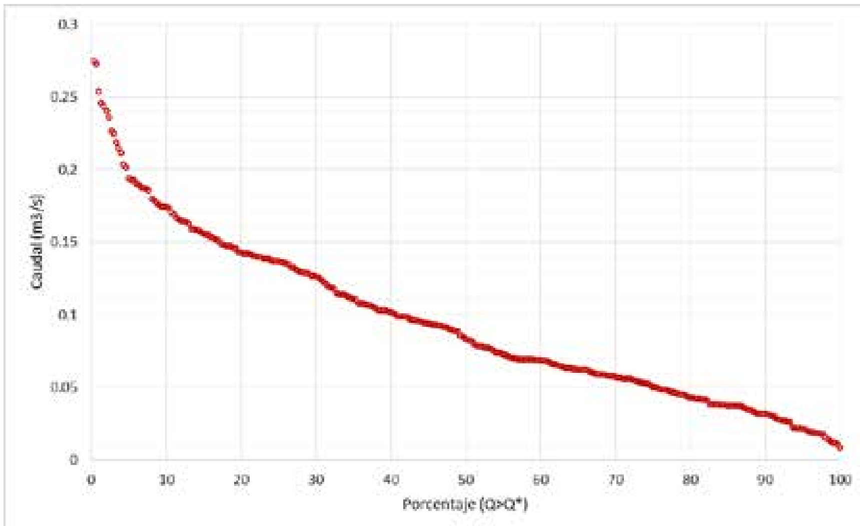
Figure 7.17 Histogram of Multiannual Monthly Minimum, Mean and Maximum Net Supply (1990-2014) for Macal Creek - Catchment 6



Source: GEOCOL CONSULTORES S.A, 2017.

Figure 7.18 shows the behavior of the curve of duration of flows for Humeadora Creek, where there can be values of up to 0.27 m^3/s and minimum values of 0.008 m^3/s, in average, in accordance with the records of precipitation of the area, a flow of 0.082 m^3/s can be generated.

Figure 7.18 Curve of Duration of Estimated Monthly Mean Flows of Total Supply for Macal Creek - Catchment 6



Source: GEOCOL CONSULTORES S.A, 2017.

Based on the foregoing, it is evidenced that the basin of Macal Creek in catchment point 6 shall have enough flow of supply only during the rainy season (February a July and October a December), given that during the dry season, specifically the months of January, August and September the source could dry for its intermittent character.

During the rainy season, the estimated value of minimum supply is 0.003 m^3/s (3.27 L/s) for the month of June, if the flow of minimum supply is compared to the flow requested in this creek (1.5 L/s), it is evidenced that the demand requested would be equal to 45.8 % of the net supply under the most critical conditions. Nonetheless, as there may be fluctuations where availability is lower; that is, where in the rainy season there is no sheet of water, catchment in the permanent sources of water as rivers Guáitara, Boquerón and Sapuyes or purchase to authorized third parties shall be considered an alternative.

- **Estimation of flows for the catchment point 7 - Sapuyes River**

Table 7.19 shows the estimated net flows of supply based on the precipitation - runoff modeling made for Sapuyes River.

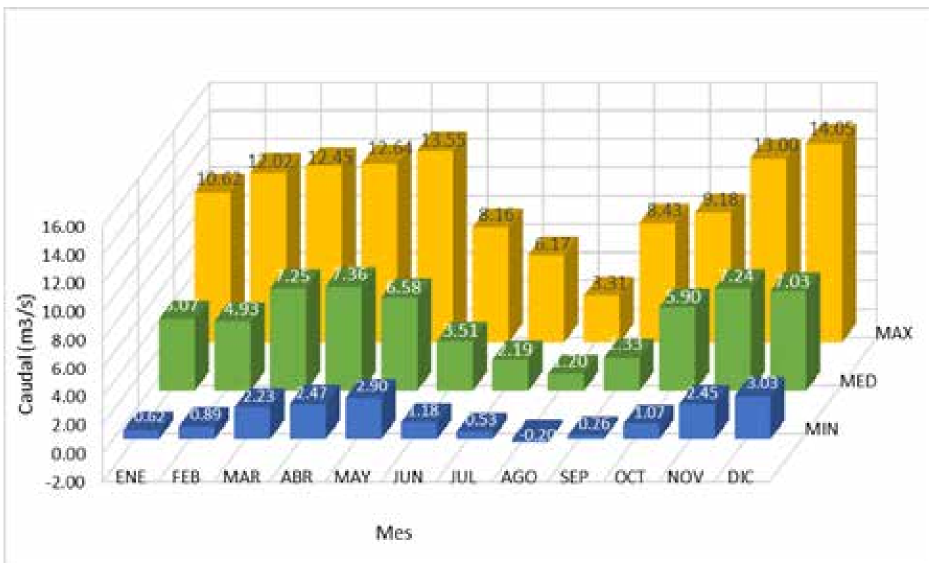
Table 7.19 Multiannual Monthly Flows (1990-2014) Estimated for the Net Supply of Sapuyes River – Catchment 7

FLOWS (m^3/s). CATCHMENT POINT 7 - SAPUYES RIVER													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
Mean	5.07	4.93	7.25	7.36	6.58	3.51	2.19	1.20	2.33	5.90	7.24	7.03	5.05
MAX	10.62	12.02	12.45	12.64	13.55	8.16	6.17	3.31	8.43	9.18	13.00	14.05	14.05
MIN	0.62	0.89	2.23	2.47	2.90	1.18	0.53	-0.20	0.26	1.07	2.45	3.03	-0.20

Source: GEOCOL CONSULTORES S.A, 2017.

Sapuyes River shows a hydrological regime of permanent character since due to its extension and for the high number of tributaries throughout its course, it is not strongly influenced by the zone precipitation, unlike the basins of the other creeks identified in the field. **Figure 7.19**, shows the histogram of minimum, mean and maximum monthly flows of the net water supply where it is evidenced that the highest flows are between October and June, with a peak in April. Considering the average values obtained of 6.10 m^3/s, it is also evidenced that the lowest flows are between July and September, with a minimum in the month of August, when by making the discounts for ecologic flow and water quality, the water body would not have available flow, but with the analysis made of frequencies of minimum flows for different return periods, it is likely that not even for a period of 100 years there is such a flow in Sapuyes River, showing the capacity of the water body during the project.

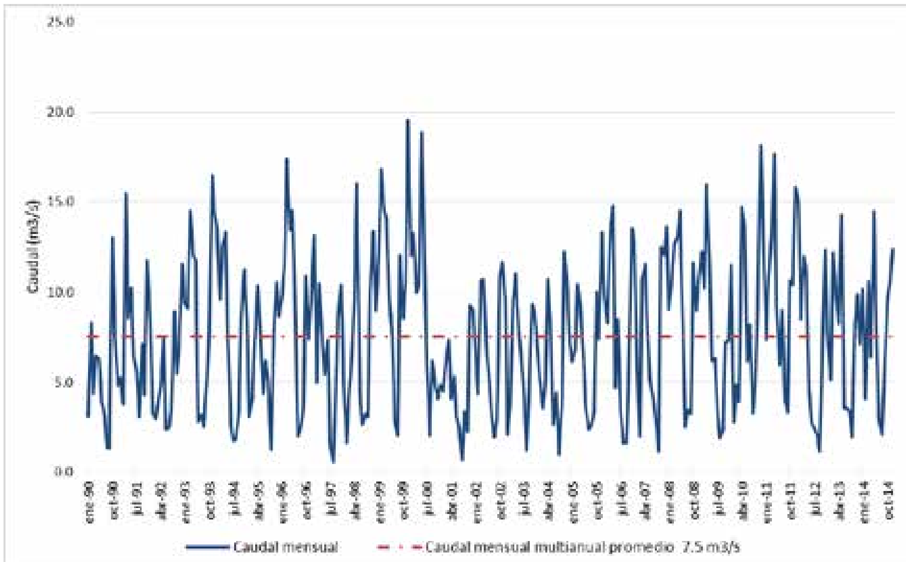
Figure 7.19 Histogram of Multiannual Monthly Minimum, Mean and Maximum Net Supply (1990 – 2014) for Sapuyes River - Catchment 7



Source: GEOCOL CONSULTORES S.A, 2017.

By analyzing the annual histogram of flows of the Total Water Supply of Sapuyes River (**Figure 7.20**), estimated from the precipitation – runoff modeling, it is evidenced that the flows have an everlasting regime or continuous flow characteristic of basins that are permanent with an average flow of 7.5 m^3/s.

Figure 7.20 Annual Hystograph of Flows for Sapuyes River

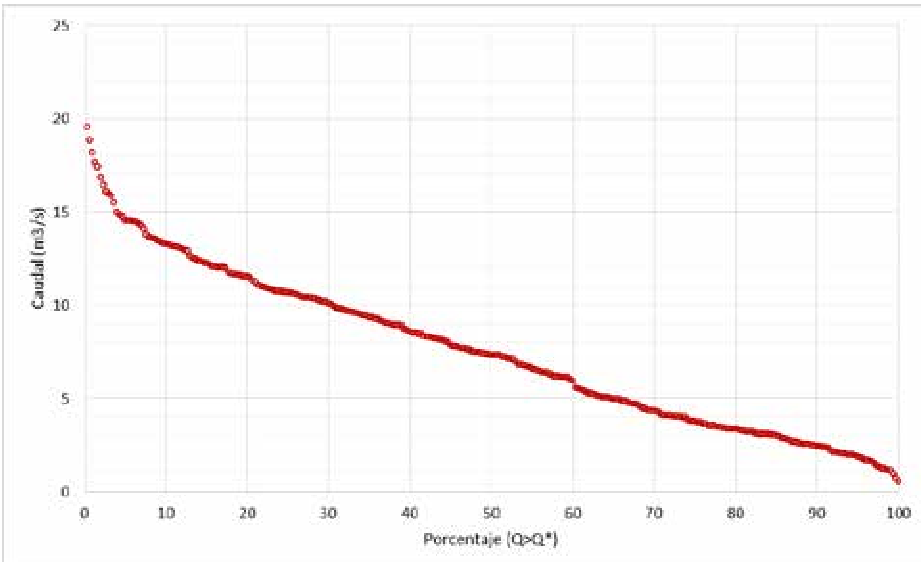


Source: GEOCOL CONSULTORES, 2017.

Figure 7.21 shows the behavior of the curve of duration of flows. This basically indicates the period in terms of percentage of the time in which a certain flow is exceeded or equaled in size. Thus, such behavior allows establishing a general knowledge about regulation of the water source to the point analyzed. In this manner, the curve of duration shows clearly persistence of the estimated flows. The flow of 19.53 m^3/s is a flow that appears on few occasions and the flow of 0.52 m^3/s is the base flow, which means that never at the times analyzed there have been values lower than such base flow. In average, it is expected to find a flow of 7.34 m^3/s.

The foregoing statement is made indicating that Sapuyes River shall have enough supply flow during the entire year since the river keeps its sheet of water 100% of the time.

Figure 7.21 Curve of Duration of Estimated Monthly Mean Flows of Total Supply for Sapuyes River - Catchment 7



Source: GEOCOL CONSULTORES S.A, 2017.

- **Estimation of Flows for Catchment Point 8 - Yamurayán Creek.**

Table 7.20 shows the estimated flows of net supply with an analysis range of 1990-2014 based on the precipitation-runoff modeling made for Yamurayán Creek.

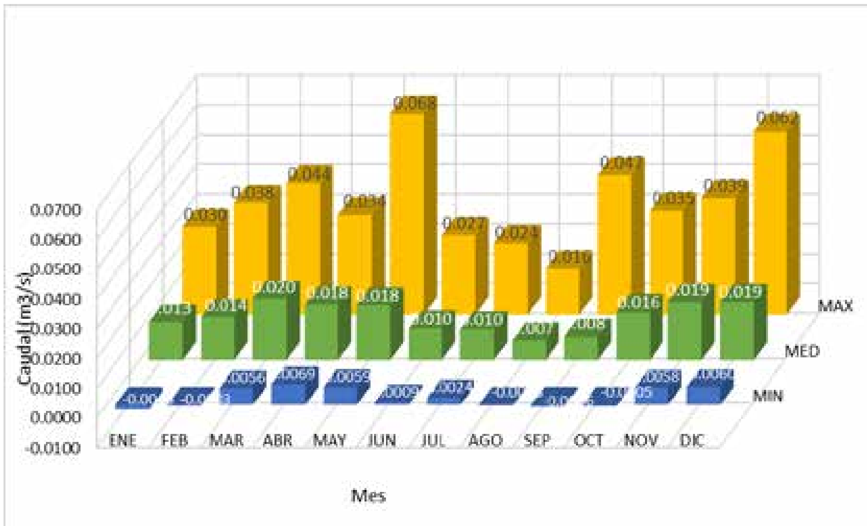
Table 7.20 Multiannual Monthly Flows (1990-2014) Estimated for the Net Supply in the Yamurayán Creek – Catchment 8

FLOWS (m^3/s). CATCHMENT POINT 8 - YAMURAYÁN CREEK													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
Mean	0.0126	0.0143	0.0204	0.0185	0.0182	0.0105	0.0102	0.0065	0.0077	0.0160	0.0193	0.0193	0.0145
MAX	0.0296	0.0376	0.0443	0.0335	0.0676	0.0268	0.0241	0.0156	0.0468	0.0350	0.0392	0.0617	0.0676
MIN	-0.0015	-0.0003	0.0056	0.0069	0.0059	0.0009	0.0024	-0.0003	-0.0006	-0.0005	0.0058	0.0060	-0.0015

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 7.22, shows the histogram of minimum, mean and maximum monthly net supply flows, where it is evidenced that the highest flows appear between the months of October a May and there is a slight peak in the month of March obtaining values between 0.0126 m^3/s para January and 0.0204 m^3/s for the month of March. It can also be evidenced that the maximum values registered are about 0.068 m^3/s for the month of May. Nevertheless, it can be observed that in accordance with the minimum values during the months of January, February and de August a October, the creek can dry and thus it does not have the condition of enough water supply during such months.

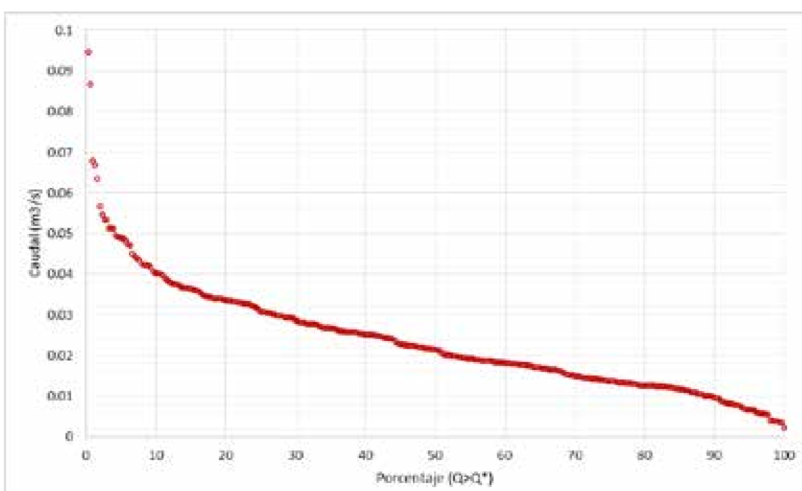
Figure 7.22 Histogram of Multiannual Monthly Minimum, Mean and Maximum Net Supply (1990-2014) for Yamurayán Creek - Catchment 8



Source: GEOCOL CONSULTORES S.A, 2017.

En la **Figure 7.23** shows the behavior of the curve of duration of flows for Yamurayán Creek, where there can be values of up to 0.094 m^3/s and minimum values of 0.002 m^3/s, in average, in accordance with the records of precipitation of the area, a flow of 0.021 m^3/s can be generated.

Figure 7.23 Curve of Duration of Estimated Monthly Mean Flows of Total Supply for Yamurayán Creek - Catchment 8



Source: GEOCOL CONSULTORES S.A, 2017.

Based on the foregoing, it is evidenced that the basin of Yamurayán Creek in catchment point 8 shall have enough flow of supply only during the rainy season (March a July and November and December), given that during the dry season, specifically the months of January and February and de August a October the source could dry for its intermittent character.

During the rainy season, the estimated value of minimum supply is 0.0024 m^3/s (2.44 L/s) for the month of July, if the flow of minimum supply is compared to the flow requested in this creek (1.5 L/s), it is evidenced that the demand requested would be equal to 61.3 % of the net supply under the most critical conditions. Nonetheless, as there may be fluctuations where availability is lower; that is, where in the rainy season there is no sheet of water, catchment in permanent water sources as rivers Guáitara, Boquerón and Sapuyes or purchase to authorized third parties shall be considered an alternative.

- **Estimation of Flows for Catchment point 9 - San Francisco Creek.**

Table 7.21 shows the estimated flows of net supply with an analysis range of 1990-2014 based on the precipitation-runoff modeling made for San Francisco Creek.

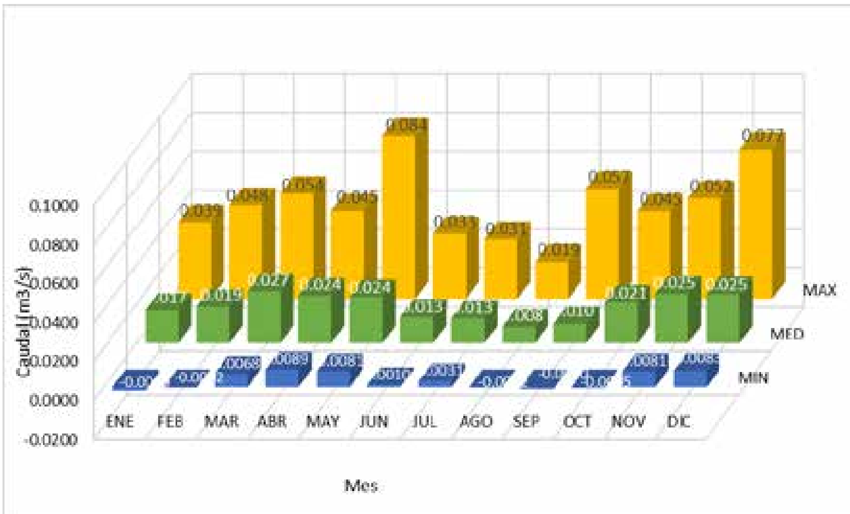
Table 7.21 Multiannual Monthly Flows (1990-2014) Estimated for the Net Supply in the San Francisco Creek – Catchment 9.

FLOWS (m^3/s). CATCHMENT POINT 9 SAN FRANCISCO CREEK													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
Mean	0.0166	0.0186	0.0265	0.0243	0.0237	0.0134	0.0129	0.0083	0.0098	0.0209	0.0253	0.0251	0.0188
MAX	0.0394	0.0482	0.0541	0.0452	0.0839	0.0334	0.0307	0.0192	0.0567	0.0452	0.0516	0.0767	0.0839
MIN	-0.0019	-0.0002	0.0068	0.0089	0.0081	0.0010	0.0031	-0.0002	-0.0010	-0.0005	0.0081	0.0083	-0.0019

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 7.24, shows the histogram of minimum, mean and maximum monthly net supply flows, where it is evidenced that the highest flows appear between the months of October a May and there is a slight peak in the month of March obtaining values between 0.017 m^3/s para January and 0.027 m^3/s for the month of March. It can also be evidenced that the maximum values registered are about 0.084 m^3/s for the month of May. Nevertheless, it can be observed that in accordance with the minimum values during the months of January, February, June and de August a October, the creek can dry and thus it does not have the condition of enough water supply during such months.

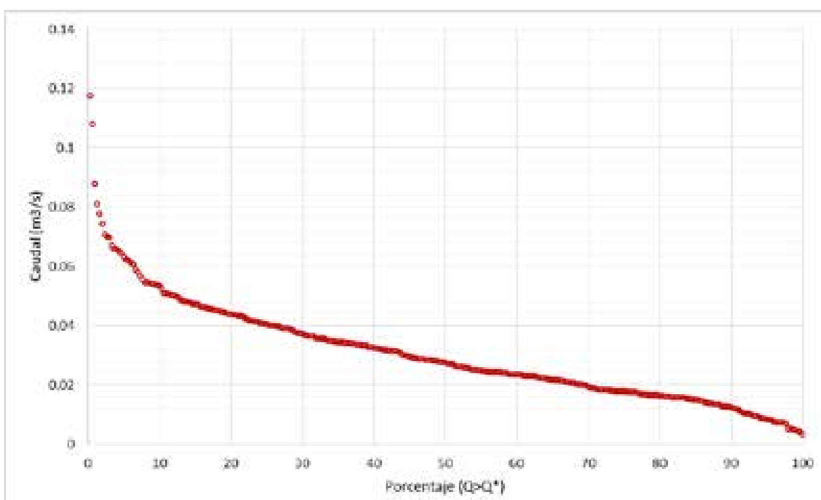
Figure 7.24 Histogram of Multiannual Monthly Minimum, Mean and Maximum Net Supply (1990-2014) for San Francisco Creek - Catchment 9



Source: GEOCOL CONSULTORES S.A, 2017.

Figure 7.25 shows the behavior of the curve of duration of flows for San Francisco Creek, where there can be values of up to 0.12 m^3/s and minimum values of 0.003 m^3/s, in average, in accordance with the records of precipitation of the area, a flow of 0.03 m^3/s can be generated.

Figure 7.25 Curve of Duration of Estimated Monthly Mean Flows of Total Supply for San Francisco Creek - Catchment 9



Source: GEOCOL CONSULTORES S.A, 2017.

Based on the foregoing, it is evidenced that the basin of San Francisco Creek in catchment point 9 shall have enough flow of supply only during the rainy season (March a May, July, November and December), given that during the dry season, specifically the months of January, February, June and de August a October the source could dry for its intermittent character.

During the rainy season, the estimated value of minimum supply is 0.003 m^3/s (3.07 L/s) for the month of July, if the flow of minimum supply is compared to the flow requested in this creek (1.5 L/s), it is evidenced that the demand requested would be equal to 48.8 % of the net supply under the most critical conditions. Nonetheless, as there may be fluctuations where availability is lower; that is, where in the rainy season there is no sheet of water, catchment in permanent water sources as rivers Guáitara, Boquerón and Sapuyes or purchase to authorized third parties shall be considered an alternative.

- **Estimation of flows for Catchment point 10 - Culantro Creek**

Table 7.22 shows the estimated flows of net supply with an analysis range of 1990-2014 based on the precipitation-runoff modeling made for Culantro Creek.

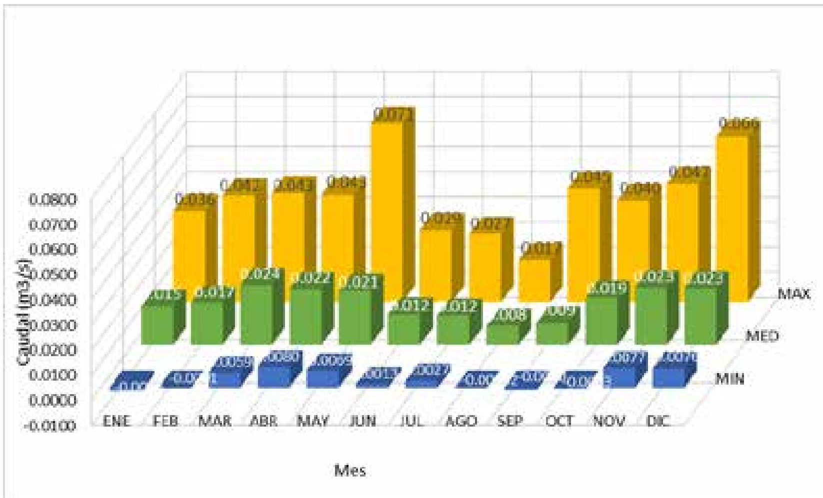
Table 7.22 Multiannual Monthly Flows (1990-2014) Estimated for the Net Supply in the Culantro Creek – Catchment 10.

FLOWS (m^3/s). CATCHMENT POINT 10 CULANTRO CREEK													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
Mean	0.01531	0.01673	0.02378	0.02224	0.02141	0.01206	0.01162	0.00757	0.00858	0.01877	0.02286	0.02260	0.01696
MAX	0.03621	0.04245	0.04335	0.04256	0.07094	0.02859	0.02720	0.01672	0.04533	0.04046	0.04717	0.06596	0.07094
MIN	-0.00158	-0.00008	0.00587	0.00803	0.00685	0.00130	0.00271	-0.00002	-0.00102	-0.00029	0.00767	0.00757	-0.00158

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 7.26, shows the histogram of minimum, mean and maximum monthly net supply flows, where it is evidenced that the highest flows appear between the months of October a May and there is a slight peak in the month of March obtaining values between 0.015 m^3/s para January and 0.023 m^3/s for the month of March. It can also be evidenced that the maximum values registered are about 0.071 m^3/s for the month of May. Nevertheless, it can be observed that in accordance with the minimum values during the months of January, February, June and de August a October, the creek can dry and thus it does not have the condition of enough water supply during such months.

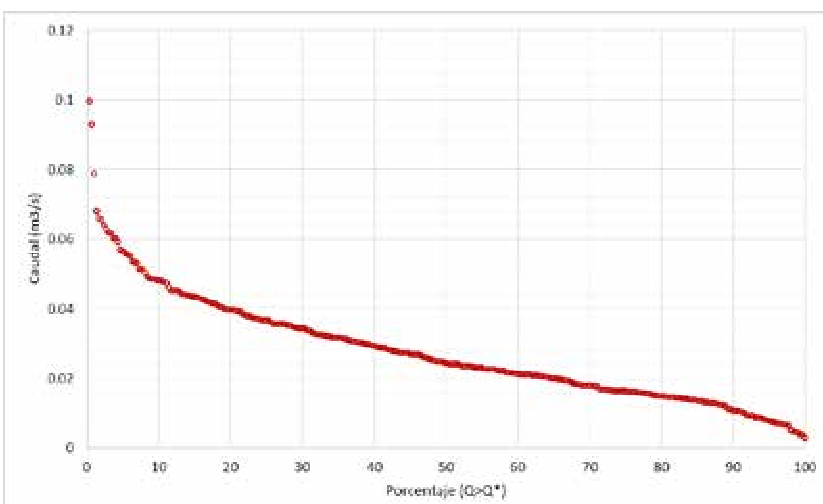
Figure 7.26 Histogram of Multiannual Monthly Minimum, Mean and Maximum Net Supply (1990-2014) for Culantro Creek - Catchment 10



Source: GEOCOL CONSULTORES S.A, 2017.

Figure 7.27 shows the behavior of the curve of duration of flows for Culantro Creek, where there can be values of up to 0.01 m^3/s and minimum values of 0.003 m^3/s, in average, in accordance with the records of precipitation of the area, a flow of 0.02 m^3/s can be generated.

Figure 7.27 Curve of Duration of Estimated Monthly Mean Flows of Total Supply for Culantro Creek - Catchment 10



Source: GEOCOL CONSULTORES S.A, 2017.

Based on the foregoing, it is evidenced that the basin of Culantro Creek in catchment point 10 shall have enough flow of supply only during the rainy season (March a May, July, November and December), given that during the dry season, specifically the months of January, February, June and de August a October the source could dry for its intermittent character.

During the rainy season, the estimated value of minimum supply is 0.002 m^3/s (2.71 L/s) for the month of July, if the flow of minimum supply is compared to the flow requested in this creek (1.5 L/s), it is evidenced that the demand requested would be equal to 55.31 % of the net supply under the most critical conditions. Nonetheless, as there may be fluctuations where availability is lower; that is, where in the rainy season there is no sheet of water, catchment in permanent water sources as rivers Guáitara, Boquerón and Sapuyes or purchase to authorized third parties shall be considered an alternative.

- **Estimation of Flows for Catchment Point 11 El Manzano Creek.**

Table 7.23 shows the estimated flows of net supply with an analysis range of 1990-2014 based on the precipitation-runoff modeling made for El Manzano Creek.

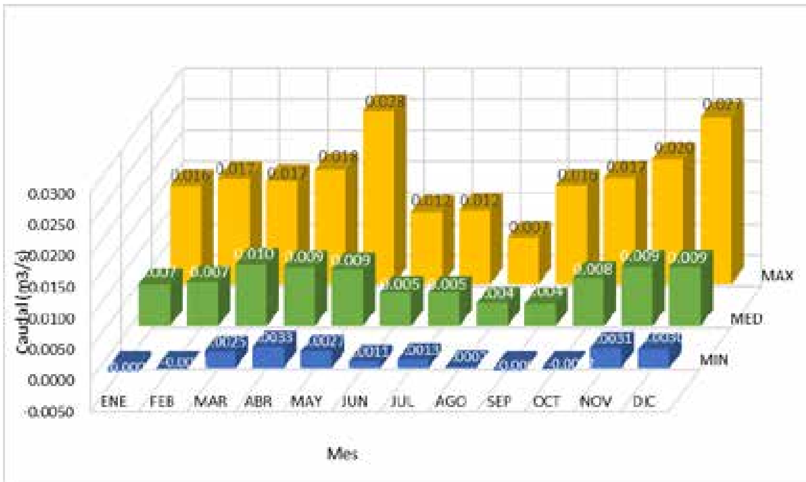
Table 7.23 Multiannual Monthly Flows (1990-2014) Estimated for the Net Supply in the El Manzano Creek – Catchment 11

FLOWS (m^3/s). CATCHMENT POINT 11 EL MANZANO CREEK													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
Mean	0.0067	0.0070	0.0098	0.0094	0.0091	0.0054	0.0054	0.0036	0.0035	0.0077	0.0095	0.0095	0.0072
MAX	0.0157	0.0170	0.0166	0.0184	0.0277	0.0116	0.0119	0.0074	0.0158	0.0170	0.0201	0.0267	0.0277
MIN	-0.0006	-0.0001	0.0025	0.0033	0.0027	0.0011	0.0013	0.0002	-0.0005	-0.0002	0.0031	0.0030	-0.0006

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 7.28, shows the histogram of minimum, mean and maximum monthly net supply flows, where it is evidenced that the highest flows appear between the months of October a May and there is a slight peak in the month of March obtaining values between 0.007 m^3/s para January and 0.001 m^3/s for the month of March. It can also be evidenced that the maximum values registered are about 0.028 m^3/s for the month of May. Nevertheless, it can be observed that in accordance with the minimum values during the months of January, February and de June a October, the creek can dry and thus it does not have the condition of enough water supply during such months.

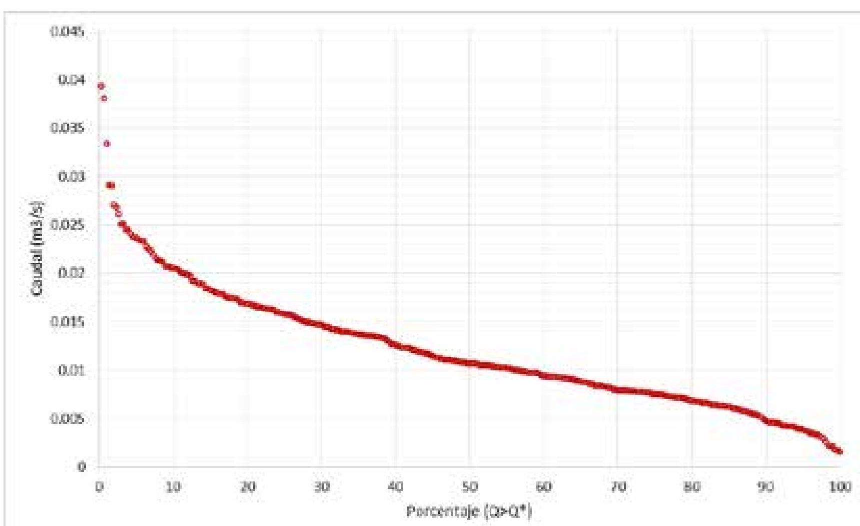
Figure 7.28 Histogram of Multiannual Monthly Minimum, Mean and Maximum Net Supply (1990-2014) for El Manzano Creek - Catchment 11



Source: GEOCOL CONSULTORES S.A, 2017.

Figure 7.29 shows the behavior of the curve of duration of flows for El Manzano Creek, where there can be values of up to 0.04 m^3/s and minimum values of 0.002 m^3/s, in average, in accordance with the records of precipitation of the area, a flow of 0.01 m^3/s can be generated.

Figure 7.29 Curve of Duration of Estimated Monthly Mean Flows of Total Supply for El Manzano Creek - Catchment 11



Source: GEOCOL CONSULTORES S.A, 2017.

Based on the foregoing, it is evidenced that the basin of El Manzano Creek in catchment point 11 shall have enough flow of supply only during the rainy season (March a May and November and December), given that during the dry season, specifically the months of January, February and de June a October the source could dry for its intermittent character.

During the rainy season, the estimated value of minimum supply is 0.002 m^3/s (2.53 L/s) for the month of March, if the flow of minimum supply is compared to the flow requested in this creek (1.5 L/s), it is evidenced that the demand requested would be equal to 59.1 % of the net supply under the most critical conditions. Nonetheless, as there may be fluctuations where availability is lower; that is, where in the rainy season there is no sheet of water, catchment in permanent water sources as rivers Guáitara, Boquerón and Sapuyes or purchase to authorized third parties shall be considered an alternative.

For a better view of the flows of minimum net supply of the rivers and creeks in which catchment is requested, **Table 7.24** shows a summary where the catchment point is related to the flow of the minimum net supply calculated which arises in the time of catchment request and their relation with the flow requested, as well as for the flow measured.

Table 7.24 Relation of the Flow of the Estimated Minimum Net Supply and the Flow Measured with the Flow Requested in the Catchment Sites

CATCHMENT	PLANAR COORDINATES DATUM MAGNA SIRGAS WEST ORIGIN		TIME	FLOW REQUESTED	FLOW OF THE ESTIMATED AVERAGE MINIMUM NET SUPPLY (for the season requested)		PERCENTAGE OF THE FLOW REQUESTED IN RELATION WITH THE FLOW OF MINIMUM NET SUPPLY	MEASURED FLOW Feb - March		PERCENTAGE OF THE FLOW REQUESTED IN RELATION WITH THE MEASURED FLOW
	EAST	NORTH		L/s	m³/s	L/s		m³/s	L/s	
1. Guáitara River	948503	590762	Entire year	**1.5**	**(Oct) 3.92**	**3923**	**0.038%**	**(Feb) 27.53**	**27530**	**0.005%**
2. Boquerón River	948589	590972	Entire year	**1.95**	**(Aug) 0.04**	**44.83**	**4.34%**	**(Feb) 13.08**	**13080**	**0.015%**
3. La Humeadora Creek	955074	597201	Rainy season (Feb – Aug and Oct – Dec)	**1.95**	**(Feb) 0.0033**	**3.34**	**58.3%**	**(March) 0.27**	**270**	**0.72%**
4. Moledores Creek	956019	598991	Rainy season (Feb – Aug and Oct – Dec)	**1.5**	**(Aug) 0.0028**	**2.8**	**53.6%**	**(March) 0.572**	**572**	**0.26%**
5. San Francisco Creek 2	953962	601557	Rainy season (Feb – May, Jul and Oct – Dec)	**1.95**	**(Jul) 0.0031**	**3.1**	**63.1%**	**(March) 0.312**	**312**	**0.63%**
6. El Macal Creek	954870	603721	Rainy season (Feb – Jul and Oct – Dec)	**1.5**	**(Jun) 0.0033**	**3.3**	**45.8%**	**(March) 2.14**	**2140**	**0.07%**
7. Sapuyes River	954844	605090	Entire year	**1.95**	**(Aug) 0.53**	**529.5**	**0.37%**	**(March) 11.07**	**11070**	**0.02%**
8. Yamurayán Creek	949128	592258	Rainy season (March – Jul, Nov and Dec)	**1.5**	**(Jul) 0.0024**	**2.44**	**61.3%**	**(Feb) 0.001**	**1**	**150%**
9. San Francisco Creek	949976	593121	Rainy season (March – May, Jul, Nov and Dec)	**1.5**	**(Jul) 0.0031**	**3.1**	**48.8%**	**(Feb) 0.002**	**2**	**75%**
10. Culantro Creek	950642	594577	Rainy season (March – May, Jul, Nov and Dec)	**1.5**	**(Jul) 0.0027**	**2.7**	**55.3%**	**(March) 0.008**	**8**	**18.75%**
11. El Manzano Creek	951631	595174	Rainy season (March – May, Nov and Dec)	**1.5**	**(March) 0.0025**	**2.5**	**59.1%**	**(March) 0.018**	**18**	**8.33%**

Source: GEOCOL CONSULTORES S.A., 2017.

In accordance with **Table 7.24** and as a summary, in case of making catchment in the rivers and creeks proposed, in the maximum flow (1.95 L/s) and time requested, this flow would be equal to a percentage with respect to the supply between 0.038% and 63.1%, based on the calculation of a flow of minimum net supply for the season requested in each one of them. With this the capacity of such water bodies to supply the project and under the conditions allowed by the water supply of the currents without causing conflicts for availability of the resource is supported.

It can also be evidenced that the percentage of the requested catchment flow, with respect to the flow reported by the measures made in the months of February and March of 2017, confirms with in-situ measurements, the capacity of water bodies where it can also be established for points 9 Yamurayán Creek and 9 San Francisco Creek, which for the month of February (month in which the measurements of such currents were made), does not have enough flow, coinciding with the estimated flows and that were the basis to establish the months in which the catchment is requested. Given that for point 8 the flow requested with respect to the flow of the water body is 150% and for point 9 it is 75%, but considering that the measurement reports a flow of total supply, by making the discounts for ecologic flow and water quality (about 50%), it would not bear the flow required in such month.

7.1.5 Infrastructure of the Catchment System, Transport and Storage of the Resource

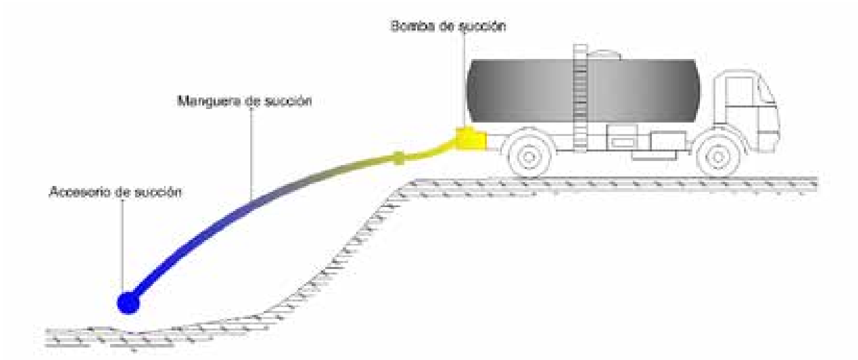
For catchment of water from the sources to be used, three alternatives are proposed without the need of building catchment works and, thus, without the need of occupying the course. The dimensions and characteristics of the mechanisms shall allow catchment of the necessary flow authorized for supply. The option chosen in each source shall be informed to the ANLA in the first Report of Environmental Compliance - ICA.

7.1.5.1 Catchment System

- **Catchment Through Motor Pump from Tanker Truck**

As one of the alternatives for catchment of the resource, it is planned to use tanker trucks with attached motor pumps and a hose for suction of the resource of up to 6”, which shall be used only for this activity. The hose shall have a meter or flow meter to control the catchment rate, as well as a grid at the end of the suction hose to avoid entry of solids or any agent suspended in the water that endangers operation of the pump. (**Figure 7.30**).

Figure 7.30 Direct Catchment System from Tanker Truck

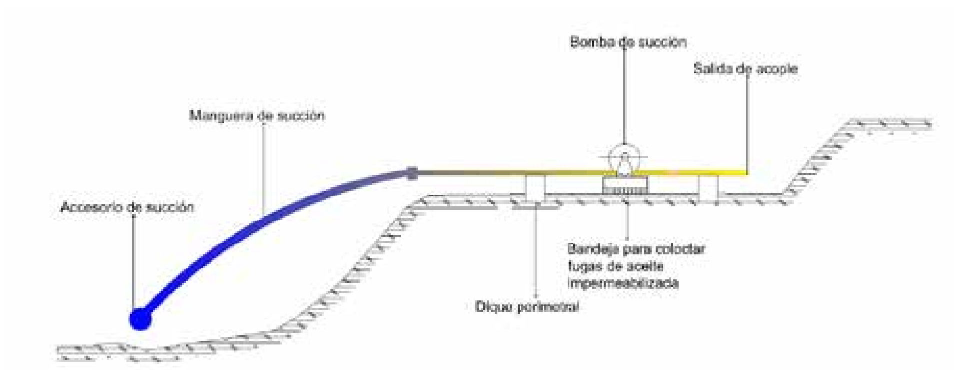


Source: GEOCOL CONSULTORES S.A., 2017.

· **Catchment Through Motor Pump and Flow Line**

As another alternative, there is the direct catchment with motor pump, installed in field and it shall have a contention and/or protection system with geomembrane to control oil and grease spills guaranteeing that it is not located within a bed or interferes with activities made in the current or its margin, as well as that it may not be possibly affected during river or creek flooding. The elements of suction shall be equal to the ones proposed for catchment by tank truck (**Figure 7.31**) and there shall be an output or connection that allows coupling the motor pump fixed to the tank truck or the water shall be transported to camps or work fronts extending a high-pressure hose over the land controlling the flow through flow meters. (**Photograph 7.12**).

Figure 7.31 Typical Scheme of Catchment with Fixed Pump



Source: GEOCOL CONSULTORES S.A., 2017.

Photograph 7.12 Flow Meter

Source: GEOCOL CONSULTORES S.A., 2017.

- **Catchment by Gravity and Flow Line**

Finally, the option of water catchment through land level difference (by gravity) is proposed. For water intake, the end of a hose fitted with a nozzle with a sieve is introduced at a depth that does not allow dragging the material of the bed of the water source. For transport of water, by gravity, from the source to camps or work fronts, as the case may be, a high-pressure hose shall be extended over the land.

7.1.5.2 Transport through Tanker Truck

Transport of the water caught shall be made through tanker trucks used exclusively for this activity. The tanker truck shall be moved from the catchment site to the temporary storage point located in camps, workshops, distribution areas or plants, depending on the demand of the resource.

The resource shall be used for the activities proposed for the project. After start of catchment activities, the corresponding cleaning of the tank shall be made. Once the tank is cleaned, it shall be filled for transport to the temporary storage area.

Tanker trucks used for water transport may not load other substances (chemicals, waste waters, fuels, among others), which can cause deterioration of the water quality or contamination. **Photograph 7.13** shows a tanker truck used for water transport.

Photograph 7.13 Transport of the Resource in Tanker Truck


Source: GEOCOL CONSULTORES S.A., 2017.

The Environmental Management Plan described in Chapter 11.1.1 contains the management measures for the surface water catchment activity.

7.1.5.3 Temporary Storage

Temporary water storage for domestic and industrial use must be separated. Therefore, plastic water storage tanks (duly marked) shall be installed in permanent lodging camps, plants, distribution centers or in other areas requiring the resource.

The temporary water and raw water storage tanks must comply with the general characteristics shown in **Table 7.25.**

Table 7.25 General Characteristics for Potable and Raw Water Storage Tanks

CHARACTERISTIC	DESCRIPTION
Safety	The tank must be located in lands not subject to mudslides or floods. Additionally, it must be stable with respect to the quality of the foundation soil and geotechnical or geological failures.
Ease of Maintenance	The tank must be placed as to be able to conduct maintenance works with the least interruptions possible, considering the following provisions: 1. For the low level of complexity, it can have only one compartment. 2. The tank must be fitted with valves to close the intake and output pipes. 3. The devices for closing the intake and output pipes must be marked in accordance with the color code for pipe and valves. 5. The method and ease of maintenance for the tank must be planned.
Access Restriction	The necessary safety measures must be implemented through fences, restricted access roads, surveillance or any other to prevent the access of strangers.
Tank Location	Location of the tanks must considered the following recommendation: If the tank is buried or semi-buried, it must be far from any source of pollution, such as septic tanks, garbage bunkers, latrines, culverts, among others; and it must have a cover.
Materials	The tank material must resist the strengths caused by pushing of land and flotation in case of being buried or semi-buried, when the tank is empty.
Waterproofing	The walls and background must be waterproofed and the material exposed to water must be resistant to the chemical attacks and corrosion.
Ventilation	Tanks must be fitted with ventilation ducts that allow intake an output of air source with a mesh of 5 mm prevent insects from entering. In case they are PVC, the NTC 1260 technical standard must be observed.

Source: Consorcio SH, 2017.

The potable and industrial water storage tanks are multiple-use polyethylene tanks that allow having a constant water flow and they are easy to clean and resistant to solar exposure and shock. **Table 7.26** contains the specifications of the storage tanks.

Table 7.26 Characteristics of Storage Tanks

CHARACTERISTICS	POTABLE WATER TANK	INDUSTRIAL WATER TANK
Capacity	2500 L	5000 L
Diameter	151 cm	228 cm
Height	165 cm	174 cm
Weight	46.4Kg	113.6 Kg

Source: Consorcio SH, 2017.

The potable water storage tank shall be White so that it refracts solar rays. It has a antimicrobial and nonstick layer in order to minimize changes in color and flavor that can be caused in water for domestic use. For the case of use of the resource in domestic activities, a treatment shall be applied so that the water conditions are appropriate for use. For this purpose, the most feasible alternative is a portable PTAP (Potabilization Treatment Plant).

Water distributional shall be made through gravity by a hydraulic system feeding the different distribution points or hydrants stipulated.

7.1.6 Analysis of the Current or Potential Conflicts about Availability and Uses of Water

According to the survey made in field, within the Area of Influence of the project, for the properties located in the basins where catchment is requested, the main uses of water identified were agriculture and farming. Transitory crops require water the most for irrigation in the agricultural sector and to a lesser extent farming, both for irrigation of pastures and drinking trough for livestock.

Likewise, it was identified that tributaries located in the high part of the basins and, thus, outside the area of influence of the project are the only important sources that supply the villages, jurisdictions and districts due to the quality and quantity conditions. Accordingly, one of the main factors of pressure on the water resource is population growth, having thus adverse consequences that reverse against the community requiring water (located in the area of influence). Given that the water demand grows, discharge of liquid wastes increase having an impact on the quality of the water resource, in some cases, causing water scarcity not for unavailability but for inappropriate quality for human consumption or for use in productive activities.

A conflict identified was the relation of neighbors because people located downstream reproach people located upstream not letting flow the water to their boundaries and/or property, littering or discharging in the source, causing important impacts in the water quality and, thus, in availability of the resource. These interests associated with domestic use, agriculture, farming use, among others, often constitute obstacles instead of searching a solution, which makes it even more complicated.

The main wastes thrown to the water bodies directly or by runoff are due to indiscriminate use of agrochemicals in good times for different crops and in the increase of use of these products to fight plagues of commercial crops as potato, peas, blackberry, among others, have generated negative impacts on the water bodies and thus on the population.

In low-rain seasons, the conflict of use in the area is basically caused by the supply of the water resource due to its fluctuation throughout the annual cycle, which affects water availability, given that a current with a very inconstant hydrological regime is unreliable as water supply source.

7.1.6.1 Minimum and Maximum Return Flows of the Total Supply for Rivers and Creeks where Catchment is required.

The functions of probability distribution are the most concise representation of any empirical distribution since use of different probability distributions and their application shall be subject to the event to be analyzed, the number of records of hydrological data, the methods used for estimation of parameters and the nest statistical adjustment of each distribution, being mathematical methods to forecast the probability of a certain event being equaled or exceeded.

For characterization of the minimum and maximum return flows, for Guáitara River, the information of the limnigraphic station PILCUAN was taken as reference, from which 25 years (1990 to 2014) of multiannual historical monthly records were used. Additionally, for other water sources where catchment is required the flows estimated from the runoff-precipitation model were used. Likewise, in a period of 25 years (1990 to 2014), the estimation of flows is contained in ***Section 5.1.5 Hydrology – Characteristic Flows (Chapter 5_Main Characteristics of the Area of Influence***).

Among the probability distribution used the most in hydrology there is Normal, Exponential, Gamma, Gumbel and Pearson Type III, choosing the one that better adjusts to this study in accordance with the Kolmogorov Smirnov goodness test.

The results obtained from the Kolmogorov Smirnov goodness test for the probability distributions that better adjust to the data of flows of the basin of Guáitara River from the station PILCUAN are contained below.

· **Guáitara River**

Once the goodness tests and the adjustment to the probability distributions made, it was determined that for the data of the station PILCUAN in the basin of Guáitara River, the probability distribution that better adjusts to this case is <u>Gamma</u>, being the best option for calculation of frequencies of minimum and maximum return flows since it generated the best estimator of goodness adjustment (**Table 7.27** and **Figure 7.32**).

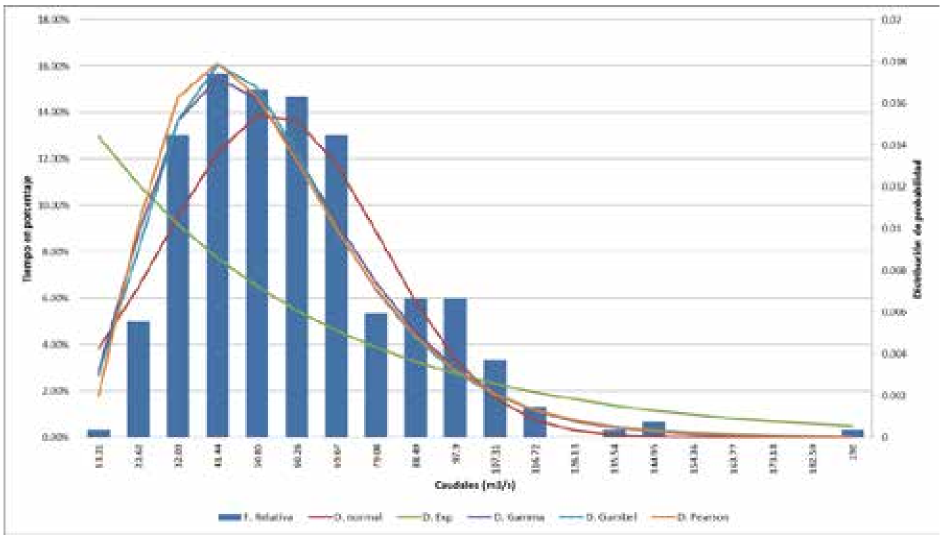
Table 7.27 Goodness Test of Adjustment of Kolmogorov Smirnov - Guáitara River

GUÁITARA RIVER					
TEST	**NORMAL**	**EXPONENTIAL**	**GAMMA**	**GUMBEL**	**PEARSON**
Kolmogorov Smirnov Estimator	0.053	0.286	**0.019**	0.022	0.024
Degrees of freedom	300	300	**300**	300	300
Level of Significance	0.001	0.001	**0.001**	0.001	0.001
n > 50	0.113	0.113	**0.113**	0.113	0.113
Test*	APPROVED	REJECTED	**APPROVED**	APPROVED	APPROVED

*APPROVED: the data of the station **DO** adjust to the function of probabilistic distribution function to estimate the minimum flows; REJECTED: the date of the station **DO NOT** adjust to the function of probabilistic distribution function to determine the minimum flows.

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.32 Hydrograph of Adjustment of Probability Distributions for Guáitara River



Source: GEOCOL CONSULTORES S.A., 2017.

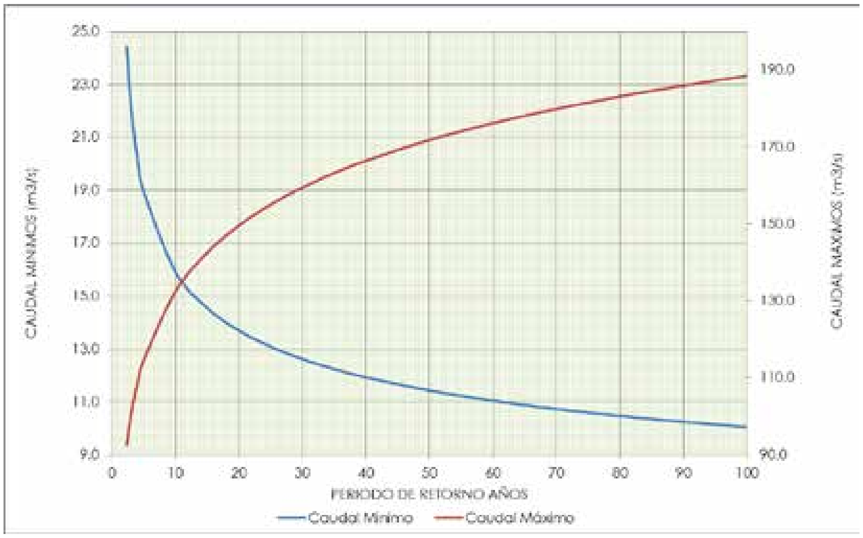
Through the Gamma distribution, the extreme flows were estimated for different periods of return in years. **Table 7.28** shows the estimated maximum and minimum values. For the period equaled exceeded by 100 years, a minimum flow of 10.0 m^3/s and a maximum flow of 188.5 m^3/s were determined. It can also be evidenced that for the period of return of 2.33, 3 and 5 years the minimum flow varies from 24.4 to 19.0 m^3/s and the maximum flow from 92.5 to 114.5 m^3/s, which indicates a significant water supply during the project. (See **Figure 7.33**).

Table 7.28 Minimum and Maximum Flows for Different Periods of Return for Guáitara River – Catchment 1

EXTREME FLOWS OF GUÁITARA RIVER											
PERIOD OF RETURN (YEARS)	2.33	3	4	5	10	15	20	25	30	35	40
MINIMUM FLOWS (m^3/s)	24.4	22.2	20.2	19.0	15.9	14.6	13.7	13.1	12.6	12.2	11.9
MAXIMUM FLOWS (m^3/s)	92.5	100.3	108.4	114.5	132.4	142.5	149.6	155.0	159.5	163.2	166.4
PERIOD OF RETURN (YEARS)	50	60	70	80	85	90	95	98	99	100	
MINIMUM FLOWS (m^3/s)	11.4	11.0	10.7	10.5	10.4	10.2	10.1	10.1	10.1	10.0	
MAXIMUM FLOWS (m^3/s)	171.8	176.2	179.9	183.1	184.6	185.9	187.2	187.8	188.2	188.5	

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.33 Behavior of Minimum and Maximum Flows for Different Periods of Return in Guáitara River – Catchment 1



Source: GEOCOL CONSULTORES S.A., 2017.

Likewise, for the other water bodies where the catchments requested are located a goodness test was conducted to determine the function of probability that better adjusts to the data. The results of extreme flows for different periods of return are presented below and the function of probability that better adjusted is indicated.

· **Extreme Flows according to the Period of Return for Boquerón River - Catchment 2**

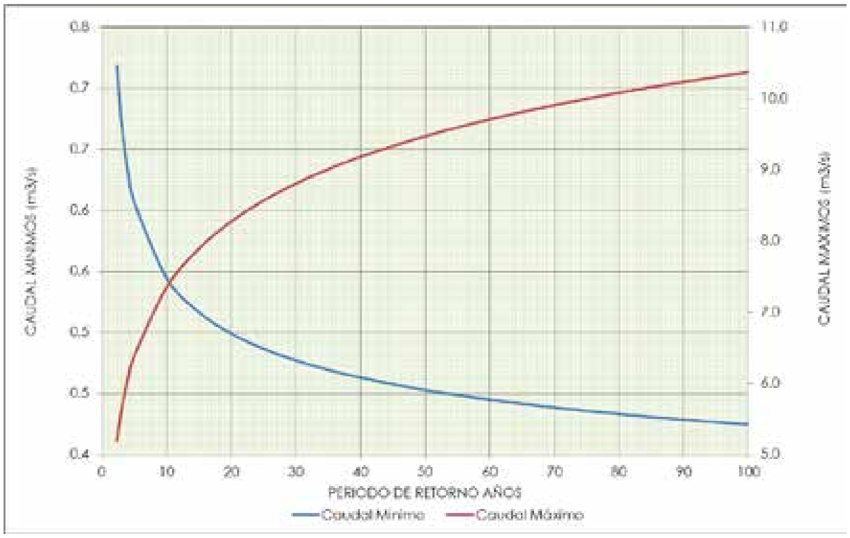
Through the Gamma distribution, the extreme flows were estimated for different periods of return in years. **Table 7.29** shows the estimated maximum and minimum values. For the period equaled exceeded by 100 years, a minimum flow of 0.42 m^3/s and a maximum flow of 10.37 m^3/s were determined. It can also be evidenced that for the period of return of 2.33, 3 and 5 years the minimum flow varies from 0.72 to 0.61 m^3/s and the maximum flow from 92.5 to 114.5 m^3/s, which indicates a significant water supply during the project. (See **Figure 7.34**).

Table 7.29 Minimum and Maximum Flows for Different Periods of Return for Boquerón River – Catchment 2

EXTREME FLOWS BOQUERÓN RIVER											
PERIOD OF RETURN (YEARS)	**2.33**	**3**	**4**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
MINIMUM FLOWS (m^3/s)	0.72	0.67	0.63	0.61	0.54	0.52	0.50	0.49	0.48	0.47	0.46
MAXIMUM FLOWS (m^3/s)	5.20	5.62	6.06	6.38	7.35	7.89	8.27	8.57	8.81	9.01	9.18
PERIOD OF RETURN (YEARS)	**50**	**60**	**70**	**80**	**85**	**90**	**95**	**98**	**99**	**100**	
MINIMUM FLOWS (m^3/s)	0.45	0.45	0.44	0.43	0.43	0.43	0.43	0.43	0.43	0.42	
MAXIMUM FLOWS (m^3/s)	9.47	9.71	9.91	10.08	10.16	10.23	10.30	10.34	10.36	10.37	

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.34 Behavior of Minimum and Maximum Flows for Different Periods of Return in Boquerón River – Catchment 2



Source: GEOCOL CONSULTORES S.A., 2017.

· **Extreme Flows according to the Period of Return for Humeadora Creek - Catchment 3**

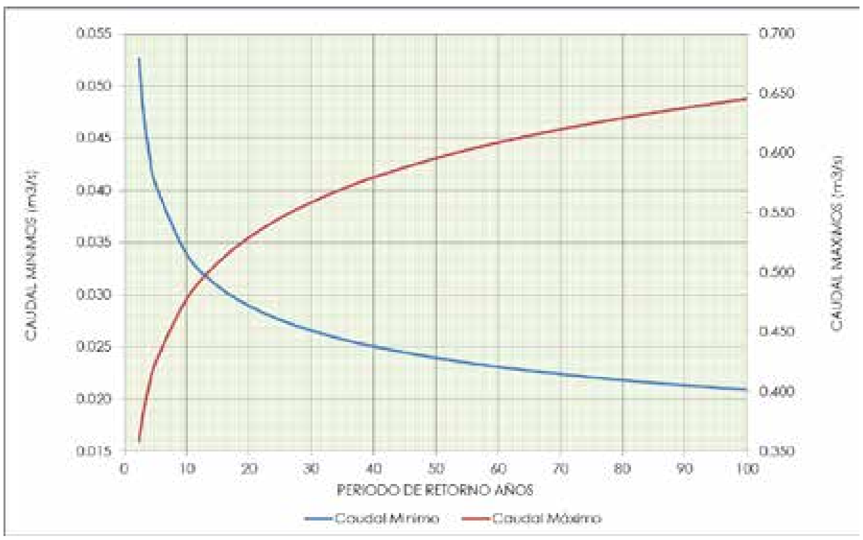
The current of Humeadora Creek presents by implementation of the Gamma distribution method to determine extreme flows for the period of 100 years a minimum flow of 0.021 m^3/s and a maximum flow of 0.646 m^3/s. It can also be evidenced that for a period of return of 2.33, 3 and 5 years the minimum flow varies from 0.053 to 0.041 m^3/s and the maximum flow from 0.359 to 0.424 m^3/s, which indicates a significant water supply for the season requested during the project. (See **Table 7.30** and **Figure 7.35**).

Table 7.30 Minimum and Maximum Flows for Different Periods of Return for Humeadora Creek – Catchment 3

EXTREME FLOWS HUMEADORA CREEK											
PERIOD OF RETURN (YEARS)	**2.33**	**3**	**4**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
MINIMUM FLOWS (m^3/s)	0.053	0.048	0.043	0.041	0.034	0.031	0.029	0.028	0.027	0.026	0.025
MAXIMUM FLOWS (m^3/s)	0.359	0.382	0.406	0.424	0.478	0.508	0.529	0.546	0.559	0.570	0.580
PERIOD OF RETURN (YEARS)	**50**	**60**	**70**	**80**	**85**	**90**	**95**	**98**	**99**	**100**	
MINIMUM FLOWS (m^3/s)	0.024	0.023	0.022	0.022	0.022	0.021	0.021	0.021	0.021	0.021	
MAXIMUM FLOWS (m^3/s)	0.596	0.609	0.620	0.630	0.634	0.638	0.642	0.644	0.645	0.646	

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.35 Behavior of Minimum and Maximum Flows for Different Periods of Return in Humeadora Creek – Catchment 3



Source: GEOCOL CONSULTORES S.A., 2017.

- **Extreme Flows according to the Period of Return for Moledores Creek - Catchment 4**

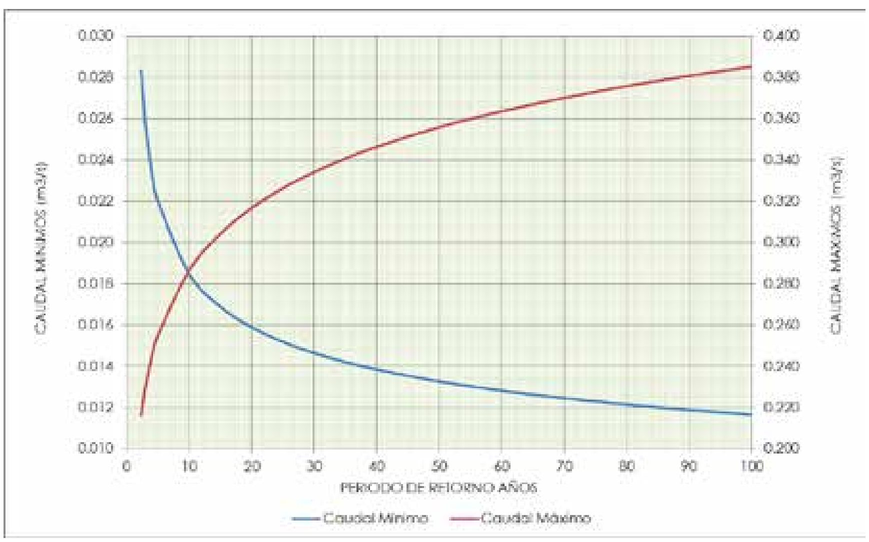
The current of Moledores Creek presents by implementation of the Gamma distribution method to determine extreme flows for the period of 100 years a minimum flow of 0.012 m^3/s and a maximum flow of 0.385 m^3/s. It can also be evidenced that for a period of return of 2.33, 3 and 5 years the minimum flow varies from 0.028 a 0.022 m^3/s and the maximum flow of 0.216 a 0.255 m^3/s, which indicates a significant water supply for the season requested during the project. (See **Table 7.31** and **Figure 7.36**).

Table 7.31 Minimum and Maximum Flows for Different Periods of Return for Moledores Creek – Catchment 4.

EXTREME FLOWS MOLEDORES CREEK											
PERIOD OF RETURN (YEARS)	**2.33**	**3**	**4**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
MINIMUM FLOWS (m^3/s)	0.028	0.026	0.023	0.022	0.018	0.017	0.016	0.015	0.015	0.014	0.014
MAXIMUM FLOWS (m^3/s)	0.216	0.230	0.244	0.255	0.286	0.304	0.317	0.326	0.334	0.341	0.346
PERIOD OF RETURN (YEARS)	**50**	**60**	**70**	**80**	**85**	**90**	**95**	**98**	**99**	**100**	
MINIMUM FLOWS (m^3/s)	0.013	0.013	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	
MAXIMUM FLOWS (m^3/s)	0.356	0.363	0.370	0.376	0.378	0.381	0.383	0.384	0.385	0.385	

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.36 Behavior of Minimum and Maximum Flows for Different Periods of Return in Moledores Creek – Catchment 4.



Source: GEOCOL CONSULTORES S.A., 2017.

· **Extreme Flows according to the Period of Return for San Francisco Creek 2 - Catchment 5.**

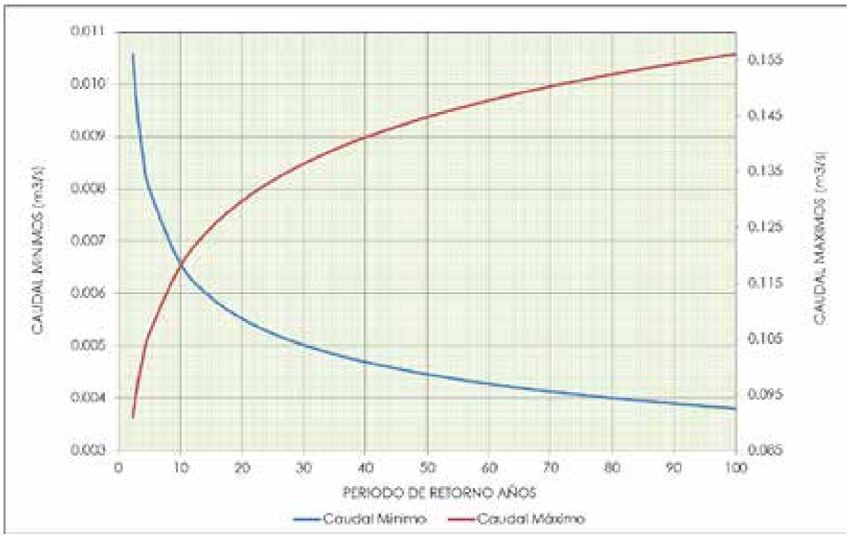
The current of San Francisco Creek 2 presents by implementation of the Gamma distribution method to determine extreme flows for the period of 100 years a minimum flow of 0.004 m^3/s and a maximum flow of 0.156 m^3/s. It can also be evidenced that for a period of return of 2.33, 3 and 5 years the minimum flow varies from 0.011 a 0.008 m^3/s and the maximum flow of 0.091 a 0.106 m^3/s, which indicates a significant water supply for the season requested during the project. (See **Table 7.32** and **Figure 7.37**).

Table 7.32 Minimum and Maximum Flows for Different Periods of Return for San Francisco Creek 2 – Catchment 5.

EXTREME FLOWS SAN FRANCISCO CREEK 2											
PERIOD OF RETURN (YEARS)	**2.33**	**3**	**4**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
MINIMUM FLOWS (m^3/s)	0.011	0.010	0.009	0.008	0.007	0.006	0.006	0.005	0.005	0.005	0.005
MAXIMUM FLOWS (m^3/s)	0.091	0.096	0.102	0.106	0.118	0.125	0.130	0.133	0.136	0.139	0.141
PERIOD OF RETURN (YEARS)	**50**	**60**	**70**	**80**	**85**	**90**	**95**	**98**	**99**	**100**	
MINIMUM FLOWS (m^3/s)	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	
MAXIMUM FLOWS (m^3/s)	0.145	0.148	0.150	0.152	0.153	0.154	0.155	0.156	0.156	0.156	

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.37 Behavior of Minimum and Maximum Flows for Different Periods of Return in San Francisco Creek 2 – Catchment 5.



Source: GEOCOL CONSULTORES S.A., 2017.

· **Extreme Flows according to the Period of Return for Macal Creek - Catchment 6.**

The current of San Francisco Creek 2 presents by implementation of the Pearson distribution method to determine extreme flows for the period of 100 years a minimum flow of 0.008 m^3/s and a maximum flow of 0.333 m^3/s. It can also be evidenced that for a period of return of 2.33, 3 and 5 years the minimum flow varies from 0.020 a 0.015 m^3/s and the maximum flow of 0.196 a 0.227 m^3/s, which indicates a significant water supply for the season requested during the project. (See **Table 7.33** and **Figure 7.38**).

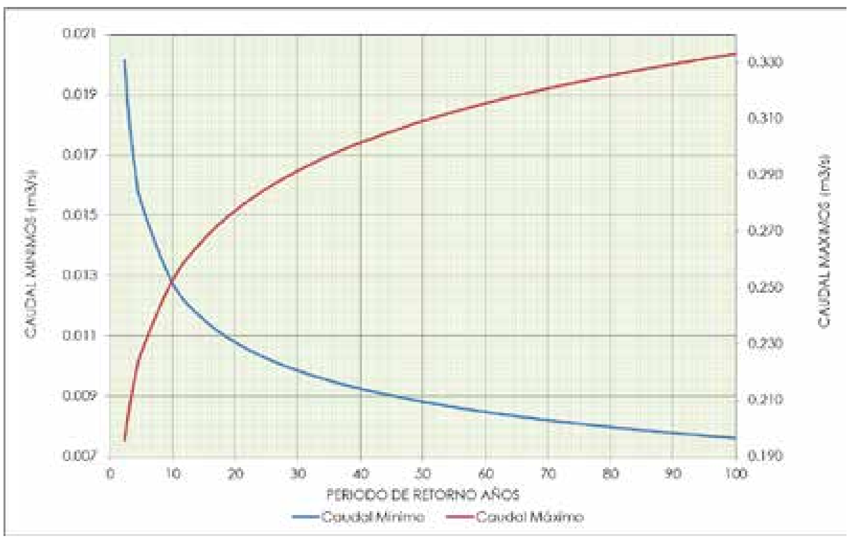
Table 7.33 Minimum and Maximum Flows for Different Periods of Return for Macal Creek – Catchment 6.

EXTREME FLOWS MACAL CREEK

EXTREME FLOWS MACAL CREEK											
PERIOD OF RETURN (YEARS)	2.33	3	4	5	10	15	20	25	30	35	40
MINIMUM FLOWS (m^3/s)	0.020	0.018	0.016	0.015	0.013	0.012	0.011	0.010	0.010	0.010	0.009
MAXIMUM FLOWS (m^3/s)	0.196	0.207	0.219	0.227	0.253	0.267	0.277	0.285	0.292	0.297	0.302
PERIOD OF RETURN (YEARS)	50	60	70	80	85	90	95	98	99	100	
MINIMUM FLOWS (m^3/s)	0.009	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	
MAXIMUM FLOWS (m^3/s)	0.309	0.316	0.321	0.325	0.328	0.329	0.331	0.332	0.333	0.333	

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.38 Behavior of Minimum and Maximum Flows for Different Periods of Return in Macal Creek – Catchment 6.



Source: GEOCOL CONSULTORES S.A., 2017.

· **Extreme Flows according to the Period of Return for Sapuyes River - Catchment 7**

Through the Pearson distribution, the extreme flows were estimated for different periods of return in years. En la **Table 7.34** shows the estimated maximum and minimum values. For the period equaled exceeded by 100 years, a minimum flow of 0.68 m^3/s and a maximum flow of 22.80 m^3/s. It can also be evidenced that for a period of return of 2.33, 3 and 5 years the minimum flow varies from 1.62 a 1.26 m^3/s and the maximum flow of 14.47 a 16.38 m^3/s, which indicates a significant water supply during the project. (See **Figure 7.39**).

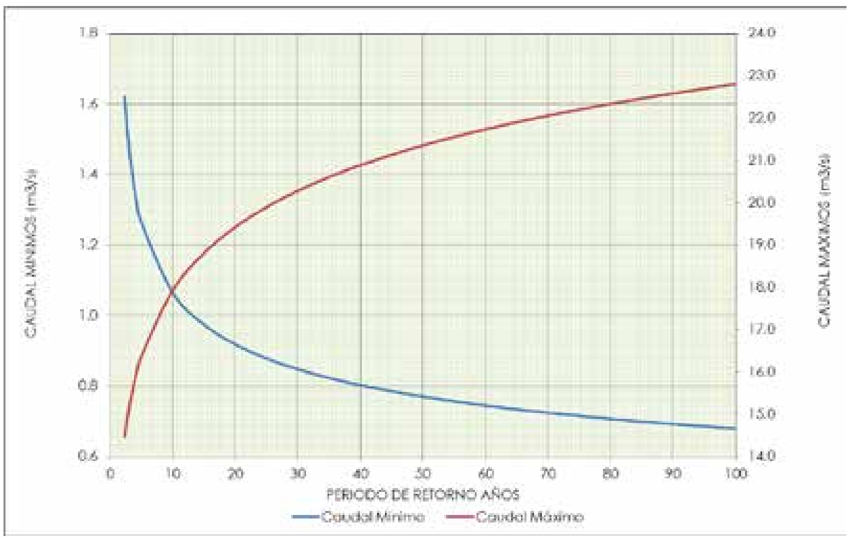
Table 7.34 Minimum and Maximum Flows for Different Periods of Return for Sapuyes River – Catchment 7

EXTREME FLOWS SAPUYES RIVER											
PERIOD OF RETURN (YEARS)	2.33	3	4	5	10	15	20	25	30	35	40
MINIMUM FLOWS (m^3/s)	1.62	1.48	1.35	1.26	1.06	0.97	0.92	0.88	0.85	0.82	0.80
MAXIMUM FLOWS (m^3/s)	14.47	15.14	15.85	16.38	17.93	18.81	19.42	19.90	20.28	20.61	20.89
PERIOD OF RETURN (YEARS)	50	60	70	80	85	90	95	98	99	100	

MINIMUM FLOWS (m^3/s)	0.77	0.74	0.72	0.71	0.70	0.69	0.69	0.68	0.68	0.68
MAXIMUM FLOWS (m^3/s)	21.36	21.74	22.06	22.34	22.46	22.58	22.70	22.75	22.78	22.80

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.39 Behavior of Minimum and Maximum Flows for Different Periods of Return in Sapuyes River – Catchment 7



Source: GEOCOL CONSULTORES S.A., 2017.

- **Extreme Flows according to the Period of Return for Yamurayán Creek - Catchment 8.**

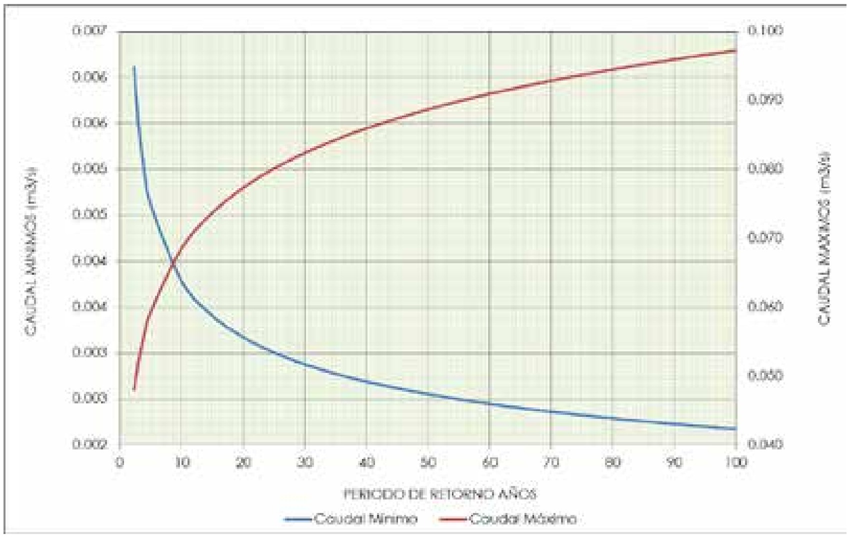
The current of Yamurayán Creek presents by implementation of the Gamma distribution method to determine extreme flows for the period of 100 years a minimum flow of 0.0022 m^3/s and a maximum flow of 0.0972 m^3/s. It can also be evidenced that for a period of return of 2.33, 3 and 5 years the minimum flow varies from 0.0061 a 0.0046 m^3/s and the maximum flow of 0.0480 a 0.0593 m^3/s, which indicates a significant water supply for the season requested during the project. (See **Table 7.35** and **Figure 7.40**).

Table 7.35 Minimum and Maximum Flows for Different Periods of Return for Yamurayán Creek – Catchment 8

EXTREME FLOWS YAMURAYÁN CREEK											
PERIOD OF RETURN (YEARS)	**2**	**3**	**4**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
MINIMUM FLOWS (m^3/s)	0.0061	0.0055	0.0050	0.0046	0.0038	0.0034	0.0032	0.0030	0.0029	0.0028	0.0027
MAXIMUM FLOWS (m^3/s)	0.0480	0.0520	0.0562	0.0593	0.0685	0.0737	0.0773	0.0801	0.0824	0.0843	0.0859
PERIOD OF RETURN (YEARS)	**50**	**60**	**70**	**80**	**85**	**90**	**95**	**98**	**99**	**100**	
MINIMUM FLOWS (m^3/s)	0.0026	0.0024	0.0024	0.0023	0.0023	0.0022	0.0022	0.0022	0.0022	0.0022	
MAXIMUM FLOWS (m^3/s)	0.0887	0.0909	0.0928	0.0945	0.0952	0.0959	0.0966	0.0969	0.0971	0.0972	

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.40 Behavior of Minimum and Maximum Flows for Different Periods of Return in Yamurayán Creek – Catchment 8



Source: GEOCOL CONSULTORES S.A., 2017.

- **Extreme Flows according to the Period of Return for San Francisco Creek - Catchment 9.**

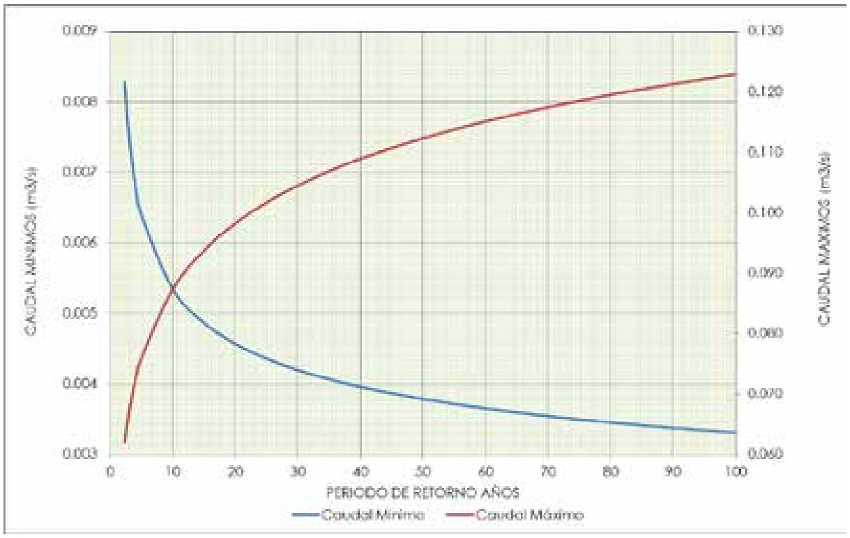
The current of San Francisco Creek presents by implementation of the Gumbel distribution method to determine extreme flows for the period of 100 years a minimum flow of 0.0028 m^3/s and a maximum flow of 0.1229 m^3/s. It can also be evidenced that for a period of return of 2.33, 3 and 5 years the minimum flow varies from 0.0078 a 0.0059 m^3/s and the maximum flow of 0.0621 a 0.0760 m^3/s, which indicates a significant water supply for the season requested during the project. (See **Table 7.36** and **Figure 7.41**).

Table 7.36 Minimum and Maximum Flows for Different Periods of Return for San Francisco Creek – Catchment 9

EXTREME FLOWS SAN FRANCISCO CREEK											
PERIOD OF RETURN (YEARS)	**2.33**	**3**	**4**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
MINIMUM FLOWS (m^3/s)	0.0078	0.0070	0.0063	0.0059	0.0048	0.0044	0.0041	0.0039	0.0037	0.0036	0.0035
MAXIMUM FLOWS (m^3/s)	0.0621	0.0670	0.0722	0.0760	0.0874	0.0938	0.0983	0.1017	0.1045	0.1069	0.1089
PERIOD OF RETURN (YEARS)	**50**	**60**	**70**	**80**	**85**	**90**	**95**	**98**	**99**	**100**	
MINIMUM FLOWS (m^3/s)	0.0033	0.0032	0.0030	0.0030	0.0029	0.0029	0.0028	0.0028	0.0028	0.0028	
MAXIMUM FLOWS (m^3/s)	0.1123	0.1151	0.1175	0.1195	0.1204	0.1213	0.1221	0.1225	0.1228	0.1229	

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.41 Behavior of Minimum and Maximum Flows for Different Periods of Return in San Francisco Creek – Catchment 9



Source: GEOCOL CONSULTORES S.A., 2017.

- **Extreme Flows according to the Period of Return for Culantro Creek - Catchment 10.**

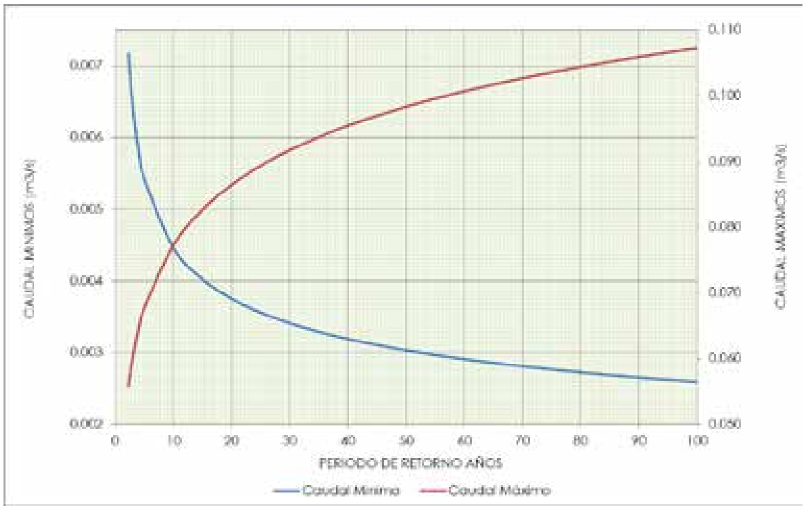
The current of Culantro Creek presents by implementation of the Gumbel distribution method to determine extreme flows for the period of 100 years a minimum flow of 0.0026 m^3/s and a maximum flow of 0.1073 m^3/s. It can also be evidenced that for a period of return of 2.33, 3 and 5 years the minimum flow varies from 0.0072 a 0.0054 m^3/s and the maximum flow of 0.0558 a 0.0676 m^3/s, which indicates a significant water supply for the season requested during the project. (See **Table 7.37** and **Figure 7.42**).

Table 7.37. Minimum and Maximum Flows for Different Periods of Return for Culantro Creek – Catchment 10.

EXTREME FLOWS CULANTRO CREEK											
PERIOD OF RETURN (YEARS)	**2.33**	**3**	**4**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
MINIMUM FLOWS (m^3/s)	0.0072	0.0065	0.0058	0.0054	0.0045	0.0040	0.0038	0.0036	0.0034	0.0033	0.0032
MAXIMUM FLOWS (m^3/s)	0.0558	0.0600	0.0644	0.0676	0.0772	0.0826	0.0864	0.0893	0.0917	0.0937	0.0954
PERIOD OF RETURN (YEARS)	**50**	**60**	**70**	**80**	**85**	**90**	**95**	**98**	**99**	**100**	
MINIMUM FLOWS (m^3/s)	0.0030	0.0029	0.0028	0.0027	0.0027	0.0027	0.0026	0.0026	0.0026	0.0026	
MAXIMUM FLOWS (m^3/s)	0.0983	0.1007	0.1027	0.1044	0.1052	0.1059	0.1066	0.1069	0.1071	0.1073	

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.42 Behavior of Minimum and Maximum Flows for Different Periods of Return in Culantro Creek – Catchment 10.



Source: GEOCOL CONSULTORES S.A., 2017.

- **Extreme Flows according to the Period of Return for El Manzano Creek - Catchment 11.**

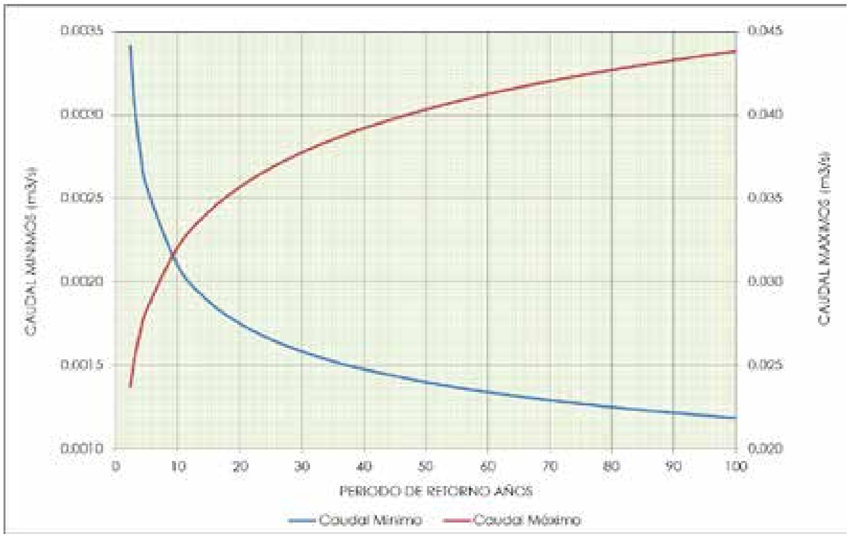
The current of El Manzano Creek presents by implementation of the Gumbel distribution method to determine extreme flows for the period of 100 years a minimum flow of 0.0012 m^3/s and a maximum flow of 0.0438 m^3/s. It can also be evidenced that for a period of return of 2.33, 3 and 5 years the minimum flow varies from 0.0034 a 0.0026 m^3/s and the maximum flow of 0.0238 a 0.0284 m^3/s, which indicates a significant water supply for the season requested during the project. (See **Table 7.38** and **Figure 7.43**).

Table 7.38 Minimum and Maximum Flows for Different Periods of Return for El Manzano Creek – Catchment 11

EXTREME FLOWS EL MANZANO CREEK											
PERIOD OF RETURN (YEARS)	**2.33**	**3**	**4**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
MINIMUM FLOWS (m^3/s)	0.0034	0.0031	0.0028	0.0026	0.0021	0.0019	0.0018	0.0017	0.0016	0.0015	0.0015
MAXIMUM FLOWS (m^3/s)	0.0238	0.0254	0.0271	0.0284	0.0321	0.0342	0.0357	0.0368	0.0378	0.0385	0.0392
PERIOD OF RETURN (YEARS)	**50**	**60**	**70**	**80**	**85**	**90**	**95**	**98**	**99**	**100**	
MINIMUM FLOWS (m^3/s)	0.0014	0.0013	0.0013	0.0013	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	
MAXIMUM FLOWS (m^3/s)	0.0403	0.0413	0.0420	0.0427	0.0430	0.0433	0.0436	0.0437	0.0438	0.0438	

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.43 Behavior of Minimum and Maximum Flows for Different Periods of Return in Culantro Creek – Catchment 10



Source: GEOCOL CONSULTORES S.A., 2017.

7.2 GROUNDWATER

No groundwater concession is requested, given that the water demand for building of the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment shall be satisfied with the sites requested in the surface water sources and with the purchase to authorized companies that provide water with optimal characteristics for human consumption.

7.3 DISCHARGES

As a result of development of the activities inherent in the project at each one of its stages, the domestic and industrial liquid wastes shall be generated and shall be handled and disposed by the company as not to generate alteration to the environment and in compliance with the provisions of the current environmental regulations, Decree 3930 of 2010 (provisions related to uses of the water resource, Water Management and discharges to water, soil and culverts) and Resolution 631 of 2015 (Whereby the parameters and maximum permissible limit values in punctual discharges to surface water bodies and culvert systems are established).

Given the conditions of the area where the activities of the Rumichaca – Pasto divided highway, segment San Juan – Pedregal are planned, the mechanisms of final disposal of liquid wastes generated by such activities, previously treated, shall be discharge to surface source, spraying and/or infiltration fields in camps and management and final disposal by authorized third parties. The general information about the methodologies of disposal proposed for the project is contained below.

7.3.1 Activities Generating Waste Waters

Domestic waste waters generated during building correspond to grey waters (coming from showers, sinks, laundry and kitchen), sewage (coming from toilets located in camps).

Additionally, industrial waste waters are the liquid effluents related to the characteristics inherent in the activity of preparation of aggregates (crushing and asphalt plants), the waters used in washing and cleaning of equipment, warehouses, workshops and rain waters contaminated with oils, chemicals or fuels that have been in contact with equipment.

Table 7.39 shows the sites generating waste waters of the project.

Table 7.39. Sites Generating Waste Waters

NAME	ABCISES	MARGIN	REMARKS
CAMP SAN JUAN	18+800	RIGHT	Lodging Camp Location of offices Concrete plant Crushing Plant
CAMP ILES	31+000	LEFT	Lodging Camp Location of offices Asphalt Plant
CAMP 35+600	35+600	LEFT	Location of offices 2 crushing plants
CAMP MINA MIKEL	41+300	LEFT	Main Camp Lodging Camp Gravity Sieve Two Crushing Plants Asphalt Plant Offices

Source: GEOCOL CONSULTORES S.A., 2015.

7.3.2 Physicochemical Characterization and Flow of Waste Waters to be Generated

7.3.2.1 Flows of Liquid Wastes to be Generated

Domestic Waste Waters

During all the operation, in camps two types of domestic waste waters shall be generated, to wit, sewage and grey waters.

In order to estimate the flow of discharge of domestic waste waters (ARD), the supply calculated in section **7.1.3 Water Flow Required** was used considering that the number of workers projected per camp are (250) and the climate of the area can be considered cold. Therefore, the water demand is 0.45 L/s for each camp. The discharge flow is about **0.36 L/s**, taking 80% as return factor.

Industrial Waste Waters

For calculation of the flow of discharge of industrial waste waters (ARI), at the operation stage 1.5 L/s shall be considered as water supply calculated for use in the process plants of the project.

Considering that the concrete plants have a waste water recirculation system, it is determined that the flow of discharge of industrial waters is **0.075 L/s** since 95 % of the water resulting from the process of the plants shall be recirculated in such a way that only 5% shall be disposed.

Accordingly, **Table 7.40** shows the flows to be discharged in each generation site.

Table 7.40. Flow of Discharge

ID	NAME	TYPE OF WATER	Water Consumption	Waste Water Generation	TOTAL DISCHARGE FLOW (L/s)
			Flow of Water Requested (L/s)	Water Discharge (L/s)	
1	Camp San Juan	ARD	0.45	0.36	0.44
		ARI	1.5	0.075	
2	Camp Iles	ARD	0.45	0.36	0.44
		ARI	1.5	0.075	
3	Camp 35+600	ARD	0.45	0.36	0.44
		ARI	1.5	0.075	
4	Camp Mikel	ARD	0.45	0.36	0.44
		ARI	1.5	0.075	

Source: GEOCOL CONSULTORES S.A., 2017.

7.3.2.2 Characteristics of the Composition of Waste Waters

Domestic Waste Waters

Domestic waste waters are composed of grey water and sewage. The former are characterized by having suspended materials and vegetal origin greases and their organic contamination rate is lower than in sewage, which is characterized by having a high content of organic load and a high population of total and fecal coliforms. (See **Table 7.41**).

Table 7.41. Characterization of Domestic Waste Waters in a Similar Project

PARAMETER	UNIT	REPORTED VALUES
Color	UPC	> 150
Chlorides	mg Cl/l	> 150
BOD	mg O_2/l	> 500
COD	mg O_2/l	> 600
Total hardness	mg $CaCO_3$/l	50
pH	Unit	7- 9
Dissolved Solids	mg/l	300 – 800
Suspended Solids	mg/l	100 – 200
Sulfates	mg SO_4/l	40 – 100
Total coliforms	NMP/100ml	900,000
Fecal coliforms	NMP/100ml	80,000
Greases and oils	mg/l	50- 100

Source: Helios Consorcio Vial, 2008.

Industrial Waste Waters

They are waters coming from activities as concrete plants with a high amount of dissolved and suspended solids and chemical wastes, as shown in **Table 7.42**. Metals vary their concentration according to the needs of the mixture and their disposal.

Table 7.42. Main Characteristics of Waste Waters of a Concrete Plant

PARAMETER	UNITS	RESULT
Chlorides	mg Cl/L	58.8
pH	Units	11
Total Solids	mg/L	499
Sulfates	mgSO_4/L	135
Sedimentable Solids	mg/L	332
COD	PPM	216
Turbidity	FTU	50
Hardness	mg$CaCO_3$/L	4220
Alkalinity	mg$CaCO_3$/L	3389
Arsenic	mg/L	0.5
Barium	mg/L	1.0
Cadmium	mg/L	0.01
Zinc	mg/L	13
Cupper	mg/L	1.0
Mercury	mg/L	0.02
Lead	mg/L	0.05
Selenium	mg/L	0.01

Source: Helios Consorcio Vial, 2008.

7.3.3 Treatment Systems

Annex 14. Use and Exploitation_Discharges_Plan of Management of Discharge Risk shows the measures to be implemented to prevent any contingency with the discharge activity.

7.3.3.1 Domestic Waste Water Treatment Systems

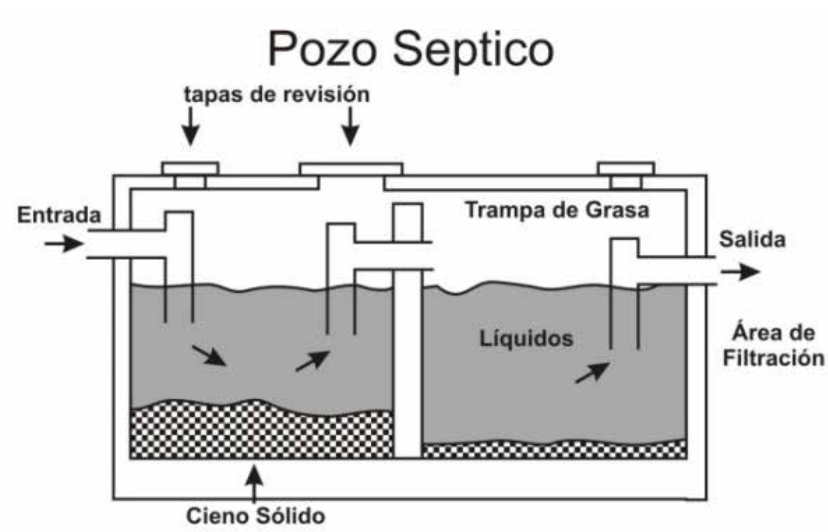
For treatment of domestic waste waters, different treatment systems can be implemented while their effluent complies with the physicochemical parameters to be discharged in the different receiving bodies. Two treatment systems which can be implemented in camps and operating areas are described below. The final decision of implementation of the systems shall depend on the conditions found the volume of waste waters to be treated.

- **OPTION 1**

Septic Tank

Domestic waste waters shall be transmitted to a septic tank which is composed of two chambers connected by a PVC pipe. In the first one for density the biggest solids are decanted and in the second one greases are caught and the smaller solid are decanted. This structure shall be covered to prevent escape of gases and entry of rain water. It can be built in any material complying with the function and not affecting the environment or prefabricated tanks can be installed (**Figure 7.44**).

Figure 7.44 Scheme of Septic Tank



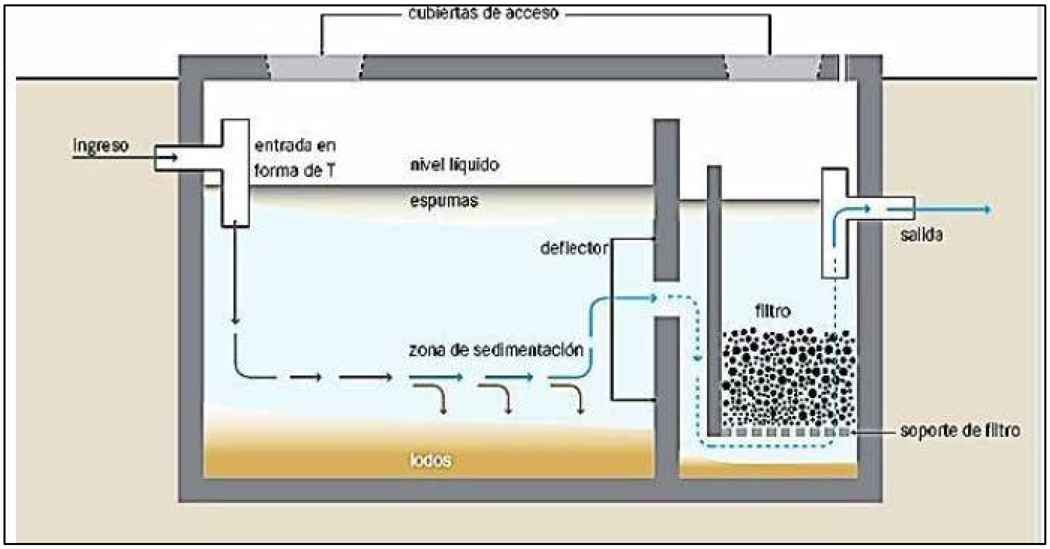
Source: Pan American Health Organization, 2009.

FAFA (Anaerobic Upward Flow Filter) System

Once the flow comes out the septic tank, it is transported to a FAFA filter. The system is composed of a tank or closed chamber composed of one gravel bed where the inflows coming from the septic tank goes upward through the interstices and the biological film formed in the surface of this granular material conducts a digestion work and anaerobia reduction.

The FAFA system is an anaerobic reactor that has an inert filling material. Over the filling material a bacterial population grows degrading the soluble BOD of the inflows resulting in an outflow clarified with a lower organic load (**Figure 7.45**).

Figure 7.45 FAFA System



Source: Alianza por el Agua, 2016.

Once the flow comes out the treatment system, a 95% removal of the contaminant load is expected and can be transported through the storage tanks for final disposal. In every disposal, the parameters that can be determined in site (pH, Color, Chlorine, Turbidity, Conductivity, Temperature and Dissolved Oxygen) shall be monitored.

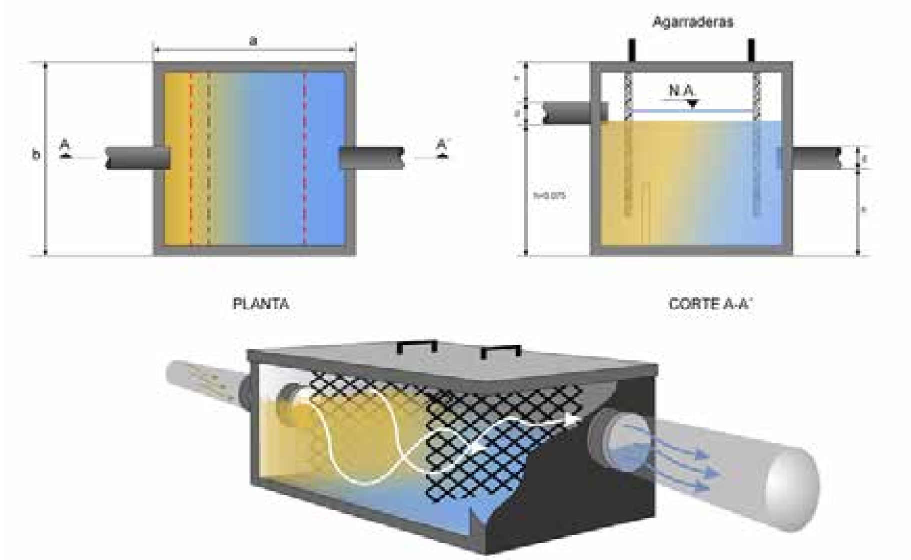
· **OPTION 2**

In order to facilitate management of the domestic waste waters generated during the building stages and guarantee effectiveness of the treatment system, grey waters (coming from showers, sinks, laundry and kitchen) shall be collected separately from sewage (coming from toilets located in camps).

Grey Waters (Grease Trap)

The grey waters shall be subject to a treatment of separation in a grease trap (**Figure 7.46**). This trap shall be conventional and shall have a cover to facilitate segregation of supernatants. It shall be built in any material that allows fulfilling its purpose.

Figure 7.46 Typical Scheme and Dimensions of Grease Trap for Grey Waters



Source: GEOCOL CONSULTORES S.A., 2017.

Cleaning of the grease traps includes manual removal of the supernatants formed, which shall be stored in fully covered trashcans and shall be delivered to companies with the permits for management of these oils. The volumes delivered shall be recorded and a certificate of the appropriate disposal by third parties shall be obtained.

Sewage (Portable Plant)

Sewage is transported from the generation points in PVC pipes of 4" or 6" towards a collecting box of dimensions of 1m * 1m * 1m, where through an electric submersible pump the flow is transported towards the portable Domestic Waste Water Treatment Plant. **Photograph 7.14**.

Treatment of waste waters in the treatment plant starts in the aeration tanks or reactor where aerobic and anaerobic facultative bacteria are formed by the action of an enzymatic complex. Aeration of the effluent with organic matter is the basic process of treatment. Bacteria are multiplied forming the bacterial mud where the organic loads contained in water are consumed. Thereafter, water goes through a section where the flow is stabilized and sedimentation is produced. Then, it is transmitted to a primary sedimentation tank where there are return tubes of floating mud towards the aeration chamber and the precipitated mud is returned to the collection or pumping box to start the process again.

Water overflows to a chlorinator where chlorine is dosed by contact in form of tablets. From there, the effluent is transported to a secondary sedimentation tank.

Each camp shall have a permanent operator in charge of the treatment plant, management of volumes and monitoring of the in-site parameters (pH, Color, Chlorine, Turbidity, Conductivity, Temperature and Dissolved Oxygen) for control and adjustment.

Photograph 7.14 Typical Treatment Plant

Source: GEOCOL CONSULTORES S.A, 2017.

Efficiencies of removal of these plants are 97% under regular operation conditions, for which a good oxygenation shall be made and entry of grey waters to the system shall be avoided since their contents of soap and detergents inhibit formation and development of bacterial mud.

Monitoring shall be made at least every three (3) months to assess efficiency of the domestic waste water treatment plant. Both the inflows and outflows shall be monitored considering the following parameters: Temperature, pH, Conductivity, Dissolved Oxygen, Turbidity, Flow, Actual Color, Total Alkalinity, Total Hardness, Chlorides, Sulfates, Phosphates, Nitrates, Total Suspended Solid, COD, DBO5, Iron, Sodium, Greases and Oils, Total Coliforms and Fecal Coliforms.

Finally, the effluent treated of the PTARD shall be transported to a distribution box where it shale b mixed with the treated grey waters and they are sent to storage tanks for final disposal. For every disposal, the parameters that can be determined in site (pH, Color, Chlorine, Turbidity, Conductivity, Temperature and Dissolved Oxygen) shall be monitored.

Portable Toilets for Domestic Sewage

During the operating stage, as far as work building is concerned, there shall be portable toilets for the staff (See **Photograph 7.15**). Toilets shall be subject to maintenance to guarantee their proper operation. Treatment and disposal of wastes shall be made by the company in charge of maintenance in sites duly authorized for such purpose of through a Public Service Company with the permit to fulfill such task.

As control mechanism, every time maintenance is made to portable toilets, a record shall be signed with the contractor specifying the volumes delivered and the treatment and final disposal site.

Portable toilets include sinks, toilet and a paper and paper towel dispenser. Depending on the number of workers in the work front and considering an average of four (4) entries/day/worker and a use capacity of 100 entries per unit, the number of units required by a work site and frequency of maintenance shall be calculated.

Photograph 7.15 Typical Portable Toilets

Source: GEOCOL CONSULTORES S.A, 2017.

7.3.3.2 Industrial Waste Waters

Industrial waste waters are the liquid effluents related to characteristics inherent in the activity of preparation of aggregates (crushing and asphalt plants), the waters used in washing and cleaning equipment, warehouses, workshops and rain waters contaminated with oils, chemicals or fuels that have been in contact with the equipment.

The basic description of the treatment system for these waters is contained below.

Entry Channel and Grease Trap

Waters that enter in contact with equipment or machinery shall be transported through sump-type perimeter channels towards a grease trap where oils and greases that could be brought by the effluent are separated.

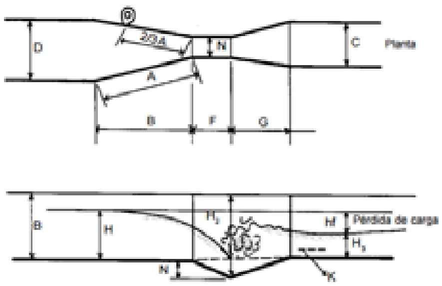
Oils and greases shall be stored in metallic cans, which shall be delivered to the service companies authorized for their treatment and final disposal. The volumes delivered shall be recorded and a certificate of their proper disposal by third parties shall be obtained.

Rapid Mixing System (Flocculator)

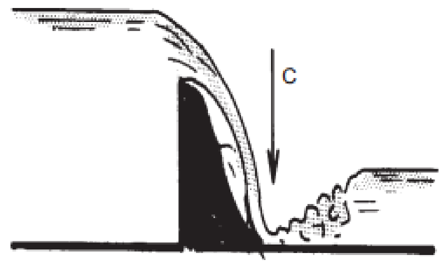
Once the effluent is removed from the supernatants (greases), it is transported to a rapid mixing system (e.g. Parshall Flume, Discharge, among others) (See **Figure 7.47**) where chemicals and flow coagulants are added to the flow. These systems may be built in any material that allows correct operation and does not affect the natural environment where they are installed.

The coagulants are polymers that allow flocculation and decantation of smaller particles. Additionally, pH adjustments and disinfection processes through application of calcium hypochlorite (chlorinated lime).

Figure 7.47 Typical Rapid Mixing Systems



Parshall Flume



Rectangular Landfill

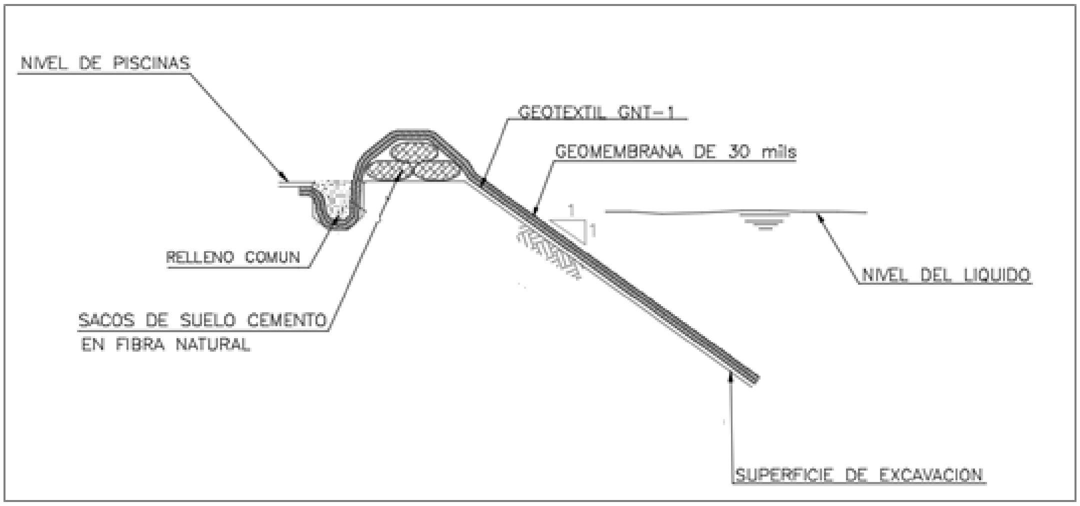
Source: Rapid Mixing Systems, Lidia de Vargas, adapted by GEOCOL CONSULTORES S.A, 2017.

Treatment Pool (Sedimentation Tank)

Once the flow goes out the rapid mixing system, it is transmitted to the treatment pool where through sedimentation processes, the biggest particles and flocs are filtered.

This pool is waterproofed through a high-density geomembrane and geotextile protecting infiltration of liquid wastes to the soil. A perimeter barrier must be built using bags of cement which shall anchor and prevent movement of the geomembrane. (See **Figure 7.48**).

Figure 7.48 Pool Anchoring Systems



Source: GEOCOL CONSULTORES S.A, 2017.

Mixing and Transport Tanks

Once the flow complies with the physicochemical characteristics and parameters to be used in the process or to be discharged, it shall be stored in storage tanks from the place where it is sent to the process plants or discharge site.

7.3.4 For Discharge in Water Bodies

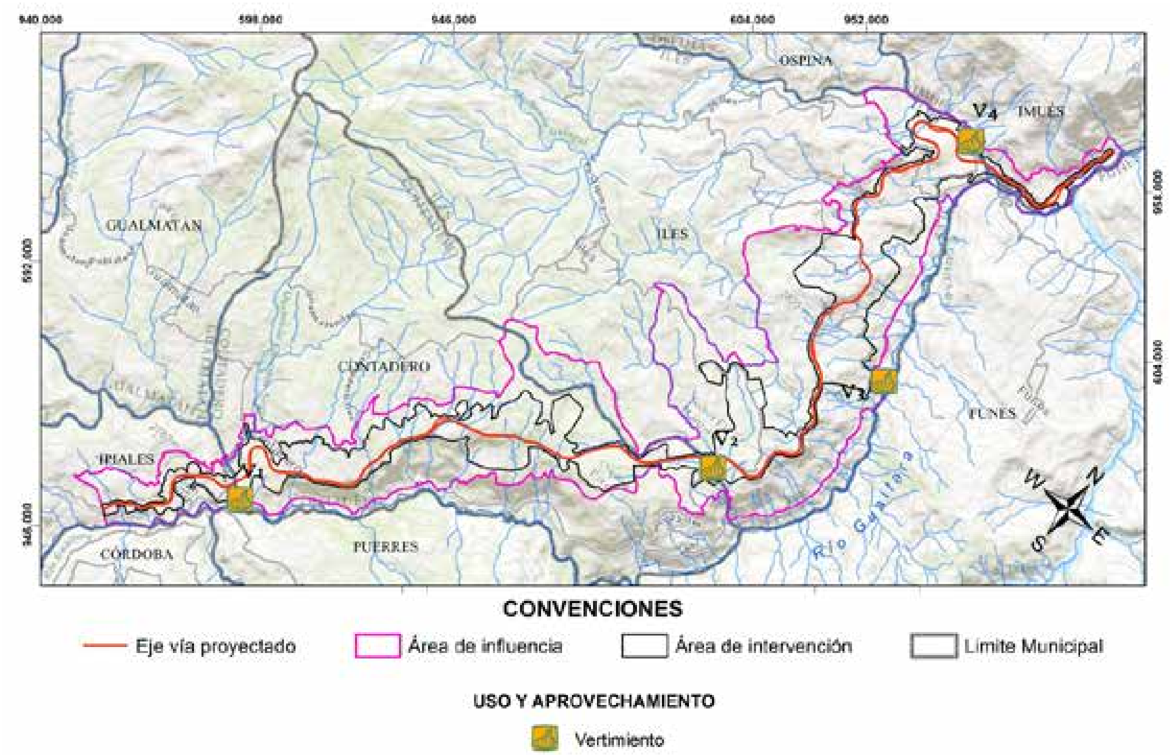
As mentioned throughout this document, the area of influence of the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment is determined at hydrological level of all types to satisfy the specific needs of the project, given the characteristics of the water bodies. Accordingly, final disposal of domestic and industrial waste waters is proposed in the sites and flows indicated in **Table 7.43** and **Figure 7.49**,

Table 7.43. Discharge Strips Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment

ID	SOURCE	MAGNAS SIRGAS COORDINATES ORIGEN WEST		FLOW (L/s)
		EAST	NORTH	
1	Boquerón River (Camp 1)	948589	590972	0.44
2	La Humeadora Creek (Camp 2)	955074	597201	0.44
3	Guáitara River (Camp 3)	956508	600552	0.44
4	Sapuyes River (Camp 4)	954844	605090	0.44

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 7.49 Location of Discharge Sites in Surface Water



Source: GEOCOL CONSULTORES S.A., 2017.

Direct discharge is proposed in three points (points 1, 2 and 4), immediately adjacent to three catchment points proposed (points 2, 3 and 7 respectively) and with a mobility range of up to 100 meters upstream and downstream of the coordinates presented. The discharge shall be made downstream from the point located for catchment. According to the information provided by the community, in dry season (January and September) in discharge point 2 of Humeadora Creek and in accordance with the hydrological analysis made, it would not have enough flow. For this reason, the discharge permit for the rainy season (February – August and October – December) is requested. In such season there would not be any difficulty.

The direct discharge alternative in surface source is proposed as a feasible option for disposal of the treated waters in order to guarantee concentration of contaminants within the ranges established in Resolution 631 dated March 17, 2015.

Identification of the discharge site was defined considering the following parameters:

- Easy access
- Minimal alteration of the existing vegetation
- Sufficient flow guaranteeing assimilation of the discharge
- Inventory of uses and users of the resource

The discharge shall be made through a hose submerged from a tanker truck, which shall have a capacity that varies between 3,200 and 2,700 gallons depending on the vehicle or through flow line from camps.

Assimilation Capacity of Receiving Bodies

Determination of the assimilation capacity of the receiving body was made base on Decree 3930 dated October 25, 2010, which establishes in section 5 of Article 43 that a *"Forecast through simulation models shall be made of the impacts causing the discharge in the water body and/or soil according to the assimilation and dilution capacity of the receiving water body and the uses and criteria of quality established in the Water Management Plan*", assimilation and dilution capacity being understood as the "Capacity of a water body to accept and degrade substances, elements or forms of energy through natural physical, chemical or biological processes without affecting the quality criteria and preventing the assigned uses" pursuant to section 10 of Article 3 of the same Decree. Likewise, Resolution 1514 of 2012 establishing the Discharge Risk Management Plan was considered.

7.3.5 For Discharge in Soils

The waste waters generated by the activities of the project, after having been treated and complied with the quality parameters established in Decree 1594/84 and Decree 3930 of October 2010 shall be subject to final disposal through spraying fields.

For characterization of the soil, sampling was made in municipalities of Ipiales, Iles, Imúes, in jurisdiction of the Department of Nariño, where camps San Juan, Mikel shall be located, 35+600 and 31+100, within the area of influence of the project. The physicochemical analyses were established considering the soils with feasible characteristics for discharge of domestic and industrial waste waters. **See Annex 15 Monitoring_Monitoring of Soils.** The physicochemical analyses of the soil were made by laboratory MCS, Consultoría and Monitoreo Ambiental accredited by the IDEAM and the infiltration tests by GEOCOL CONSULTORES S.A.

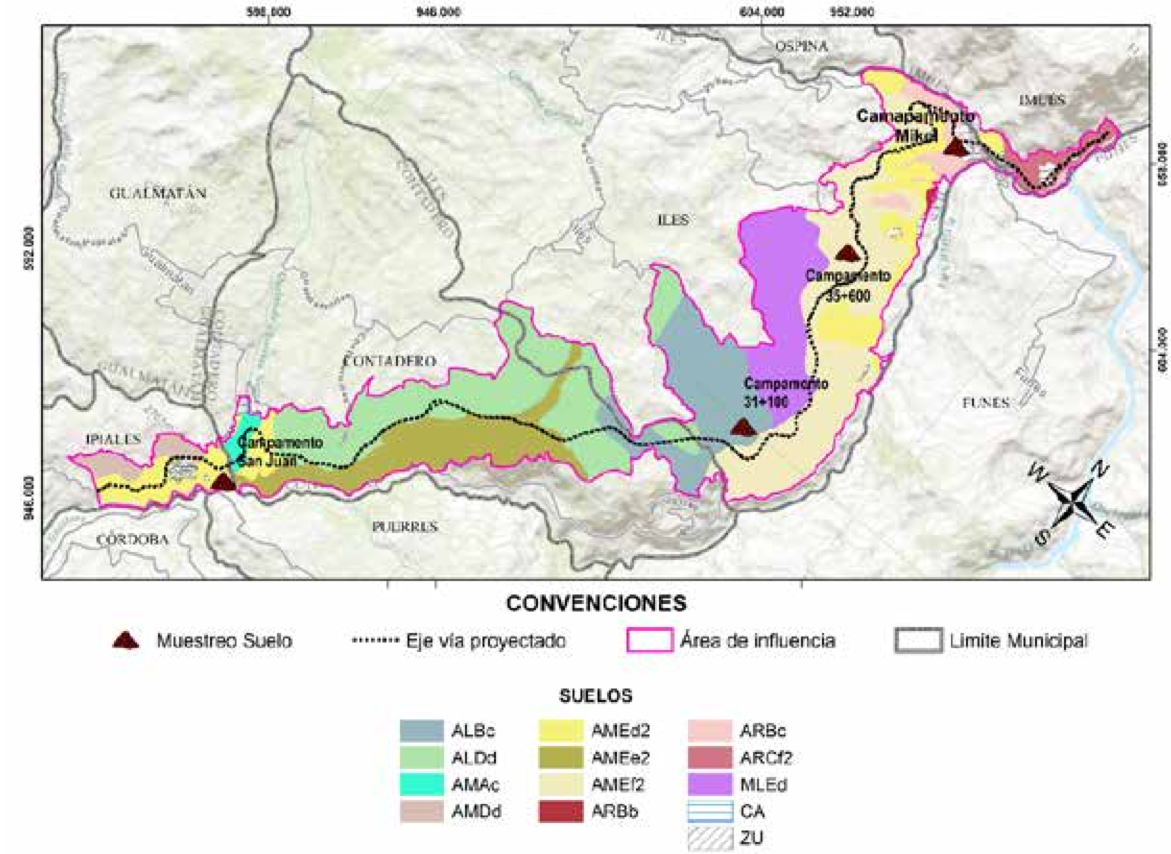
Table 7.44 shows the coordinates and **Figure 7.50** the space distribution of the sites where characterization of the soil (physicochemical analysis) and infiltration tests were made. Two (2) samples of soils, corresponding to the first 2 modal profile horizons surveyed in the soil pit were taken and the infiltration tests were conducted in neighboring areas.

Table 7.44 Soil Sampling Points in the Area of Influence

CAMPS	COORDINATES	
	EAST	NORTH
San Juan	948435	590850
Mikel	954992	604592
35+600	954708	601747
31+100	955307	597957

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.50 Space Distribution of Sampling Points in the Area of Influence



Source: GEOCOL CONSULTORES S.A., 2017.

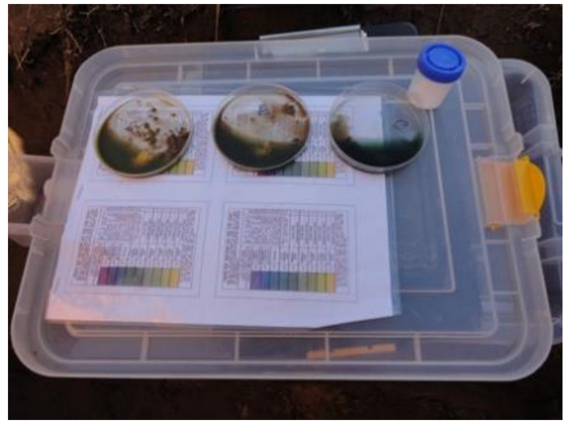
The methodologies used for physicochemical analysis and infiltration tests are described below.

- **Methodology Developed in Filed for Collection of Soil Samples**

Soil samples for the physicochemical analysis were collected in the Area of Influence, specifically where camps were located. Soil samples were taken from horizon A and B of the modal profile, that is, two samples were collected per point. Once the soil samples were taken, they were deposited in Ziploc bags to be later sent to the laboratory for the corresponding analysis. See **Photograph 7.16** and **Photograph 7.19.**

Photograph 7.16 Determination of the Color of the Soil.	**Photograph 7.17 In-Site Characterization of the Soil pH.**

Photograph 7.18 Collection of Samples for Bulk density.



Photograph 7.19 Collection of Soil Samples.

Source: GEOCOL CONSULTORES S.A., 201.7

For general characterization of soils, the following parameters were considered: texture (sand, silt, clay), cationic exchange capacity, pH, RAS, PSI, greases and oils, total hydrocarbons, humidity, field capacity, permanent wilting point, % of aluminum saturation, % of organic carbon, saturation of bases, % of saturation of bases, exchangeable phosphorus, exchangeable potassium, bulk density, electric conductivity, calcium, magnesium, mercury and sodium. The analytical techniques used for the physicochemical analysis of the soil and the quantification limits are shown below. See **Table 7.45.**

Table 7.45 Analytical Methods and Limits of the Louisiana 29B Standard Used for the Physicochemical Analysis of the Soil

PARAMETER	UNITS	ANALYTICAL TECHNIQUE	LIMITS OF THE PROTOCOL OF LOUISIANA 29B
Ph 1:1	Units	Electrometric	6 – 9
Electric conductivity	mmhos/cm	Electrometric	4
Humidity	%	Gravimetric	N.E.
Bulk density	g/cm3	Gravimetric	N.E.
Total organic carbon	% Organic C	Wet oxidation	N.E.

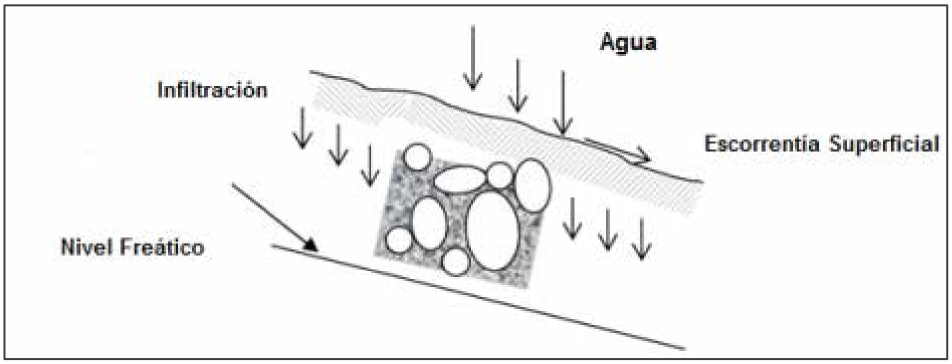
% of aluminum saturation	%	Extraction with KCL 1n. Volumetric - calculation	N.E.
Exchangeable potassium	meq/100cc.s	E.E.A.	N.E.
Calcium	mg/kg (ppm)	E.E.A.	N.E.
Magnesium	mg/kg (ppm)	E.E.A.	N.E.
Sodium	mg/kg (ppm)	E.E.A.	N.E.
Mercury	mg/kg (ppm)	E.E.A./YF	10
RAS		Calculated	<12
Percentage of exchangeable sodium	%	Calculated	<15
Greases and oils	%	extraction with n-hexane	<1
Total hydrocarbons	%	extraction with n-hexane	N.E.
Saturation of bases (Ca, Mg, Na and K -CIC)	%	Calculation	N.E.
Filed capacity	%	Dispersing agent - calculation	N.E.
Permanent wilting point	%p/v		N.E.
Sand	%	Dispersing agent	N.E.
Clay	%	Dispersing agent	N.E.
Silt	%	Dispersing agent	N.E.
Texture	%	Bouyoucos	N.E.
Cationic Exchange capacity	Meq/100g	Volumetric	N.E.

N.E.: NOT ESTABLISHED - N.A.: NON APPLICABLE - E.A.A.: ATOMIC ABSORPTION SPECTROMETRY - E.A.A./V.F. : ATOMIC ABSORPTION SPECTROMETRY WITH COLD VAPOR - NOTE 1: F-A, SANDY-LOAMY - NOTE 2: THE UNITS DE mg/Kg ARE EQUIVALENT TO ppm - NOTE 3: RESULTS EXPRESSED IN DRY BASE. - NOTE 4: TESTS ACCREDITED BY MCS CONSULTORIA RESOLUTION IDEAM 2892 OF DECEMBER 30 2016 AND 0049 OF JANUARY 16 2017 - NOTE 5: TESTS SUBCONTRACTED WITH LABORATORIO CIAN LTDA. ACCREDITED BY THE IDEAM BY RESOLUTIONS 2428 OF OCTOBER 9 2013, 2023 OF AUGUST 11 2014 AND 1951 OF SEPTEMBER 1 2016.

- **Methodology Developed in Filed for Infiltration Tests**

The infiltration is defined as the vertical entry of water in the soil. It decreases gradually with time. It is higher when starting the project and tends to decrease to a minimum value. For the design and application of any soil irrigation method, irrigation must be less than any basic infiltration of soil as not to provoke water access, runoff and saturation over the surface of the soil. See **Figure 7.51** and **Table 7.46** (Classification of the infiltration speed).

Figure 7.51 Soil Infiltration



Source: GEOCOL CONSULTORES S.A., 2017.

Table 7.46 Classification of Infiltration Speed

INFILTRATION cm/hour	INTERPRETATION
<0.1	Very slow
0.1 – 05	Slow
0.5 –2	Moderately slow
2.0 – 6.3	Moderate
6.3 – 12.7	Moderately fast
12.7 – 24.4	Fast
>25.4	Very fast

Source: SOCIEDAD COLOMBIANA DE CIENCIAS DEL SUELO, 2003.

The steps followed for development of the filed infiltration tests are described below.

The infiltration tests were made in surface searching a flat point which shall represent properly the soil characteristics to be assessed following these steps:

- Election of location of rings.
- Placement, water filling and measuring
- Calculation of hydraulic conductivity (K) with the data obtained by the KOSTIACOV method.

Photograph 7.20 Installation of Infiltrometer Before Infiltration Test


Source: GEOCOL CONSULTORES S.A. 2017.

Once the rings are introduced in the land at a depth of 5 cm, it was filled with water at a height of 28 cm. **Photograph 7.21.**

Photograph 7.21 Filling of the Cylinder before the Infiltration Test


Source: GEOCOL CONSULTORES S.A. 2017.

The readings of the height of water infiltrated in the land were made obtaining the accumulated infiltration I(t) = h(t), h being the decrease measured in the instant t. See **Photograph 7.22.**

Photograph 7.22 Descent of the Sheet of Water in the Infiltration Test

Source: GEOCOL CONSULTORES S.A. 2017.

The tests were made in times of up to 180 minutes having as monitoring point a follow-up of the sheet of water during about two (2.5) hours. Once the tests are made, the information corresponding to monitoring was registered in field forms, including date and time, person responsible for the test, origin and other pertinent remarks. See **Photograph 7.23.**

Photograph 7.23 Recordings of Infiltration Tests – Point One (1).

Source: GEOCOL CONSULTORES S.A. 2017.

The results of the infiltration speed were obtained with the formula: $f = at^b$ of the KOSTIAKOV Method (where: *f* is the infiltration speed, *a* and *b* are adjustment coefficients and *t* is the time elapsed from the beginning of infiltration, according to the time) for the test site. When the speeds tend to stabilize and trying to take the highest number of points, the infiltration speed (cm/h), drawn up with a red line, is determined.

The conditions in the land may be varied. It is possible that at the beginning of the experience, the soil is dry or partially wet and, thus, in non-saturation conditions. Then, initial data measurement can provide very high values which shall be decreasing very fast as a result of the pressure exerted by the water column. The higher the water column the higher the pressure shall be. The time elapsed until reaching the final conditions of saturation shall depend on the previous humidity, the texture and the structure of the soil, the thickness of the horizon through which the water passes, and the height of the water in the inner ring.

§ **Results of Physicochemical Analysis**

Table 7.47 shows the laboratory results obtained for the samples taken in filed, which are also presented in **Annex 15 Monitoring_Soil Monitoring**. Additionally, the limit permissible values are presented according to the Louisiana 29B standards.

Table 7.47 Results of the Analysis for Soil Samples

RESULTS OF SOILS ANALYZED											
PARAMETER	UNIT	ANALITYCAL TECHNIQUE	San Juan		Mikel		35+600		31+100		Permissible Limits
			Horizon		Horizon		Horizon	Horizon	Horizon	Horizon	Louisiana 29B
			A	B	A	B	A	B	A	B	
pH 1:1 -	UNITS	ELECTROMETRIC	6.52	6.68	6.21	6.33	5.11	5.35	5.01	5.35	6 - 9
ELECTRIC CONDUCTIVITY	mmhos/cm	ELECTROMETRIC	0.08	0.085	0.26	0.312	0.05	0.065	0.06	0.073	4
HUMIDITY -	%	GRAVIMETRIC	1.52	1.55	1.38	1.42	1.43	1.51	1.48	1.63	N.E.
BULK DENSITY -	g/cm3	GRAVIMETRIC	1.72	1.77	1.73	1.75	1.69	1.71	1.71	1.75	N.E.
TOTAL ORGANIC CARBON	% ORGANIC C	WET OXIDATION	0.29	0.32	0.24	0.26	0.33	0.35	0.25	0.27	N.E.
% OF ALUMINUM SATURATION	%	EXTRACTION WITH KCl 1N. VOLUMETRIC – CALCULATION	0.76	0.79	0.65	0.66	0.79	0.81	0.85	0.87	N.E.
EXCHANGEABLE POTASSIUM	meq/100cc.S	E.E.A.	0.6	0.64	0.62	0.67	0.52	0.53	0.58	0.62	N.E.
CALCIUM	mg/Kg (ppm)	E.A.A.	59.5	60.2	71.2	70.6	42.5	46.2	68.3	69.3	N.E.
MAGNESIUM	mg/Kg (ppm)	E.A.A.	12.3	13.5	15.4	15.1	8.56	7.86	14.2	15.2	N.E.
SODIUM	mg/Kg (ppm)	E.A.A.	85.3	86.5	103	105	65.3	65.3	99.3	102	N.E.
MERCURY	mg/Kg (ppm)	E.A.A./V.F.	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	10
RAS		CALCULATED	0.86	0.89	1.12	1.15	0.69	0.71	1.06	1.13	<12
PERCENTAGE OF EXCHANGEABLE SODIUM	%	CALCULATED	0.43	0.46	0.51	0.66	0.39	0.41	0.35	0.35	<15
GREASES AND OILS	%	EXTRACTION WITH N-HEXANE	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<1
TOTAL HYDROCARBONS	%	EXTRACTION WITH N-HEXANE	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	N.E.
SATURATION OF BASES (Ca. Mg. Na and K -CIC)	%	CALCULATION	0.28	0.29	0.38	0.42	0.27	0.29	0.31	0.33	N.E.
FIELD CAPACITY	%	DISPERSING	26.8	27.1	30.4	31.2	31.5	32.6	28.2	29.2	N.E.

RESULTS OF SOILS ANALYZED											
PARAMETER	UNIT	ANALITYCAL TECHNIQUE	San Juan		Mikel		35+600		31+100		Permissible Limits
			Horizon		Horizon		Horizon	Horizon	Horizon	Horizon	Louisiana 29B
			A	B	A	B	A	B	A	B	
		AGENT – CALCULATION									
PERMANENT WILTING POINT	%P/V		15.4	16.2	15.2	14.6	14.6	15.3	14.9	15.3	N.E.
SAND	%	DISPERSING AGENT	66	68	64	66	62	63	68	71	N.E.
CLAY	%	DISPERSING AGENT	14	15	14	12	12	13	16	15	N.E.
SILT	%	DISPERSING AGENT	20	17	22	22	26	24	16	14	6 - 9
TEXTURE	%	BOUYOUCOS	F-A	F-A	F-A	F-A	F-A	F-A	F-A	F-A	4
CATIONIC EXCHANGE CAPACITY	meq/100g	VOLUMETRIC	13.4	14.1	16.2	17	11.5	12.2	12.5	12.6	N.E.

Source: CIAN LTDA., 2017

- **Analysis of Results**

Then, the analysis of results for each parameter is presented.

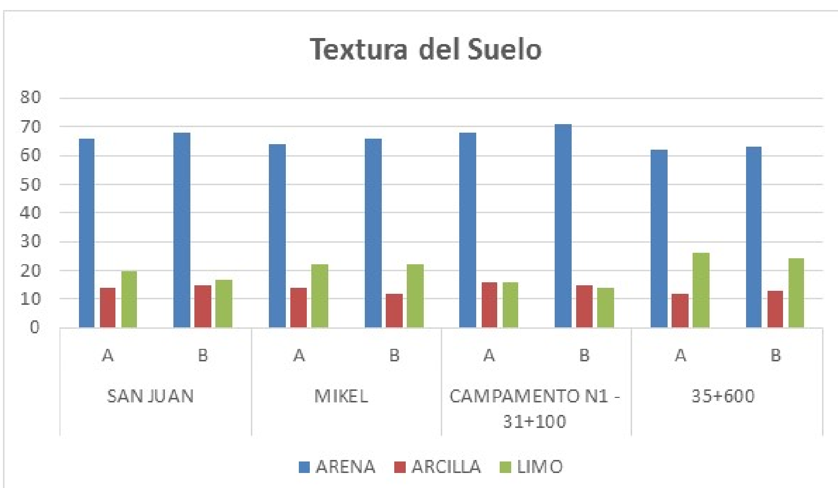
Texture: The texture is related to the ease with which soil can be worked, the amount of water and air that it retains and the speed at which water penetrates or goes through the soil. The monitoring points are homogeneous reporting loamy-sandy textures. This is reflected in the proportion of sand, clay and silt obtained in the laboratory (See **Table 7.48** and **Table 7.49**). In all the soils, there is a higher percentage of sand, which allows a significant aeration and even though they absorb water well, they do not have the capacity to retain it. Therefore, the nutrients, dragged by lixiviation to the subsoil, are not kept either.

Table 7.48 Results of the Analysis of Texture for each Soil

REPORT OF TEXTURE RESULTS				
IDENTIFICATION	TEXTURE (PERCENTAGE)			TEXTURE CLASS
	SAND	CLAY	SILT	
SAN JUAN HA	66	14	20	F-A
SAN JUAN HB	68	15	17	F-A
MIKEL HA	64	14	22	F-A
MIKEL HB	66	12	22	F-A
CAMP N1 - 31+100 HA	68	16	16	F-A
CAMP N1 - 31+100 HB	71	15	14	F-A
35+600 HA	62	12	26	F-A
35+600 HB	63	13	24	F-A

F: Loamy A: Sand Ar: Clay
Source: CIAN LTDA., 2017

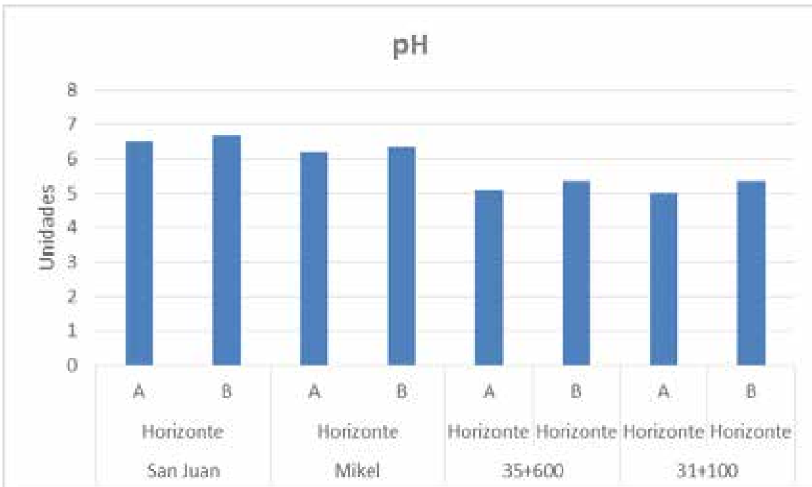
Table 7.49 Percentages of Texture Present in Horizons A and B of the Soil



Source: CIAN LTDA., 2017

pH: The samples obtained from Horizons A and B of the soil registered the highest pH value in camp San Juan, reporting values of 6.68 units in Horizon B; having a similar behavior between each Horizon and minimal variation in the other points assessed; which confirms that the soils have an acid trend. See **Table 7.50.**

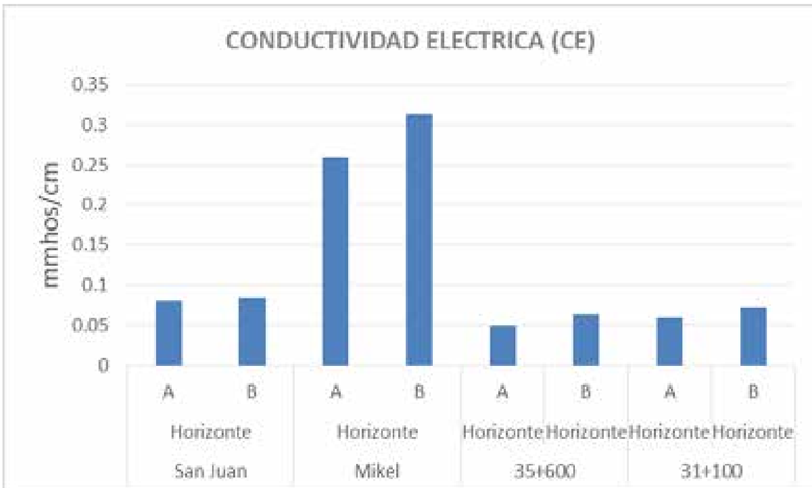
Table 7.50 PH Variation



Source: CIAN LTDA., 2017

Electric Conductivity: it is influenced by a combination of physicochemical properties of the soil, as texture, content of organic matter, soil humidity, cationic exchange capacity, salinity, pH and concentration of some ions. As for behavior of this variable in the samples of Horizons A and B, in the different camps, it can be established that the soils having a higher conductivity correspond to camp Mikel; however, they are within the permissible limit. See **Table 7.51.**

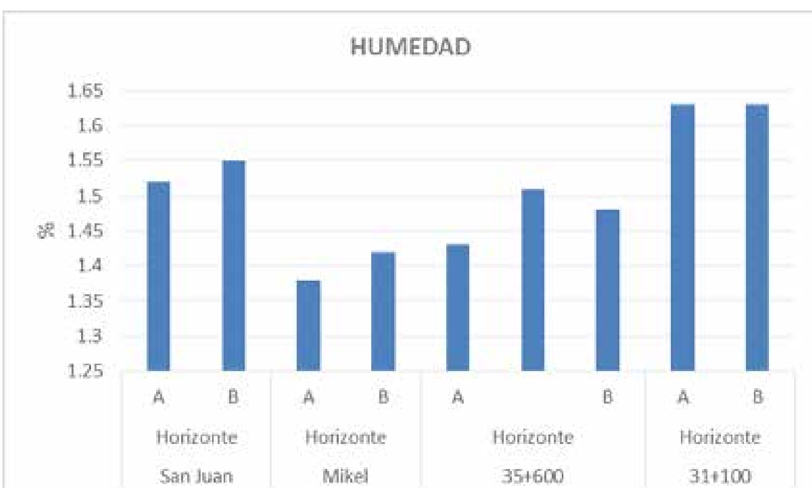
Table 7.51 Variation of Electric Conductivity



Source: CIAN LTDA., 2017

Humidity: Table 7.52 shows that the soils with the highest humidity percentage correspond to camp 31+100. In general, the values are very low for the points assessed since they have a value below 1.65%.

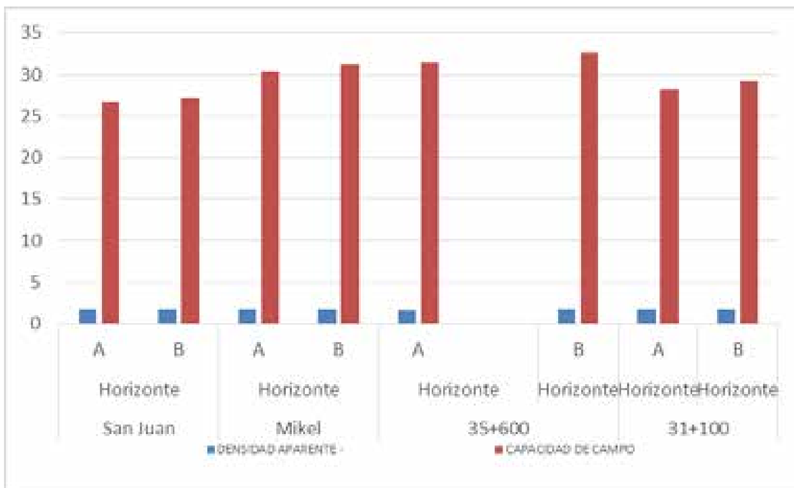
Table 7.52 Variation of Humidity



Source: CIAN LTDA., 2017

Permanent Wilting Point and Filed Capacity: The PWP is defined as the content of humidity of the soil in which plants present an irreversible wilting degree; while the field capacity is defined as the content of humidity that the soil is capable of retaining. In the points assessed it is evidenced that the results do not vary significantly, still corresponding to the texture group. See **Table 7.53**.

Table 7.53 Variation of the Permanent Wilting Point and Field Capacity



Source: CIAN LTDA., 2017

Relation of Sodium Absorption (RAS) and Exchangeable Sodium Percentage (ESP): the RAS recorded values between 0.69 for Horizon A from the point 35+600 and of 1.15 for Horizon B from the point Mikel, being considered low values. Therefore, it is possible to dismiss problems of soil sodification, consistent with the results for the exchangeable sodium percentage (ESP) which recorded values of 0.39 % and 0.66% of content of exchangeable sodium, respectively. This confirms the soil low salinization for the possible undue use of components with sodium content, also verified by the low concentration of conductivity present in the samples.

Cationic Exchange Capacity (CIC): In relation with the cationic exchange capacity, it is defined as the capacity of organic and inorganic colloids of the soil to absorb ions and exchange them with the ions of the soil solution. The soils assessed have appropriate values for different uses for not presenting dramatic alterations for the possible supply of fertilizing components since it is possible to exclude the influence of the intensive agriculture in the monitored point.

Greases and Oils and Hydrocarbons: for Horizons A and B greases and oils in all the monitoring points had values below the permissible limits of the analytical technique used in the laboratory (<0.02 %,). Therefore, it is possible to dismiss presence of this type of organic component in the soil horizons. Additionally, total hydrocarbons had the same behavior, registering values below the limit of the technique of the method used by the laboratory (<0.002%), which determines that the soil analyzed does not have any alteration degree for the effects of organic components, which involves that there are not anthropogenic activities that affect the soil in relation with the latter parameter which is not contained in the regulations.

Mercury: concentrations below the limit of the analytical technique used in the laboratory <0.200 mg/Kg (ppm) were registered for all the monitoring points. Alteration of the soil for this component is dismissed.

Macronutrients: The contents of macronutrients of the soil are as exchangeable potassium, Calcium and Magnesium recorded values that are found naturally in soils. The values indicate that they are soils rich in nutrients.

§ **Results of Infiltration Tests**

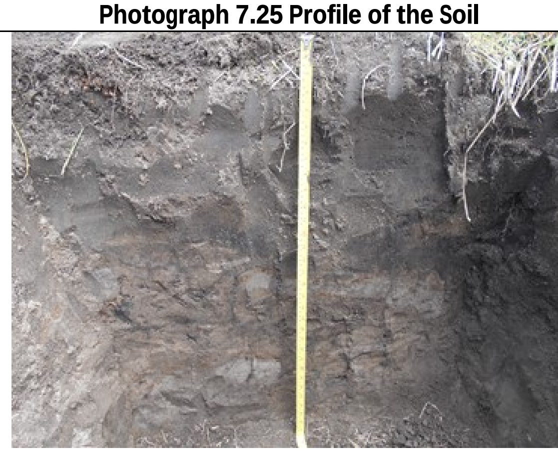
Results of the infiltration tests made in each one of the camps within the Area of Influence are shown below.

§ **Camp San Juan**

Soils in the area proposed for discharge are used for agriculture (crops of blackberries, peas and potatoes), are generally characterized by having a loamy-sandy texture, granular structure and in blocks in Horizon A and B. See **Photograph 7.24** and **Photograph 7.25**.

Photograph 7.24 Spraying Area

Photograph 7.25 Profile of the Soil

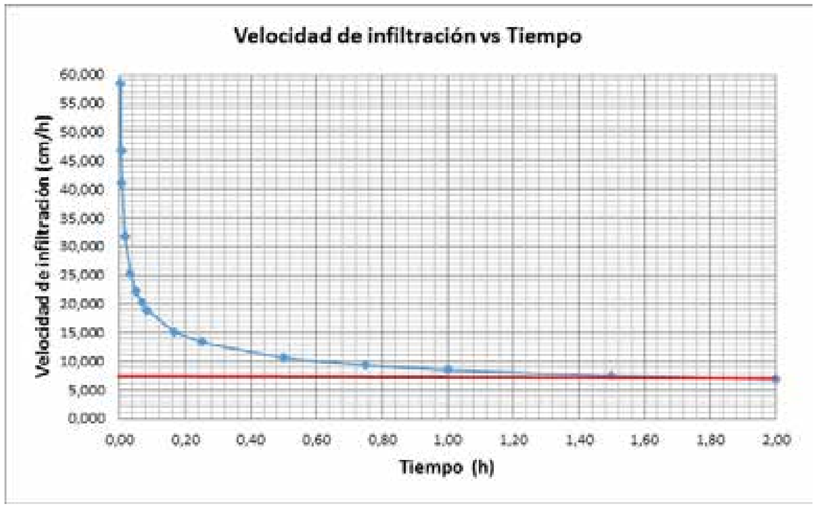


Source: GEOCOL CONSULTORES S.A. 2017.

Considering the results of the infiltration test corresponding to Camp San Juan, it is possible to establish that the soil has an infiltration speed of 7.3cm/h, being described as fast. See **Figure 7.52**.

Figure 7.52 Infiltration Speed of Camp San Juan.

Infiltration Speed (min)	Infiltrated Sheet (cm)
0.00	57.50
0.15	57.20
0.30	57.00
0.45	56.90
1.00	56.60
2.00	55.50
3.00	54.50
4.00	54.00
5.00	53.50
10.00	50.50
15.00	48.00
30.00	42.00
45.00	34.50
60.00	28.50
90.00	21.00
120.00	15.00
150.00	10.00



Source: GEOCOL CONSULTORES S.A. 2017.

§ **Camp Mikel**

Soils in the area proposed for discharge in camp Mikel are used for agriculture (crops of corn, beans and coffee). In general, they are characterized by having a loamy-sandy texture, granular structure in Horizon A and B. See **Photograph 7.26** and **Photograph 7.27**.

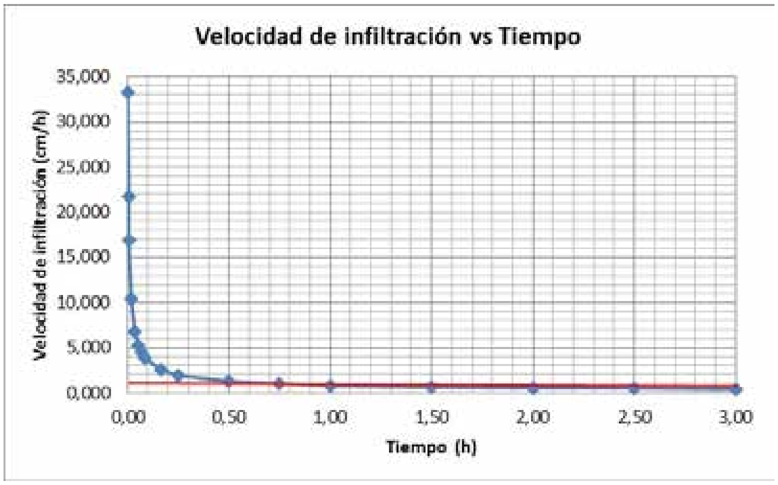
Photograph 7.26 Spraying Area	Photograph 7.27 Soil profile
	

Source: GEOCOL CONSULTORES S.A. 2017.

Considering the results of the infiltration test corresponding to Camp Mikel, it is possible to establish that the soil has an infiltration speed of 1,1cm/h, being described as moderately slow. See **Figure 7.53.**

Figure 7.53 Infiltration Speed of Camp Mikel

Infiltration Time (min)	Infiltrated Sheet (cm)
0.00	27.00
0.15	27.00
0.30	27.00
0.45	27.00
1.00	26.90
2.00	26.80
3.00	26.60
4.00	26.50
5.00	26.40
10.00	26.00
15.00	25.60
30.00	24.40
45.00	22.50
60.00	21.50
90.00	18.60
120.00	16.00
150.00	14.00
180.00	12.50



Source: GEOCOL CONSULTORES S.A. 2017.

§ **Camp 35+600**

Soils in the area proposed for discharge of camp 35+600 are used for agriculture (Crop of onion-Farming). In general, they are characterized by having a loamy-sandy texture. See **Photograph 7.28** and **Photograph 7.29**.

Photograph 7.28 Spraying Area	Photograph 7.29 Soil Profile
	

Source: GEOCOL CONSULTORES S.A. 2017.

Considering the results of the infiltration test corresponding to Camp 35+600, it is possible to establish that the soil has an infiltration speed of 0.08cm/h being described as very low. See **Figure 7.54.**

Figure 7.54 Infiltration Speed of Camp 35+600.

Infiltration Time (min)	Infiltrated Sheet (cm)
0.00	28.50
0.15	28.40
0.30	28.40
0.45	28.40
1.00	28.40
2.00	28.40
3.00	28.30
4.00	28.30
5.00	28.30
10.00	28.30
15.00	28.30
30.00	28.30
45.00	28.10
60.00	28.10
90.00	28.00
120.00	27.90
150.0	27.80
180.00	27.60

Source: GEOCOL CONSULTORES S.A. 2017.

§ **Camp 31+100**

The soils in the area proposed for discharge in camp 31+100 are used for agriculture (crop of potato) and farming. In general, they are characterized by having a loamy-sandy texture in the entire profile. See **Photograph 7.30** and **Photograph 7.31**.

Photograph 7.30 Spraying Are	Photograph 7.31 Soil Profile
	

Source: GEOCOL CONSULTORES S.A. 2017.

Considering the results of the infiltration test corresponding to Camp 31+100, it is possible to establish that the soil has an infiltration speed of 0.06cm/h, being described as very slow. See **Figure 7.55.**

Figure 7.55 Infiltration Speed in Camp 31+100

Infiltration Time (min)	Infiltrated Sheet (cm)
0.00	27.00
0.15	27.00
0.30	27.00
0.45	27.00
1.00	27.00
2.00	26.90
3.00	26.90
4.00	26.90
5.00	26.90
10.00	26.90
15.00	26.80
30.00	26.60
45.00	26.00
60.00	26.00
90.00	25.50
120.00	25.00
150.0	24.20
180.00	24.00

Source: GEOCOL CONSULTORES S.A. 2017.

Table 7.54 shows the infiltration speeds within the Area of Influence indicating that the soils have infiltration speeds from very fast to very slow. Los infiltration speeds are due to the state of saturation of soils at the moment of tests.

Table 7.54 Infiltration Speeds in the Area of Influence

CAMP	INFILTRATION SPEED (CM/H)	INTERPRETATION
San Juan	7.3	Very fast
Mikel	1.1	Moderately slow
35+600	0.08	Very slow
31+100	0.06	Very slow

Source: GEOCOL CONSULTORES S.A. 2017.

7.3.5.1 Assessment of the Risk of Contamination of the Aquifer

With the purpose of establishing the risk of contamination of aquifers due to discharge of treated waste waters in the soil, the flow of water was modeled for each one of camps, as well as theoretical degradation of some substances of environmental interest present in the industrial and domestic waste waters.

In order to model discharge in soil, software HYDRUS 1D (Šimůnek et al., 2014) version 4.16 was used. Such software solves numerically the Richards equation for the flow of waters in porous means with variable saturation, as well as advection-dispersion equations for transport of solutes.

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x}\left[K\left(\frac{\partial h}{\partial x} + \cos\alpha\right)\right] - S$$

Where:

h: pressure head [L].

θ: Volumetric content of water [L^3L^{-3}].

t: time [T].

x: spatial coordinate [L] (positive upward).

S: volume of water removed by the plants from a volume unit of soil per time unit [$L^3L^{-3}T^{-1}$].

α: angle between the direction of flow and the vertical axis.

K: function of unsaturated hydraulic conductivity [LT-1].

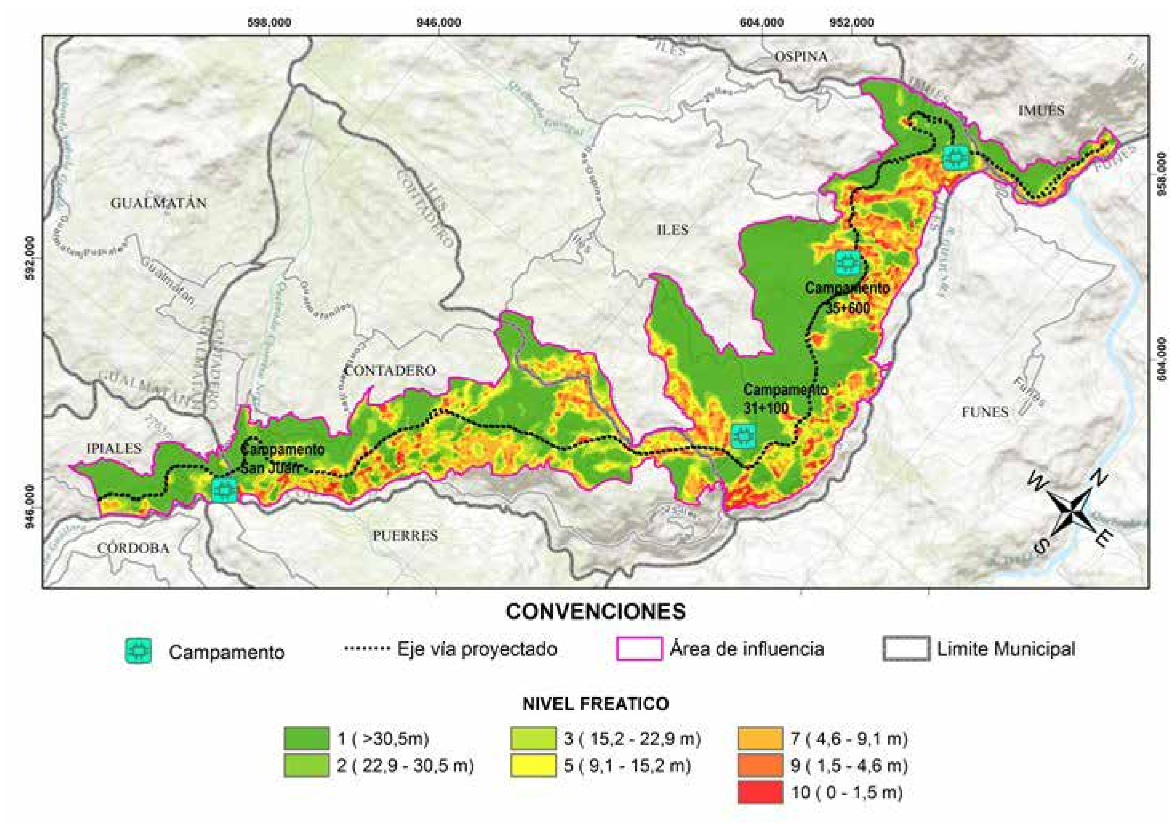
Modeling was made considering the physicochemical characteristics of soils, initial concentration of six (6) substances of environmental interest present in industrial and domestic waste waters, variation of the phreatic level according to depth of the soil (see **Figure 7.56**), and the weather elements that could affect disposal of waste waters, including daily values of precipitation and evaporation available registered by the IDEAM station closest to the area of influence *Station 52055010 APTO SAN LUIS - 2015, municipality of Aldana Nariño* (**Annex 5. Soils_Climate Data**) in order to assess possible impacts of users of the groundwater.

The input data for calculation of the infiltration areas and environmental modeling were a period of operation of the system of 12 months and a waste water discharge flow of 6.3 m^3/d, which was calculated based on the maximum waste water discharge flow of 0.4l/s and a daily operation time of four (4) hours so that the areas calculated correspond to a scenario of operation of the infiltration system at maximum capacity.

The contaminants assessed in modeling were hydrocarbons, greases and oils, ammoniacal nitrogen, linear alkylbenzene sulphonate, sulfates and chlorides; since these substances are the most relevant in the composition of industrial and domestic waste waters. The initial concentrations of the solutes modeled were taken from monitoring of inflows of PTARI of similar projects, that is, that the initial concentrations of contaminants correspond to waste water without previous treatment.

Modeling of discharge of untreated waters in the soil is intended for assessing conditions of risk of groundwater, considering a scenario in which the water treatment systems are out of operation.

Figure 7.56 Distribution of Phreatic Level in the Area of Influence



Source: GEOCOL CONSULTORES S.A. 2017.

Table 7.55 shows the physical properties of the soils where the infiltration tests were conducted and **Table 7.56** shows the chemical properties of each solute, including the air diffusion coefficients (Da) and water diffusion coefficients (Dw), the constant of the Law of Henry (H), the soil-water partition coefficient (Kd) and the initial concentration.

Table 7.55 Input Data for Discharge Modeling

CAMP POINT	INFILTRATION SPEED (CM/H)	AREA (M2)	DEPTH OF THE PHREATIC LEVEL (M)	DISCHARGE FLOW (L/S)	TEXTURE	BULKY DENSITY – DA (G/CM3)	FIELD CAPACITY – CC (%P/V)	PERMANENT WILTING POINT – PWP (%)
San Juan	7.3	920	32	0,4	Loamy Sandy	1.72	26.8	15.4
				0,4		1.77	27.1	16.2
Mikel	1.1		12	0,4	Loamy Sandy	1.73	30.4	15.2
				0,4		1.75	31.2	14.6
35+600	0.08		19	0,4	Loamy Sandy	1.69	31.5	14.6
				0,4		1.7	32.6	15.3
31+100	**0.06**		8	0,4	Loamy Sandy	1.71	28.2	14.9
				0,4		1.75	29.2	15.3

Source: GEOCOL CONSULTORES S.A. 2017.

Table 7.56 Chemical Properties of Modeled Solutes

Parameter	Kd (cm3/kg)	Da (cm2/d)	Dw (cm2/d)	H	Concentration - Untreated (mg/cm3)
Hydrocarbon	1580000	5702.4	0.73008	12.8	0.0701
Greases and oils	1580000	5702.4	0.73008	12.8	0.099
Ammoniacal Nitrogen	6.1806	22377.6	5.98752	0.01363496	0.0125
Linear alkylbenzene sulphonate	4178.5923	-	-	0.00635	0.00594
Chlorides (Cl-1)	-	-	1.75392	-	0.025
Sulfates (SO4-2)	-	-	0.91584	-	0.015

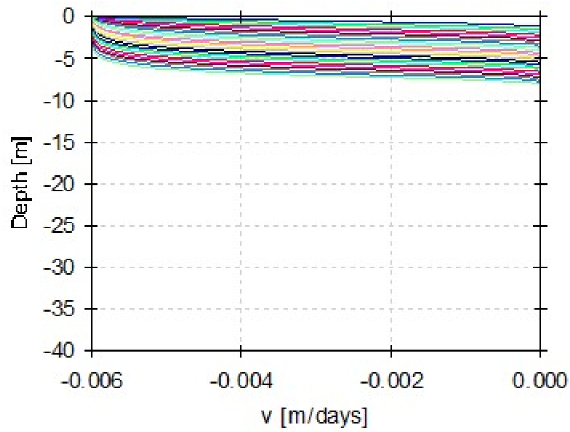
Source: GEOCOL CONSULTORES S.A. 2017.

The results of modeling for each one of the points where the infiltration tests were made are shown below.

7.3.5.1.1 Camp San Juan

The environmental modeling for Camp San Juan is shown below.

Figure 7.57 Variation of the Water Flow



Considering the result of the water flow (**Figure 7.57**), after 365 days of discharge, it is possible to establish that the water flow reaches a depth of 10 meters in the soil profile, not reaching the depth of the phreatic level. This estimation is made based on the daily values of the water flow, precipitation and evaporation.

Figure 7.58 Variation in Concentration of Hydrocarbons	**Figure 7.59 Variation in the Concentration of Greases and oils**

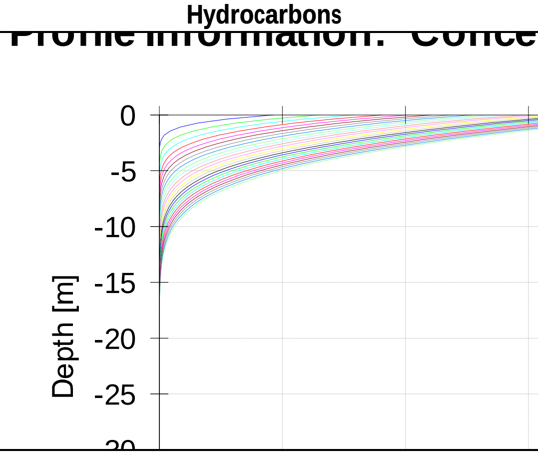
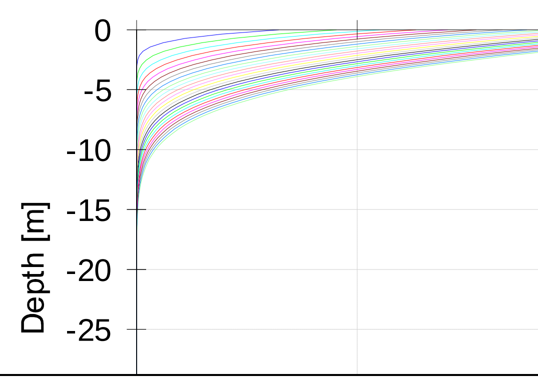

	

Figure 7.60 Variation in the Concentration of Ammoniacal Nitrogen	**Figure 7.61 Variation in the Concentration of Linear alkylbenzene sulphonate**

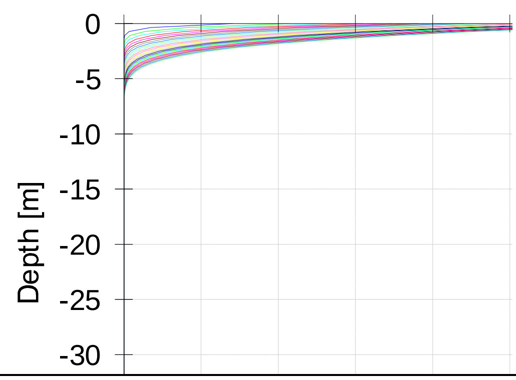


Figure 7.62 Variation in the Concentration of Chlorides

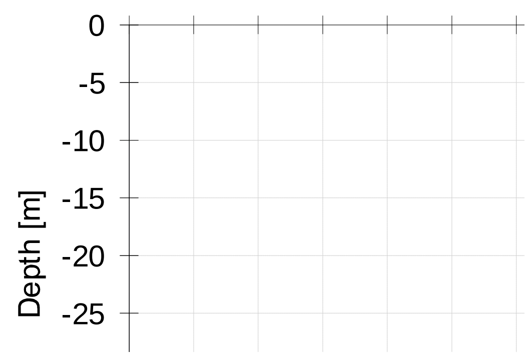
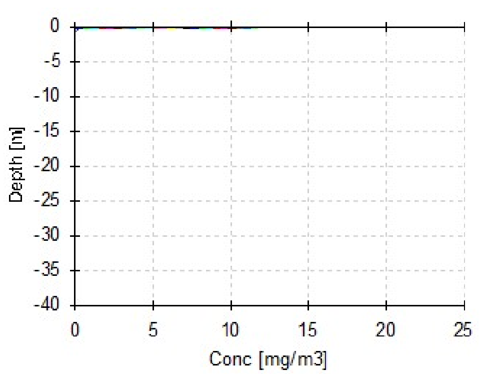
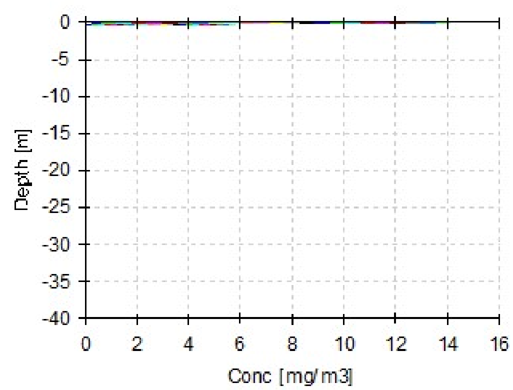


Figure 7.63 Variation in the Concentration of Sulfates





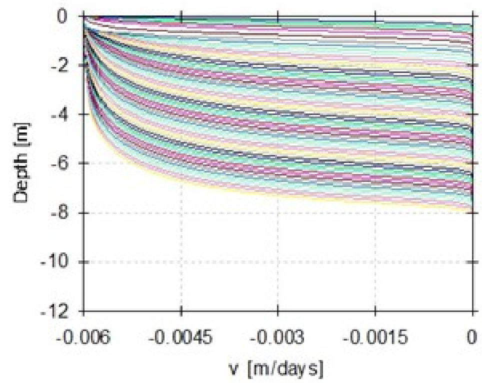
According to the results obtained, it is possible to establish that the concentrations of solutes as hydrocarbons, greases and oils, linear alkylbenzene sulphonate, ammoniacal nitrogen, sulfates and chloride, do not reach the bottom of the profile or phreatic level by decreasing to their minimum levels, reaching a depth of up to 15.00 meters for most of solutes.

Source: GEOCOL CONSULTORES S.A. 2017.

7.3.5.1.2 Camp Mikel

The environmental modeling for Camp Mikel is shown below.

Figure 7.64 Variation of Water Flow



Considering the result of the water flow in **Figure 7.64**, it is possible to establish that the flow reaches the phreatic level after 365 days of discharge with a flow of 0.00000001m/d. It is estimated that the flow is very low not saturating the soil.

Figure 7.65 Variation in Concentration of Hydrocarbons	**Figure 7.66 Variation in the Concentration of Greases and Oils**

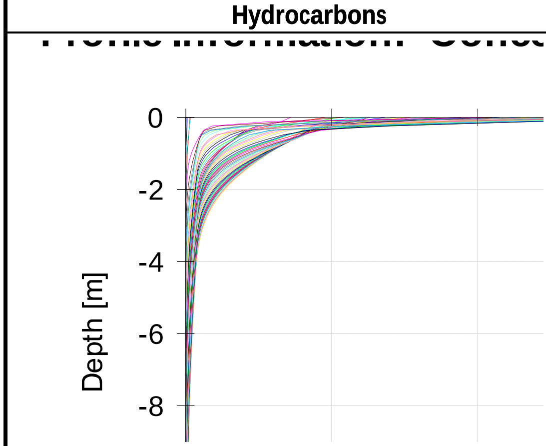
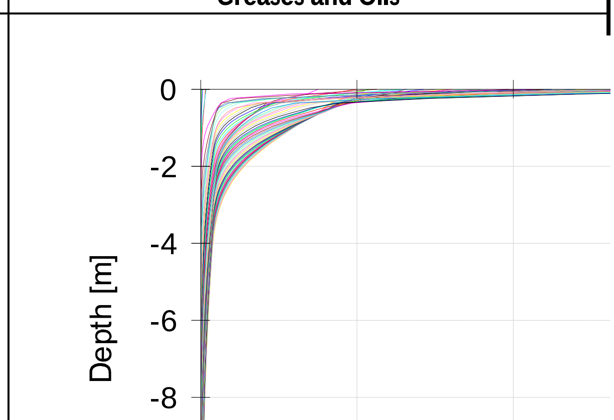

	

Figure 7.67 Variation in the Concentration of Ammoniacal Nitrogen	**Figure 7.68 Variation in the Concentration of Linear Alkylbenzene Sulphonate**

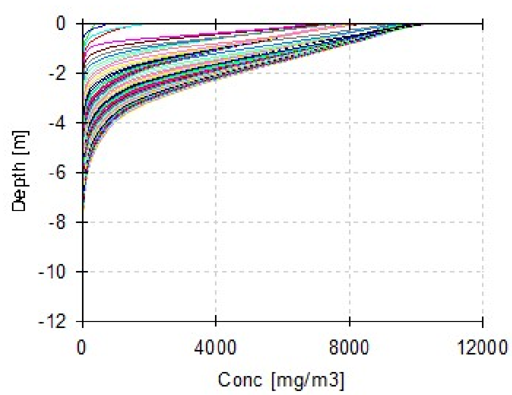


Figure 7.69 Variation in the Concentration of Chlorides

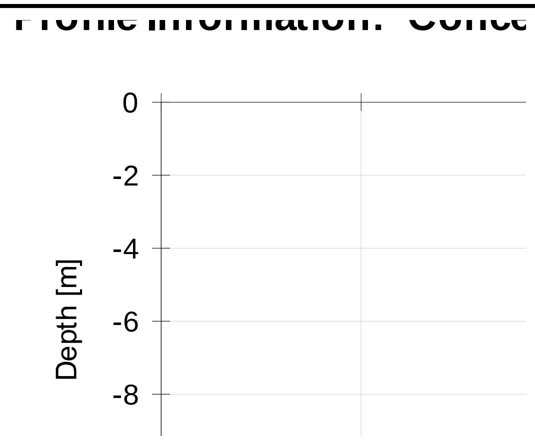
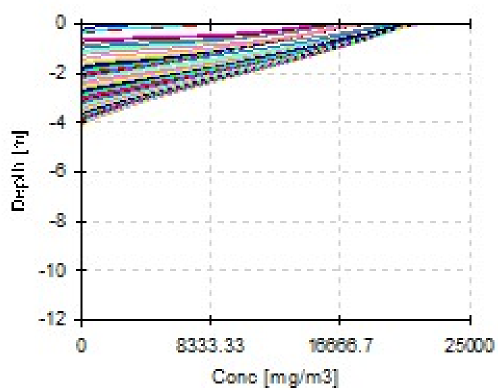
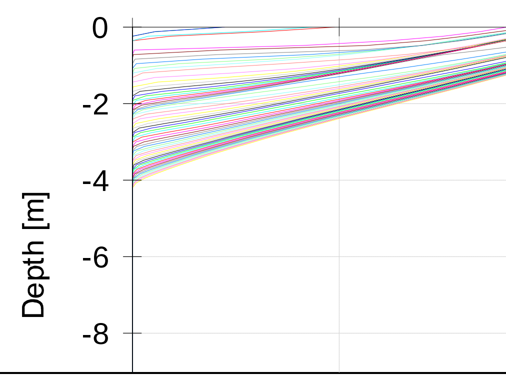


Figure 7.70 Variation in the Concentration of Sulfates





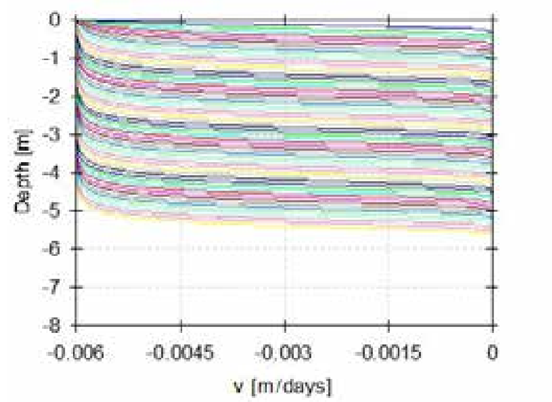
According to the results obtained, it is possible to establish that the concentrations of solutes, as hydrocarbons, greases and oils, reach the bottom of the profile in very low concentrations. Likewise, the linear alkylbenzene sulphonate, ammoniacal Nitrogen, sulfates and chloride do not reach the bottom of the profile or phreatic level when falling to their minimum values, reaching a depth of 6.00 meters for most of the solutes.

Source: GEOCOL CONSULTORES S.A. 2017.

7.3.5.1.3 Camp 31+100

The environmental modeling for Camp 31+100 is shown below.

Figure 7.71 Variation in the Flow of Water



Considering the result of water flow in **Figure 7.71**, it is possible to establish that the water flow reaches the phreatic level after 30 days of discharge with a flow of 0.0000000004m/d, before falling to their minimum values it reaches a depth of six (6) meters.

Figure 7.72 Variation in Concentration of Hydrocarbons

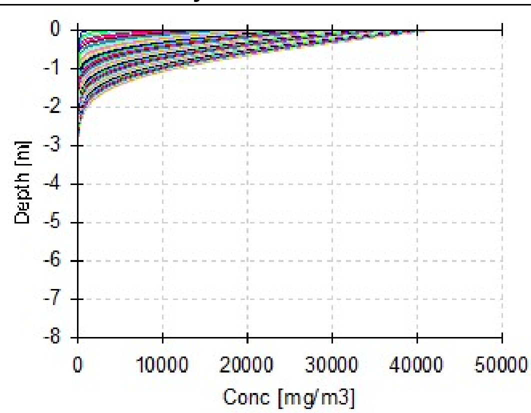


Figure 7.73 Variation in the Concentration of Greases and oils

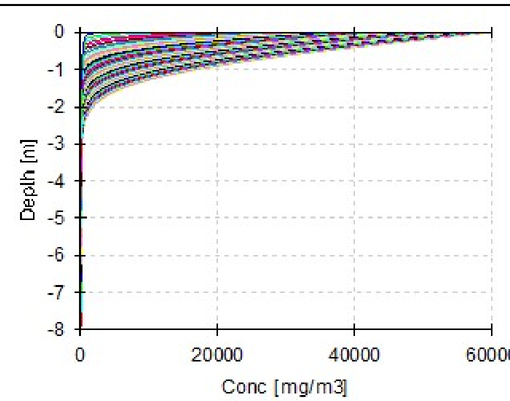


Figure 7.74 Variation in the Concentration of Ammoniacal Nitrogen

Figure 7.75 Variation in the Concentration of Linear Alkylbenzene Sulphonate

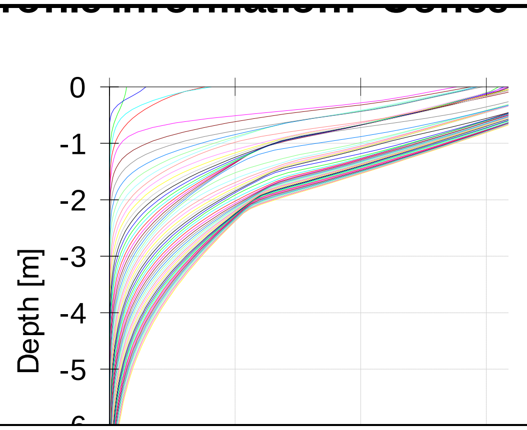


Figure 7.76 Variation in the Concentration of Chlorides

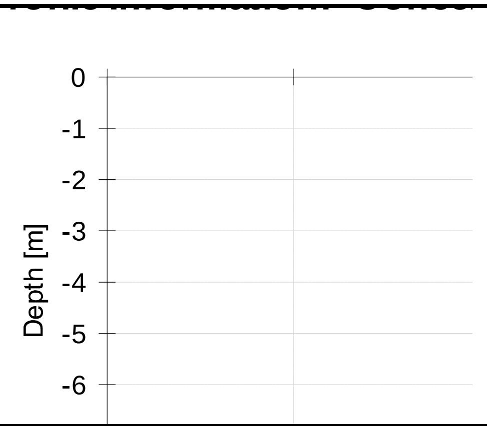
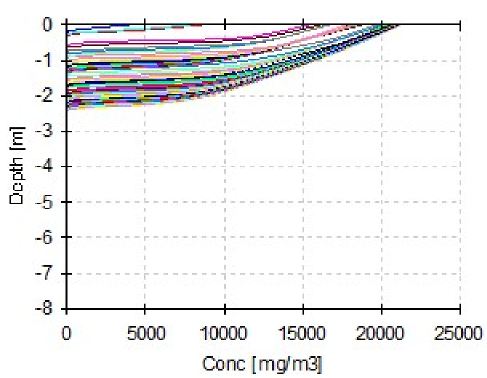
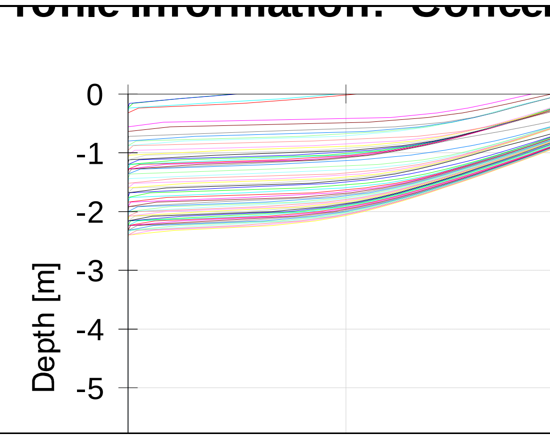


Figure 7.77 Variation in the Concentration of Sulfates





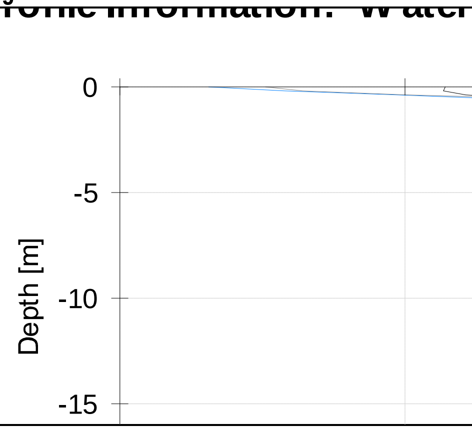
According to the results obtained, it is possible to establish that the concentrations of solutes, as hydrocarbons, greases and oils, linear alkylbenzene sulphonate, reach the bottom of the profile in very low concentrations. Additionally, the ammoniacal nitrogen, sulfates and chlorides do not reach the bottom of the profile or phreatic level when falling to their minimum values, reaching a depth of 6.00 meters for most of the solutes.

Source: GEOCOL CONSULTORES S.A. 2017.

7.3.5.1.4 Camp 35+600

The environmental modeling for Camp 35+600 is shown below.

Figure 7.78 Variation in the Flow of Water



Considering the result of the water flow en la **Figure 7.78**, after 365 days of discharge, it is possible to establish that it reaches a depth of 11 meters in the soil profile, not reaching the depth of the phreatic level. This estimation is made based on the daily values of precipitation and evaporation.

Figure 7.79 Variation in Concentration of Hydrocarbons

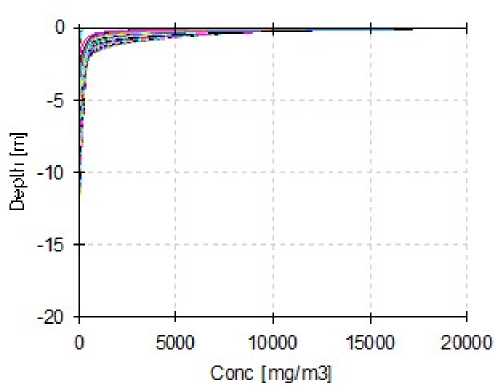


Figure 7.80 Variation in the Concentration of Greases and Oils

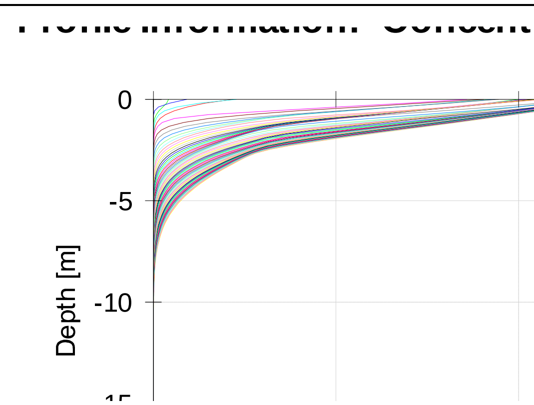


Figure 7.81 Variation in the Concentration of Ammoniacal Nitrogen

Figure 7.82 Variation in the Concentration of Linear Alkylbenzene Sulphonate

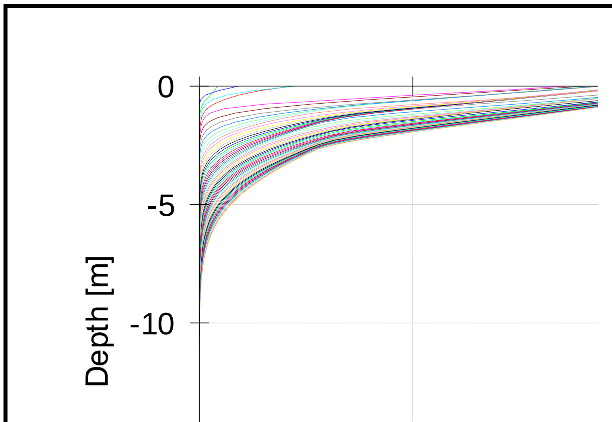


Figure 7.83 Variation in the Concentration of Chlorides

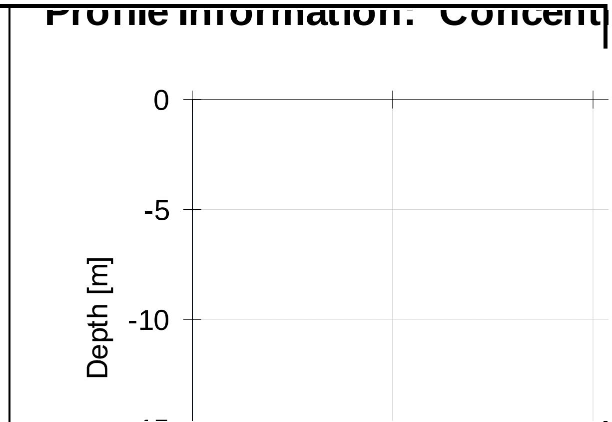
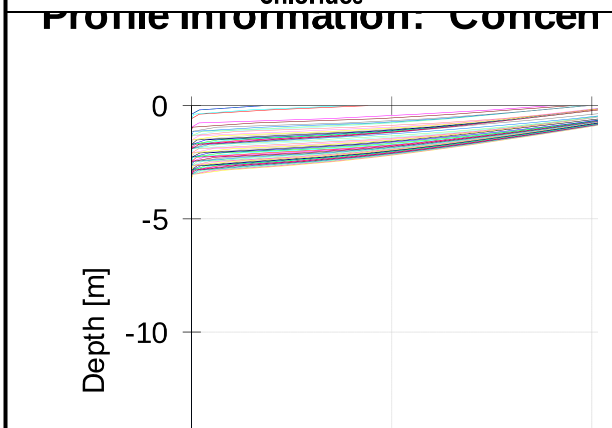
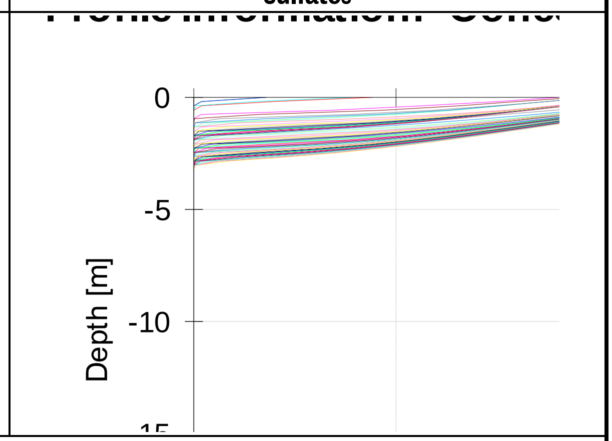


Figure 7.84 Variation in the Concentration of Sulfates





According to the results obtained, it is possible to establish that the concentrations of solutes, as hydrocarbons, greases and oils, linear alkylbenzene sulphonate, ammoniacal nitrogen, sulfates and chloride, do not reach the bottom of the profile or phreatic level when falling to their minimum values, reaching a depth of 9.00 meters for most of solutes.

Source: GEOCOL CONSULTORES S.A. 2017.

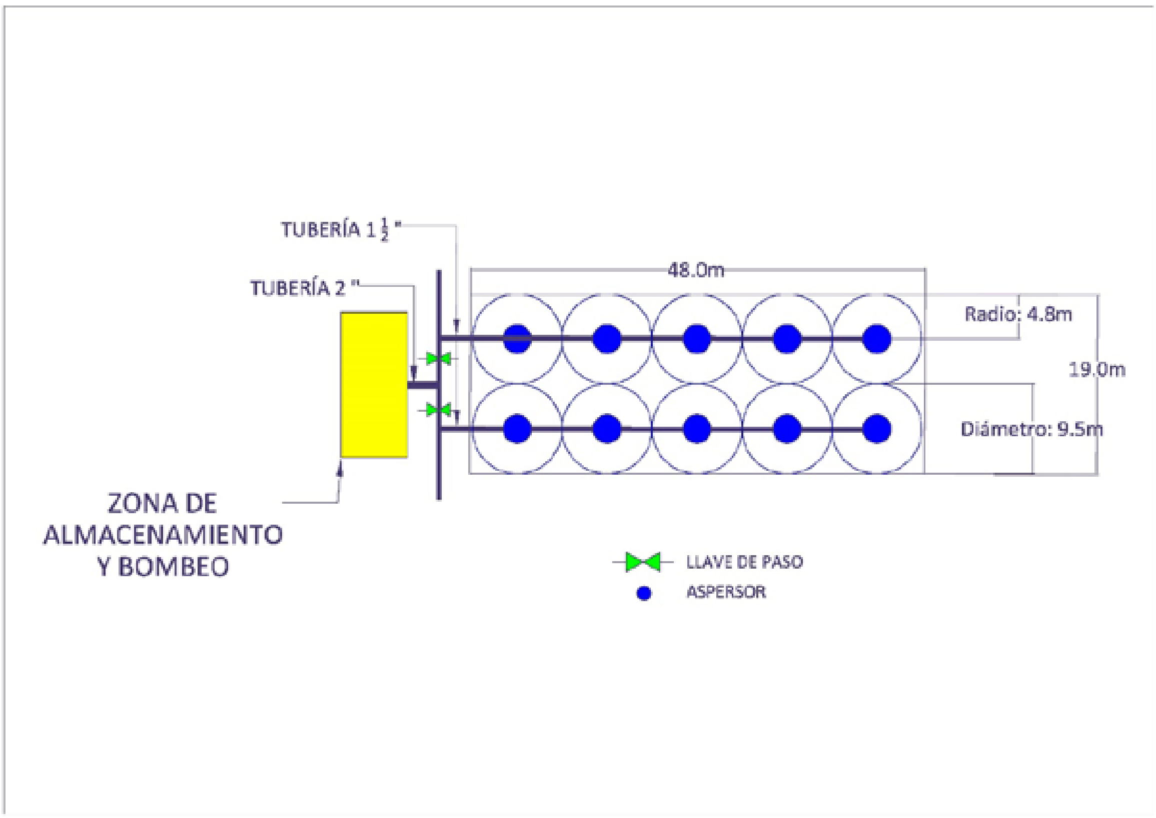
According to the results obtained for the model of discharge for camps: San Juan, Mikel, 35+600 and 31+100, it is possible to establish the following: after a continuous discharge of 365 days, the water flow reaches the bottom of the profile in camps 31+100 and Mikel, with a very low flow of 0.00000004m/d, without saturating the soil. Likewise, the concentration of solutes does not reach the bottom of the profile in significant concentrations that may affect quality of groundwater. Therefore, there would not be risk of contamination of groundwater.

Additionally, it can be concluded that treated industrial and domestic waste waters do not represent a threat for the groundwater quality and would not generate deterioration of the aquifer. It is also guaranteed that users of groundwater shall not be affected by discharge in the soil according to the limits established in decree 1594 of 1984 for human and domestic use (Articles 38 and 39).

- **Calculation of the Areas Required for Infiltration Fields**

Figure 7.85 below shows the typical design used for discharge of domestic and industrial waste waters in a spraying field. It is estimated that the spraying filed shall have an area of 912 m^2 with 10 sprinklers, wetting diameter of 9.5 meters with an approximate flow of 0.64 m3/day. It is recommended, according to the aforementioned characteristics, to use pipes in branches of 1.5", with a IHM 20H – 5 Motor 5HP pump for crops of pastures.

Figure 7.85 Typical Spraying Field Design



Source: GEOCOL CONSULTORES S.A. 2017.

o **Conclusions and Recommendations**

Based on the information generated during modeling, it is possible to establish that after a continuous discharge of 365 days, the water flow and the concentration of hydrocarbons, greases and oils and ammoniacal nitrogen reach the depth of groundwater, but in very low concentration, being within the limits established in decree 1594 of 1984 for human and domestic use (Articles 38 and 39). In the case of the linear alkylbenzene sulphonate, sulfates and chlorides, the concentrations do not reach maximum depths where the phreatic level is located. Accordingly, the treated industrial and domestic waste waters do not represent a threat for the groundwater and would not cause a deterioration of the aquifer. Likewise, it is guaranteed that users of groundwater shall not be affected by discharge in the soil.

The domestic and industrial waste water treatment systems made by the operator allow removal of a high amount of the contaminant load present, decreasing the possibility of contamination of water bodies, supported by the depuration capacity and physicochemical characteristics of the soil.

Water discharge must be made when the temperature and solar shine are at the highest point, facilitating evaporation.

It is important to establish covers of cluster radicular system that allows that the evapotranspiration is higher than the infiltration rate minimizing the water amount going into the soil.

Rest periods of the spraying field are proposed in case of saturation of the land with delivery to third parties of the treated waste water.

Before installing the discharge system, a piezometer in the discharge area to control the soil saturation level.

The spraying field must guarantee that processes of saturation by the water disposed or surface runoff causing soil pollution and affecting human health, and erosive processes and/or alteration of crops or areas near the spraying sites shall not be generated.

7.4 OCCUPATION OF RIVERBEDS

7.4.1 Design Flow Analysis

- Considering that the water bodies on which the occupation works shall be executed belong to basins with areas of less than 2.5 km^2, the analysis of flows was made through the rational method for determination of the maximum instantaneous flows of currents in the points of intersection with the road subject to study, as established in the specifications of the Handbook for Drainage of Roads of INIVIAS, as follows:

7.4.1.1 Rational Method (Basins < 2.5 km²).

The rational method involves that maximum flow is the flow generated by the rain with a period of duration equal to the concentration time of the basin, defining a runoff coefficient estimated based on the use of soil and the materials of the area where the runoff is generated.

The general equation of the rational method is:

$$Q_p = 0.278 \times C \times I \times A$$

Where:

Qp= flow (m³/s).

C= runoff coefficient (adimensional).

I= rainfall intensity (mm/h).

A= Area of the basin to the intersection with the road (km²).

7.4.1.1.1 Runoff Coefficient

The runoff coefficient is determined according to the type of soil, the permeability degree of the area, the slope of the land and other factors determining the fraction of the precipitation becoming runoff.

In its determination, losses for infiltration in the soil and other effects delaying runoff shall be considered. Likewise, it shall include considerations of urban development and predictable variations of the use of soil.

For estimation of the runoff coefficient value, the cartography, the geotechnical map and land use (See **Annex 2. Civil. VII. Drain Drawings CSH-1-PL-G-G-7104-4_PLANT USES (40.000)** and **CSH-1-PL-G-G-7105-4_SOIL USES (2.500)**), as well as the visits to the project area, were consulted to determine the soil texture, topography and vegetation of the basins associated with the road.

For determination of the runoff coefficient, the following expression is used from the Handbook for Drainage of Roads of the INVIAS:

$$C = \left[(P_d - P_o)(P_d + 23P_o)\right] / (P_d + 11P_o)^2$$

Where:

C= Runoff coefficient.

Pd= Maximum annual punctual precipitation in 24 hours for a specific period of return, in millimeters (mm).

Po= Parameter that depends on the use and type of soil, of the vegetation cover of the basin and the humidity of the soil before the design downpour in millimeters (mm). The Po value is obtained from the following expression that relates it with the runoff curve number CN of the *Soil Conservation Service* method:

$$Po = (5080 – 50.8 CN) / CN$$

In this manner, first, Pd has been calculated for the different periods of return.

The statistical adjustment has been made with Gumbel and Log-Pearson for the series of data from the selected pluviometric stations. Results of the adjustments are contained in **Annex 2. Civil. VII. Drains. Report. Annexes. Annex Nº 1. IDEAM Records and Distribution Results** and below in **Table 7.57** there is a summary. From the adjustments made, for all the stations the probabilistic distribution of Gumbel has been chosen and its results are higher values:

Table 7.57 Pd mm (Results of Adjustment of Gumbel Probabilistic Distribution)

PERIOD OF RETURN (YEARS)	WEATHER STATIONS				
	Puerres	Gualmatán	Santa Rosa Potosí	Airport San Luis	IMUÉS
2	41.18	42.42	42.81	35.02	48.11
5	52.96	66.46	55.79	43.12	63.91
10	60.75	82.38	64.38	48.49	74.37
20	68.23	97.65	72.63	53.63	84.40
25	70.61	102.49	75.24	55.26	87.59
50	77.92	117.41	83.30	60.29	97.39
100	85.17	132.22	91.29	65.28	107.12

Source: Consorcio SH, 2017.

Likewise, the characteristics of soil were studied to determine the curve number.

As for hydrological classification of soil, the areas subject to study are classified in group B (Moderately low runoff potential) (See **Annex 2. Civil. III. Geology**).

As far as land covers are concerned, there are mainly crops mixed with other covers (with the filed information, majority presence of pasture in such mixture cover is evidenced). There is a minority of forest areas and moor vegetation. There are also urban areas in populated areas.

In this manner, according to the tables of the Handbook of Drain for Roads of INVIAS, the following curve numbers CN were determined:

- Crops CN 75 (crops in rows, level curves, good).
- Pastures CN 69 (pasture, regular).
- Urban Areas CN 79 (urban areas totally developed (vegetation already established). Por condition (less than 50% covered with pasture)).

Once the curve numbers are established according to the cover, the runoff coefficient is calculated for each period of return and influence station. The results are contained in **Table 7.58**.

Table 7.58 Runoff Coefficient

PUERRES						
			Runoff Coefficient C			
			10	20	25	100
		Pd (mm)	60.75	68.23	70.61	85.17
	CN	**Po (mm)**				
Crops	75	16.93	0.32	0.36	0.37	0.44
Pastures	69	22.82	0.23	0.26	0.28	0.34
Mixture Crops/Pasture		0.28	0.31	0.32	0.39	
Urban Areas	79	13.50	0.40	0.44	0.45	0.52
GUALMATAN						
			Runoff coefficient C			
			10	20	25	100
		Pd (mm)	82.38	97.65	102.49	132.22
	CN	**Po (mm)**				
Crops	75	16.93	0.43	0.49	0.50	0.59
Pastures	69	22.82	0.33	0.38	0.40	0.49
Mixture Crops/Pasture		0.38	0.44	0.45	0.54	
Urban Areas	79	13.50	0.51	0.57	0.58	0.67
STA. ROSA POTOSI						
			Runoff coefficient C			
			10	20	25	100
		Pd (mm)	64.38	72.63	75.24	91.29
	CN	**Po (mm)**				
Crops	75	16.93	0.34	0.38	0.40	0.46
Pastures	69	22.82	0.25	0.28	0.30	0.36
Mixture Crops/Pasture		0.29	0.33	0.35	0.41	
Urban Areas	79	13.50	0.42	0.46	0.48	0.54
AEROPUERTO SAN LUIS						
			Runoff coefficient C			
			10	20	25	100
		Pd (mm)	48.49	53.63	55.26	65.28
	CN	**Po (mm)**				
Crops	75	16.93	0.25	0.28	0.29	0.35
Pastures	69	22.82	0.16	0.19	0.20	0.25
Mixture Crops/Pasture		0.21	0.24	0.25	0.30	
Urban Areas	79	13.50	0.32	0.36	0.37	0.43
IMUES						
			Runoff coefficient C			
			10	20	25	100
		Pd (mm)	74.37	84.40	87.59	107.12
	CN	**Po (mm)**				
Crops	75	16.93	0.39	0.44	0.45	0.52
Pastures	69	22.82	0.29	0.33	0.35	0.42

Mixture Crops/Pasture		0.34	0.38	0.40	0.47	
Urban Areas	79	13.50	0.47	0.52	0.53	0.60

Source: Consorcio SH, 2017.

7.4.1.1.2 Rainfall Intensity

Rainfall intensity for calculation of flows corresponds to the value obtained from the IDF curves for the periods of return of design defined and for a duration equal to the time of concentration of the basin, this time being understood as the time required for a water drop to go from the most remote point of the basin to the station.

The periods of return of calculation are as follows (See **Table 7.59**):

Table 7.59 Periods of Return of Calculation

STRUCTURE	PERIOD OF RETURN (YEARS)
Culverts Ø<= 900 mm	10
Culverts Ø> 900 mm	20
Box Culvert	25

Source: Consorcio SH, 2017.

The concentration time has been estimated through the Kirpich formula. Nonetheless, a minimum concentration time has been considered for all the basins equal to 15 minutes, as indicated in the Handbook of Drainage for Roads of the INVIAS.

The Kirpich formula has the following expression:

$$Tc = 3.9780 \times L^{0.77} \times S^{-0.385}$$

Where:

Tc= concentration time of the basin (min).

L= length of the main course (km).

S= total slope of the main course, equal to the total fall between the length of the course (m/m).

According to the rational method, the design flows were obtained and are presented in **Table 7.60**.

Table 7.60 Design Flows

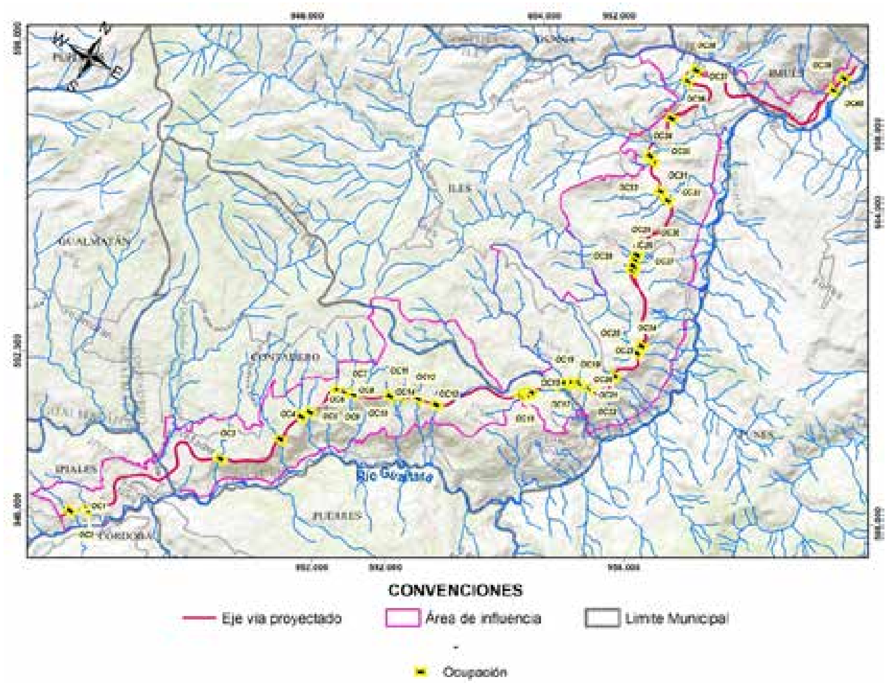
ID	NAME OF THE WATER BODY	ABSCISE OF THE PROJECT	PERIOD OF RETURN (years)	DESIGN FLOW (m^3/s)
OC1	NN1	PK16+120	Q25	5.70
OC2	NN2	PK16+503	Q25	10.87
OC3	Yamurayán Creek	PK20+831	Q25	18.28
OC4	NN3	PK22+428	Q25	19.88
OC5	Creek Guayarín	PK23+157	Q25	10.08
OC6	NN4	PK23+370	Q25	2.85
OC7	NN5	PK24+136	Q25	12.14
OC8	NN5	PK24+136	Q25	12.14
OC9	NN6	PK24+315	Q25	9.04
OC10	NN7	PK24+525	Q25	7.84
OC11	NN8	PK25+529	Q10	0.06
OC12	Creek Manzano	PK25+589	Q20	2.13
OC13	Creek Brigada	PK25+952	Q20	1.22
OC14	NN9	PK26+440	Q10	0.60
OC15	NN1 Tributary La Humeadora Creek	PK28+516	Q10	0.48
OC16	NN2 Tributary La Humeadora Creek	PK28+516	Q10	0.48
OC17	NN10	PK28+677	Q10	0.36
OC18	Creek Los Arrayanes	PK29+212	Q25	9.60
OC19	Creek Manzano	PK29+437	Q25	9.90
OC20	NN11	PK29+593	Q25	6.26
OC21	Creek Urbano	PK29+756	Q25	12.85
OC22	NN12	PK30+040	Q10	0.43
OC23	NN13	PK30+880	Q10	0.22
OC24	NN14	PK31+746	Q20	1.71
OC25	Moledores Creek	PK32+103	Q10	0.14
OC26	Creek El Tablón	PK32+729	Q10	0.05
OC27	NN15	PK33+863	Q20	1.95
OC28	NN16	PK34+018	Q25	2.94
OC29	NN17	PK34+107	Q20	1.44
OC30	NN18	PK34+350	Q25	3.12
OC31	NN19	PK35+732	Q25	4.81
OC32	NN1 Tributary San Francisco Creek	PK35+917	Q10	0.15
OC33	San Francisco Creek	PK36+000	Q25	28.31
OC34	NN20	PK36+751	Q25	5.52
OC35	NN21	PK36+878	Q10	0.84
OC36	NN22	PK37+959	Q25	6.76
OC37	NN23	PK39+700	Q25	4.83
OC38	NN23	PK40+085	Q25	17.51
OC39	NN24	PK44+013	Q10	0.07
OC40	NN25	PK44+425	Q25	5.39

Source: Consorcio SH, 2017.

7.4.2 Georeferenced Location

Table 7.61 shows the location of sites of intersection of surface water bodies with respect to layout of the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment (see *(sic)*

Figure 7.86 Location of Points of Watercourse Occupation



Source: GEOCOL CONSULTORES S.A., 2017.

), for which a bed occupation permit is requested *(sic)*. Bed occupations are requested with a mobility range of 50 m upstream and 50 m downstream, with respect to the point required.

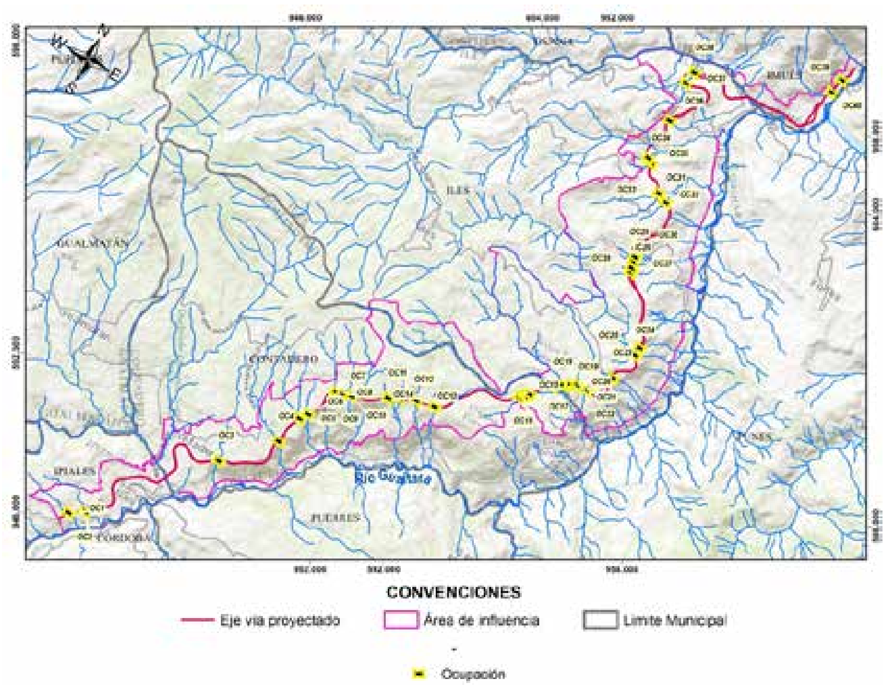
Table 7.61 Location of Watercourse Occupation Points

ID	NAME OF THE WATER BODY	ABSCISE OF THE PROJECT	MAGNA SIRGAS COORDINATES ORIGIN 3 WEST		WORK PROPOSED
			EAST	NORTH	
OC1	NN1	PK16+120	946811.93	589397.70	Box culvert 2 x 2 m

ID	NAME OF THE WATER BODY	ABSCISE OF THE PROJECT	MAGNA SIRGAS COORDINATES ORIGIN 3 WEST		WORK PROPOSED
			EAST	NORTH	
OC2	NN2	PK16+503	947121.83	589603.72	Box culvert 3 x 2 m
OC3	Yamurayán Creek	PK20+831	949114.02	592065.11	Box culvert 3 x 3 m
OC4	NN3	PK22+428	950054.08	593102.63	Box culvert 3 x 3 m
OC5	Creek Guayarín	PK23+157	950212.94	593774.90	Box culvert 2 x 2 m
OC6	NN4	PK23+370	950321.61	593956.90	Box culvert 1.5 x 1.5 m
OC7	NN5	PK24+136	950636.07	594629.81	Box culvert 3 x 2 m
OC8	NN5	PK24+136	950617.38	594684.56	Box culvert 3 x 2 m
OC9	NN6	PK24+315	950764.62	594725.77	Box culvert 2 x 2 m
OC10	NN7	PK24+525	950967.72	594782.47	Box culvert 2 x 2 m
OC11	NN8	PK25+529	951686.27	595151.47	Culvert 900 mm
OC12	Creek Manzano	PK25+589	951906.14	595274.20	Culvert 1200 mm
OC13	Creek Brigada	PK25+952	952253.56	595420.32	Culvert 1200 mm
OC14	NN9	PK26+440	952669.62	595499.39	Culvert 900 mm
OC15	NN1 Tributary La Humeadora Creek	PK28+516	954206.18	596624.50	Culvert 900 mm
OC16	NN2 Tributary La Humeadora Creek	PK28+516	954290.20	596720.59	Culvert 900 mm
OC17	NN10	PK28+677	954363.00	596797.00	Culvert 900 mm
OC18	Creek Los Arrayanes	PK29+212	954729.44	597199.25	Box culvert 3 x 2 m
OC19	Creek Manzano	PK29+437	954925.68	597342.18	Box culvert 3 x 2 m
OC20	NN11	PK29+593	955050.07	597431.63	Box culvert 3 x 2 m
OC21	Creek Urbano	PK29+756	955178.38	597501.33	Box culvert 3 x 2 m
OC22	NN12	PK30+040	955429.67	597508.01	Culvert 900 mm
OC23	NN13	PK30+880	955776.28	598034.29	Culvert 900 mm
OC24	NN14	PK31+746	955959.13	598715.59	Culvert 1200 mm
OC25	Moledores Creek	PK32+103	955961.93	598913.93	Culvert 900 mm
OC26	Creek El Tablón	PK32+729	954964.97	600264.24	Culvert 900 mm
OC27	NN15	PK33+863	954928.86	600362.86	Culvert 1200 mm
OC28	NN16	PK34+018	954892.74	600499.78	Box culvert 1.5 x 1.5 m
OC29	NN17	PK34+107	954867.24	600605.07	Culvert 1200 mm
OC30	NN18	PK34+350	954841.74	600838.89	Box culvert 1.5 x 1.5 m
OC31	NN19	PK35+732	954860.08	601994.55	Box culvert 2 x 2 m
OC32	NN1 Tributary San Francisco Creek	PK35+917	954632.16	602074.88	Culvert 900 mm
OC33	San Francisco Creek	PK36+000	954609.64	602099.98	Box culvert 5 x 3.5 m
OC34	NN20	PK36+751	954134.22	602589.08	Box culvert 2 x 2 m
OC35	NN21	PK36+878	954020.90	602661.87	Culvert 900 mm
OC36	NN22	PK37+959	954012.69	603620.06	Box culvert 2 x 2 m
OC37	NN23	PK39+700	953918.82	604516.47	Box culvert 2 x 2 m
OC38	NN23	PK40+085	953963.00	604813.00	Box culvert 3 x 3 m
OC39	NN24	PK44+013	956818.81	605952.00	Culvert 900 mm
OC40	NN25	PK44+425	956886.56	606301.41	Box culvert 2 x 2 m

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.86 Location of Points of Watercourse Occupation



Source: GEOCOL CONSULTORES S.A., 2017.

7.4.3 Fluvial Dynamics and Scour

Major works, their foundations and piles (Bridge Boquerón, Bridge of Macal Creek, Bridge of District El Porvenir and Bridge Sapuyes River) are not planned within the bed of the water bodies crossed by the course of the project. Additionally, as shown in **Annex 2. Civil. III. Geology and VII. Drains**, the studies indicate that the sheet of water in a period of return of 100 years does not reach the piles and abutments. Therefore, it is concluded that there shall not be perceptible scour that affects bridges.

Table 7.62 below shows the characteristics of the sites where building of the drain works are proposed for highway crossing.

Table 7.62 Fluvial Dynamics of the Water Bodies Crossed in the Project Layout

ID	NAME OF THE WATER BODY	DESCRIPTION OF THE WATER BODY	PHOTOGRAPHIC RECORD
OC1	NN1	Width: 0.90 m approx. Depth of the sheet of water: 0 m. Geomorphologic Classification: Rectilinear with low sinuosity Remark: Dry drain intervened by culvert with the existing road.	
OC2	NN2	Width: 0.70 m approx. Depth of the sheet of water: 0 m. Geomorphologic Classification: Rectilinear with low sinuosity Remark: Dry drain intervened by culvert with the existing road.	
OC3	Yamurayán Creek	Width: .0 m approx. Depth of the sheet of water: 0.20 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	

ID	NAME OF THE WATER BODY	DESCRIPTION OF THE WATER BODY	PHOTOGRAPHIC RECORD
OC4	NN3	Width: 1.50 m approx. Depth of the sheet of water: 0.40 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC5	Creek Guayarín	Width: 0.80 m approx. Depth of the sheet of water: 0.15 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC6	NN4	Width: 0.40 m approx. Depth of the sheet of water: 0.08 m approx. Geomorphologic Classification: Rectilinear with low sinuosity. Remark: Highly intervened with crops on the sides.	
OC7	NN5	Width: 0.40 m approx. Depth of the sheet of water: 0.10 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	

ID	NAME OF THE WATER BODY	DESCRIPTION OF THE WATER BODY	PHOTOGRAPHIC RECORD
OC8	NN5	Width: 0.40 m approx. Depth of the sheet of water: 0.10 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC9	NN6	Width: 0.80 m approx. Depth of the sheet of water: 0.25 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC10	NN7	Width: 0.80 m approx. Depth of the sheet of water: 0.25 m approx. Geomorphologic Classification: Rectilinear with low sinuosity. Remark: There are inorganic solid wastes in the course of the water body.	
OC11	NN8	Width: 0.60 m approx. Depth of the sheet of water: 0.15 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	

ID	NAME OF THE WATER BODY	DESCRIPTION OF THE WATER BODY	PHOTOGRAPHIC RECORD
OC12	Creek Manzano	Width: 0.60 m approx. Depth of the sheet of water: 0.20 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC13	Creek Brigada	Width: 0.80 m approx. Depth of the sheet of water: 0.05 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC14	NN9	Width: 0.80 m approx. Depth of the sheet of water: 0.25 m approx. Geomorphologic Classification: Rectilinear with low sinuosity. Remark: Cover for protection of the intervened water body.	
OC15	NN1 Tributary La Humeadora Creek	Width: 0.60 m approx. Depth of the sheet of water: 0.05 m. Geomorphologic Classification: Rectilinear with low sinuosity.	

ID	NAME OF THE WATER BODY	DESCRIPTION OF THE WATER BODY	PHOTOGRAPHIC RECORD
OC16	NN2 Tributary La Humeadora Creek	Width: 0.70 m approx. Depth of the sheet of water: 0.10 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC17	NN10	Width: 0.40 m approx. Depth of the sheet of water: 0.02 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC18	Creek Los Arrayanes	Width: 1.0 m approx. Depth of the sheet of water: 0.30 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC19	Creek Manzano	Width: 1.0 m approx. Depth of the sheet of water: 0.20 m. Geomorphologic Classification: Rectilinear with low sinuosity.	

ID	NAME OF THE WATER BODY	DESCRIPTION OF THE WATER BODY	PHOTOGRAPHIC RECORD
OC20	NN11	Width: 0.80 m approx. Depth of the sheet of water: 0.30 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC21	Creek Urbano	Width: 1.0 m approx. Depth of the sheet of water: 0.50 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC22	NN12	Width: 0.30 m approx. Depth of the sheet of water: 0.05 m approx. Geomorphologic Classification: Rectilinear with low sinuosity. Remark: Intervened with redefinition of alignment through excavation.	
OC23	NN13	Remark: Intervened with potato crop. Plowing changed morphology of the water body which runs through the plowing channels.	

ID	NAME OF THE WATER BODY	DESCRIPTION OF THE WATER BODY	PHOTOGRAPHIC RECORD
OC24	NN14	Width: 0.40 m approx. Depth of the sheet of water: 0.10 m approx. Geomorphologic Classification: Rectilinear with low sinuosity. Remark: Intervened with redefinition of alignment through excavation.	
OC25	Moledores Creek	Width: 1.70 m approx. Depth of the sheet of water: 0.35 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC26	Creek El Tablón	Width: 1.20 m approx. Depth of the sheet of water: 0.30 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC27	NN15	Width: 0.95 m approx. Depth of the sheet of water: 0.10 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	

ID	NAME OF THE WATER BODY	DESCRIPTION OF THE WATER BODY	PHOTOGRAPHIC RECORD
OC28	NN16	Width: 1.20 m approx. Depth of the sheet of water: 0.05 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC29	NN17	Width: 1.0 m approx. Depth of the sheet of water: 0.05 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC30	NN18	Width: 0.40 m approx. Depth of the sheet of water: 0.05 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC31	NN19	Width: 1.0 m approx. Depth of the sheet of water: 0.01 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	

ID	NAME OF THE WATER BODY	DESCRIPTION OF THE WATER BODY	PHOTOGRAPHIC RECORD
OC32	NN1 Tributary San Francisco Creek	Width: 0.85 m approx. Depth of the sheet of water: 0.10 m approx. Geomorphologic Classification: Rectilinear with low sinuosity. Remark: Photographic record, approximately 400 m downstream from the occupation site.	
OC33	San Francisco Creek	Width: 1.10 m approx. Depth of the sheet of water: 0.20 m approx. Geomorphologic Classification: Rectilinear with low sinuosity. Remark: Photographic record, approximately 400 m downstream from the occupation site.	
OC34	NN20	Width: 0.60 m approx. Depth of the sheet of water: 0.15 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC35	NN21	Width: 0.30 m approx. Depth of the sheet of water: 0.10 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	

ID	NAME OF THE WATER BODY	DESCRIPTION OF THE WATER BODY	PHOTOGRAPHIC RECORD
OC36	NN22	Width: 0.60 m approx. Depth of the sheet of water: 0.10 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC37	NN23	Width: 1.10 m approx. Depth of the sheet of water: 0.10 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC38	NN23	Width: 1.30 m approx. Depth of the sheet of water: 0.20 m approx. Geomorphologic Classification: Rectilinear with low sinuosity.	
OC39	NN24	Width: 0.20 m approx. Depth of the sheet of water: 0 m Geomorphologic Classification: Rectilinear with low sinuosity. Remark: Dry at the moment of inspection, intervened by the existing road (Rumichaca Pasto)	

ID	NAME OF THE WATER BODY	DESCRIPTION OF THE WATER BODY	PHOTOGRAPHIC RECORD
OC40	NN25	Width: 0.20 m approx. Depth of the sheet of water: 0 m Geomorphologic Classification: Rectilinear with low sinuosity. Remark: Dry at the moment of inspection, intervened by the existing road (Rumichaca Pasto)	

Source: GEOCOL CONSULTORES S.A., 2017.

7.4.4 Preliminary Designs and Building Procedure

The infrastructure proposed for course occupations requested for the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment involves minor works, such as culverts and/or box culvert. Likewise, building of five bridges are proposed for crossing of bigger drains.

7.4.4.1 Hydraulic Works of Culverts

7.4.4.1.1 Design Criteria

Considering that the course planned passes over the existing road, the divided highway shall be doubled provided that the conditions and specification allow so. For definition of culverts of this segment, the existing culverts have been considered. In this manner, an inventory was made of the existing culverts and their structural and conservation state was reviewed.

Based on the flows calculated for each river basin, validity of the hydraulic section of the existing works has been determined establishing the following criteria at the moment of determining the dimension of the culverts planned:

- Keep the existing culverts with a diameter of lower than 900 mm if hydraulically compliant, in a good conservation state and located in the segments of roadway regardless of the culverts where only improvement actions are required.
- Extend the existing culverts with a diameter lower than 900 mm, provided that they are hydraulically compliance and in a good conservation state. Extension shall be made in two situations:

ü Downstream extension: extension of the culvert downstream shall be made with one culvert with a diameter of 900 mm.

ü Upstream extension: if the extension required is upstream, the culvert shall be replaced by a culvert with a diameter of 900 mm.

- Have culverts with a minimum diameter of 900 mm in all the new projected culverts.

In order to determine validity of the culverts, the following criteria have been considered:

- The maximum water height at the entry/height of the work is as maximum 1.2 (He/D=1.2).
- The speed inside the works is lower than 6 m/s.

7.4.4.1.2 Methodology

Hydraulic calculations of the culverts projected have been made following the methodology proposed by the Bureau of Public Roads of the United States.

This methodology distinguishes eight different possibilities of operation of culvert, divided in two big groups, depending on the section at the entrance being partially or totally filled. In order to know the type of operation, it is necessary to introduce a series of parameters:

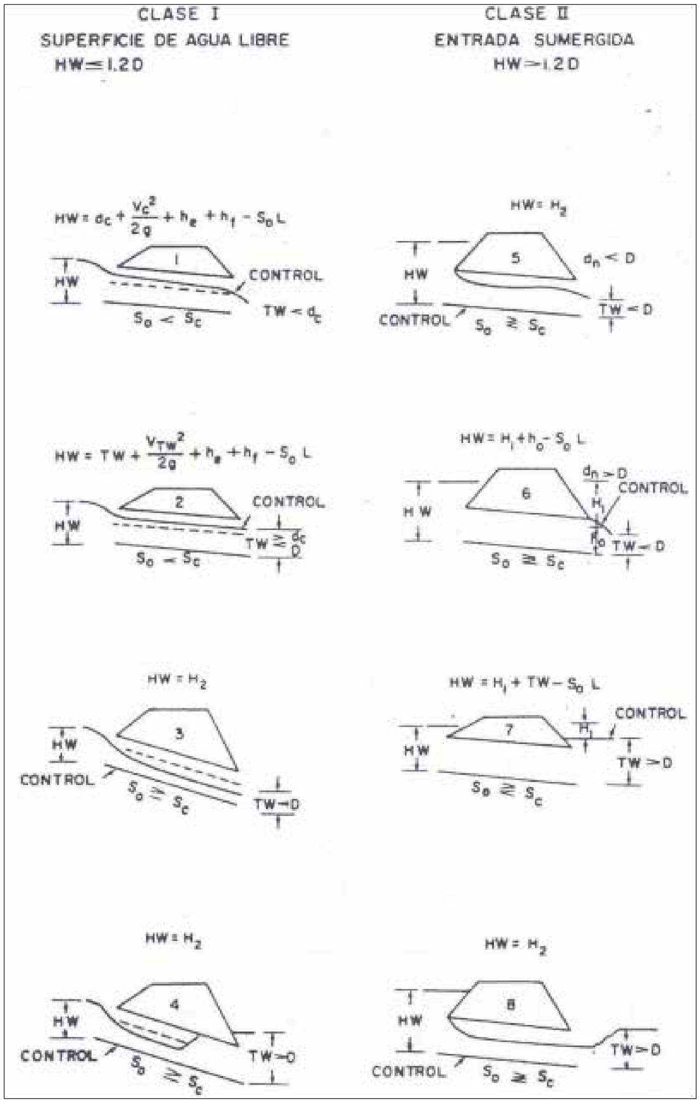
- Type of mouth: it determines the coefficient of losses at the entrance, ke.
- Data of the culvert: dimensions, roughness, length and slope.
- Design flow: the culverts projected are dimensioned for the flow of design period of return, function of its dimension:

Culverts □┘ ╭■┼糎	10 years
Culverts □╮─■┼	20 years
Frames/Box Culvert	25 years
Pontoons (bridges of L<10m)	25 years
Bridges	100 years

The height of water at the entrance of the culvert is calculated as if operation was of each one of the types planned, obtaining, at the same time, a series of parameters that indicate later the type of operation.

Figure 7.87 shows the operation types and the calculations included are indicated below:

Figure 7.87 Types of Operation of Culverts



Source: Consorcio SH, 2017.

Entrance Load Losses:

$$h_e = k_e \cdot \frac{v^2}{2g}$$

Where:

v: speed of eater at the entrance of the conduit (m/s)

ke: coefficient of losses at the entrance. The following values are taken (**Table 7.63**):

Table 7.63 Entrance Loss Coefficient

TYPE OF STRUCTURE AND CHARACTERISTICS OF THE ENTRANCE	K_e
1. Tubos de hormigón	
Conducto prolongado fuera del terraplén	
-arista ranurada	0.2
-arista viva	0.5
Con muro de cabecera con o sin aletas	
-arista ranurada	0.2
-arista viva	0.5
-arista redondeada (r=1/12 D)	0.2
-arista biselada	0.2
2. Tubos circulares de metal corrugado	
Conducto prolongado fuera del terraplén	
-sin muro de cabecera	0.9
-con muro de cabecera perpendicular al eje del tubo sin o con aletas y aristas vivas	0.5
-con muro de cabecera perpendicular al eje del tubo con o sin muro de aristas biseladas	0.25
3. Alcantarillas de cajón en concreto reforzado con muro de cabecera paralelo al terraplén:	
-sin aletas, y bordes de aristas vivas	0.5
-bordes aristas redondeadas (r=1/12 D) o biseladas	0.2
Con aletas formando ángulos entre 30º y 75º con el eje del conducto:	
-bordes de aristas vivas	0.4
-bordes del dintel con aristas redondeadas (r=1/12 D) o biseladas	0.2
-con aletas formando ángulos entre 10º y 25º con el eje del conducto, y aristas vivas.	0.5
-con muros de ala paralelos y aristas vivas en el dintel	0.7
-con muros de ala alabeados y aristas redondeadas (r=1/4 D) en el dintel	0.2

Source: Consorcio SH, 2017, taken from the Manual of Roadway Drains of IINVIAS.

Load Losses for friction within the culvert:

$$h_f = \frac{n^2 \cdot v^2}{R_H^{4/3}} \cdot L$$

Where:

n: Manning number of value 0.014 for concrete elements

RH: hydraulic radio (m)

L: length of the culvert (m)

Uniform Draught:

$$I = \frac{n^2 \cdot v^2}{R_H^{4/3}}$$

Where:

I: slope of the conduit (m/m)

Height of water is calculated at the entrance of the culvert (HW) for each type of operation through the following equations:

Type 1

$$HW = d_c + \frac{v_c^2}{2g} + k_e \frac{v_e^2}{2g} + h_f - IL$$

Type 2

$$HW = d_c + \frac{v_{TW}^2}{2g} + k_e \frac{v_e^2}{2g} + h_f - IL$$

Type 3

$$HW = d_c + (1 + k_e) \cdot \frac{v_c^2}{2g}$$

Type 4

$$HW = d_c + (1 + k_e) \cdot \frac{v_c^2}{2g}$$

Type 5

$$HW = D + (1 + k_e) \cdot \frac{v_D^2}{2g}$$

Type 6

$$HW = h_0 + h_f + (1 + k_e) \cdot \frac{v_D^2}{2g} - I \cdot L$$

h_0 being the higher draught between TW and (dc+D)/2 and not exceeding the value of D, and hf the draughts corresponding the full section.

Type 7

$$HW = TW + h_f + (1 + k_e) \cdot \frac{v_D^2}{2g} - I \cdot L$$

hf being the losses corresponding to the full section

Type 8

$$HW = D + (1 + k_e) \cdot \frac{v_D^2}{2g}$$

The type of operation of the culvert for the design flow is determined verifying compliance with the conditions listed in **Table 7.64**

Table 7.64 Types of Operation of Culverts

CONDITIONS	CLASS. TYPE OF OPERATION							
	I.1	**I.2**	**I.3**	**I.4**	**II.5**	**II.6**	**II.7**	**II.8**
HW <= 1,2*D (CLASS I)	YES	NO	YES	YES	NO	NO	NO	NO
So < Sc	YES	YES	NO	NO	-	-	-	-
TW < D	YES	YES	YES	NO	YES	YES	NO	NO
TW < dc	YES	NO	-	-	-	-	-	-
dn < D	-	-	-	-	YES	NO	NO	-
(TW+hf) < (So*L+D)	-	-	YES	YES	-	-	NO	-
Control Section	EXIT	EXIT	ENTRANCE	ENTRANCE	ENTRANCE	EXIT	EXIT	ENTRANCE

Source: Consorcio SH, 2017.

The process followed consists in determining the height of water at the entrance of each culver as if it was of each one of the 8 types presented in

Figure 7.87.

In this manner, the conditions of the parameters defining each type of operation are determined and if the conditions are fulfilled, that type of operation is feasible within the culvert subject to study, otherwise, it shall be dismissed.

In the event there is only one type of the 8 that complies with all the necessary conditions, that type shall be the solution.

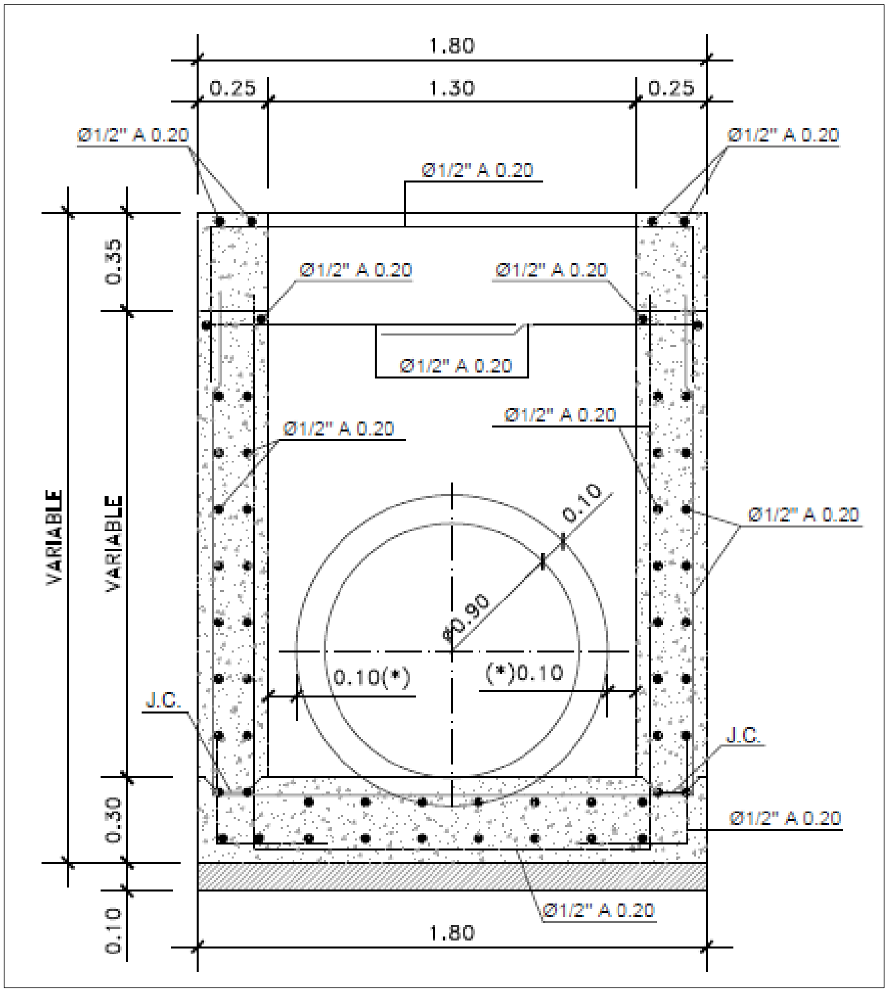
If there is more than one type, the most conservative one shall be adopted as to increase safety in dimensions of the culvert and not reduce it.

It is proven, as indicated, that the speed values inside each one of the culverts are within the permissible values comprised between 0.6 m/s (minimum permissible speed to prevent sedimentations) and 6 m/s (maximum speed allowed to avoid erosions and excessive wear).

In the course of San Juan – Pedregal Segment, circular culverts with concrete pipes with 900 mm and 1200 mm diameters and box culverts georeferenced in **Table 7.61** from which the sectional view is shown in **Figure 7.88**, **Figure 7.89** and

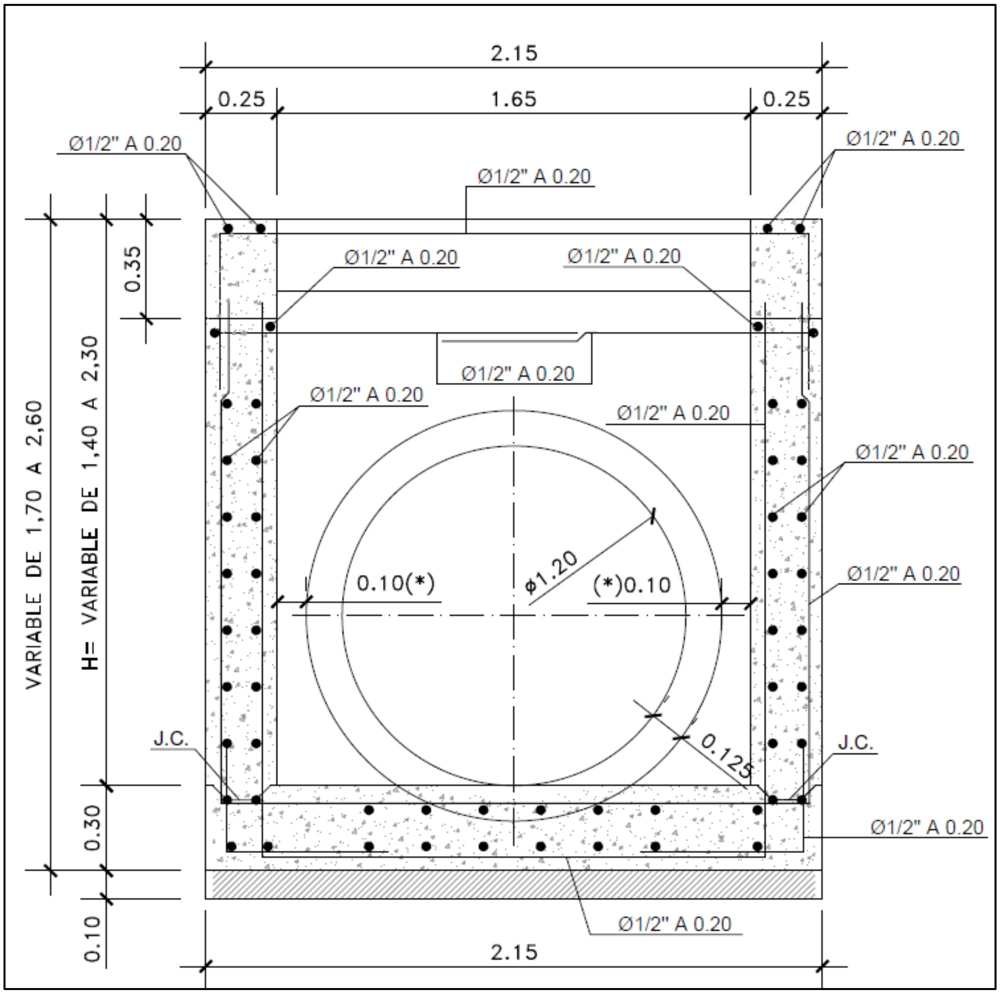
Figure 7.90, respectively, shall be built, extended and/or replaced (as the case may be).

Figure 7.88 Sectional View of Circular Culvert Ø 900 mm.



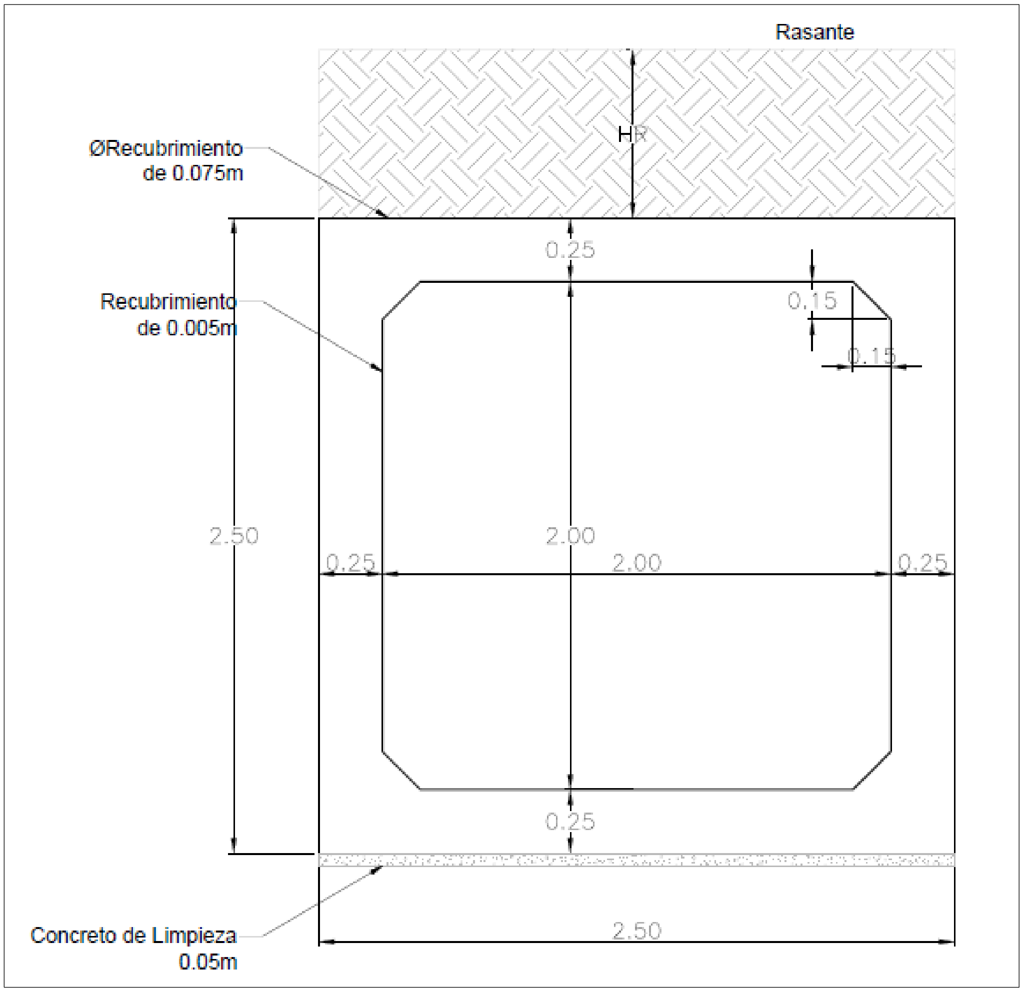
Source: Consorcio SH, 2017.

Figure 7.89 Sectional View of Circular Culvert Ø 1200 mm



Source: Consorcio SH, 2017.

Figure 7.90 Sectional View Box Culvert with Box of 2.0 x 2.0 m.



Source: Consorcio SH, 2017.

The characteristics of the culverts projected and the calculation results are attached in **Annex 2. Civil. VII. Drains ANNEX Nº 3 SUMMARY TABLE OF CULVERTS** and **Annex 2. Civil. VII. Drain. Drawings CSH-1-PL-G-G-7106-5_DRAIN PLANT, CSH-1-PL-G-G-7107-5_DETALLES, CSH-1-PL-OD-G-7110-5_CULVERTS TUBO, CSH-1-PL-OD-G-7111-5_CULVERTS BOX** contains the location, ground plan, elevation and details of culverts.

7.5 FOREST HARVESTING

In order to develop the Rumichaca – Pasto Divided Highway Project, segment San Juan –Pedregal, Concesionaria Vial Unión del Sur requires a unique forest harvesting permit for the activities inherent in the project as: Building of a second roadway parallel to the existing roadway from PK15+750 to PK17+000, building of a new divided highway from PK17+000 to PK42+261, building of a second roadway parallel to the existing one, from PK42+261 to PK44+909, building of 5 bridges and/or viaducts. Building of four (4) exchangers, building of three (3) U-turns, building of Bypass de Pilcuán and execution of geotechnical works for stabilization of slopes. All this shall be made considering the characteristics of the biotic environment, environmental and management zoning, as well as the activities planned in the Environmental Management Plan of this study.

Therefore, a harvesting permit is requested for the natural covers of: dense forest of solid ground in the high orobiome of the Andes (BD), riparian forest in the medium orobiome of the Andes (Br), high secondary vegetation in the high orobiome of the Andes (VSAoaA) and high secondary vegetation in the medium orobiome of the Andes (VSAomA). Additionally, the anthropogenic covers (mainly mosaic of pastures and crops) were inventoried 662.63 ha (survey of 100% of small trees) equivalent to 40.67% of the intervention area.

7.5.1 Location of Forest Sampling Units

In order to estimate the harvesting volume in each one of the natural covers subject to intervention, plots (forest sampling units) were established over the dense forest of firm land in the high orobiome of the Andes (BD), riparian forest in the medium orobiome of the Andes (Br), high secondary vegetation in the high orobiome of the Andes (VSAoaA) and high secondary vegetation in the medium orobiome of the Andes (VSAomA), which comply with a sampling mistake not higher than 15% and a probability of 95%.

Table 7.65 shows the Forest Sampling Units established, which are the basis of the statistical analysis of this study and the flora characteristics contained in **Chapter 5. Biotic Environment.**

Table 7.65 Location of Forest Sampling Units

VEGETATION COVER	SYMBOL OF FOREST SAMPLING UNIT	COORDINATES MAGNA SIRGAS WEST ORIGIN, COLOMBIA			
		ENTRANCE		EXIT	
		East	North	East	North
Dense forest of firm land in the high orobiome of the Andes	BD1	951992	596318	952042	596327
	BD2	952551	596876	952557	596828
	BD3	952543	596826	952533	596873
	BD4	952675	596988	952618	597021
	BD5	951669	596946	951712	596971
	BD6	951754	595931	951772	595887
Riparian forest in the medium orobiome of the Andes	BR1	955120	600556	955170	600565
	BR2	954446	603176	954393	603174
	BR3	954413	602583	954457	602609
	BR4	954353	603059	954317	603020

VEGETATION COVER	SYMBOL OF FOREST SAMPLING UNIT	COORDINATES MAGNA SIRGAS WEST ORIGIN, COLOMBIA			
		ENTRANCE		EXIT	
		East	North	East	North
	BR5	956767	598731	956778	598682
	BR6	955875	599490	955917	599520
	BR7	955236	597981	955220	597956
	BR8	954908	599309	954942	599346
High secondary vegetation in the high Orobiome of the Andes	VSA-OaA1	951889	595282	951934	595263
	VSA-OaA2	951473	594964	951432	594933
	VSA-OaA3	951250	594916	951251	594864
	VSA-OaA4	952470	596301	952469	956352
	VSA-OaA5	952292	595975	952265	596018
	VSA-OaA6	952100	596241	952077	596214
High secondary vegetation in the medium Orobiome of the Andes	VSA-OmA1	955341	600187	955316	600144
	VSA-OmA2	954968	600777	955013	600752
	VSA-OmA3	955165	603442	955205	603411
	VSA-OmA4	954712	603434	954750	603465
	VSA-OmA5	956643	598698	956635	598647

Source: GEOCOL CONSULTORES S.A., 2017.

7.5.2 Size of Sampling Units

From the standardized basic sampling unit for the studies of diversity in natural forests of the neotropic of 0.1 ha established by Gentry (1982), the size of the plots was adapted and established for each cover unit in accordance with the vegetation size for the cover of dense forest of firm land in the high orobiome of the Andes (BD), riparian forest in the medium orobiome of the Andes (Br), high secondary vegetation in the high orobiome of the Andes (VSAoaA) and high secondary vegetation in the medium orobiome of the Andes (VSAomA). The size used was 50m * 10 m or 0.05 ha.

Accordingly, the sizes of the sampling units for each vegetation cover analyzed are as follows:

Table 7.66 Size of the Forest Sampling Units for each Cover

UNIT OF LAND COVER	SAMPLING AREA		
	SMALL TREE	SAPLING	SEEDLING
Dense forest of firm land in the high orobiome of the Andes	50m*10m	5m*5m	2m*2m
Riparian forest in the medium orobiome of the Andes	50m*10m	5m*5m	2m*2m
High secondary vegetation in the high Orobiome of the Andes	50m*10m	5m*5m	2m*2m
High secondary vegetation in the medium Orobiome of the Andes	50m*10m	5m*5m	2m*2m

Source: GEOCOL CONSULTORES S.A., 2017.

7.5.3 Forbidden, Endemic Threatened or in Critical Danger Species Reported in the Study

Once the forest sampling made and the list of species found and reported consolidated for the area of influence of the project, the lists of threatened flora species in Colombia were consulted, as listed by the Ministry for the Environment and Sustainable Rural Development, Resolution 0192 of 2014, and the Red Books of Humboldt Institutes and SINCHI; among others, obtaining the following results:

Table 7.67 Threatened Vegetal Species within the Area of Influence of the Project

SPECIES	COMMON NAME	RES. 0192/MADRS	RED BOOKS	RED LIST UICN	CITES	ENDEMISM	CLOSED SEASONS
Juglans neotropica Diels.	Walnut tree	EN	-	EN	-	-	Resolution 316 of 1974
Cedrela odorata L.	Cedar	EN		EN	III		-

Source: GEOCOL CONSULTORES S.A., 2017.

According to the review, there are two threatened forest species which are in the endangered (EN) category. The species Cedrela odorata L. (cedar) has been classified as threatened according to the reports of corporation since about 60% of their populations are located in intensive exploitation regions. This exploitation record has led to include Colombia in Appendix II of the Convention on International Trade in Threatened Species of Wild Fauna and Flora –CITES-, from October 30, 2001.

As for *Juglans neotropica* Diels., it was classified as Endangered (EN) since 52% of its populations have faced an intensive process of wood exploitation and, thus, population decrease. By Resolution 0316 of 1974, the INDERENA established the indefinite closed season for all kinds of use and exploitation of wild populations of *Juglans neotropica* Diels. in the entire national territory (SINCHI, MADRS, 2006).

Before the start of the building activities, the procedure for lifting of the closed season for species that require so (See **Annex 1. Communiqués_ Request of Lifting of Closed Season_MAVDT**) shall be conducted. Likewise, Chapter 11 Environmental Management Plan **SHEET 17. Flora Protection** shall be considered for management of species threatened to a certain extent.

7.5.4 Statistical Analysis

A forest inventory was prepared with a probability of 95% and a sampling error below 15% per cover unit. The purpose of calculating the sampling error is to define the optimal sampling size for each vegetation cover in accordance with the heterogeneity of its biomass, basal area or volume and based on that be able to provide approximate an less biased values of the volume to be removed by hectare in each cover, if required. In this manner, it is also a logic premise that in calculation of this sampling error, variables measured are used for each one of the individuals of the population and with a known sampling surface (m^2).

The parameter used to measure accurately sampling of in the covers of dense forest of firm land in the high orobiome of the Andes (BD), riparian forest in the medium orobiome of the Andes (Br), high secondary vegetation in the high orobiome of the Andes (VSAoaA) and High secondary vegetation in the medium orobiome of the Andes (VSAomA) is the total volume, where the value of volume of small trees was only used. The statistic used was Student's t-distribution (probability of 95% and degrees of freedom (n-1) in accordance with the number of sampling units in each cover).

Having the corresponding mean volumes (□) and basal area for each cover, the standard deviation (DE), the variation coefficient (CV), the sampling error (EM) and number of plots (n) necessary to comply with an error of < 15% were calculated. According to the following formulas:

$$DE = \sqrt{\frac{\text{Suma } X^2 - \frac{(\text{Suma } X)^2}{N}}{n-1}}$$

$$CV\ \% = (DE / X) \times 100\ \%$$

$$EM\ \% = (t \times CV) / \sqrt{n}$$

$$n = (CV\ \% \times t\ 2) / EM\%^2$$

7.5.5 Volume Calculation

The total volume for small trees was calculated according to the basal area, the total height and a morphic factor (FM) of 0.70 according to the form of the cylinder, this factor being a constant used to calculate the volumes depending on the phenotype of broad-leaved species and species of tropical forests, in this case there are small trees with conic form and they are not completely cylindrical since if being completely cylinders their morphic coefficient would correspond to 1. The equation used for calculation of the volume to the different covers is the following:

Total Volume = $0.7854 \times (D)^2 \times Ht \times FM$

Commercial Volume = $0.7854 \times (D)^2 \times Hc \times FM$

Where: Constant: 0.7854

D: Diameter in meter

FM: Morphic Factor (0.70)

Ht: Total height in meters

Hc: Commercial Height

7.5.6 Sampling Representativeness

Based on the statistical requirements for the forest inventory according to the terms of reference under which this document is conceived (probability of 95% and sampling error below 15%) and using the values of total exploitable volume of the plots of dense forest of firm land in the high orobiome of the Andes (BD), riparian forest in the medium orobiome of the Andes (Br), high secondary vegetation in the high orobiome of the Andes (VSAoaA) and High secondary vegetation in the medium orobiome of the Andes (VSAomA). It was concluded that the number of sampling units is statistically representative for the covers analyzed.

As shown in **Table 7.68**, for the dense forest in the high orobiome of the Andes (BD) six (6) forest sampling units (plots) were made, each one with an area of 500m^2 (10m*50m) for a total area of 3,000 m^2 or 0.3 ha, where a total volume of 58.94 m^3 corresponding to 96,45 m^3/ha and a sampling error of 14.37% were reported. In the riparian forest in the medium orobiome of the Andes, eight (8) plots were made, each one with an area of 500 m^2 (10m*50m) for a total area of 4,000 m^2 or 0.4 ha, where a total volume of 24.6 m^3 corresponding to 61.5m^3/ha and a sampling error of 14.12% were reported. For the high secondary vegetation cover in the high orobiome of the Andes, six (6) plots were added, each one with an area of 500m^2 (10m*50m) for a total area of 3,000 m^2 or 0.3 ha, where a total volume of 15.95m^3 corresponding to 53.17m^3/ha and a sampling error of 14.7% were reported. Finally, for the high secondary vegetation cover in the medium orobiome of the Andes, five (5) plots were made, each one with an area of 500 m^2 (10m*50m) for a total area of 2,500 m^2 or 0.25 ha, with a total volume of 7.98m^3 corresponding to 31.92m^3/ha and a sampling error of 14.6%.

Table 7.68 Calculation of the Sampling Error Based on the Volume

COVER	N° OF PLOTS	MAXIMUM ERROR	STANDARD DEVIATION	VARIATION COEFFICIENT	STUDENT'S T-DISTRIBUTION	ERROR OBTAINED
Dense forest in the high orobiome of the Andes	6	15	1.34	13.69	2.57	14.37
Riparian forest of the Medium Orobiome of the Andes	8	15	0.52	16.89	2.36	14.12
High Secondary Vegetation in the High Orobiome of the Andes	6	15	0.37	14.01	2.57	14.7
High secondary vegetation in the medium orobiome of the Andes	5	15	0.19	11.76	2.78	14.6

Source: GEOCOL CONSULTORES S.A, 2017.

7.5.7 Volume to be Removed

For proper development of the project, forest harvesting is necessary in order to conduct different activities composing the project. The main activities are as follows:

- Building of a second roadway parallel to the existing roadway, from PK15+750 to PK17+000.
- Building of a new divided highway from PK17+000 to PK42+261.
- Building of a second roadway parallel to the existing roadway from PK42+261 to PK44+909.
- Building of 5 bridges and/o viaducts. Building of four (4) exchangers.
- Building of three (3) U-turns.
- Building of Bypass of Pilcuán.
- Execution of geotechnical works for slope stabilization.

Development of the aforementioned activities shall require a maximum intervention area of **1629.23 ha** and a total volume of **13048.25 m^3** distributed as follows:

7.5.7.1 Calculation of Maximum Volumes of Exploitation for Natural Covers

Considering the aforementioned activities, the maximum exploitation volume required for each activity was estimated in the different natural covers based on the volume obtained for each activity in the forest inventory made. In this manner, this volume in m^3/Ha obtained was taken to the hectares required for each activity.

Table 7.69 below shows the maximum exploitation volume required for each cover.

Table 7.69 Volume of Maximum Exploitation Area to be Intervened according to the Vegetation Cover

ACTIVITY	TYPE OF COVER												TOTAL	
	Dense forest in the high Orobiome of the Andes			Riparian Forest of the Medium Orobiome of the Andes			High Secondary Vegetation in the High Orobiome of the Andes			High Secondary Vegetation in the Medium Orobiome of the Andes				
	Maximum Area to be Intervened (ha)	Average Volume per Cover (m³/ha)	Maximum Volume to be Intervened (m³)	Maximum Area to be Intervened (ha)	Average Volume per Cover(m³/ha)	Maximum Volume to be Intervened (m³)	Maximum Area to be Intervened (ha)	Average Volume per Cover(m³/ha)	Maximum Volume to be Intervened (m³)	Maximum Area to be Intervened (ha)	Average Volume per Cover(m³/ha)	Maximum Volume to be Intervened (m³)	Total Maximum Area to be Intervened (ha)	Total Maximum Volume Requested (m³)
· Building of a second roadway parallel to the existing roadway from PK15+750 to PK17+000. · Building of a new divided highway from PK17+000 to PK42+261. · Building of a second roadway parallel to the existing roadway from PK42+261 to PK44+909. · Building of 5 bridges and/or viaducts. Building of four (4) exchangers. · Building of three (3) U-turns. · Building of Bypass of Pilcuán. · Execution of geotechnical works for slope stabilization.	3.1	196.45	608.99	50.69	61.5	3117.43	21.18	53.17	1126.14	27.1	31.92	865.03	102.07	5717.60
TOTAL	**3.1**	**196.45**	**608.99**	**50.69**	**61.5**	**3117.43**	**21.18**	**53.17**	**1126.14**	**27.1**	**31.92**	**865.03**	**102.07**	**5717.60**

Source: GEOCOL CONSULTORES S.A, 2017.

According to **Table 7.69**, the forecast of maximum wood volume to be removed in natural covers for the activities of the Rumichaca – Pasto Divided Highway Project, San Juan –Pedregal segment would be **5717.60 m^3** in **102.07 ha**, distributed as follows:

- **Dense forest in the high orobiome of the Andes:** A total volume of 608.99 m^3 of wood is projected to be removed in 3.1 ha.

- **Riparian Forest in the Medium Orobiome of the Andes:** A total volume of 3117.43 m^3 of wood is projected to be removed in 50.69 ha.

- **High Secondary Vegetation in the High Orobiome of the Andes:** A total volume of 1126.14 m3 is projected to be removed in 21.18ha.

- **High Secondary Vegetation in the Medium Orobiome of the Andes:** A total volume of 865.03 m^3 is projected to be removed in 27.01 ha.

7.5.7.2 Calculation of Maximum Volumes of Exploitation for Living Fences and Isolated Trees

In addition to forest harvesting in natural covers for proper development of the Rumichaca – Pasto Divided Highway Project, San Juan –Pedregal Segment, it is necessary to request forest harvesting in the intervened covers, mainly in the mosaic cover of pastures and crops, which is the widest cover in the intervention area with 78.46% (1278.37 ha) (See **Table 7.70**). Such area is subject to forest harvesting since it has living fences and isolated trees. This calculation of forest harvesting also includes less abundant covers intervened but also present in the intervention area of the project and subject to forest harvesting as mosaic of crops, forest plantation and clean pastures.

Table 7.70 Covers Present in the Intervention Area of the Rumichaca – Pasto Divided Highway Project, San Juan –Pedregal Segment

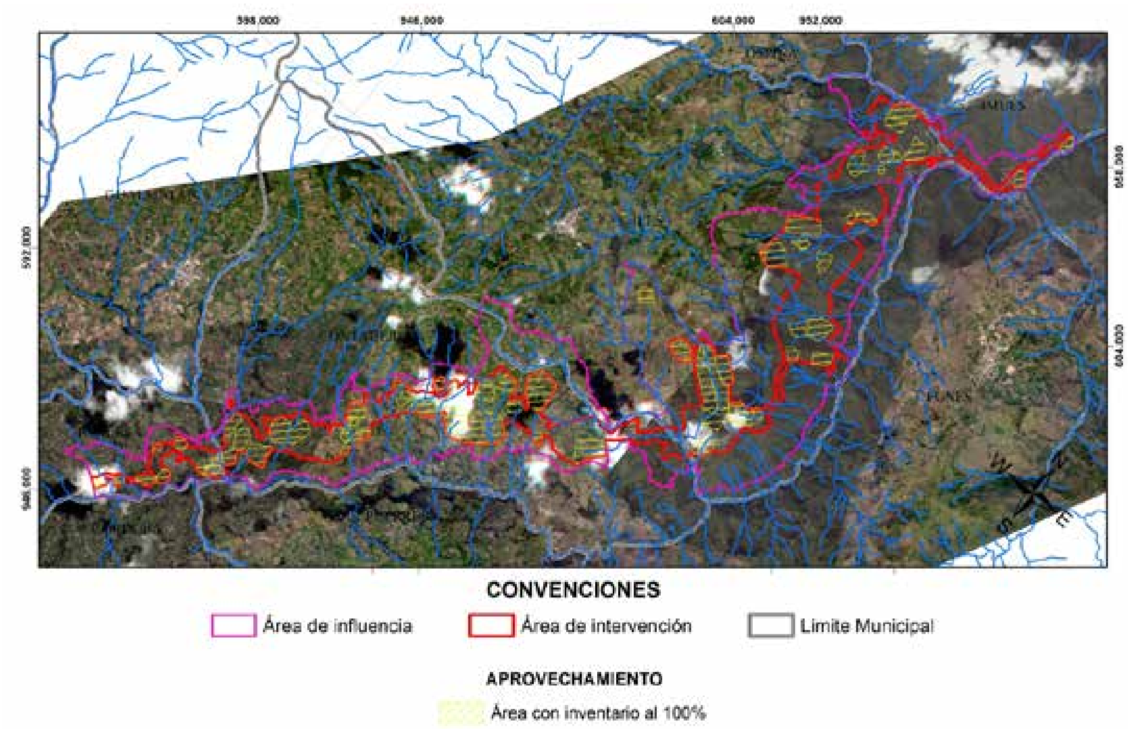
COVER	AREA	PERCENTAGE %
Mosaic of pastures and crops	1278.38	78.46
Low secondary vegetation*	116.95	7.18
Riparian forest*	50.69	3.11
High secondary vegetation*	48.29	2.96
Forest plantation	47.32	2.90
Discontinuous urban tissue	35.47	2.18
Clean Pastures	16.63	1.02
Mosaic of crops	14.04	0.86
Road network and associated lands	5.97	0.37
Discontinuous urban tissue	4.90	0.30
Exploitation of building materials	4.32	0.27
Dense forest in the high orobiome of the Andes*	3.10	0.19
Rivers	2.34	0.14
Open rocky grassland*	0.83	0.05
TOTAL	**1629.23**	**100**

*Natural covers for which forest harvesting was already calculated (See **7.5.7.1 CALCULATION OF MAXIMUM VOLUMES OF HARVESTING FOR NATURAL COVERS**)
Source: GEOCOL CONSULTORES S.A, 2017.

For calculation of the forest harvesting for the covers intervened an inventory of 100% of small trees was made (census) in 662.63 ha of the intervention area. This inventory corresponds to 40.67% of the total intervention area of the project and al 47.02% of the intervention area without natural covers for which calculation of forest harvesting was made (See Section **7.5.7.1 Calculation of Maximum Volumes of Harvesting for Natural Covers**).

The area with 100% of inventoried small trees (census) is shown below.

Figure 7.91 Inventoried Area of Intervention of the Rumichaca – Pasto Divided Highway Project, San Juan –Pedregal Segment



Source: GEOCOL CONSULTORES S.A., 2017.

9535 small trees were inventoried and a total inventoried volume of 3443.57m3 was registered in 662.63 ha **(Annex 9. Flora)** for an average volume of 5.2 m3/ha. Based on these calculations, forest harvesting is projected for the total area of anthropogenic covers to be intervened.

Photograph 7.32 Tree measurement in living fence	Photograph 7.33 Tree marked with yellow paint with a single code in the inventory within the intervention area
E: 948411- N:591588	E: 948138 – N: 591671
	

Source: GEOCOL CONSULTORES S.A., 2017.

The maximum volumes to be exploited for proper development of the Rumichaca – Pasto Divided Highway Project, San Juan –Pedregal segment are shown below.

Table 7.71 Volume of Maximum Exploitation of Anthropogenic-Origin Vegetation Cover to be Intervened

ACTIVITY	TYPE OF COVER						TOTAL	
	Mosaic of pastures and crops			Other anthropogenic covers subject to forest harvesting				
	Maximum Area to be Intervened (ha)	Average inventoried volume (m^3/ha)	Maximum Volume to be Intervened (m^3)	Maximum Area to be Intervened (ha)	Average inventoried volume (m^3/ha)	Maximum Volume to be Intervened (m^3)	Total Maximum Area to be Intervened (ha)	Total Maximum Volume Requested (m^3)
· Building of a second roadway parallel to the existing roadway from PK15+750 to PK17+000. · Building of a new divided highway from PK17+000 to PK42+261. · Building of a second roadway parallel to the existing roadway from PK42+261 to PK44+909. · Building of 5 bridges and/or viaducts. Building of four (4) exchangers. · Building of three (3) U-turns. · Building of Bypass of Pilcuán. · Execution of geotechnical works for slope stabilization.	1278.38	5.20	6649.30	130.99	5.20	681.35	1409.37	7330.65
TOTAL	**1278.38**	**5.20**	**6649.30**	**130.99**	**5.20**	**681.35**	**1409.37**	**7330.65**

Source: GEOCOL CONSULTORES S.A, 2017.

In accordance with **Table 7.71**, the maximum wood volume projected to be removed in anthropogenic covers required for the activities of the Rumichaca – Pasto Divided Highway Project, San Juan –Pedregal Segment would be: **7330.65 m^3** in **1409.37 ha**, distributed as follows:

- **Mosaic of Pastures and Crops:** A total volume of 6649.30 m^3 of wood is projected to be removed in 1278.38 ha.
- **Other Anthropogenic Covers Subject to Forest Harvesting:** A total volume of 681.35m^3 of wood is projected to be removed in 130.99 ha.

7.5.8 Forest Harvesting System

Forest harvesting shall be made before the works of the project through a total cutting or clear felling in delimited areas, consisting in exclusive extraction of the inventoried trees in the selected areas, forest harvesting shall be made according to the activities described in **Sheet 15. Management of Stripping and Vegetation Cover**.

The activities necessary to develop tree felling.

7.5.8.1 Pre-Cutting

- Trees must be prepared for cutting observing the following:

- Verify if the direction of fall recommenced is viable and if there are accident risks. For example, broken branches hanging in the top tree.

- Clean the trunk to be cut. Cut the lianas and very young trees and remove eventual termite houses, broken branches or other obstacles located next to the tree.

- Make the hollow test. In order to certify that the tree is hollow, the chainsaw operator introduces the blade of the chainsaw in the trunk in a vertical direction. In accordance with the entrance resistance, presence and size to the hole can be assessed.

- Remove elements that had been placed on trees during the inventory and transfer them to the basis of the tree (under the cutting line). Removal of such elements is importance since they can cause damages to the saw during felling of trees.

- Clean the area and prepare escape roads through which the team can run away when a tree is falling. The roads must be built in opposite sense to the trend of tree fall. For trees with trunks of good quality (little inclination and without planks) and the natural felling direction favorable to the dragging operation, the pattern cutting technique is used. Other techniques classified as special cutting are used for trees with at least one of the following characteristics: large diameter, excessive leaning, trees that side scar easily, presence of planks, existence of big holes and felling direction unfavorable for dragging.

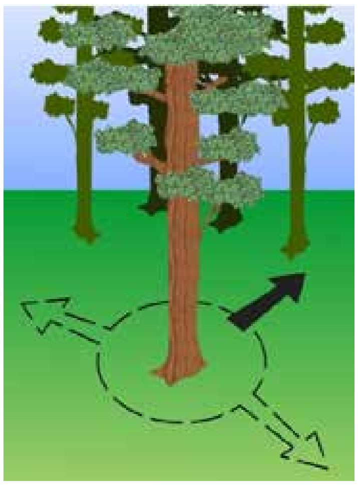
Figure 7.92 Pre-cutting

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.93 Cleaning of Area

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.94 Building of Escape Roads



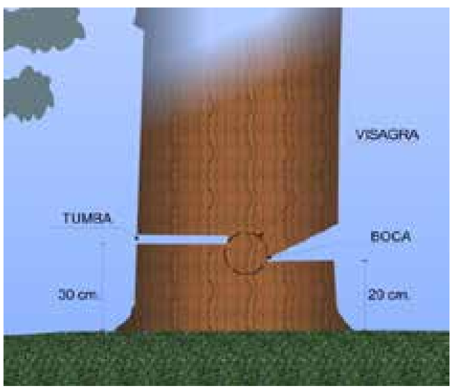
Source: GEOCOL CONSULTORES S.A., 2017.

7.5.8.2 Cutting

The pattern technique consists in a sequence of three incisions: face notch opening, diagonal cut and oriented back cut.

- The face notch opening is a horizontal cut in the trunk (always on the falling site of the tree) and at a height of 20 cm above the ground. This cut must penetrate the trunk until reaching approximately one third of the diameter of the tree.
- Another diagonal cut is made until reaching the horizontal cutting line, forming a 45 degree angle.
- Last, the back cut is made horizontally opposite to the face notch. The height of this cut is 30 cm with respect to the ground and the depth reaches half of the trunk. The uncut part of the trunk (between the back cut and face notch), named hinge, serves to support the tree while falling, allowing the tree to fall in the direction of the notch opening. The hinge thickness must be near 10% of diameter of the tree.

Figure 7.95 Pattern Technique



Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.96 Face Notch Opening

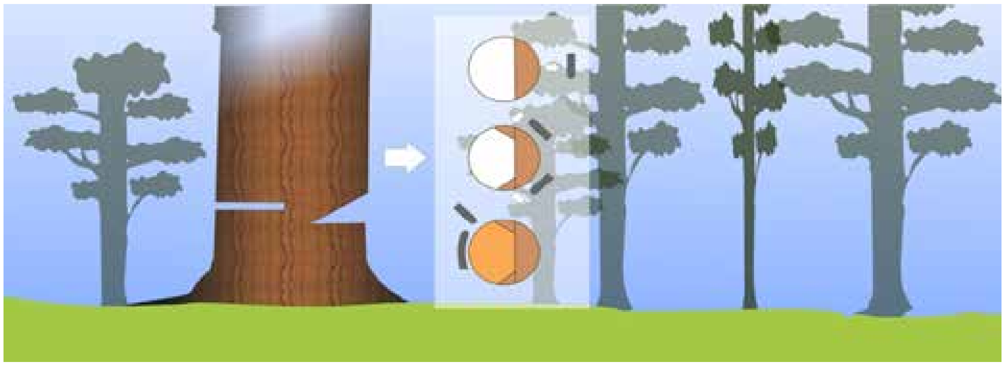
Source: GEOCOL CONSULTORES S.A., 2017.

7.5.8.2.1 Special Cutting Techniques

The special cutting techniques are based on the pattern, being used for the following situations:

- Trees requiring felling direction change. In order to facilitate dragging and protection of the remaining trees, on some occasions, it is necessary to orient the tree to be cut towards a direction different to the natural trend. The helper introduces the wedge in the back cut orienting fall of the tree. It works as a support making more difficult fall in that direction. Control of the felling direction can be reinforced by leaving the hinge narrower in the side of the natural fall. This part breaks first causing a torsion an orienting the fall of the tree towards the desired side.
- Trees that side scar easily. In order to reduce the tension and thus the possibilities of scars during the cutting operation, the borders of the hinge must be cut.

Figure 7.97 Trees that Scar Easily



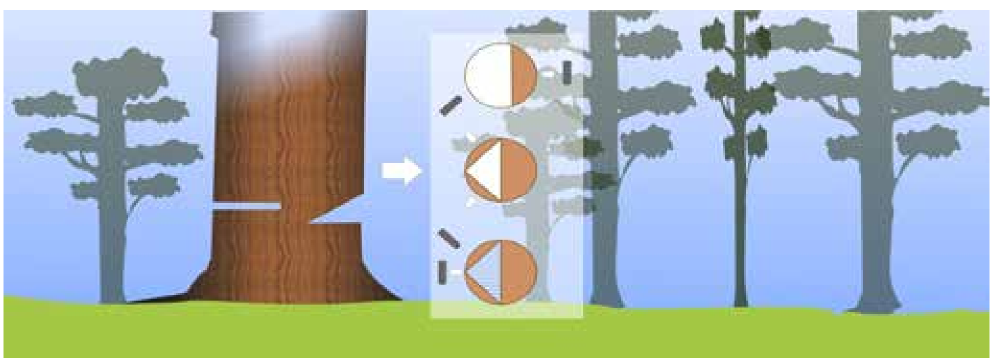
Source: GEOCOL CONSULTORES S.A., 2017.

- Hollow Trees. Most of serious accidents in the cutting are caused by the fall of hollow trees since they tend to fall fast and in an unpredictable direction. If the tree is hollow only at the base of the trunk (one meter high), cutting above the hollow part shall solve the problem. Nonetheless, if the hollow part goes beyond the trunk, a special cutting method shall be required.

- Large trees. Large trees need to be cut by stages as to facilitate management of the chainsaw and prevent the blade to get stuck in the tree.

- Trees with leaned trunks. Trees with a marked leaning involve greater risks of accidents during cutting because they tend to fall very fast. Additionally, the cracks caused by cutting mistakes are more common in these trees.

Figure 7.98 Big Trees

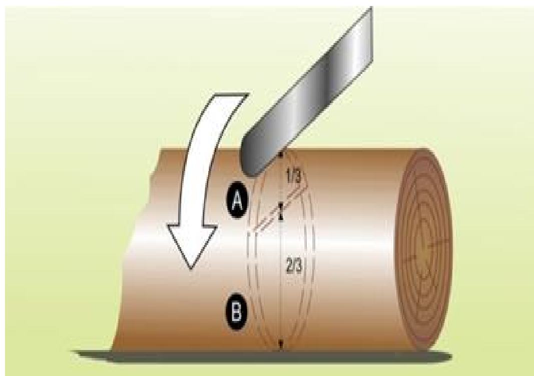


Source: GEOCOL CONSULTORES S.A., 2017.

7.5.8.3 Post-Cutting

The post-cutting activities consist initially in the topping (separate the treetop from the trunk of the tree) and divide the logs in smaller logs (log cutting). The number of logs depends on the initial length of the trunk, the density of wood (heavy logs are difficult to transport) and the felling position with respect to the dragging ramification. Thereafter, the chainsaw operator shall verify if there are potential obstacles in the hooking log, as small trees or stumps in the way. If any, the operator must remove them. The cutting team must cut in small parts the trees that have fallen naturally and go through the dragging trails.

Figure 7.99 Opening of the Face Notch



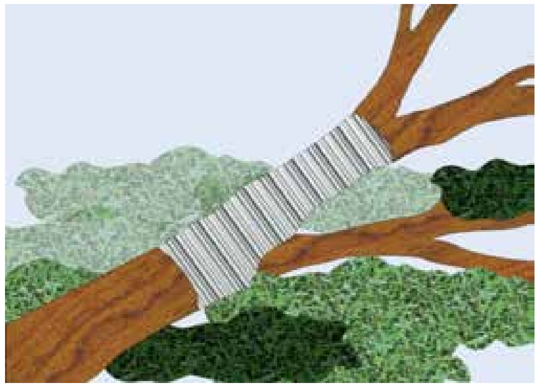
Source: GEOCOL CONSULTORES S.A., 2017.

7.5.8.3.1 Common Mistakes in Post-Cutting

- Topping Mistake: cut made under the recommended level. This type of mistake causes an average waste of 0.83 m3 per hectare.

- Mistake in Estimation of the Hole: Overestimation of the length of the hollow part of the tree causes an average waste of 0.03 m3 per hectare.

Figure 7.100 Topping Mistake



Source: GEOCOL CONSULTORES S.A., 2017.

7.5.8.3.2 Prevention of Accidents in Tree Cutting

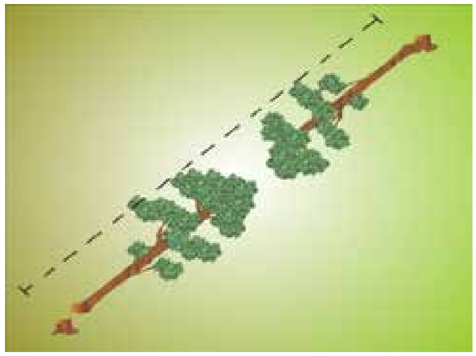
Most of the accidents in wood exploitation (some fatal) occur at the tree-cutting stage. In order to prevent such accidents, in addition to using the proper cutting techniques, the following preventive measures must be adopted:

Liana Cutting: It is common to find trees intertwined by lianas. In this manner, felling of one tree would be enough for the other trees to fall too. Liana cutting reduces significantly the number of risks of accidents for the exploitation equipment.

Building an escape route: The cutting team cleans the area around the tree to be cut, removing the eventual obstacles as small trees and broken branches. Thereafter, it defines and opens the escape route, outside the probable tree felling radio.

Keep a minimum distance between the pieces of work equipment: When two or more devices are working in the same exploitation area, it is necessary that they are at a minimum distance of 100 meters between each other.

Figure 7.101 Escape Route from Topping



Source: GEOCOL CONSULTORES S.A., 2017.

- Use of Safety Tools: The cutting team must use appropriate clothes for forest work as anti-sliding boots with a steel point, helmets and gloves. In case of the chainsaw operator, a helmet with protection for the eyes and ears, and nylon pants.

- Correct use of the chainsaw: Several hazardous situations during cutting are caused by inappropriate use of the chainsaw.

7.5.8.3.3 Other Management Measures

- The staff of the activity shall be trained with respect to the exploitation system described above in order to prevent unnecessary damages (excessive cuts, injuries caused by trees, etc.). This training shall be oriented to the proper management of tools, marking, industrial safety, among others. Likewise, inappropriate activities as burning, disposal of material on the roads, removal of unauthorized trees, non-observance of the basic and essential industrial safety measures of development of inappropriate or risky methodologies, shall be detected and indicated.

- There shall be talks for induction to the staff about management of the vegetation cover and use of soils.

- The effective clearing area of the different areas defined for the building areas shall be delimited as not to affect vegetation for overestimation.

- Before starting the stripping activity, conservation of trees that do not hinder the building works in the area to be occupied shall be assessed, in accordance with the works to be developed and availability of the equipment to be installed.

- Mixing the excavated material with the vegetation cover removed in the cleaning and stripping works must be avoided.

- Non-exploitable vegetation material shall be deposited in the areas indicated in the location. This material shall not be burnt.

7.5.9 Use of Wood-Based Products

The volume of wood obtained from the activities of forest removal and harvesting shall be used in building activities of the project in which this type of material is required (See **Sheet 15. Management of Stripping and Vegetation Cover**).

7.6 ATMOSPHERIC EMISSIONS

Concesionaria Vial Unión del Sur requests a permit of emissions of fixed sources for operation of asphalt, concrete and crushing plants, as well as electric generators in camps. Such plants shall be located in conformity with **Table 7.72**.

Table 7.72 Sites of Generation of Atmospheric Emissions in the Rumichaca – Pasto Divided Highway Project, San Juan – Pedregal Segment

NAME	ABCISES	MARGIN	REMARKS	COORDINATES DATUM MAGNA SIRGAS WEST ORIGIN	
				EAST	NORTH
CAMP SAN JUAN	18+800	Right	Concrete plant	948159	590955
CAMP ILES	31+000	Left	Mobile crushing plant	955531	598238
CAMP 35+600	35+600	Left	Mobile crushing plant	954891	601759
CAMP MINA MIKEL	41+300	Left	Crushing plant	954927	604465
			Asphalt Plant	955000	604467
			Concrete Plant	954936	604379

Source: GEOCOL CONSULTORES S.A., 2017.

7.6.1 Sources of Emission

Clean air is considered a basic required of health and human well-being. Nonetheless, its pollution remains an important threat for health worldwide.

In order to establish the alteration, the sources of emission of atmospheric pollution are identified and classified. For this purpose, the current Colombian laws are considered. In such laws the following types of pollution sources are established. See **Table 7.73**.

Table 7.73. Types of Sources of Atmospheric Pollution

APPLICABLE LEGISLATION	SOURCE CLASSIFICATION		DESCRIPTION
×Resolution 909/2008 ×Resolution 910/2008	Fixed	Punctual	It is the fixed source that emits pollutants to the air through conduits or chimneys.

<table>
<tr><th>APPLICABLE LEGISLATION</th><th colspan="3">SOURCE CLASSIFICATION</th><th>DESCRIPTION</th></tr>
<tr><td>×Resolution 1309/2010</td><td></td><td colspan="2">Dispersed</td><td>It refers to the source in which the emission points of a fixed source are dispersed in an area because of movement of the emission triggering action, as open controlled burning in rural areas.</td></tr>
<tr><td rowspan="4">×Resolution 909/2008
×Resolution 910/2008
×Resolution 1309/2010</td><td rowspan="4">Fixed</td><td rowspan="4">Source Areas: It is a certain suburban or urban area or region That for having multiple fixed sources of emission it is considered as an area especially generating pollutant air substances.</td><td>Class I – High Pollution Areas</td><td>Those areas in which concentration of pollutant, given the natural or basic conditions and ventilation or dispersion conditions, exceeds a frequency equal to or higher than seventy-five percent (75%) of the cases of the annual quality standard.</td></tr>
<tr><td>Class II – Areas of medium pollution</td><td>Those areas in which the concentration of pollutants, given the natural or basic conditions and the ventilation and dispersion conditions, exceeds with a frequency over fifty percent (50%) and below seventy-five percent (75%) of the cases of the annual quality standard.</td></tr>
<tr><td>Class III – Areas of moderate pollution</td><td>Those areas in which the concentration of pollutants, given the natural or basic conditions and the ventilation and dispersion conditions, exceeds with a frequency over twenty-five percent (25%) and below fifty percent (50%) of the cases of the annual quality standard.</td></tr>
<tr><td>Class IV – Areas of marginal pollution</td><td>Those areas in which the concentration of pollutants, given the natural or basic conditions and the ventilation and dispersion conditions, exceeds with a frequency over ten percent (10%) and below twenty-five percent (25%) of the cases of the annual quality standard.</td></tr>
<tr><td rowspan="4">×Resolution 909/2008
×Resolution 910/2008
×Resolution 1309/2010</td><td rowspan="4">Mobile</td><td colspan="2">Air</td><td rowspan="4">They are sources of emission that, because of their use or purpose, are subject to be displaced, as motor vehicles, airplanes or engine-driven vehicles of any nature.</td></tr>
<tr><td colspan="2">Land</td></tr>
<tr><td colspan="2">River</td></tr>
<tr><td colspan="2">Sea</td></tr>
</table>

Source: GEOCOL CONSULTORES S.A., 2017.

In the project area, three class of atmospheric emission source were identified, to wit: Fixed, punctual and dispersed and mobile.

7.6.1.1.1 Fixed Sources

It corresponds to the source of emission located in a certain unmovable place, even when discharge of pollutants occurs in a dispersed manner.

In the area of influence of the project, the fixed sources come from agro-industrial activity characteristic of plantations of crops as potato (**Photograph 7.34**), cabbage, onion, etc. (**Photograph 7.35**), mainly due to fumigation applied to crops.

Photograph 7.34 Crop of Potato "*Solanum tuberosum*" in the Area of Influence of the Project
E: 955766; N 598044.

Photograph 7.35 Crops in the Area of Influence of the Project
E: 948454; N 591477.

Source: GEOCOL CONSULTORES S.A., 2017.

Likewise, open-air controlled burning, a recurrent practice in agriculture and burning of solid wastes as a disposal measure (**Photograph 7.36**), is a fixed source of atmospheric pollutants. This activity is regular and extended, which causes its impact to be moderate.

In turn, it was determined that the domestic activities in the rural area, as food cooking, are a fixed source of emissions due to the use of wood as source of heat. Nonetheless, since their generation is dispersed and the population is low, the impact is mild.

Photograph 7.36. Source of Emission Produced by Garbage Burning
E: 954388; N 596850.

Source: GEOCOL CONSULTORES S.A., 2017.

Another common fixed source of emission in the area of the study corresponds to quarries in **Table 7.74** is the relation of this type of fixed sources that are present in the project area. **Figure 7.102** shows location of the identified fixed sources. It is appropriate to indicate that although source 1 seems outside the area of influence, it is actually within such area and it is due to the size of the object used to represent it.

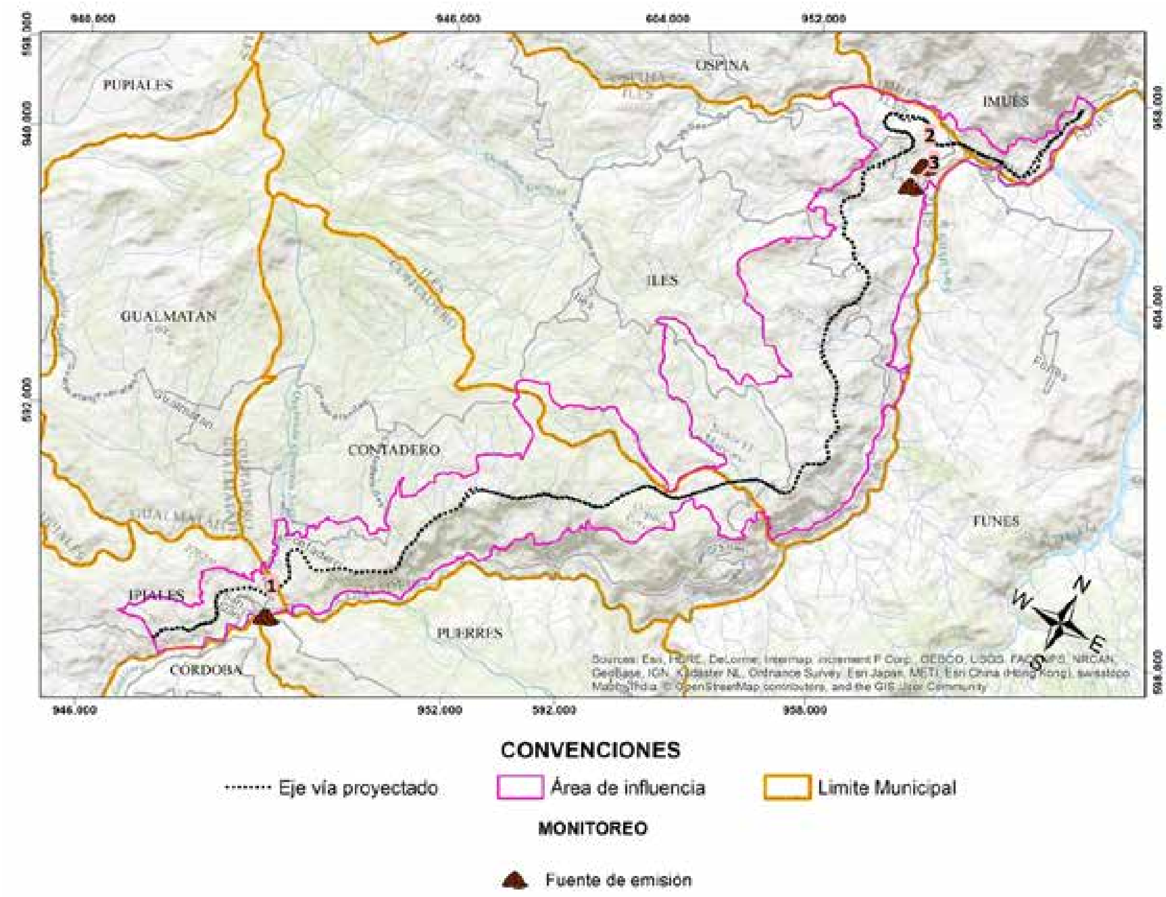
Table 7.74 Relation of Fixed Sources in the Area of Influence of the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment

ID	ACTIVITY INDUSTRIAL	LOCATION	MAGNA SIRGAS COORDINATES WEST ORIGIN		PHOTOGRAPHIC RECORD
			EAST	NORTH	
1	Quarry	**District:** San Juan **Municipality**: Ipiales	948385	590581	

ID	ACTIVITY INDUSTRIAL	LOCATION	MAGNA SIRGAS COORDINATES WEST ORIGIN		PHOTOGRAPHIC RECORD
			EAST	NORTH	
2	Quarry	**District:** Porvenir **Municipality**: Iles	954922	604213	
3	Quarry	**District** Porvenir **Municipality:** Iles	954898	603765	

Source: GEOCOL CONSULTORES S.A., 2017.

Figure 7.102 Fixed Sources of Emission in the Area of Influence of the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment



Source: GEOCOL CONSULTORES S.A., 2017.

- **Description of Fixed Sources**

<u>Quarries and Crushing Plant</u>

Quarries are places approved by the environmental entity for extraction or exploitation of Stone materials, from which, the main pollutant emitted is the particulate material. The components of the crushing plant and the description of the productive process are the following:

- Receiving Hopper: deposit where the raw material of the exploitation area is discharged.
- Primary Crushing: the first fragmentation is made reducing the size of the mineral pieces to the desired size.
- Sieve: the products are passed through a vibrating sieve in order to separate those particles which are already sufficiently fine with the subsequent increase of the secondary crushing capacity.

In general, the primary crushing is made through a primary jaw crusher which is composed of two steel planks (jaws) placed one in front of the other, one fixed and the other mobile and it can turn forwards and backwards over one axis located on the top or at the bottom using a proper short-range device. The mineral is charged in the space between the jaws and falls through the opening that forms the jaws at the bottom.

- Secondary crushing: in secondary crushing, the size of the particles coming from primary crushing are reduced to a size between 3"and 2'' as to leave them appropriate for operations of milling or preliminary concentration.
- Conveyor belts: they pick up the material already fragmented by the primary crushing or coming from subsequent processes, raise it and transported to the distribution centers or new stages of the process. The system uses closed rubber and canvas bands that turn cyclically over rollers with the electric traction.

7.6.1.1.2 Mobile Sources

They are the ones that can move in an autonomous manner emitting pollutants in their course. The main source of emission in the area subject to study corresponds to vehicles moving in the road corridor San Juan – Predregal , composed of cars, trucks, traction trucks, motorcycles and buses designed to operate in public roads. Such motor vehicles contribute, to a great extent, to emissions of CO, NOx, SOx and particulate material and, to a lesser extent, the vehicles circulating through the roads leading to the municipal head towns of Contadero and Iles and the district roads between these two municipalities.

The inventory of mobile sources that circulate through the main road corridor was derived from the study of traffic volumes 2010 -2011 of the National Road Institute – INVIAS (See **Table 7.75**).

Table 7.75 Historical Series and Composition of the Average Daily and Weekly Traffic TPDs

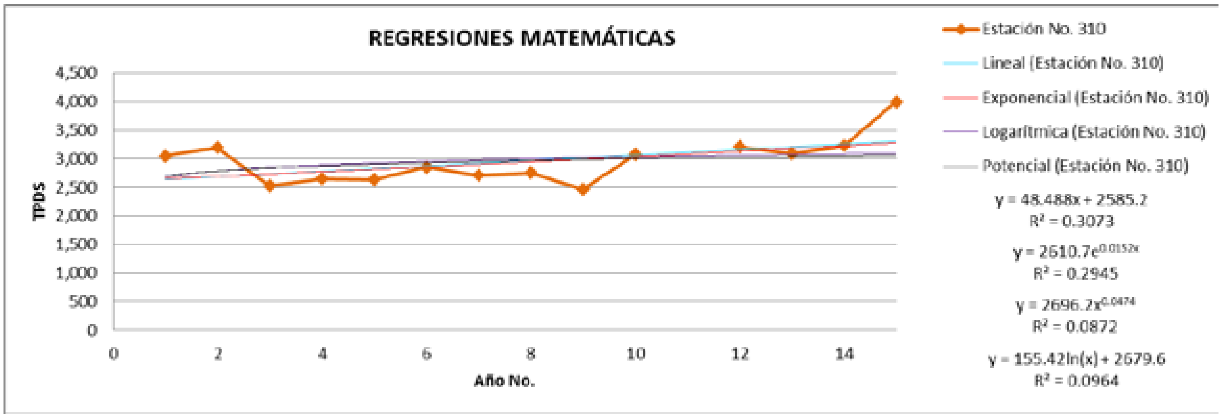
STATION No.	SECTOR	HISTORICAL SERIES AND COMPOSITION OF THE AVERAGE DAILY AND WEEKLY TRAFFIC TPDS															
		TERRITORY NARIÑO															
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	STANDARD DEVIATION (σ)
310	SAN JUAN - PEDREGAL	3053	3198	2529	2652	2637	2855	2710	2758	2466	3076	---	3214	3094	3232	4004	399

Source: Study of Traffic Volumes, INVIAS, 2010 - 2011.

By analyzing the data to establish the projection of the TPDs for 2017, the result was that the linear function is the ones that better adjusts to historical data of the road

Figure 7.103, with which a TPDs of 3603 vehicles was obtained for 2017.

Figure 7.103 Adjustment of Probability Distributions for the San Juan – Pedregal Road



Source: GEOCOL CONSULTORES S.A., 2017.

Table 7.76 Projections of the TPDs in the Ipiales San Juan – Pedregal road for 2017

YEAR	YEAR No.	TPDS	TPD
1997	1	3053	21371
1998	2	3198	22386
1999	3	2529	17703
2000	4	2652	18564
2001	5	2637	18459
2002	6	2855	19985
2003	7	2710	18970
2004	8	2758	19306
2005	9	2466	17262
2006	10	3076	21532
2007	11	---	---
2008	12	3214	22498
2009	13	3094	21658
2010	14	3232	22624
2011	15	4004	28028
2012	16	3361	23527
2013	17	3409	23866
2014	18	3458	24206
2015	19	3506	24545
2016	20	3555	24885
2017	21	3603	25224

Source: GEOCOL CONSULTORES S.A., 2017.

7.6.2 Estimation of Atmospheric Pollutants

In order to estimate the possible pollutants that arise during execution of the project, the type of plants to be used and the emissions that can generate pollutants to the atmosphere were considered. The asphalt and crushing plants which are the ones that for their processes can generate emissions were also taken into consideration. It is worth noting that the machinery to be used for operations has perimeter sprinklers and sleeve filters and fume hoods that allow concentration of PM_{10}. It is estimated that the emissions are minimal since use of hoods and filters allows recirculation of such materials in the processes. Additionally, in order to guarantee effectiveness in the measures implemented, change and maintenance of filters shall be made regularly.

- **Asphalt Plant**

The type of plants to be used in the project is continuous. This involves that they generate less wastes and are more efficient in their processes with a counter-flow drying in which the aggregates enter into the drying drum by the end opposite to the flame and flow in opposite direction of the system gases. This allows drying to occur at a lower temperature using less fuel and causing, thus, fewer emissions.

Emissions of the asphalt plant have two main sources:

Conducted Sources: They are the ones that reach the atmosphere through vents, chimneys or conduits.

Fugitive Sources: They are not driven by conduits or breathers, but are emitted directly from the source to the atmosphere. The main conducted emission source is the drying drum where in addition to generating water vapor, products of combustion and MP produce small amounts of organic compounds that result both from incomplete combustion and warming and mixing of the asphalt cement.

The main emissions generated by the asphalt plants are the following: carbon monoxide (CO), sulphur (S), nitrogen oxide (NO_X), polycyclic aromatic hydrocarbons, phenol, toluene, xylene, naphtha, styrene, formaldehyde, benzene, arsenic and cadmium.

Release of these pollutants to the atmosphere results in the following processes:

Reaction of nitrogen and oxygen in the wryer generates nitrogen oxide NO_x emissions in the combustion area.

Emissions of sulphur dioxide SO_2 are a result of oxidation of the sulphur contained in the fuel compounds. Emission of particles results in volatilization of materials that are later condensed and handling of such materials.

The emissions of volatile organic compounds COV are the byproduct of an incomplete combustion.

The amount of fine material determines the amount of dust emitted to the atmosphere, as well as the amount of asphalt cement that is consumed by unit of volume of asphalt mixture that is consumed by unit of volume of asphalt mixture produced.

Table 7.77: Emissions Estimated in Asphalt Plants

Annual Emissions Estimated in Continuous Plants			
Pollutant	EMISSIONS lb/year		
	Gasoline Dryer	Natural Gas Dryer	Emissions generated in processes
PM-10	4600	4600	104
COV	6400	6400	780
CO	26000	26000	270
SO_2	2200	680	---
NO_X	11000	5200	---

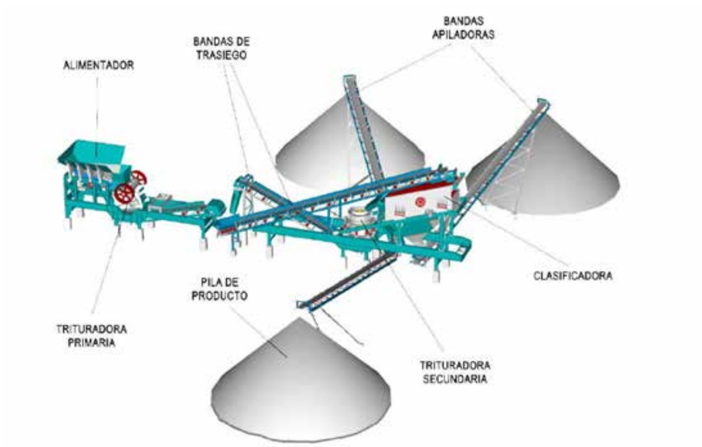
Source: States, 2000.

- **Crusher**

It is composed of stages: feeder, crusher, classifier and conveyor belts (**Figure 7.104**).

The main source of pollution of crushers is emission of particulate material due to the process of crushing and movement by the conveyor belts since they are outdoors. It shall also be considered that during transport and storage of materials previously crushed in piles volatile organic compounds and particulate material are released.

Figure 7.104 Crushing Plant Model



Source: Ciber, s.f.

The measures to mitigate the impact include:

- Reduce the height of fall of the material during movement (loading and unloading)
- Covering of the crushing plant with geotextile.
- Enclosing of the conveyor belts, which shall allow a 90% decrease of the rate of total suspended particles.

- Use of water sprinklers that keep the material wet as to prevent dust release. The times of irrigation established and the amount of water to be used require special care as to prevent excessive wetting of the material.

7.6.3 Description of the Emission Equipment

The plants to be used for development of the activities of the project are described below:

- **Asphalt Plant**

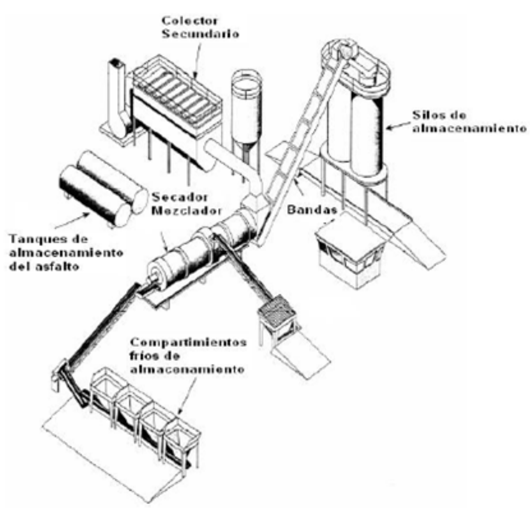
The process begins in predosage in the feeding silos when aggregates are transported to the dryer. After moist enters, the bucket conveyor takes hot and dry materials to the top of the tower. The dosage tower, which is the main center of the plant, is formed by shale shakers (sieves or sifts) with different openings for the granulometric classification that separates aggregates in different sizes. The plant system, fully computerized, allows the scale of aggregates to control the doors to integrate the necessary amounts of the materials stored temporarily in hot silos. The silos have a sealing system to prevent dust release to the environment and access covers for maintenance, as well as sample containers in each compartment. Discharged in the mixer, aggregates receive the precise amount of binder, measured by the bitumen scale. The system controls the mixing time. Upon conclusion of the process, the discharge doors release the material directly over the transport truck.

The asphalt plant is composed of the aggregate feeding system, drying system, burning system, conveyor of hot aggregates, vibrating sieve, warehouse of aggregates, measurement and mixing system, bitumen supply system, dust filtering system, warehouse of end products, control system, among others.

The type of plants to be used in the project is continuous with a counter-flow drying where aggregates enter into the drying drum by the end opposite to the flame and flow in the opposite direction of the system gases which decreases wastes and increases efficiency in the processes (See

Figure 7.105).

Figure 7.105 Scheme of the Continuous Production Asphalt Plant



Source: States, 2000.

- **Crushing Plants**

The components of the crushing plant and the description of the production process are as follows:

Receiving hopper: deposit where the raw material from the exploitation area is discharged.

Primary Crushing: It is made in the first fragmentation, reducing the size of mineral pieces to the desired size.

Sieve: the products are sieved in a vibrating sieve in order to separate particles that are already sufficiently fine with the ensuing increase in the secondary crushing capacity.

In general, the primary crushing is made through a primary jaw crusher which is composed of two steel planks (jaws) placed one in front of the other, one fixed and the other mobile and it can turn forwards and backwards over one axis located on the top or at the bottom using a proper short-range device. The mineral is charged in the space between the jaws and falls through the opening that forms the jaws at the bottom.

Secondary crushing: in secondary crushing, the size of the particles coming from primary crushing are reduced to a size between 3"and 2'' as to leave them appropriate for operations of milling or preliminary concentration.

Conveyor belts: they pick up the material already fragmented by the primary crushing or coming from subsequent processes, raise it and transported to the distribution centers or new stages of the process. The system uses closed rubber and canvas bands that turn cyclically over rollers with the electric traction.

- **Power Plants**

The type of power plant required by the project depends on the energy requirements of the asphalt, concrete and crushing plants; the place where it shall be located and if it shall work in a continuous manner or only in case of power failures. See **Figure 7.106**.

Figure 7.106: Typical Model of Power Plant

Source CATERPILLAR, 2016.

Therefore, it is proposed for power generation a KAT plant of C13 reference that has the following specifications. See **Table 7.78.**

Table 7.78: Technical Characteristics of the Power Plant

REMARK	CHARACTERISTIC
Minimum Classification	320 ekW (350 kVA)
Maximum Classification	400 ekW (450 kVA)
Voltage	380 to 415 volts
Frequency	50 or 60 Hz
Speed	1,500 or 1,800 RPM

Source CATERPILLAR, 2016.

Some of the advantages considered in the plant are that it has a reliable, resistant and long lasting, it has a four-stoke cycle diesel engine, and it combines a constant performance and an excellent fuel economy with a minimum weight. Additionally, it is under the Stage IIIA emission standards of the European Union for non-road use and standards of emissions for non-road use III from China.

The diesel engines involve a priceless contribution when reaching the environmental protection objectives. Unlike gasoline engines, thanks to their low fuel consumption, they produce about 20% less carbon dioxide.

Exhaust gases of the power plant can be eliminated using local extraction vent. This vent must use both supply vents and extraction vents to extract escape gases from the diesel power plant where they are produced.

7.6.4 Emission Control Devices or Systems

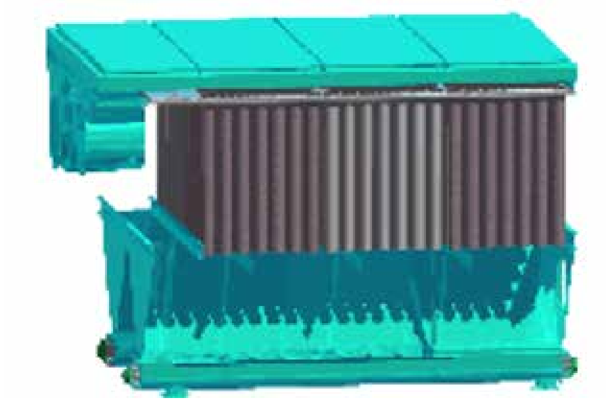
The asphalt plant has in its system sleeve filters, which are fitted with a filtering conduit in textile. Therefore the air current enters with particulate material resulting from the crushing and asphalt production process. The conduit is closed at the top so that the air goes through the walls of the conduit having thus an effect similar to a sieve. The particles are trapped in the filter and the clean air comes out the system.

The sleeve filter systems are composed of compartments (baghouse) where a big among of filters are placed. For cleaning of the filets a shaking system or injection of counter-flow air is used. These processes reintegrate these materials to the production process decreasing the negative impacts generated by generation of particulate material. Since it is not possible to apply maintenance while the system is operating, it is necessary for the continuous flow system to have compartment in parallel for recirculation of particulate material.

- **Straight Sleeve Filter**

It uses straight or folded high capacity sleeves that allow production of asphalt without hazards of environmental pollution. Sleeves filter the smaller particles that the static separator did not catch through passing of gases by a fabric filters. See **Figure 7.107**.

Figure 7.107: Straight Sleeve Filter



Source: Ciber, s.f.

- **Foldable Sleeve Filter**

Folded sleeves are used for surface filtering, which guarantees a minor risk of impregnation, better cleaning efficiency and increase of their useful life. See **Figure 7.108**.

Their filtering characteristics are as follows: Surface filtering, washable sleeves, filtering area 5 times bigger than the straight sleeves. Total filtering efficiency and fines collector.

Figure 7.108: Foldable Sleeve Filters

Source: Ciber, s.f.

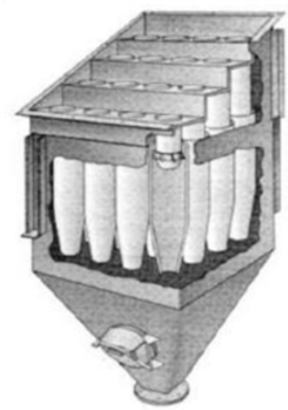
- **Cyclones**

The good operation is associated with the fall of pressure of gas flow through the system (See **Figure 7.109**). They are classified in:

High-Capacity Cyclones: They are capable of catching big amounts of particles, but not the finest particles.

Highly-Efficient Cyclones: They retain very fine particles, but the capacity is much reduced.

Figure 7.109 Cyclone Filter Model



Source: Ciber, s.f.

- **Wet Scrubbers:**

It is a system in which gases, before being released to the atmosphere, are subject to a scrubbing so that the sprayed water recovers the particles floating on gases and transports them to a settling pond (mud pool), where heavier particles are decanted and water and lighter particles flow.

- **Filtering Process for Gases and Recovery of Fines are divided in two stages:**

Electrostatic Precipitators PES

They are characterized by their high effectiveness in removal of particulate material, especially when the volume of emission gases is high and it is necessary to recover valuable materials without physical modifications. It uses an electric field to move the particles outside the gas current and over the collector plates.

Pollutant emissions containing particulate material go through an electric field where particles are negatively charged and attracted by a collecting electrode with opposite charge by a knocking system the electrode is cleaned and particles are collected in a hopper located in the bottom part of the precipitator.

Particle Precollector

The dust precollector retains in a highly effective manner particles with a size of up to 75 um and returns them in a continuous and direct manner to the conveyor of hot aggregates.

The following control measures were established:

Plant lines of trees as windbreaks around the plant

Increase the height of chimneys

Moisturizing of crushing material to prevent emission of particles

7.6.5 Dispersion Model

The purpose of this section is to conduct the mathematic modeling of pollutant dispersion (particulate material, carbon monoxide, nitrogen oxides and sulphur oxides) produced by building of the Rumichaca – Pasto divided highway, in the San Juan – Pedregal segment, as established in the environmental regulations about air quality.

7.6.5.1 Project Assumptions

The plume of pollutant emission follows a behavior that is similar to the Gaussian distribution equation, that is, it occurs at only one concentration (mass emission) and it does not change during operation of the emission sources.

$$\chi = \frac{Q}{2\pi \sigma_y \sigma_z u} e^{\frac{-1}{2}\left(\frac{y}{\sigma_y}\right)^2} \left\{ e^{\frac{-1}{2}\left(\frac{z-H}{\sigma_z}\right)} + e^{\frac{-1}{2}\left(\frac{z+H}{\sigma_z}\right)^2} \right\}$$

In order to obtain the plume model with Gaussian distribution, the mathematical formulation adopts the following premises:

- Plume dispersion is the regular distribution (Gaussian distribution).
- The emission rate (Q) is constant and continuous.
- The speed and direction of wind are uniform during transport of pollutants.
- Existence of a constant flow and weather conditions.
- Conservation of the mass within the plume.
- Constant transport in horizontal direction.
- Changes of the wind speed with the height are ignored.

7.6.5.2 Methodology

7.6.5.2.1 AERMOD Modeling System

AERMOD has several regulatory components of the AERMOD (AERMOD, AERMAP, AERMET) modeling system and non-regulatory components of the AERMOD (BPIPPRIME, AERSURFACE, AERMINUTE, AESCREEN) modeling system.

BPIPPRIME is also a model or preprocessor. The acronym means Building Profile Input Program – Plume Rise Model Enhancements (BPIP-PRIME) and it was designed to incorporate the enhanced data analysis of washing data by buildings in the U.S. EPA ISC-PRIME model.

AERSURFACE is one of the software used as a supporting tool to generate input data for the AERMOD modeling system. This software was developed to estimate the soil characteristics (albedo, Bowen coefficient and roughness) which are used by AERMET to generate weather data required by AERMOD.

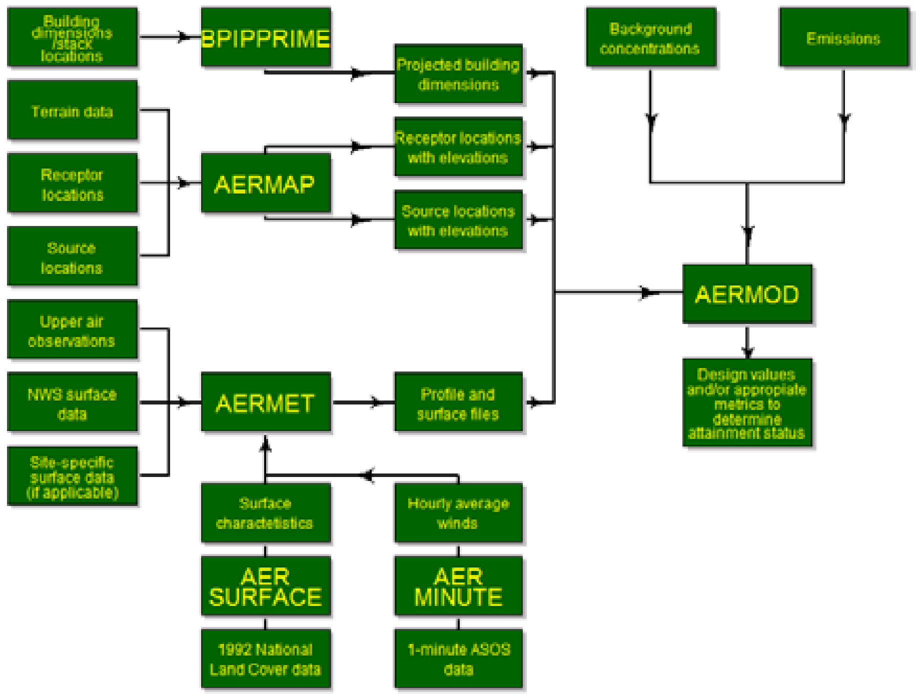
AERMINUTE processes wind data recorded every minute from Automated Surface Observing Stations, ASOS. The input data of AERMINUTE are limited to data with format of the U.S. National Climatic Data Center, NCDC known as DS-6405, only recorded by ASOS stations from the United States.

AERSCREEN estimates the maximum concentration of the soil for the impact of a fixed source simulating thus the worst-case scenario from the AERMOD model in its SCREEN version. The possible scenarios that can be simulated are the following: simple land (flat), complex land (plain and mountainous), washing of buildings and NO_2 chemistry.

7.6.5.2.2 Model Overview

AERMOD is a plume model in stable state. In the stable boundary layer (SBL), it is assumed that the distribution of the concentration is Gaussian vertically and horizontally. In the convective boundary layer (CBL), it is assumed that the horizontal distribution is Gaussian, but the vertical distribution is described as a of probability distribution function (pdf) of bi-Gaussian behavior. This behavior of distribution of the concentration in the CBL was demonstrated by Willis & Deardorff (1981) and Briggs (1973). Additionally, in the CBL, AERMOD treats the plume lofting as a portion of plume mass, released from a floating source, which rises to and remains near the top of the boundary layer before mixing within the CBL. AERMOD also follows any plume mass that penetrates into the elevated SBL and later re-enters into the boundary layer if the conditions are given. For sources in both layers, SBL and CBL, AERMOD considers enhancement of the lateral dispersion resulting from twists and turns of the plume.

Figure 7.110 General Structure of the AERMOD Modeling System. EPA (2004)



Using a relatively simple approximation, AERMOD has incorporated the current concept about flow and dispersion in complex terrains. When appropriate, the plume is modeled with impact and/or flow parallel to the terrain. This approximation has been designed so that it is more accurate with respect to reality, has been easy to implement and avoids the need of differentiating between simple, intermediate and complex terrain, as required by the previous regulatory model (*Industrial Source Complex Short Term*, ISCST3 and *Industrial Source Complex Long Term*, ISCLT3). All the terrains are handled in a consistent and continuous manner. At the same time, the concept of division of lines of current is considered (Snyder et al., 1985) under stable stratified conditions.

One of the big improvements that the AERMOD brings to the pollutant dispersion modeling is the ability to characterize the PBL through "scaling" of the surface layer and the mixture layer. AERMOD builds the vertical profile of the weather variables required based on measurements and extrapolations of these measurements using relations (scaling) of similarity. The vertical profiles of wind speed, turbulence, temperature and gradients of temperature are estimated using all the weather observations available. AERMOD is designed to be executed with a minimum of weather observations (or parameters).

Unlike other models (ISC3), AERMOD considers heterogeneity of the PBL in its dispersion calculations. This is made "weighting" the PBL parameters in effective parameters of an equivalent homogenous PBL.

The characteristics of the land surface in form of albedo, roughness and Bowen quotient plus the standard weather observations (wind speed, wind direction, temperature and cloud cover) are input data for AERMET. AERMET calculates later the PBL parameters: friction speed ($u*$), Monin-Obukhov (L) length, convective scale speed ($w*$), scale temperature ($\theta*$), mixture height (zi) and flow of surface heat (H). These parameters are transferred to the INTERFACE (within AERMOD) subroutine, and the similarity parameters (with the field observations) are used to calculate the vertical profiles of wind speed (u), lateral and vertical turbulence fluctuations (σv, σw), the potential temperature gradient ($d\theta/dz$) and the potential temperature (θ).

- **Weaknesses and Strengths of the AERMOD Modeling Suite**

In 1991, the American Meteorological Society/Environmental Protection Agency Regulatory Model Improvement Committee (AERMIC) was created to introduce the concepts of state of the art in models of air quality of the EPA-USA. Through AERMIC, AERMOD modeling system integrated dispersion in the air base don the concepts of the structure and turbulence scale of the planetary boundary layer (PBL), including treatment of ground-level and elevated sources for simple and complex terrains. AERSURFACE is a tool that processes land cover data to determine the surface characteristics, information which is required by AERMET. AERMET uses weather data of the surface layer, radio-sounding in the atmosphere profile and specific weather information of the site. This makes quality assurance tests about the data and generates reports if it finds any problem. The final result is two weather data files that feed AERMOD.

AERMAP processes files of digital elevation models (DEM) and creates two files of data used by AERMOD.

AERMOD includes the Plume Rise Model Enhancements (PRIME) to determine the effects of the trails left by buildings near and distant to the punctual fixed sources. This model also supports variable emission rates, multiple year, and events for short periods of time. Hourly emissions can also be provided for some or all the sources of emission. Multiple receiver meshes of solar or Cartesian type are included in the same simulation. Discrete receivers, as receivers at different heights can also be included.

The modeling system has some limitations and the most important limitations are indicated below:

The model requires a big amount of data, particularly emissions and meteorology. On some occasions, it is not possible to build 100% of the inventory of emissions and the mobile sources constitute a serious limitation at the time of obtaining a good inventory. The methodology is not always available and of easy access. The Institute of Hydrology, Meteorology and Environmental Studies (IDEAM), the Colombian authority in generation of official weather information does not record surface weather information at the detail level required by AERMET I.

The ability of the models to represent the real world is very limited, for example, in the space resolution and processes that they describe. For this reason, models must be observed as a "representation of reality."

AERMOD was designed for dispersion of pollutants of stationary source at short distances (up to 50 km).

The model deals with the chemistry of SO_X and NO_X through an exponential decay rate, contrary to the detailed mechanism used by other models that deal with SO_X, NO_X, organic chemistry, chemistry in aqueous phase and production of secondary aerosols.

7.6.5.2.3 AERMET Preprocessor

AERMET processes data of the weather observations to generate the input methodology of AERMOD in the form of two files: a surface file (.sfc) and a profile file (.pfl). The surface file contains the following variables on an hourly basis:

- Flow of sensitive heat,

- Surface friction speed,
- Convective scale speed,
- Gradient of temperature over the mixed layer,
- Height of convective boundary layer,
- Height of the mechanic boundary layer,
- Monin-Obukhov (M-O) Length,
- Height of soil roughness,
- Bowen quotient,
- Surface Albedo,
- Wind speed,
- Wind direction,
- Temperature,

The file of weather profile contains the following variables according to the height:

- Standard deviation of fluctuations of the vertical speed component,
- Standard deviation of fluctuations of the horizontal speed component.

These variables are estimated using a one-dimensional boundary layer model which assumes that the horizontal conditions are homogeneous. The most relevant mathematic formulation used by the model to build input variables is shown below.

- **Surface Energy Balance**

Operation of AERMOD is based on a one-dimensional boundary layer model which assumes that the Monin-Obukhov (M-O) length remains constant near the surface. The behavior of the boundary layer is contingent upon the surface energy balance:

$$S(1 - a) + T_i – T_o = R_N = H_S + H_L + G,$$

Where S is the incoming solar radiation, Ti is the incoming thermal radiation, and To is the outgoing thermal radiation. The right side contains the sensitive heat flow (HS), latent heat flow (HL) and flow of ground heat (G). In this equation, a is the surface albedo, which is the fraction of incoming solar radiation reflected so that (1 – a) is the fraction of solar radiation absorbed by the soil.

The flow of sensitive heat, HS, plays an important role in production and destruction of turbulence: it determines the turbulence level during the day and night and governs the evolution of the boundary layer during the day. I is the flow of energy transferred from or to the land and it is estimated using the surface energy balance.

The radiative entry to the surface involves two components: solar radiation, S, and thermal radiation, T. Solar radiation refers to the region of the wave length corresponding to solar radiation, the effective temperature of which the black body is near 6000ºK. A big part of the energy is in the region of wave length of 0 <u><</u>l <u><</u> 4 mm with a peak of about 0.5 mm.

Thermal radiation refers to the energy emitted at typical temperatures of the land surface, about 300ºK. The energy is located in the region 4 <u><</u>l <u><</u> 100 mm, with a peach of about 10 mm. Input thermal radiation refers to the radiation emitted by phases constituting the atmosphere, as water vapor, carbon dioxide and other gases called greenhouse effect. Outgoing thermal radiation is the energy emitted by the soil. Given that the soil is usually hotter than the atmosphere, outgoing thermal radiation generally exceeds incoming thermal radiation.

The flow of sensitive heat is the flow of energy of the atmosphere to the land, led by temperature differences between the land and the atmosphere. During the day, the energy flows from the soil to the ground boundary layer while during the night the boundary layer provides energy to the land.

The flow of latent heat refers to the energy used to evaporate humidity of the ground. The ground heat flow refers to the energy provided to the land and ultimately determines temperature of the ground layer.

By definition, net radiation, RN, is the difference between the solar radiation absorbed by the surface and the net thermal radiation emitted by the surface. HS is the sensitive flow of heat provided to the boundary layer. HL is the latent head flow, related to evaporation of the surface water, and G is the ground heat flow.

During the el day, HS is usually over zero: the heat is provided to the atmosphere. During the night, HS < 0; the head collected from the atmosphere and the soil to resist cooling of the soil since net radiation RN becomes negative. Cooling can be inhibited in presence of clouds that irradiate energy to the ground.

When the soil is wet, a big part of incoming radiation escapes with evaporation. An approximate method usually used to consider this phenomenon is to assume that the quotient of the latent head flow, named Bowen quotient, is a number that depends only on the type of surface of the site. In the following section we shall consider the methods used by AERMET to calculate the components of the surface energy balance.

- **Solar Radiation**

In AERMET, the solar radiation reached by the soil is calculated reducing the solar flow of the top of the atmosphere (1350 W/m^2) through different factors that consider different physical effects. First, the regular solar radiation flow to the surface is determined with the cosine of the zenith angle which is the angle between the regular surface of the site and the incident solar flow direction. The zenith angle is a function of the latitude of the receiving, time of day and the declination angle. The declination angle is the angle between the normal to the earth rotation drawing around the sun and the axis of rotation of the land. Due to movement of the earth around the sun, the value of this angle varies during the entire year. The sign of declination is positive (+) when the sun has a perpendicular incidence on somewhere in the north hemisphere between March 21 (spring equinox) and September 23 (autumn equinox), and negative (-) when it has a perpendicular incidence somewhere in the south hemisphere, between September 23 (autumn equinox) and March 21 (spring equinox), and it varies between -23.45º when the sun is in the lowest part of the south hemisphere (winter solstice December 21/22), and +23.45º, when it is in the highest part of the north hemisphere (summer solstice June 21/22). Twice in the year it takes a zero value, when sun passes over the terrestrial Equator during equinoxes.

The floe of sun energy is reduced by absorption and dispersion by effect of gases, particles and clouds while it travels until reaching the ground. A fraction of the dispersed radiation reaches the ground as diffuse radiation, which is added to the direct solar radiation. In AERMET, these effects are considered by semi-empirical factors that depend on location and cover of clouds. It seems that the maximum solar radiation reached by the soil is about 1000 W/m^2, and this value is multiplied by the cosine of the zenith angle (sine of the elevation angle) to obtain in a flow per unit of normal area to the son the soil surface. This value is multiplied by the cosine of the zenith angle (sine of the elevation) to obtain in a flow of the normal to the surface of the ground. This value is later reduced by a factor which is function of cloud cover.

· **Incoming and Outgoing Thermal Radiation**

The surface of the land emits long waive radiation (4 ≤l ≤ 100 mm), which can estimate the surface temperature, which is usually 10 degrees higher than the temperature at 10 m. Since the ground temperature is not measured AERMET accepts the suggestions of Holtslag and Van Ulden (1983[3]), although it assumes that the outgoing thermal radiation is the one that could be associated with the temperature at 10 m plus a value that depends on the difference between surface temperature and the temperature at 10 m. These additional values are empirically related to net radiation. Then, during the day when the surface temperature us higher than the temperature at 10 m, the correction is added to the calculated value with the temperatures at 10 m. at night, the surface is colder than with the temperature at 10 m, the correction subtracts from the calculated radiation with the temperature at 10 m.

The outgoing short wave radiation is a complicated function of the vertical profiles of temperature and the concentration of the gases that shall be absorbed and emitted in the thermal spectrum. Clouds are the biggest emitters of thermal radiation. The downward thermal radiation can be increased substantially with the presence of clouds. In AERMET, the incoming thermal is calculated based on the empirical expressions that depend on the sixth power of temperature at 10 m and cloud cover.

· **Flows of Sensitive Heat and the Soil**

During the day, the heat ground flow, G, is usually small with respect to the flow of sensitive heat. In AERMET, it is assumed that it is a tenth part of the net radiation according to observations. This guarantees that during the day, G is inside the soil and thus net since net radiation is positive during the night, G goes to the surface because the net radiation is negative.

The difference between the net radiation and the flow of ground heat is partitioned with the sensitive heat flow, H, and the latent heat flow, L. AERMET assumes that the coefficient of the latent heat flow to the sensitive heat flow, known as the Bowen Quotient, Bo, depends only on the type of surface of the site. This relatively simple approach can be improved used other techniques as the proposals made by Holtslag and Van Ulden (1983). Nonetheless, it is worth stating that none of these methods is considered reliable since evaporation on the surface depends on a process, soil humidity transport, which is very hard to be parameterized. The expression of sensitive case flow, H, becomes

$$H_S + H_L = H_S \left(1 + \frac{1}{Bo}\right) = R_N - G$$

So that,

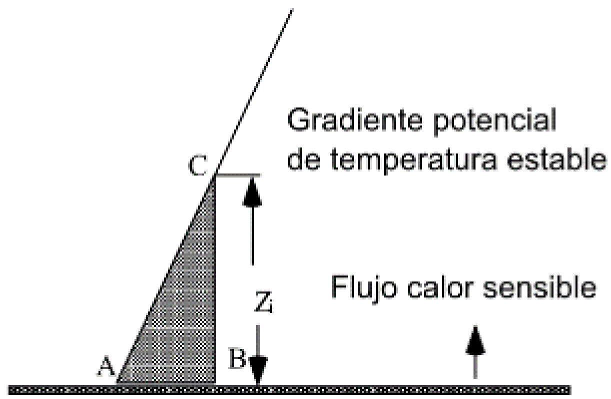
$$H_S = \frac{Bo}{1 + Bo}\left(R_N - G\right)$$

When the source is dry, the sensitive heat flow is much higher than the latent heat flow, Bo is big and the heat flow is essentially $0.9R_N$ because $G = 0.1R_N$. When the surface is wet, Bo is small. The heat flow is sensitive to the Bo values when the quotient is about 1. It is hard to determine Bo since it can vary substantially with a unique location. Nonetheless, the activities required in simulation of air pollution are not directly proportional to the sensitive head flow.

[3]Holtslag, A.A.M., and A.P. van Ulden, 1983: A simple scheme for daytime estimates of the surface fluxes from routine weather data, J. Clim. Appl. Meteorol., 22, 517-529.

- **Height of the Convective Boundary Layer (zic)**

The height of the mixed layer, z_{ic}, is estimated assuming that the sensitive heat flow entering to the atmosphere. It is used to modify the potential temperature in the mixed layer. A procedure is shown below considering a mixed layer that grows causing erosion of a layer with a potential gradient of stable temperature. Symbol H_H, instead of H_S, shall be used to identify the sensitive heat flow.



Assume that the initial potential temperature at dawn is stable and can be represented by the AC profile of the figure. The rising surface heat flow after the dawn results in a modification of the temperature of the boundary layer. In a period of time T, the temperature of the boundary layer changes from AC to BC. Note that the potential temperature (not the current temperature) is uniform in almost the entire boundary layer. The rising heat flow on the surface is led by a difference of temperature between the surface and the mixed layer.

Change of energy in the boundary layer is caused by sensitive warming in the surface corresponding to the area of the triangle ABC. If the potential gradient of temperature ABC is g, AB change of temperature is Dq, this change of energy can be expressed as follows:

$$\text{Energia en } ABC = \frac{1}{2}\rho C_p \Delta\theta z_{ic}$$

Note that Dq = gz_{ic}, we can equal this energy to the sensitive heat flow integrated over T to obtain

$$\frac{1}{2}\rho C_p \gamma z_{ic}^2 = \int_0^T H(t)dt$$

Where H(t) is the variable sensitive heat flow variable in time. For simplicity purposes, we assumed that the heat flow varies in a linear manner with time so that

$$H(t) = H_{max}\frac{t}{T}$$

Where t is a convenient time scale, the value of which is not important for this explanation. Replacing the latter equation in the previous equation we have,

$$\frac{1}{2}\rho C_p \gamma z_{ic}^2 = H_{max}\frac{T^2}{2T}$$

Which leads to,

$$z_{ic} = \left(\frac{H_{max}}{\rho C_p \gamma T}\right)^{1/2} T$$

In AERMET, the initial temperature profile at the dawn corresponds to the current sounding of the morning so that the potential temperature gradient,g, above the mixed layer varies in time with growth of the mixed layer. Additionally, the flow of surface heat, calculated from the surface energy balance generally increases from dawn to noon and thereafter, it decreases to zero at night.

Although the simple model considered herein does not integrate these temporary variations, it provides an understanding of the variables that control height of the layer mixed in AERMET. Note that the height of the mixed layer, z_{ic}, is proportional to the square root of the heat flow so that the possible mistakes in estimation of the heat flow are diminished with this calculation. We have a similar situation with the potential temperature gradient: $z_{ic} \propto 1/\gamma^{1/2}$ So that the calculation of z_{ic}, is exonerated for mistakes in determination of the potential temperature profile of the morning. This equation also tells us that z_{ic}, can be very big is the potential temperature gradient is close to zero.

The foregoing sections allow us to examine the convective scale speed, w*

- **Convective Scale Speed (w*)**

The convective scale speed, w*, is a measurement of turbulent speeds created for surface warming, referred to as convection. In order to understand this, let's examine a simple model for movement of a plot of air which becomes floating after warming on the surface. Assume that the mass of the plot is 1 kg, and that an excess of Temperature T' with respect to its surroundings which are at the Temperature T. This causes a floating rising strength of gT'/T, which accelerates the air plot upwards. If this strength acts in z distance, we can estimate the speed, w, acquired by the air plot equaling it with the work made by the strength of the kinetic energy of the plot in z,

$$g\frac{T'}{T} z \sim w^2$$

The left side of the equation is the result of the floating strength and the z distance over which it acts and the right side of the equation is the kinetic energy of the plot with a mass unit.

Introducing the sensitive heat flow to the equation and multiplying both sides of the equation by w, we obtain

$$g\frac{wT'}{T} z \sim w^3$$

Now term wT' represents the excess temperature that takes up the air plot. Actually, multiplying the term by r Cp, we find that

$$C_p w T' \sim H_S$$

or

$$wT' \sim \frac{H_S}{\rho C_p}$$

The H_S/r Cp combination is known as kinematic heat and has units of speed multiplied by the temperature and is used instead of the sensitive heat flow in building the micro-weather variables. If we replace the latter equation in the previous one, we can define the speed of free convection, u_f

$$u_f \equiv \left(\frac{g}{T_0} \frac{H_S}{\rho C_p} z \right)^{1/3}$$

Where To is a reference temperature, taken as a value closet o the surface, and HS is the sensitive heat flow. Note that u_f depends on power 1/3 of the heat flow, which suggests that a heat flow estimation mistake is reduced with estimation of uf,

The observations made indicate that the turbulence speed, S_{WC}, associated with the generation of floating is given by

$$S_{WC} = 1.3 u_f \text{para } z < 0.1\, z_{ic}$$

Over $z > 0.1 z_{ic}$, S_{WC} it is relatively constant

$$S_{WC} = 1.3 u_f \text{evaluado in } z = 0.1 z_{ic}$$

$$= 0.6 w_*$$

Where the convective scale speed, w_*, is defined by

$$w_* \equiv \left(\frac{g}{T_0} \frac{H_S}{\rho C_p} z_{ic} \right)^{1/3}$$

Therefore, the convective scale speed, w_*, is an estimation of the turbulence speed created by floating or free convection estimating its value for height of mixed layer of 1000 m, and a surface heat flow of 200 W/m^2. Taking r Cp = 1200 $J/(m^{3o}K)$, and To = 300ºK, we obtained that w_*= 1.76 m/s. So that in the upper part of the convective boundary layer, the turbulence speeds are about 1 m/s. Likewise, at 10 m the speed estimated with the latter equation is about 0.5 m/s.

It seems that the standard deviation of fluctuations of the horizontal turbulent speed, S_V, are about $0.6 w_*$ in the entire depth of the boundary layer.

Surface Friction Speed (u_*) and Height of Mechanically Mixed Layer (z_{im})

The air flowing over a surface exerts a sheer stress that depends upon the turbulence level in the boundary layer. It is possible to establish a relation between the turbulence speeds, S_W and S_V, and the sheer stress on the surface, t_o, through definition of the surface friction speed as follows

$$u_* \equiv \sqrt{\frac{\tau_0}{\rho}}$$

Where r is the air density,

When the boundary layer is stable or neutral, the turbulence speeds close to the surface are related to the surface friction speed through

$$\sigma_{ws} = 1.3u_*$$
$$\sigma_{vs} = 2u_*$$

's ' have been used in the sub-rates to emphasize the fact that these turbulent speeds are generated by cutting winds.

As mentioned before, turbulence on the stable boundary layer is caused by cutting wind and it is inhibited by the potential gradient of stable temperature. Observations made indicate that the height of the boundary layer, which is the height until which turbulence extends, is related to the surface friction speed. AERMET uses the relation of the boundary layer generated mechanically

$$z_{im} = Au_*^{3/2}$$

Where A is an empirical constant. It is evident that the height of the boundary layer is sensitive to the surface friction speed.

The vertical turbulent speed in the stable boundary layer decreases the height as follows

$$\sigma_{ws}(z) = 1.3u_* \left(1-\frac{z}{z_{im}}\right)^{1/2}$$

The median speed under almost neutral conditions is also related to the surface friction speed through a well known logarithmic profile:

$$U(z) = \frac{u_*}{k} ln \left(\frac{z-h}{z_0}\right)$$

Where *k* is the von-Karman constant=0.4, z_o is roughness, and *h* is the movement height. Roughness, z_o, is function of the physical height of the obstacles of the surface over which the air flows, and d=5z_o. AERMET modifies the foregoing equation, as described below, to consider the effects of the surface heat flow on the surface friction speed, u_*.

- **Monin-Obukhov Length (L)**

The free convection speed, u_f, is a measurement of turbulent speeds generated by floating. This speed is increased with the *z* height. Likewise, turbulent speeds generated by sheer are relatively constant in several dozens of distance under the boundary layer. The height at which the turbulence levels generated by floating layer are comparable to the ones generated by sheer is the Monin-Obuhkov length, L, obtained from the equation of u_f assessed at the height z = L until u_*,

$$\left(\frac{g}{T_0}\frac{H_S}{\rho C_p}L\right)^{1/3} \sim u_*$$

$$or$$

$$L \sim \frac{T_0}{g}\frac{\rho C_p}{H_S}u_*^3$$

The equal sign has not been used in the expression at the moment to emphasize the physical meaning of the Monin-Obuhkov length. It is observed that the sheer production dominates the floating production of turbulence below the L height. The floating production dominates over L. So, z << L, u_* rules the turbulent speeds, and he boundary layer is essentially neutral at this point. The boundary layer is convective for z >> L.

The M-O length is formally defined as

$$L \equiv -\frac{T_0}{g}\frac{C_p}{kH_S}u_*^3$$

Where k is the von-Karman constant. Therefore, H_S> 0 during the day, L is negative during the day. At night, the heat flow is negative so that L is positive. The physical interpretation discussed much earlier makes reference to the absolute value of L.

Before discussing the use that the interface AERMOD makes of L, we shall show how turbulent speeds corresponding to floating and sheer are combined.

- **Estimation of Turbulent Speeds in the Boundary Layer**

Turbulent speeds are calculated for situations when floating and sheer dominate production of turbulence. In order to consider the fact that both mechanisms act jointly in the real boundary layer, AERMET combines the speeds using a method shown below

$$\sigma_w = \left(\sigma_{wc}^3 + \sigma_{ws}^3\right)^{1/3}$$

Replacing the expressions obtained before the previous equation, for S_{WC} and S_{WS}, and using definition of L, we obtain

$$\sigma_w = 1.3u_*\left(1-\frac{z}{kL}\right)^{1/3}$$

- **Monin-Obukhov (M-O) Similarity**

The AERMOD interface uses several micro-weather variables estimated using the AERMOD model for building of profiles of medium horizontal speed and median temperature and three components of turbulence speeds. These profiles are built using similarity M-O, which shall be seen in two equations hereinafter. The principles involved in the theory are shown below considering the profile of the median speed in the stable boundary layer.

Let's consider the logarithm of the speed profile in the neutral boundary layer,

$$U(z) = \frac{u_*}{k} ln \frac{z-h}{z_0}$$

Which can be rewritten as follows

$$\frac{U(z)}{u_*} = \frac{1}{k} ln \frac{z-h}{z_0}$$

The foregoing equation affirms that the speed profile in all the neutral boundary layers, ruled by roughness, are similar if the wind speed is normalized by the scale speed, u_*, and the height (z – h) is normalized by the scale length, z_0. This is one of the premises of the similarity theory. Literature provides other interpretations which reduce the hypothesis that a small value of speed, length, time and temperature of scale can be used to summarize the median and turbulent structure of the atmospheric boundary layer.

When the floating effects are important, the additional scale length is the M-O length, L. For instance, under stable conditions, the profile of speed can be expressed as follows

$$\frac{U(z)}{u_*} = \frac{1}{k} \; ln \; \frac{z-h}{z_0} \; + \beta \frac{z-z_0}{L}$$

The speed profile in unstable boundary limit can be described using a function other than z/L.

The temperature profile can be described similarly using a temperature scale, T_*, defined by

$$T_* \equiv -\frac{H_S}{\rho C_p u_*}$$

Which can be used to describe the temperature profile in the stable boundary layer

$$\frac{T(z)-T_0}{T_*} = \frac{1}{k} \; ln \; \frac{z-h}{z_0} \; + \beta \frac{z-z_0}{L}$$

Where T_0 is the effective surface temperature

The third and last equations apply for heights of the order of M-O length, L, which define the extension of the surface boundary layer. Over the surface layer, the relevant scale is the height of the boundary layer, z_{ic} o z_{im}, and the profiles of the median and turbulent variables become functions of *z* divided by the boundary height.

The analysis of the data obtained from field studies made within the last 30 years has led to semi-empirical formulations that describe the structure of the boundary layer. The AERMOD interface uses these formulations to build the profiles required by AERMOD. The inputs are the parameters: z_0, L, u_*, w_*, z_{ic}, z_{im}, U(z) and T(z) which are in the surface file produced by AERMET.

If there were data available in the project site about measurements of speed, temperature and turbulence, at different heights in the boundary layer, the AERMOD interface can integrated these data to build these profiles.

- **Soil Characteristics for Different Seasonal Periods**

The Albedo, Bowen quotient and Roughness are soil parameters used in calculation of flows and stabilities of the atmosphere.

Similarities of the environmental conditions between the North Hemisphere are for which the AERMET/AERMOD model was developed, and the intertropical are (between the Cancer Tropic and the Equator) are established below. This similarity analysis allows identifying the three soil properties. For the North Hemisphere, four (4) seasonal periods are presented spring, summer, autumn and winter. In the North Hemisphere, the rainy season occurs in summer and the dry season occurs in autumn.

On the contrary, for the intertropical convergence are the environmental conditions are rainy period and dry period, which are similar to the environmental constants of summer and autumn. In the following tables the constants recommended by the EPA for different types of use of soil are reproduced for different seasons and the three types of soil (Albedo, Bowen and Roughness).

Table 7.79 Behavior of Albedo by Use of Soil and Season

Soil Use	Spring	Summer	Autumn	Winter
Sea, lakes, rivers	0.12	0.10	0.14	0.20
Deciduous forests	0.12	0.12	0.12	0.50
Coniferous forest	0.12	0.12	0.12	0.35
Marshes	0.12	0.14	0.16	0.30
Crops	0.14	0.20	0.18	0.60
Pastures, meadows	0.18	0.18	0.20	0.60
Urban	0.14	0.16	0.18	0.35
Desert scrublands	0.30	0.28	0.28	0.45

Source: EPA (2004).

Table 7.80 Behavior of Roughness by Use of Soil and Season

Soil Use	Spring	Summer	Autumn	Winter
Sea, lakes, rivers	0.0001	0.0001	0.0001	0.0001
Deciduous forests	1.00	1.30	0.80	0.50
Coniferous forest	1.30	1.30	1.30	1.30
Marshes	0.20	0.20	0.20	0.05
Crops	0.03	0.20	0.05	0.01
Pastures, meadows	0.05	0.10	0.01	0.001
Urban	1.00	1.00	1.00	1.00
Desert scrublands	0.30	0.30	0.30	0.15

Source: EPA (2004).

Table 7.81 Behavior of the Bowen Quotient by Use of the Soil and Seasonal Period under Dry Conditions

Soil Use	Spring	Summer	Autumn	Winter
Sea, lakes, rivers	0.1	0.1	0.1	2.0
Deciduous forests	1.5	0.6	2.0	2.0
Coniferous forest	1.5	0.6	1.5	2.0
Marshes	0.2	0.2	0.2	2.0
Crops	1.0	1.5	2.0	2.0
Pastures, meadows	1.0	2.0	2.0	2.0
Urban	2.0	4.0	4.0	2.0
Desert scrublands	5.0	6.0	10.0	10.0

Source: EPA (2004).

Table 7.82 Behavior of the Bowen Quotient by Use of the Soil and Seasonal Period under Wet Conditions

Soil Use	Spring	Summer	Autumn	Winter
Sea, lakes, rivers	0.1	0.1	0.1	0.3
Deciduous forests	0.3	0.2	0.4	0.5
Coniferous forest	0.3	0.2	0.3	0.3
Marshes	0.1	0.1	0.1	0.5
Crops	0.2	0.3	0.4	0.5
Pastures, meadows	0.3	0.4	0.5	0.5
Urban	0.5	1.0	1.0	0.5
Desert scrublands	1.0	1.5	2.0	2.0

Source: EPA (2004).

7.6.5.2.4 AERMAP Preprocessor

AERMAP is a topography preprocessor that uses the land data to calculate a representative height of influence of the land, also referred to as land height scale. This preprocessor is also used to create grids (meshes) of receivers.

AERMAP is a land preprocessor designed to simplify and standardize the land data of AERMOD. The input data are elevations of receivers, roads, coordinates and curves of level. The output data include for each receiver: location and scale in z, which are used for calculations of hillside wind flow.

There are two types of basic data required by AERMAP for execution. The first one is the file that orients execution through a set of processing options and defines location of receivers and sources of emission. The structure and syntax of an execution file is based on the same routes and tabs that use the execution control file of AERMOD.

The second one makes reference to computerized files that contain codified land data. These data are available in three types of formats. There is Digital Elevation Model (DEM) format which follows the old USGS standard of the Blue Book and there is a new format Spatial Data Transfer Standard (SDTS) which structures DEM files and other data associated in form of metadata. Finally, there is the National Elevation Dataset (NED) which is constantly updated and available in several formats for import by commercial software packages as ARCGRID, GridFloat and BILS. From these formats and standards, AERMAP is programmed to read only USGS formats of Blue Book. The SDTS, XYZ and NED data have to be converted to a Blue Book format. The EPA provides in its web site SDTS and XYZ conversion software.

Each DEM file covers a segment of the land based on the coordinates in latitude and length. These data files are available through several URL commercial sites and in the USGS portal. There are several suppliers that offer free download of USGS SDTS files in DEM format.

The DEM data can be obtained in a different spacing resolution of horizontal data. AERMAP is able to process files in Blue Book format of 7.5 minutes and 1 degree, DEM data with any uniform distance among nodes. The DEM files of 1 degree are obtained for free through the Internet (HTTP protocol) and via FTP. The DEM data of 7.5 minutes can be acquired through an international supplier of this service.

Some cartographic organizations offer freely to the public important databases that can be accessed through the Internet. Some of such organizations are as follows: the NASA (DEM ASTER, SRTM-1, SRTM-3, SRTM30, MOLA MEGDR), the National Imagery and Mapping Agency (NIMA) (SRTMs) and the USGS (DEM SDTS, 1 degree, 7.5 minutes, NED, GTOPO30).

The resolution, that is, the distance among adjacent points of the digital file offered by them varies. For instance, the DEM Aster file has a resolution of 30 m. See Table 7.83

Table 7.83 Digital Files of Elevation and their Resolution

Name	Resolution	Geographic Cover	Editor
DEM ASTER	30 m	The entire Earth planet	NASA
DEM 1 degree	90 m	United States	USGS
DEM 7.5 minutes	10 and 30 m	United States	USGS
DEM CDED	23 m and 90 m	Canada	CCOG
GTOPO30	30" of arch (~ 1 km)	The entire Earth planet	USGS/NASA
DEM SDTS	10 and 30 m	United States	USGS
NED	10 and 30 m	United States	USGS
Visual DEM France	75 m	France	IGN
MNT BD Alti*	50 a 1.000 m	France	IGN
Litto3D	1 m	France	IGN/SHOM
SRTM-3	90 m	80% of emerged lands	NASA/NIMA
SRTM-1	30 m	United States	NASA/NIMA

Source: EPA (2004)

AERMAP use the Universal Transverse Mercator (UTM) to identify location of sources and receivers. The coordinate system is a method that represents the meridians and parallel from the surface of the land in flat format.

Grids are drawn based on these zones and UTM zones and it is valid in a significant part of the total surface of the Earth but not in the surface. In a concrete manner, projection of the UTM is defined between 80º S and 84 º N parallels, while the rest of the areas of the Earth – polar areas – use the UPS (Universal Polar Stereographic) coordinate system.

Therefore, in the UTM the Earth is divided in 60 areas of 6º of length which complete 360º. Each area is identified with a number between 1 and el 60, area 1 being limited between 180° and 174° W lengths, centered in the meridian 177º W. The areas are numbered in rising order towards the East.

As for the areas, the zones, the Earth is divided in 20 zones of 8º Latitude Degrees, which are named through letters from the "C" to "X" inclusive (excluding CH, I and LL to avoid confusions and A, B, Y and Z which are served for polar areas).

7.6.5.2.5 AERMOD Processor

In general, AERMOD models plume as combination of limiting cases: horizontal plume (having an impact on the land) and a plume that follows the land. Nonetheless, for all the situations, total building and a receiver is defined by prediction of concentration based on these states. In flat land, these sates are equivalent. Introducing the concept of line division of height current, in elevated land, AERMOD calculates total concentration as the weighed sum in the concentrations associated with these limiting cases or limiting cases or states of the plume (Venkatram et al., 2001).

In AERMOD, the land preprocessor (AERMAP) uses a land data mesh to calculate a representative influence representativeness (hc) for each receiver. Through this approximation, AERMOD calculates impact of pollutants on flat and elevated land with the same modeling structure no considering the need of differentiating between formulations for simple land and complex land (which was required for previous regulatory models).

7.6.5.3 Basic Weather Information

Weather information has been obtained through a simulation using the MM5 model. The MM5 model details are contained below,

- The weather model of mesh scale of fifth generation MM5 was developed by Atmospheric by the Penn State University, PSU) and the National Center for Atmospheric Research, NCAR). It was chosen by the National Meteorological System for its high definition in detection of atmospheric systems of mesh scale and has all the necessary characteristics for adaptation to specific conditions of any region of the planet. Some characteristic of the MM5 are described below.
- Multiple nesting capacity with interaction (up to nine domains running simultaneously and exchange of information among them) (two-way") among domains in a hydrostatic or non-hydrostatic manner de design of forecasts at a very high resolution.
- Formulation of non-hydrostatic dynamics which allows that the model can be used effectively to represent phenomena with dimensions of few kilometers.
- Automatic start with different sources of weather analysis and observations including their 4-dimension data assimilation capacity.
- Variation assimilation of conventional and satellite data during prediction.
- Integration of the most modern and realistic parameterization schemes of physical processes related to atmosphere radiation, microphysics of clouds and precipitation, convection by clusters, turbulence and energy flows and moment over the land surface.
- It is a diagnosis and prognosis model. It can be sued for simulations of previous dates (*reanalysis*), current or for forecast.
- It is a Eurelean type model.
- It uses FDDA (Four-Dimensional Data Assimilation), that is, in the X, Y, Z, and time axes.

It can be applied to any area of the world since it is possible to develop the input information (meteorological fields, topography and soil use) necessary for its operation, even for areas with high spatial resolution with a complex topography.

Bearing in mind that the information obtained by the MM5 model corresponds to years 2013 and 2014, these data are analyzed below.

7.6.5.3.1 Temperature

The air temperature regime is determined by the geographic location and the physiographic characteristics of the area. For the area subject to study there are significant geographic accidents, and the annual average value of the temperature in the areas is 11.53 °C.

According to the MM5 forecast model, the median temperature values recorded indicate that in average the minimum temperature of the area is above 8.1°C and the maximum average temperature exceeds 18ºC. Additionally, during 11 out of 12 months of the year there are mean temperatures above 12 °C. Figure 7.111

shows the data of the dry bulb temperature for maximum average daily values (orange), minimum average daily values (blue) and daily averages (green) and Figure 7.112 contains the wet bulb temperature data for maximum daily average values (orange), minimum daily average values (blue) and daily averages (green))

Figure 7.111 Dry Bulb Temperature

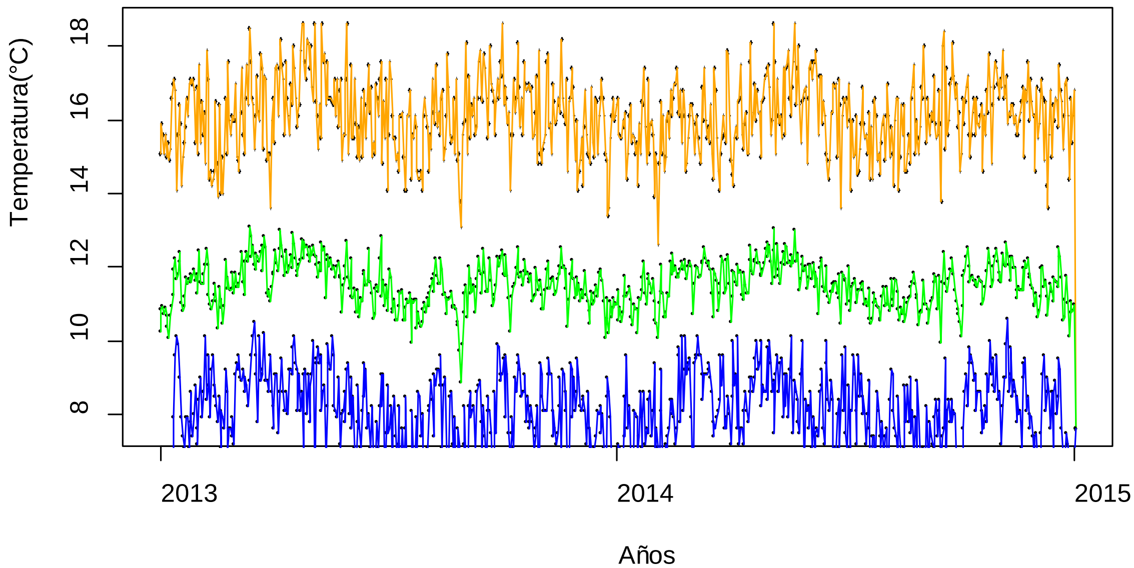
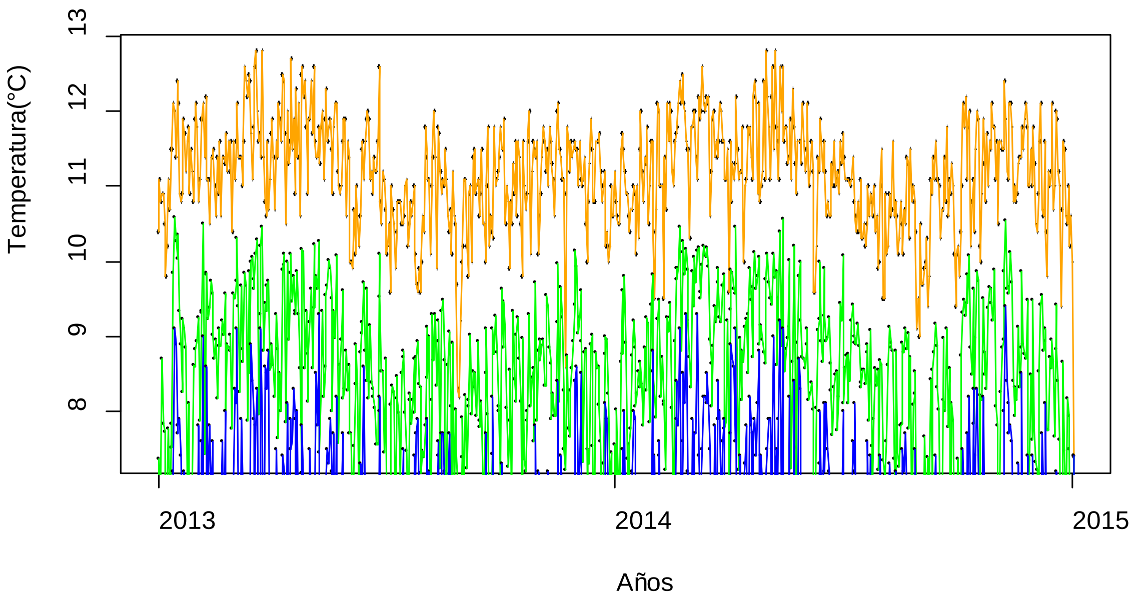


Figure 7.112 Wet Bulb Temperature



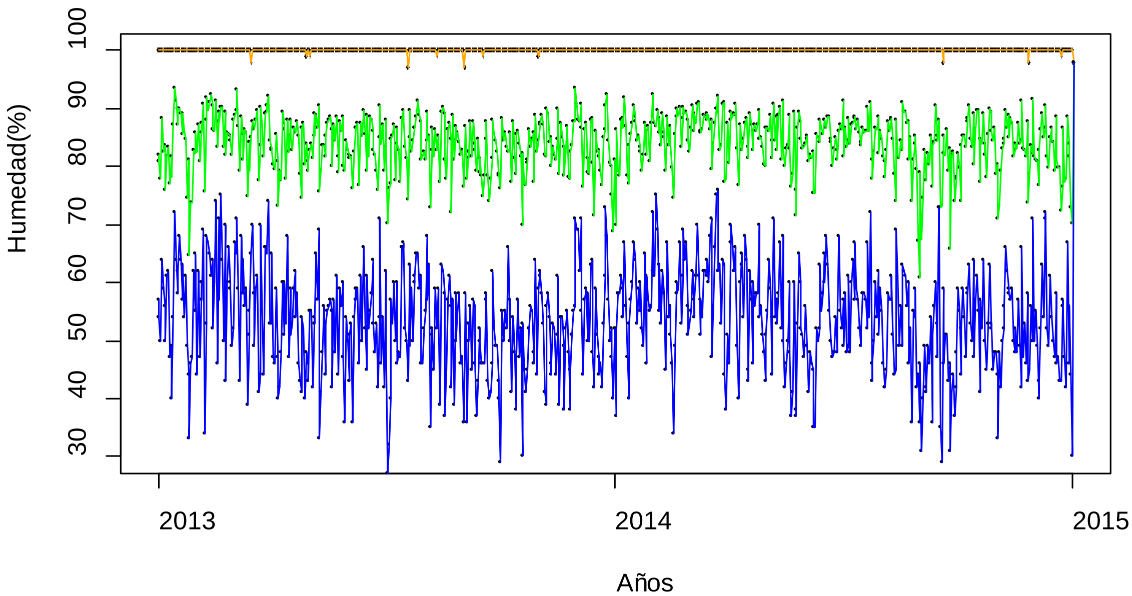
The dry bulb temperature is more stable against the wet bulb temperature. There is a great variability and this is very likely due to high variability of the relative humidity which is indicated below.

7.6.5.3.2 Relative Humidity

Humidity indicates the amount of water vapor present in the air and depends on the temperature, precipitation and presence of water bodies as marshes, creeks and rivers that increase evapotranspiration. The humidity that arises is for the latitude and for being a cloud transition area. It is expressed in percentage form (%) of water in the air.

According to the MM5 forecast model, relative humidity values recorded indicate that in average minimum humidity in the area is above 60 % and maximum humidity exceeds 86%. (See Figure 7.113).

Figure 7.113 Relative Humidity

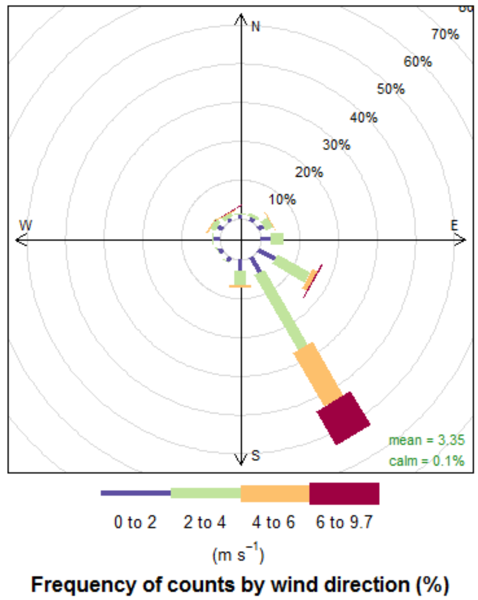


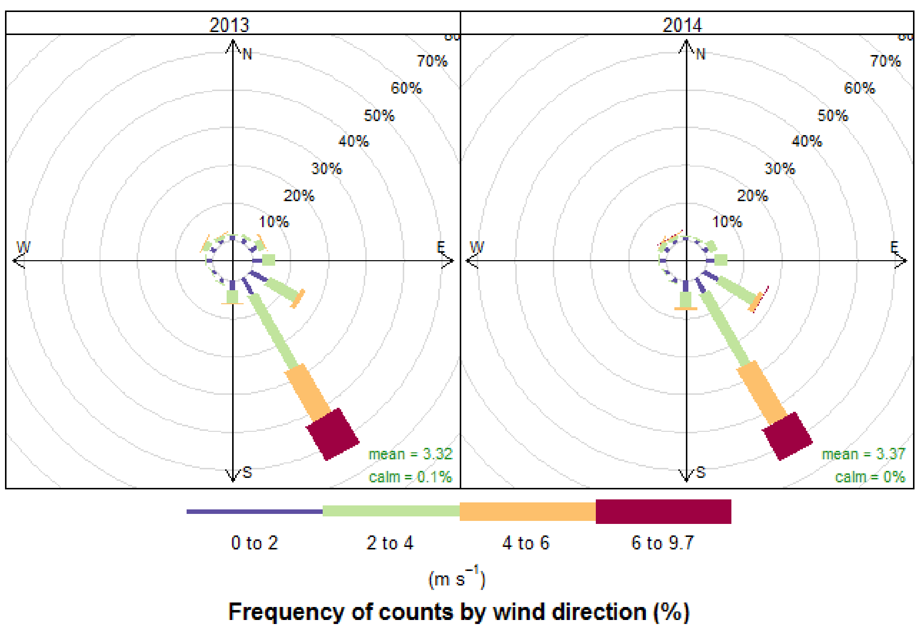
7.6.5.3.3 Wind Direction and Speed

Colombia, for being geographically located in the intertropical convergence areas, is subject to trade winds that blow from the northeast in the North Hemisphere and the south east in the South Hemisphere. In order to represent graphically behavior and wind speed of the area subject to study data from the MM5 forecast model were used in periods comprised between 2013 and 2014.

According to the wind rose prepared, the predominant direction of wind in the region in the entire year is SE-NW. The behavior is similar for years 2013 and 2014. Maximum wind speed values for direction SE-NW are between 2 a 4 and 4 a 6 m/s, with percentages of frequency between 20% and 15%, respectively.
There is a second component of the wind direction in the direction ESE-WNW with speed vectors of 2 to 4 and 4 to 6 m/s and frequency percentages between 5% and 10%, respectively. There are speed vectors in all the directors with speed values below 2 m/s, which arise with a frequency of less than 2%.

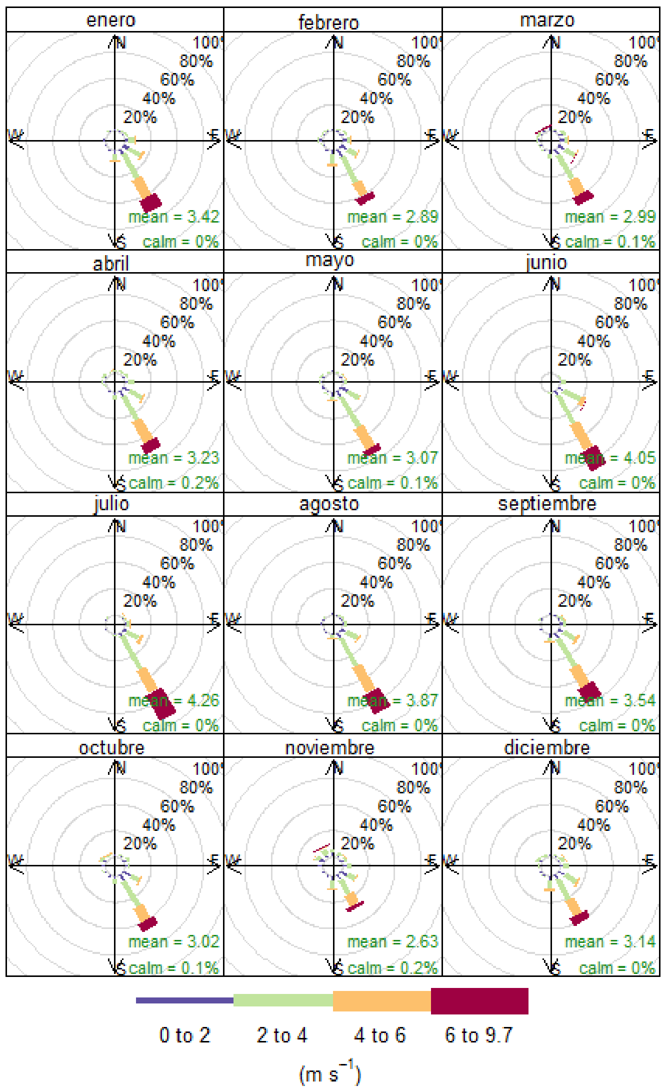
Figure 7.114 Annual Wind Rose. Multiannual Average (up) and for years 2013 and 2014 (down)





According to the MM5 forecast, there are not big variations in the wind speed. The highest monthly average values correspond to the months of September, October and November between 2.0 m/s and more than 6.0 m/s, in the SE-NW direction.

Figure 7.115 Multiannual Monthly Wind Rose



Frequency of counts by wind direction (%)

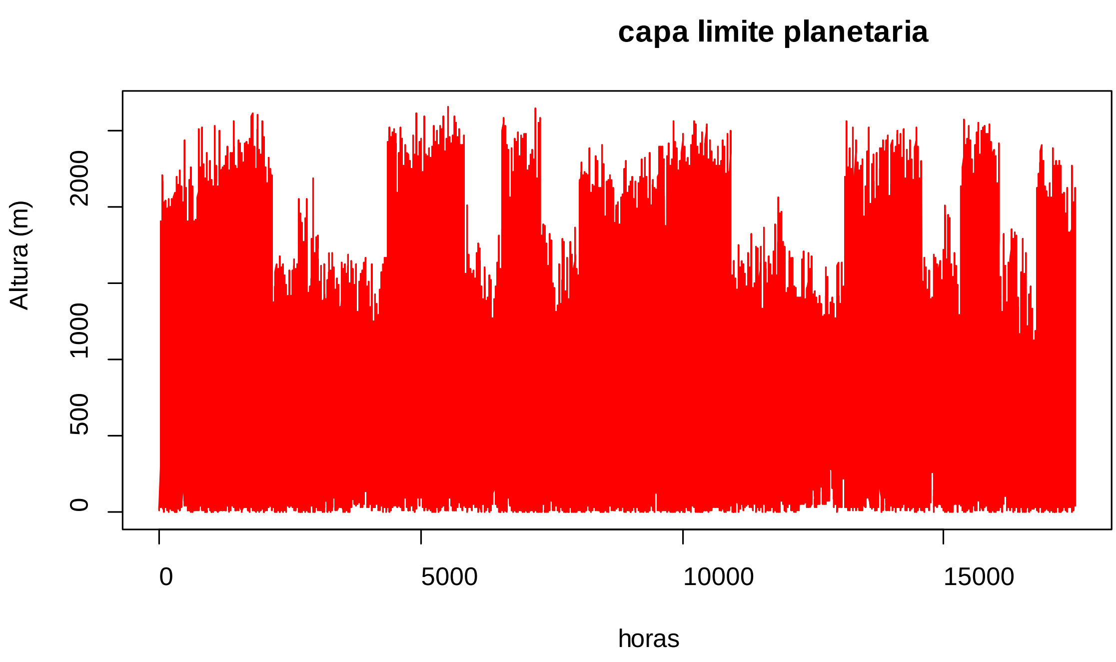
7.6.5.3.4 Height or Mechanical Mixture Layer

The height of mixture generated mechanically is determined based on the expression introduced by Venkatram (1980) and the friction speed. This mixture height is determined by the AERMET model. The mechanic mixture layer is always present in the air and some times in the layer formed by the effects of heat transfer. In average, height of the mechanic mixture is 954 m, minimum height 15 m, and the maximum height is 4000 m.

7.6.5.3.5 Height or Layer of Convective Mixture

The height of the mixture generated by convection is based on the formulation proposed by Carson (1973), modified by Weil & Brower (1983). The Carson model is based on a one-dimensional energy balance proposed where a flow of heat closet o the surface or ground level is introduced from the stable layer to high strata. Vertical mixing is made. There is inversion of the temperature with the vertical mixing and an energy increase of the air boundary layer. In average the convective mixture height is 1264 m, minimum 3 m, and maximum 3180 m.

Figure 7.116 Planetary Boundary Layer



The planetary boundary layer or boundary layer depth (See Figure 7.116) is ruled by the height of convective mixture layer (during the day) and in the mechanic mixture layer (at night).

7.6.5.4 Results of the AERMET Preprocessor

AERMET is designed to be executed in three stages and operate with three types of data – surface time observations obtained from a weather network, data of two daily radio soundings (morning and afternoon) and data collected in in-site measurement software as a weather tower with all the climatologic instruments and sensors. The first stage extracts (recovers) data from a file and assesses data quality. The second stage combines (mixture) the data of 24 h periods and writes in an intermediate processing file. The third and last stage reads the file of combined data and generates the parameters of the boundary layer necessary so that AERMOD makes the necessary dispersion calculations.

7.6.5.4.1 SAMSON Format File

The file of surface meteorological data SAMSON (*Solar and Meteorological Surface Observational Network*) contains multiple records. The first record contains data from the station with the information indicated in Table 7.84. The FORTRAN format of this record is: (1X,A5,1X,A22,1X,A2,1X,I3,2X,A1,I2,1X,I2,2X,A1,I3,1X,I2,2X,I4). Each variable is represented by a position number. This position belongs to this variable, regardless of how many variables are recovered or used. The second record contains the list of variables (referred by a position number) that are evidenced in the data file. There is not a particular format. The number of variable appears above the data column that is represented at least with a blank space (and usually many more) between the number positions. The third and following records contain the climatologic data recovered from the SAMSON database.

The formats are in free format, that is, there is at least one blank space between each element in the record or row. In each record, the year, month, day, time and indicator of observation shall be indicated in each record. This is followed by the variables recovered by the user. The meteorological variables appear in the order indicated in Table 7.85.

Figure 7.117 Stages of Weather Information Processing by AERMET. EPA. (2010)

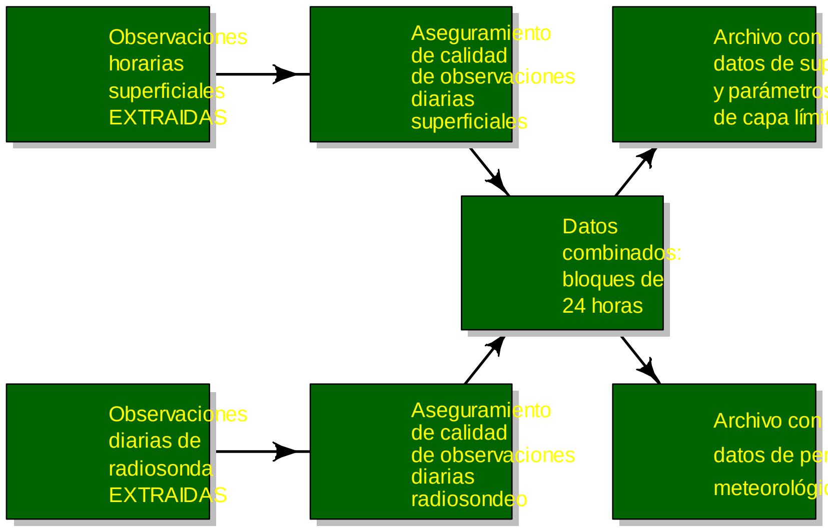


Table 7.84 Content of the First Record of the File of Surface Weather Data

Columns	Element	Definition
001	Indicator	~ to indicate that it is a header record
002-006	Number	Identification of the station number
008-029	City	City where the station is located
031-032	State	State (department) where the station is located
033-036	Time	Number of hours of delay with the universal time
039-044	Latitude	Latitude of the station
039		N = North of the Equator
040-041		Degrees
043-044		Minutes
047-053	Length	Length of the station
047		W = West, E = East
048-050		Degrees
052-053		Minutes
056-059	Elevation	Elevation of the station in meters above the sea

Source: EPA (2004)

Table 7.85 Content of the Third Record of the File of Surface Weather Data

POSITION	DESCRIPTION
	Year, month, day, time and indicator of observation in each record
1	Extraterrestrial horizontal radiation
2	Extraterrestrial direct normal radiation

POSITION	DESCRIPTION
3	Global horizontal radiation
4	Normal direct radiation
5	Diffused horizontal radiation
6	Total snow cover
7	Dense cloud cover
8	Dry bulb temperature
9	Wet bulb temperature
10	Relative humidity
11	Barometric pressure in the station
12	Wind direction
13	Wind speed
14	Visibility
15	Height of the ceiling
16	Current climate
17	Precipitable water
18	Width of band of optical depth of the aerosol
19	Snow depth
20	Days since the last snowfall
21	Amount of hourly irrigation and flag

Source: EPA (2004)

7.6.5.4.2 TD-6201 File Format

The first seven fields correspond to a portion called ID PORTION and appear at the beginning of each record. The following ten fields of the record contain a portion called DATA PORTION. The latter is repeated by each level of observation. The maximum number of levels is 200.

Each logical record is of variable length with a maximum of 7232 characters. Each logical record contains a complete observation of height air of the measurement station for a specific time of release of the meteorological probe. Usually, it is made in the first hours of the morning and at the end of the afternoon.

Table 7.86 Data Structure of TD-6201 File

Field	Position	Description
001	001-008	Identification of the station
002	009-012	Latitude
003	013	N/S Code Latitude
004	014-018	Length
005	019	E/W Code Length
006	020-029	Date and time (YY/MM/DD/T)
007	030-032	Number of the following portion of data groups
008	033	Quality level indicators
009	034-037	Time (time elapsed since release)
010	038-042	Pressure
011	043-048	Height
012	049-052	Temperature

Field	Position	Description
013	053-055	Relative humidity
014	056-058	Wind direction
015	059-061	Wind speed
016	062-067	(Quality) Flag
017	068	Type of level

Source: EPA (2004)

7.6.5.5 Use of Soil

The Albedo, Bowen coefficient and roughness are parameters used in calculation of flows and stabilities of the atmosphere. The Albedo is the fraction of incident solar radiation reflected by the surface without absorption. The range of typical values goes from 0.1 for thick forests to 0.90 for fresh snow. The Bowen coefficient or humidity indicator is the coefficient of heat flow sensitive to the latent head flow. Although the Bowen coefficient can have significant daily variations, it is used to determine the parameters of the planetary boundary layer for convective conditions. During the day, the Bowen coefficient achieves a constant positive value with a range of 0.1 over the water and 10.0 over a desert at noon. Roughness of the surface is related to the height of obstacles for the wind flow and it is, in principle, the height at which the median horizontal wind speed is zero. The values go from less than 0.001 meters over the surface water in calm to 1.0 meter or more over the urban area or forests.

It is necessary to make an inventory of the type of use of the soil of the place for a radio of 1 km, and it can extend to 5 km. For this project, a radio of 1 km has been chosen for the following reason: the impact of emissions of the road.

Since the EPA-USA assigns different values to the physical parameters for four season periods (spring, summer, autumn and winter) and this is reasonable because they affect significantly the thermodynamic balance of the atmosphere. It is necessary to establish a conceptual compromise that allows us to use the values adjusted to the physical conditions characteristic of Colombia.

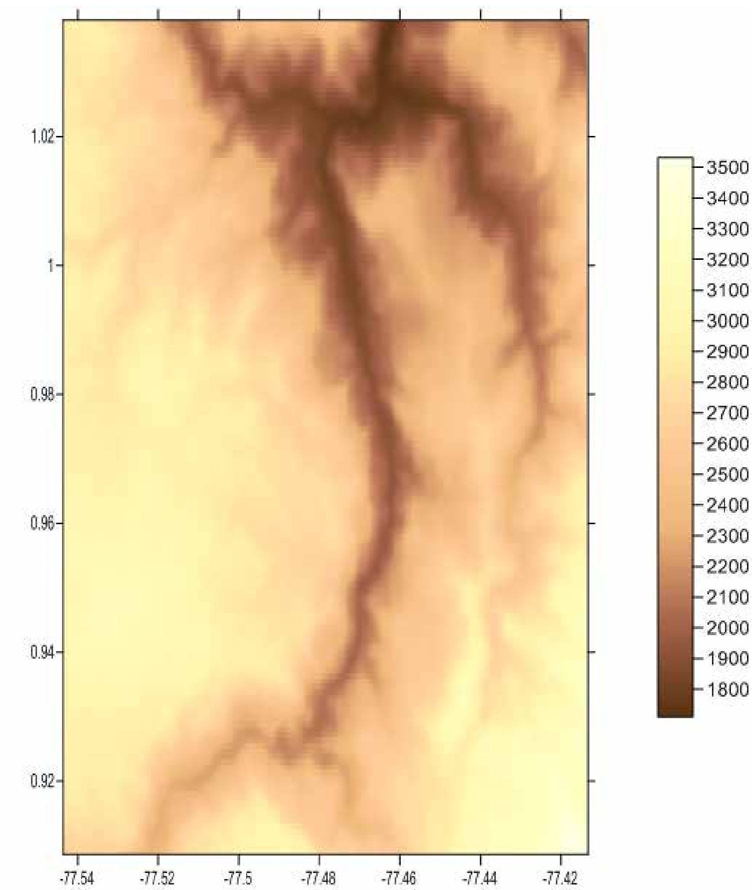
Even though the seasons of the two hemispheres are not consistent with the phenomena that occur near the Equator, it is possible to make an approach for the behavior of the parameters of Albedo, Bowen and roughness. Accordingly, the rainy season of the tropic is similar to summer in which rains and hurricanes arise and water excess affects especially reflection of the solar radiation. In contrast, the dry season of the tropic is similar to the dry season and leaf falling of autumn, where the energy balance has a strong impact for the increase of the Bowen quotient.

7.6.5.6 Base Topography

7.6.5.6.1 Results of the AERMAP Preprocessor

Topography of the land is extracted from the land digital model also used for processing in the AERMAP. The minimum height is about 2678 msnm, and the maximum height is about 3250 msnm. (Figure 7.118)

Figure 7.118 Land Topography



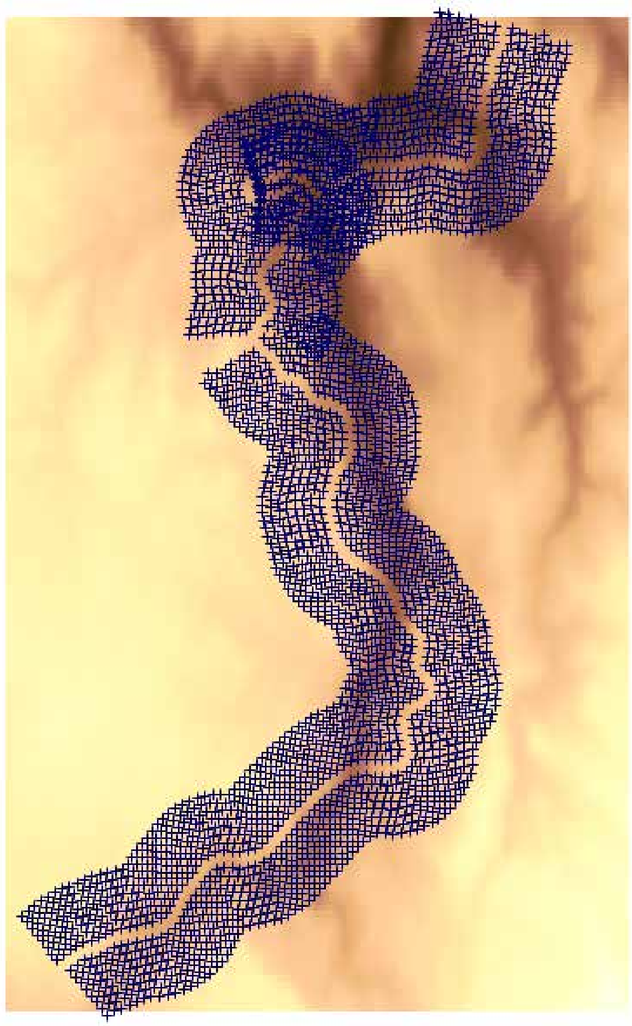
Source: GEOCOL CONSULTORES S.A, 2017

Modeling of pollutant dispersion is made over a mesh of small size indicated in the digital model of land elevation. The mesh is composed of receivers or sites where the information of simulation is meant to be obtained.

Receivers are introduced in the preprocessor of land AERMAP in a manner identical to the model of dispersion AERMOD. AERMAP allows the user to use a system of discrete receivers and also a mesh of polar and Cartesian receivers. When in AERMOD discrete polar receivers are used, the position of the source related to specific receiver shall be indicated.

The domain of modeling (Figure 7.119) starts in coordinate UTM East 216972.20 m; North 102850.29 m, and ends in coordinates UTM East 231397.79 m; North 114775.09 m. A mesh was defined parallel to the road spaced 800 meters to the west and 800 meters to the east of every 100 meters.

Figure 7.119 Mesh of Receivers of Modeling Domain



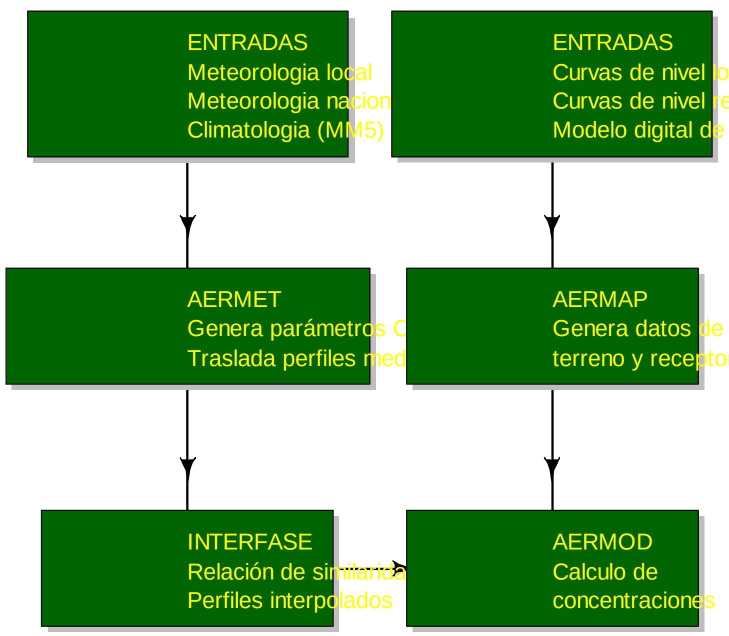
Source: GEOCOL CONSULTORES S.A, 2017

7.6.5.7 Results of the AERMOD Model

The EPA established by the end of 2005 that AERMOD would be the recommended model for analysis of pollutant dispersion at local scale in replacement of ISCST3 (Industrial Source Complex Short-Term 3), used until that moment. AERMOD represents a solid and significant progress with respect to ISCST3; integrates the most advanced parameterization techniques of the planetary boundary layer, convective dispersion, formulation of the elevation of the plume and complex interactions of the land with the plume. Compared to the ISCT3, AERMOD contains new and enhanced algorithms for: i) dispersion in the stable and convective boundary layer; ii) buoyancy and elevation of the plume; iii) penetration of the plume within the elevated inversion; iv) treatment of elevated and low sources; v) vertical wind profiles, temperature and turbulence, and vi) treatment of receivers in all type of lands. One of the essential advantages of AERMOD is complex land modeling.

AERMOD is capable of managing multiple sources, including punctual sources, volume and area. The linear sources can be modeled as a sequence of sources, volume or sources of elongated area. Several groups can be specified in one single execution with contribution of combined sources per groups. The system of coordinates used for this analysis consists in the system coordinates WGS84/UTM (Universal Transversal Mercator).

Figure 7.120 Data Flow of the AERMOD Modeling System



7.6.5.7.1 Input Data

The emission data are the ones registered in the chapter of inventory of emissions. For execution of the AERMOD modeling system, a series of tabs are introduced with the values indicated in Table 7.87, Source: GEOCOL CONSULTORES S.A, 2017

Table 7.88, Source: GEOCOL CONSULTORES S.A, 2017

Table 7.89 and **¡Error! No se encuentra el origen de la referencia.**, for the ones lower than 10 micros (PM10), carbon monoxide (CO)

Table 7.87 Input Data for PM10 Modeling

TABS	VALUE
TITLEONE	Air quality modeling MP10
TITLETWO	NARIÑO ROAD PROJECT
MODELOPT	CONC FASTALL
AVERTIME	24 ANNUAL
POLLUTID	MP
RUNORNOT	RUN
ERRORFIL	ERRORS.OUT
LOCATION	Identification and location of each one of the sources of emission.
SRCPARAM	Identification and emission rate
SRCGROUP	ALL
GRIDCART	Location and height above the sea level of receiving meshes or air quality monitoring stations
SURFFILE	" AERMET15_16.SFC "
PROFFILE	"AERMET15_16.PFL"
SURFDATA	66666 2015
UAIRDATA	66666 2015
STARTEND	15 01 01 16 12 31
PROFBASE	14.0 METERS
RECTABLE	ALLAVE FIRST-SEVENTH
MAXTABLE	ALLAVE 50
PLOTFILE	PM10 Simulation: 24 ALL SEVENTH 10MP24H.PLT ANNUAL ALL MPANN.PLT
SUMMFILE	SRC_10PM.SUM

Source: GEOCOL CONSULTORES S.A, 2017

Table 7.88 Input Data for CO Modeling

Tabs	Value
TITLEONE	Air quality modeling CO
TITLETWO	NARIÑO ROAD PROJECT
MODELOPT	CONC FASTALL
AVERTIME	1 8
POLLUTID	CO
RUNORNOT	RUN
ERRORFIL	ERRORS.OUT
LOCATION	Identification, location and height above sea level of each one of the emission sources.
SRCPARAM	Identification, emission rate

Tabs	Value
SRCGROUP	ALL
GRIDCART	Location and height above sea level of receiving meshes or air quality monitoring stations
SURFFILE	" AERMET15_16.SFC "
PROFFILE	" AERMET15_16.PFL "
SURFDATA	66666 2015
UAIRDATA	66666 2015
STARTEND	15 01 01 16 12 31
PROFBASE	14.0 METERS
RECTABLE	ALLAVE FIRST-SEVENTH
MAXTABLE	ALLAVE 50
PLOTFILE	CO Simulation: 1 ALL SEVENTH CO1H.PLT 8 ALL SEVENTH CO8H.PLT
SUMMFILE	SRC_CO.SUM

Source: GEOCOL CONSULTORES S.A, 2017

Table 7.89 Input Data for NOx Modeling

Tabs	Value
TITLEONE	NO2 air quality modeling
TITLETWO	NARIÑO ROAD PROJECT
MODELOPT	CONC FASTALL
AVERTIME	1 24 ANNUAL
POLLUTID	NO2
RUNORNOT	RUN
ERRORFIL	ERRORS.OUT
ELEVUNIT	Identification, location and height above sea level of each one of the emission sources
LOCATION	Identification and emission rate
SRCPARAM	ALL
SRCGROUP	Location and height above sea level of receiving meshes or air quality monitoring stations
SURFFILE	" AERMET15_16.SFC "
PROFFILE	" AERMET15_16.PFL "
SURFDATA	66666 2015
UAIRDATA	66666 2015
STARTEND	15 01 01 16 12 31
PROFBASE	14.0 METERS
RECTABLE	ALLAVE FIRST-SEVENTH
MAXTABLE	ALLAVE 50
PLOTFILE	1 ALL SEVENTH NOX01H.PLT 24 ALL SEVENTH NOX24H.PLT ANNUAL ALL NOXANN.PLT
SUMMFILE	SRC_NOX.SUM

Source: GEOCOL CONSULTORES S.A, 2017

Table 7.90 Input Data for SOx Modeling

Tabs	Value
TITLEONE	SO2 air quality modeling
TITLETWO	NARIÑO ROAD PROJECT
MODELOPT	CONC FASTALL
AVERTIME	3 24 ANNUAL
POLLUTID	SO2
RUNORNOT	RUN
ERRORFIL	ERRORS.OUT
ELEVUNIT	Identification, location and height above sea level of each one of the emission sources
LOCATION	Identification and emission rate
SRCPARAM	ALL
SRCGROUP	Location and height above sea level of receiving meshes or air quality monitoring stations
SURFFILE	" AERMET15_16.SFC "
PROFFILE	" AERMET15_16.PFL "
SURFDATA	66666 2015
UAIRDATA	66666 2015
STARTEND	15 01 01 16 12 31
PROFBASE	14.0 METERS
RECTABLE	ALLAVE FIRST-SEVENTH
MAXTABLE	ALLAVE 50
PLOTFILE	1 ALL SEVENTH NOX01H.PLT 24 ALL SEVENTH NOX24H.PLT ANNUAL ALL NOXANN.PLT
SUMMFILE	SRC_NOX.SUM

Source: GEOCOL CONSULTORES S.A, 2017

7.6.5.8 Results of Inventory of Emissions

The results presented below correspond to data obtained from preparation of the inventory of atmospheric emissions for the functional units of the road project.

Table 7.91 Results of the San Juan – Iles Segment

(SAN JUAN – ILES) SEGMENT
PM-10

(SAN JUAN – ILES) SEGMENT

UNIDAD FUNCIONAL		UF2 - AUTOS (LIVIANOS)
Contaminante	F.E. (g/km)	Principal derecha
PM 10	0,27	729,40
	g/s	0,20261175
	g/s-volumen	0,00033825
		Principal izquierda
	0,27	723,31
	g/s	0,20092050
	g/s-volumen	0,00033825

UNIDAD FUNCIONAL		UF2 - CAMIONES Y BUSES (PESADOS)
Contaminante	F.E. (g/km)	Principal derecha
PM 10	2,38	3851,55
	g/s	1,06987501
	g/s-volumen	0,00178610
		Principal izquierda
	2,38	3851,55
	g/s	1,06987501
	g/s-volumen	0,00180114

EMISIÓN TOTAL	
Emisión total g/s-volumen PM 10	Principal derecha
	0,00212435
	Principal izquierda
	0,00213939

NOx

UNIDAD FUNCIONAL		UF2 - AUTOS (LIVIANOS)
Contaminante	F.E. (g/km)	Principal derecha
NOx	0,11	297,16
	g/s	0,08254553
	g/s-volumen	0,00013781
		Principal izquierda
	0,11	297,16
	g/s	0,08254553
	g/s-volumen	0,00013781

UNIDAD FUNCIONAL		UF2 - CAMIONES Y BUSES (PESADOS)
Contaminante	F.E. (g/km)	Principal derecha
NOx	18,9	30585,84
	g/s	8,49606625
	g/s-volumen	0,01418375
		Principal izquierda
	18,9	30330,53
	g/s	8,42514750
	g/s-volumen	0,01418375

Emisión total g/s-volumen Nox	Principal derecha
	0,01432156
	Principal izquierda
	0,01432156

SO_2

UNIDAD FUNCIONAL		UF2 - AUTOS (LIVIANOS)
Contaminante	F.E. (g/km)	Principal derecha
SO2	0,1	270,15
	g/s	0,07504139
	g/s-volumen	0,00012528
		Principal izquierda
	0,1	267,89
	g/s	0,07441500
	g/s-volumen	0,00012528

UNIDAD FUNCIONAL		UF2 - CAMIONES Y BUSES (PESADOS)
Contaminante	F.E. (g/km)	Principal derecha
SO2	2,82	4563,60
	g/s	1,26766703
	g/s-volumen	0,00211631
		Principal izquierda
	2,82	4525,51
	g/s	1,25708550
	g/s-volumen	0,00211631

Emisión total g/s-volumen SO_2	Principal derecha
	0,00224158
	Principal izquierda
	0,00224158

CO

UNIDAD FUNCIONAL		UF2 - AUTOS (LIVIANOS)
Contaminante	F.E. (g/km)	Principal derecha
CO	8,27	22341,32
	g/s	6,20592286
	g/s-volumen	0,01036047
		Principal izquierda
	8,27	22154,83
	g/s	6,15412050
	g/s-volumen	0,01036047

UNIDAD FUNCIONAL		UF2 - CAMIONES Y BUSES (PESADOS)
Contaminante	F.E. (g/km)	Principal derecha
CO	385,2	623368,52
	g/s	173,15792167
	g/s-volumen	0,28907833
		Principal izquierda
	385,2	618165,11
	g/s	171,71253000
	g/s-volumen	0,28907833

Emisión total g/s-volumen	Principal derecha
	0,29943881
	Principal izquierda
	0,29943881

Source: GEOCOL CONSULTORES S.A, 2017

Table 7.92 Results of Iles- Pedregal Segment

(ILES –PEDREGAL) SEGMENT

PM-10

UNIDAD FUNCIONAL		UF3 - AUTOS (LIVIANOS)
Contaminante	F.E. (g/km)	Principal derecha
PM 10	0,27	726,98
	g/s	0,20193788
	g/s-volumen	0,00052451
		Principal izquierda
	0,27	467,26
	g/s	0,12979313
	g/s-volumen	0,00033713

UNIDAD FUNCIONAL		UF3 - CAMIONES Y BUSES (PESADOS)
Contaminante	F.E. (g/km)	Principal derecha
PM 10	2,38	2311,37
	g/s	0,64204632
	g/s-volumen	0,00166765
		Principal izquierda
	2,38	2311,37
	g/s	0,64204632
	g/s-volumen	0,00166765

EMISIÓN TOTAL	
Emisión total g/s-volumen PM 10	Principal derecha
	0,00219217
	Principal izquierda
	0,00200478

NOx

UNIDAD FUNCIONAL		UF3 - AUTOS (LIVIANOS)
Contaminante	F.E. (g/km)	Principal derecha
NOx	0,11	296,18
	g/s	0,08227099
	g/s-volumen	0,00021369
		Principal izquierda
	0,11	296,18
	g/s	0,08227099
	g/s-volumen	0,00021369

UNIDAD FUNCIONAL		UF3 - CAMIONES Y BUSES
Contaminante	F.E. (g/km)	Principal derecha
NOx	18,9	18354,97
	g/s	5,09860313
	g/s-volumen	0,01324313
		Principal izquierda
	18,9	18354,97
	g/s	5,09860313
	g/s-volumen	0,01324313

Emisión total g/s-volumen Nox	Principal derecha
	0,01345682
	Principal izquierda
	0,01345682

SO_2

UNIDAD FUNCIONAL		UF3 - AUTOS (LIVIANOS)
Contaminante	F.E. (g/km)	Principal derecha
SO2	0,1	269,25
	g/s	0,07479181
	g/s-volumen	0,00019426
		Principal izquierda
	0,1	173,06
	g/s	0,04807153
	g/s-volumen	0,00012486

UNIDAD FUNCIONAL		UF3 - CAMIONES Y BUSES
Contaminante	F.E. (g/km)	Principal derecha
SO2	2,82	2738,68
	g/s	0,76074396
	g/s-volumen	0,00197596
		Principal izquierda
	2,82	2738,68
	g/s	0,76074396
	g/s-volumen	0,00197596

Emisión total g/s-volumen SO 2	Principal derecha
	0,00217022
	Principal izquierda
	0,00210082

CO

(ILES –PEDREGAL) SEGMENT

UNIDAD FUNCIONAL		UF3 - AUTOS (LIVIANOS)
Contaminante	F.E. (g/km)	Principal derecha
CO	8,27	22267,02
	g/s	6,18528232
	g/s-volumen	0,01606567
		Principal izquierda
	8,27	14311,86
	g/s	3,97551535
	g/s-volumen	0,01032601

UNIDAD FUNCIONAL		UF3 - CAMIONES Y BUSES (PESADOS)
Contaminante	F.E. (g/km)	Principal derecha
CO	385,2	374091,80
	g/s	103,91438750
	g/s-volumen	0,26990750
		Principal izquierda
	385,2	374091,80
	g/s	103,91438750
	g/s-volumen	0,26990750

Emisión total g/s-volumen CO	Principal derecha
	0,28597317
	Principal izquierda
	0,28023351

Source: GEOCOL CONSULTORES S.A, 2017

7.6.5.9 Results of Simulation of Building of the Road

7.6.5.9.1 Dispersion of Breathable Particles (PM10)

For an average of 24 hours

106.30242 ON 16080824: AT (225031.68, 106557.33, 2498.59, 0.00, 0.00) DC

94.10489c ON 15120424: AT (223991.29, 105689.90, 2700.02, 0.00, 0.00) DC

85.82771 ON 15013124: AT (223658.71, 105469.76, 2685.61, 0.00, 0.00) DC

80.59572 ON 16080824: AT (223578.09, 105410.54, 2697.45, 0.00, 0.00) DC

78.95961 ON 15121624: AT (224994.20, 106831.36, 2638.40, 0.00, 0.00) DC

73.39829c ON 16031224: AT (225062.73, 106937.51, 2566.62, 0.00, 0.00) DC

70.85277 ON 15120624: AT (224994.20, 106831.36, 2638.40, 0.00, 0.00) DC

The maximum concentrations reported correspond to the emissions in the center of the road and exceed the permissible hourly concentration of NOX, which is 100 ug/m3

For the annual average

24.61069 AT (224659.33, 106395.39, 2664.74, 0.00, 0.00) DC

24.38747 AT (223563.06, 105660.00, 2701.06, 0.00, 0.00) DC

24.21355 AT (223644.50, 105718.13, 2701.30, 0.00, 0.00) DC

23.89625 AT (224725.56, 106465.52, 2646.22, 0.00, 0.00) DC

23.64162 AT (224665.82, 106296.27, 2667.81, 0.00, 0.00) DC

23.61913 AT (222529.81, 104765.13, 2785.34, 0.00, 0.00) DC

23.56324 AT (222429.81, 104768.49, 2792.86, 0.00, 0.00) DC

23.44689 AT (222629.25, 104773.23, 2785.96, 0.00, 0.00) DC

23.42442 AT (224680.97, 106197.38, 2662.98, 0.00, 0.00) DC

23.40550 AT (224824.46, 107070.72, 2582.10, 0.00, 0.00) DC

The maximum concentrations reported correspond to the emissions in the center of the road and exceed the permissible hourly concentration of NOX, which is 50 ug/m3

7.6.5.9.2 Carbon Monoxide (CO) Dispersion

71044.07316 ON 15082020: AT (224795.69, 106109.28, 2617.23, 0.00, 0.00) DC

69009.25168 ON 16082822: AT (221055.96, 103607.39, 2888.27, 0.00, 0.00) DC

69009.24537 ON 15032203: AT (221055.96, 103607.39, 2888.27, 0.00, 0.00) DC

67477.84131 ON 16020221: AT (220965.09, 103568.11, 2889.76, 0.00, 0.00) DC

67477.83276 ON 15080423: AT (220965.09, 103568.11, 2889.76, 0.00, 0.00) DC

66268.44401 ON 16102701: AT (220965.09, 103568.11, 2889.76, 0.00, 0.00) DC

66257.65082 ON 16012905: AT (224994.20, 106831.36, 2638.40, 0.00, 0.00) DC

The maximum concentrations reported correspond to the emissions in the center of the road and exceed the permissible hourly concentration of CO, which is 40000 ug/m3

7.6.5.9.3 Dispersion of Sulphur Oxides (SOx)

3 H CONCENTRATION OF SOX

438.61056 ON 15012403: AT (224994.20, 106831.36, 2638.40, 0.00, 0.00) DC

428.68713 ON 15072003: AT (224994.20, 106831.36, 2638.40, 0.00, 0.00) DC

393.32777 ON 15121606: AT (225062.73, 106937.51, 2566.62, 0.00, 0.00) DC

366.35960 ON 15022406: AT (224994.20, 106831.36, 2638.40, 0.00, 0.00) DC

358.00580 ON 16080824: AT (225062.73, 106937.51, 2566.62, 0.00, 0.00) DC

316.39317 ON 16110624: AT (223862.84, 110297.08, 2279.31, 0.00, 0.00) DC

312.91650 ON 16011206: AT (224994.20, 106831.36, 2638.40, 0.00, 0.00) DC

24 H CONCENTRATION OF SOX

111.77080 ON 16080824: AT (225031.68, 106557.33, 2498.59, 0.00, 0.00) DC

98.95290c ON 15120424: AT (223991.29, 105689.90, 2700.02, 0.00, 0.00) DC

90.24641 ON 15013124: AT (223658.71, 105469.76, 2685.61, 0.00, 0.00) DC

84.74582 ON 16080824: AT (223578.09, 105410.54, 2697.45, 0.00, 0.00) DC

83.03244 ON 15121624: AT (224994.20, 106831.36, 2638.40, 0.00, 0.00) DC

77.17316c ON 16031224: AT (225062.73, 106937.51, 2566.62, 0.00, 0.00) DC

74.49563 ON 15120624: AT (224994.20, 106831.36, 2638.40, 0.00, 0.00) DC

ANNUAL CONCENTRATION SOX

25.87769 AT (224659.33, 106395.39, 2664.74, 0.00, 0.00) DC

25.64134 AT (223563.06, 105660.00, 2701.06, 0.00, 0.00) DC

25.45875 AT (223644.50, 105718.13, 2701.30, 0.00, 0.00) DC

25.12717 AT (224725.56, 106465.52, 2646.22, 0.00, 0.00) DC

24.85871 AT (224665.82, 106296.27, 2667.81, 0.00, 0.00) DC

24.83335 AT (222529.81, 104765.13, 2785.34, 0.00, 0.00) DC

24.77426 AT (222429.81, 104768.49, 2792.86, 0.00, 0.00) DC

24.65234 AT (222629.25, 104773.23, 2785.96, 0.00, 0.00) DC

24.63054 AT (224680.97, 106197.38, 2662.98, 0.00, 0.00) DC

24.61058 AT (224824.46, 107070.72, 2582.10, 0.00, 0.00) DC

7.6.5.9.4 Dispersion of Nitrogen Oxides (NOx)

HOURLY CONCENTRATION OF NOX

3397.89517 ON 15082020: AT (224795.69, 106109.28, 2617.23, 0.00, 0.00) DC

3300.57375 ON 16082822: AT (221055.96, 103607.39, 2888.27, 0.00, 0.00) DC

3300.57345 ON 15032203: AT (221055.96, 103607.39, 2888.27, 0.00, 0.00) DC

3227.32947 ON 16020221: AT (220965.09, 103568.11, 2889.76, 0.00, 0.00) DC

3227.32906 ON 15080423: AT (220965.09, 103568.11, 2889.76, 0.00, 0.00) DC

3169.48643 ON 16102701: AT (220965.09, 103568.11, 2889.76, 0.00, 0.00) DC

3168.97021 ON 16012905: AT (224994.20, 106831.36, 2638.40, 0.00, 0.00) DC

The maximum concentrations reported correspond to the emissions in the center of the road and exceed the permissible hourly concentration of NOX, which is 200 ug/m3.

24 H CONCENTRATION OF NOX

714.10771 ON 16080824: AT (225031.68, 106557.33, 2498.59, 0.00, 0.00) DC

632.21369c ON 15120424: AT (223991.29, 105689.90, 2700.02, 0.00, 0.00) DC

576.58763 ON 15013124: AT (223658.71, 105469.76, 2685.61, 0.00, 0.00) DC

541.44417 ON 16080824: AT (223578.09, 105410.54, 2697.45, 0.00, 0.00) DC

530.49727 ON 15121624: AT (224994.20, 106831.36, 2638.40, 0.00, 0.00) DC

493.06216c ON 16031224: AT (225062.73, 106937.51, 2566.62, 0.00, 0.00) DC

475.95531 ON 15120624: AT (224994.20, 106831.36, 2638.40, 0.00, 0.00) DC

The maximum concentrations reported correspond to the emissions in the center of the road and exceed the permissible 24 h concentration of NOX, which is 150 ug/m3.

ANNUAL CONCENTRATION OF NOX

165.33354 AT (224659.33, 106395.39, 2664.74, 0.00, 0.00) DC

163.82347 AT (223563.06, 105660.00, 2701.06, 0.00, 0.00) DC

162.65686 AT (223644.50, 105718.13, 2701.30, 0.00, 0.00) DC

160.53841 AT (224725.56, 106465.52, 2646.22, 0.00, 0.00) DC

158.82324 AT (224665.82, 106296.27, 2667.81, 0.00, 0.00) DC

158.66120 AT (222529.81, 104765.13, 2785.34, 0.00, 0.00) DC

158.28368 AT (222429.81, 104768.49, 2792.86, 0.00, 0.00) DC

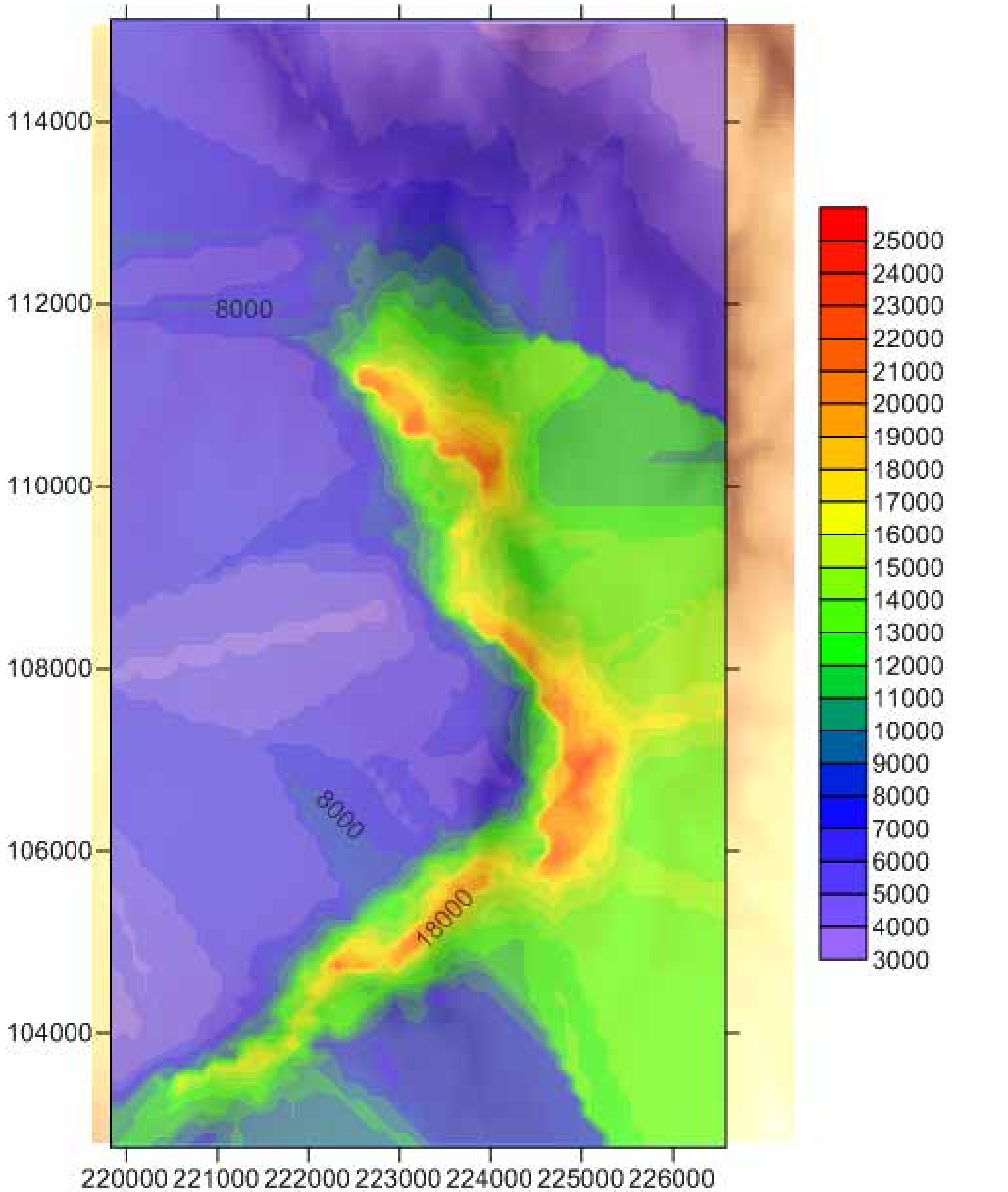
157.50473 AT (222629.25, 104773.23, 2785.96, 0.00, 0.00) DC

157.36545 AT (224680.97, 106197.38, 2662.98, 0.00, 0.00) DC

157.23789 AT (224824.46, 107070.72, 2582.10, 0.00, 0.00) DC

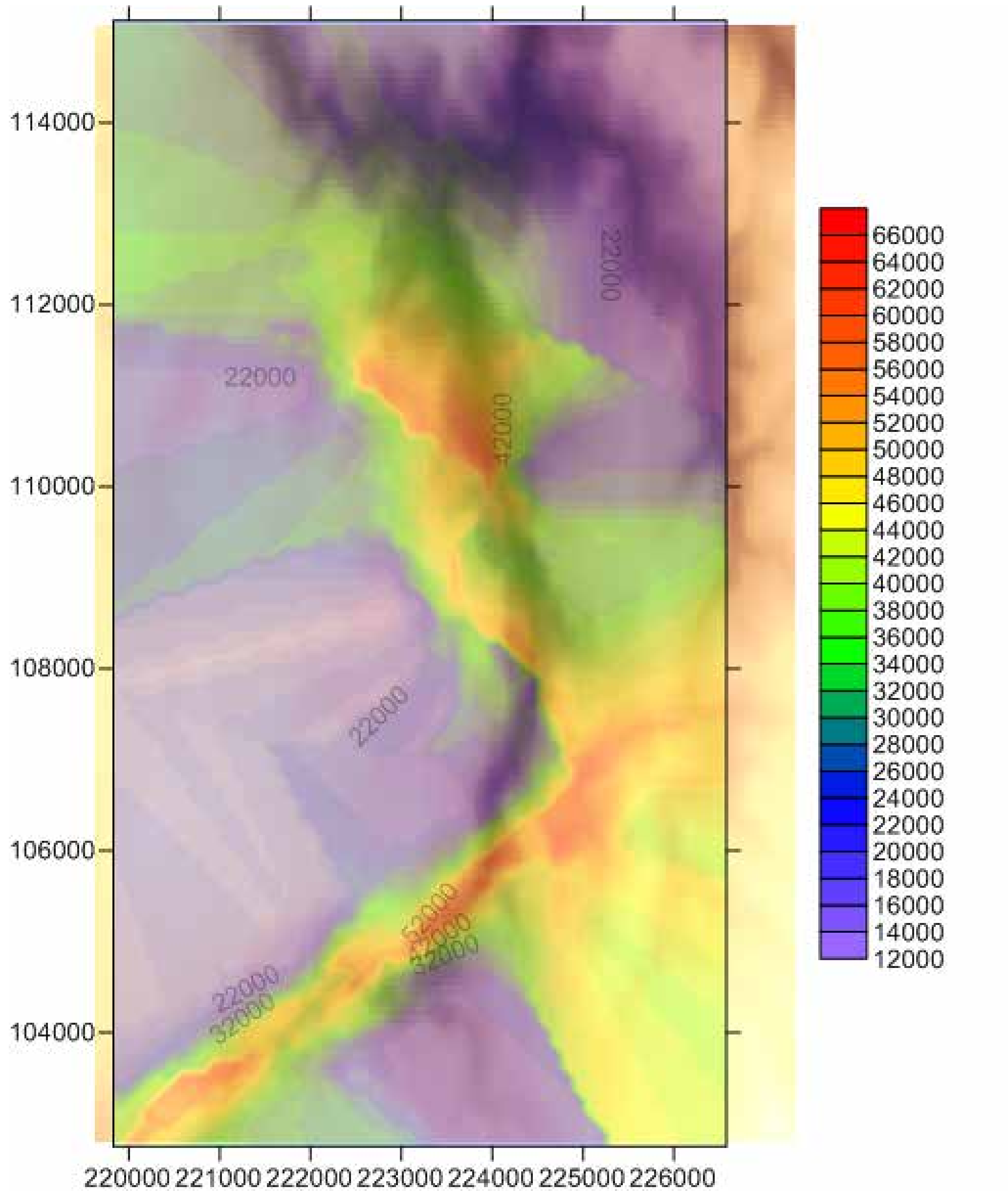
The maximum concentrations reported correspond to the emissions in the center of the road and exceed the permissible annual concentration of NOX, which is 100 ug/m3.

Figure 7.121 Isopleths of CO Concentration - 8 h Average



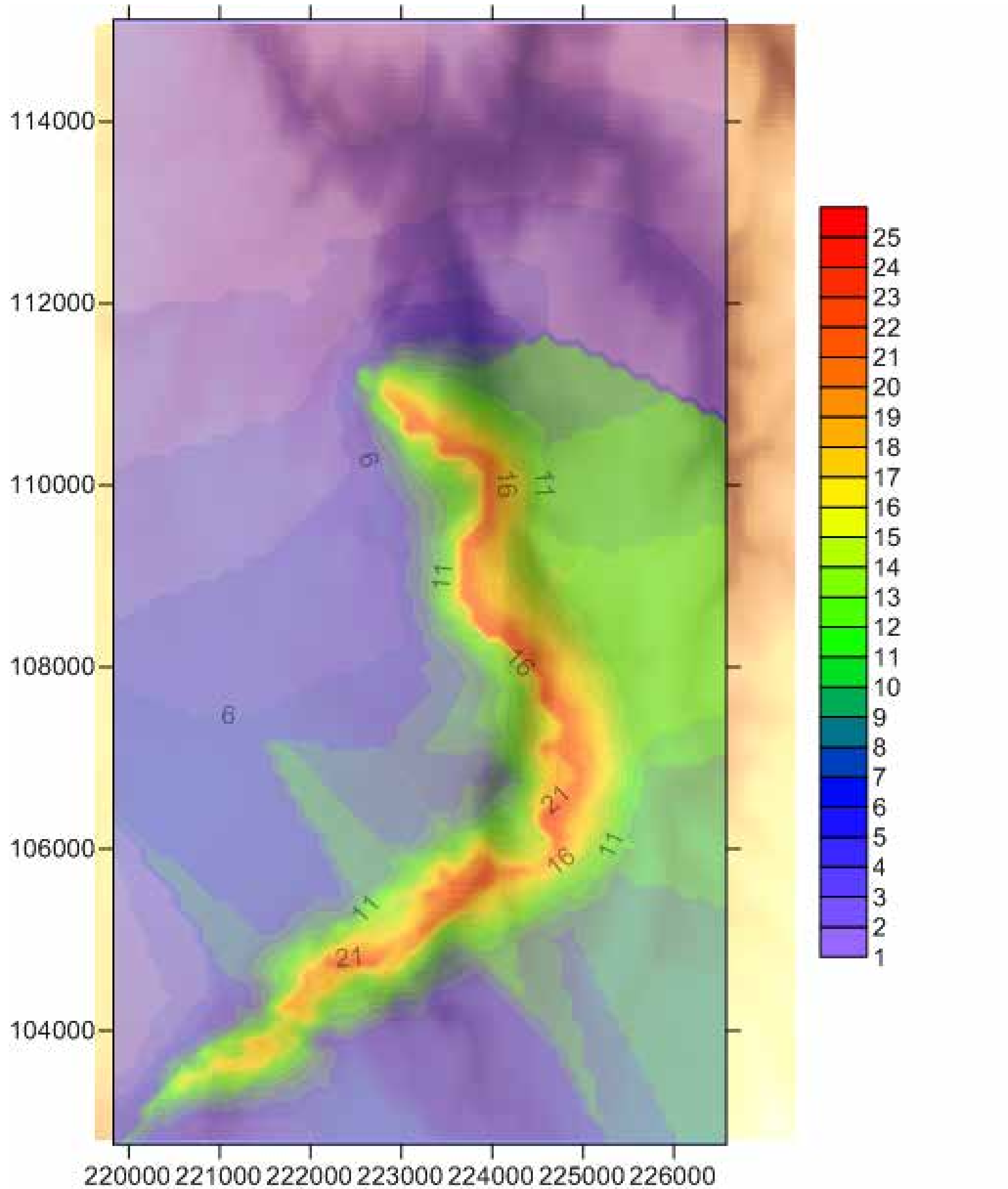
Source: GEOCOL CONSULTORES S.A, 2017

Figure 7.122 Isopleths of CO Concentration - 1 h Average



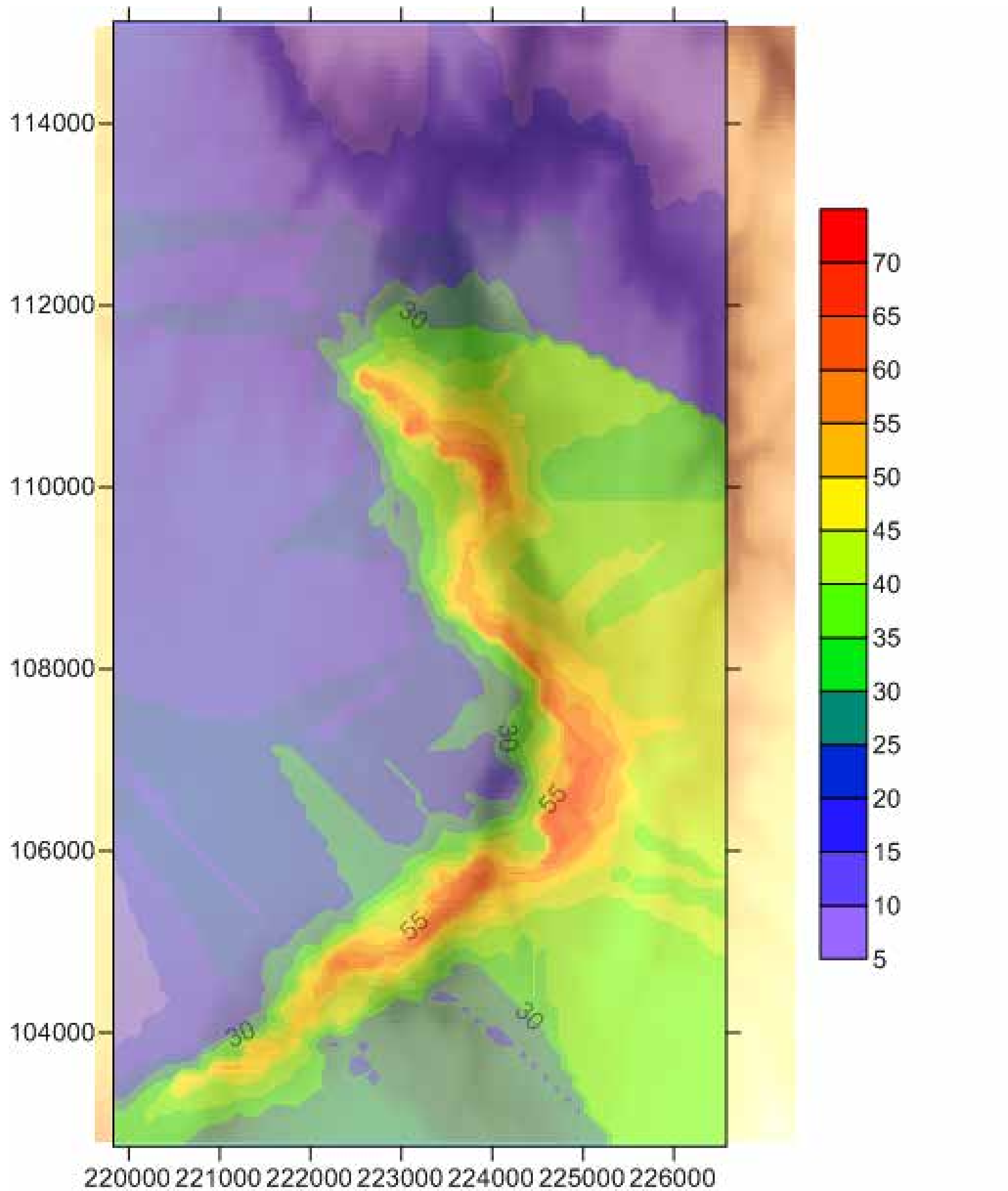
Source: GEOCOL CONSULTORES S.A, 2017

Figure 7.123 Isopleths of PM10 Concentration – Annual Average



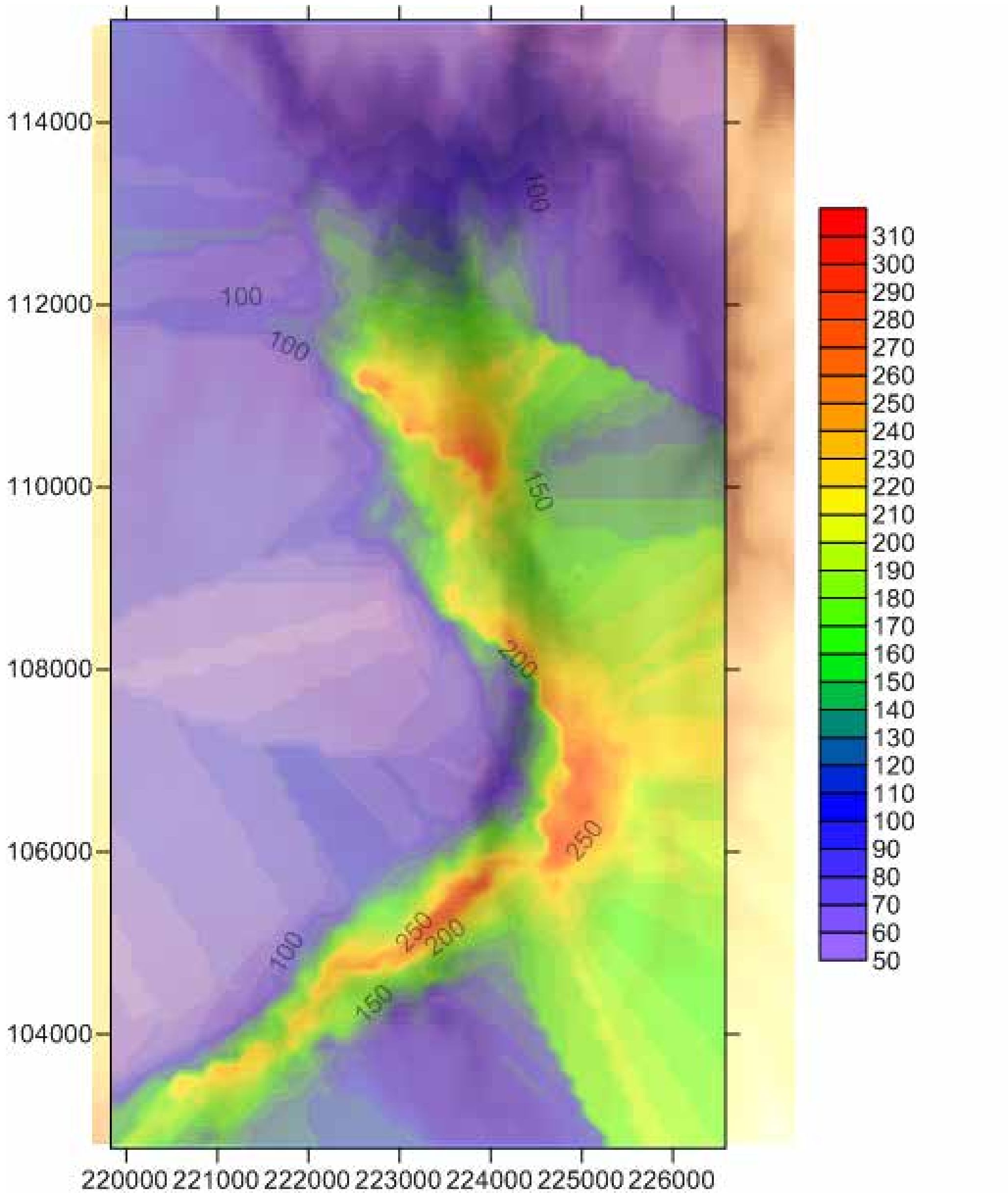
Source: GEOCOL CONSULTORES S.A, 2017

Figure 7.124 Isopleths of PM10 Concentration - 24 h Average



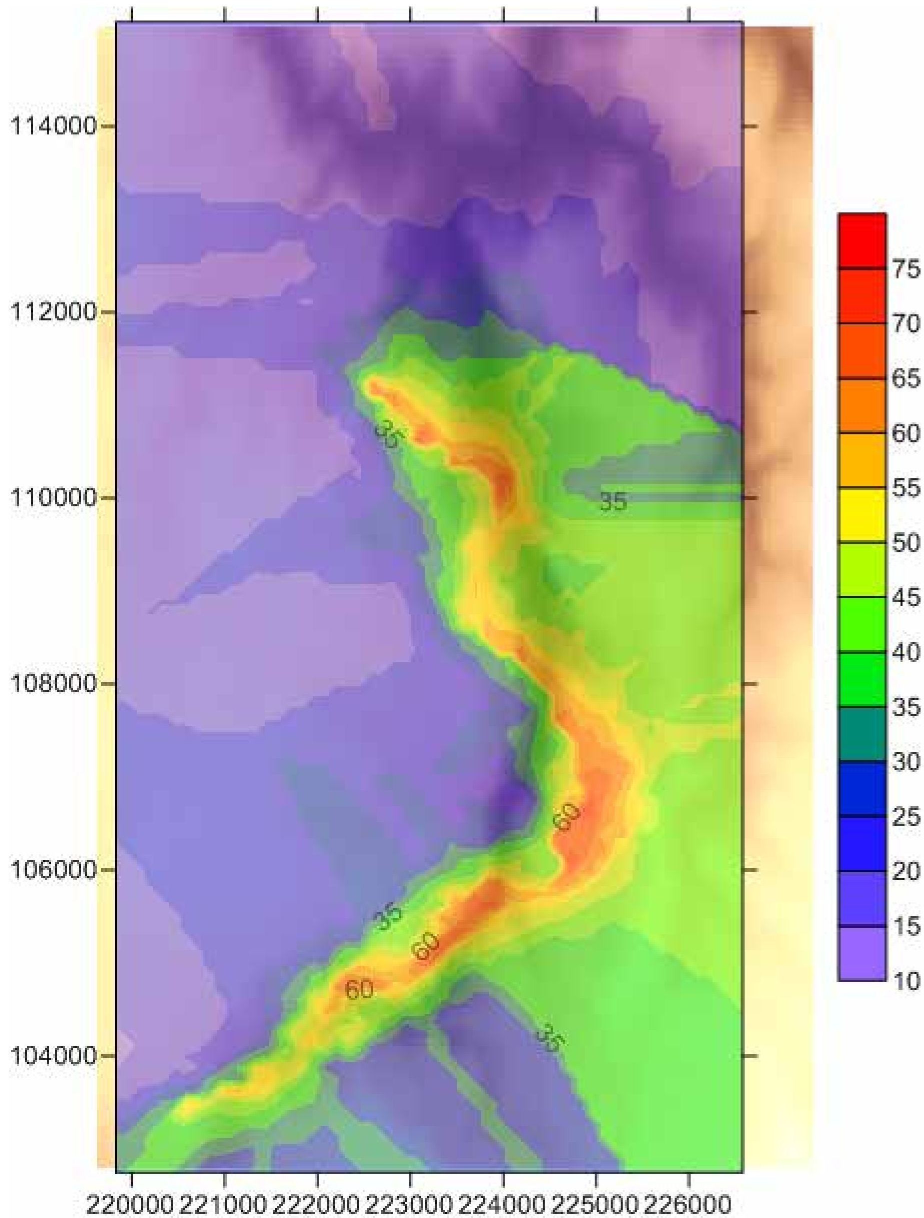
Source: GEOCOL CONSULTORES S.A, 2017

Figure 7.125 Isopleths of SO2 Concentration - 3 h Average



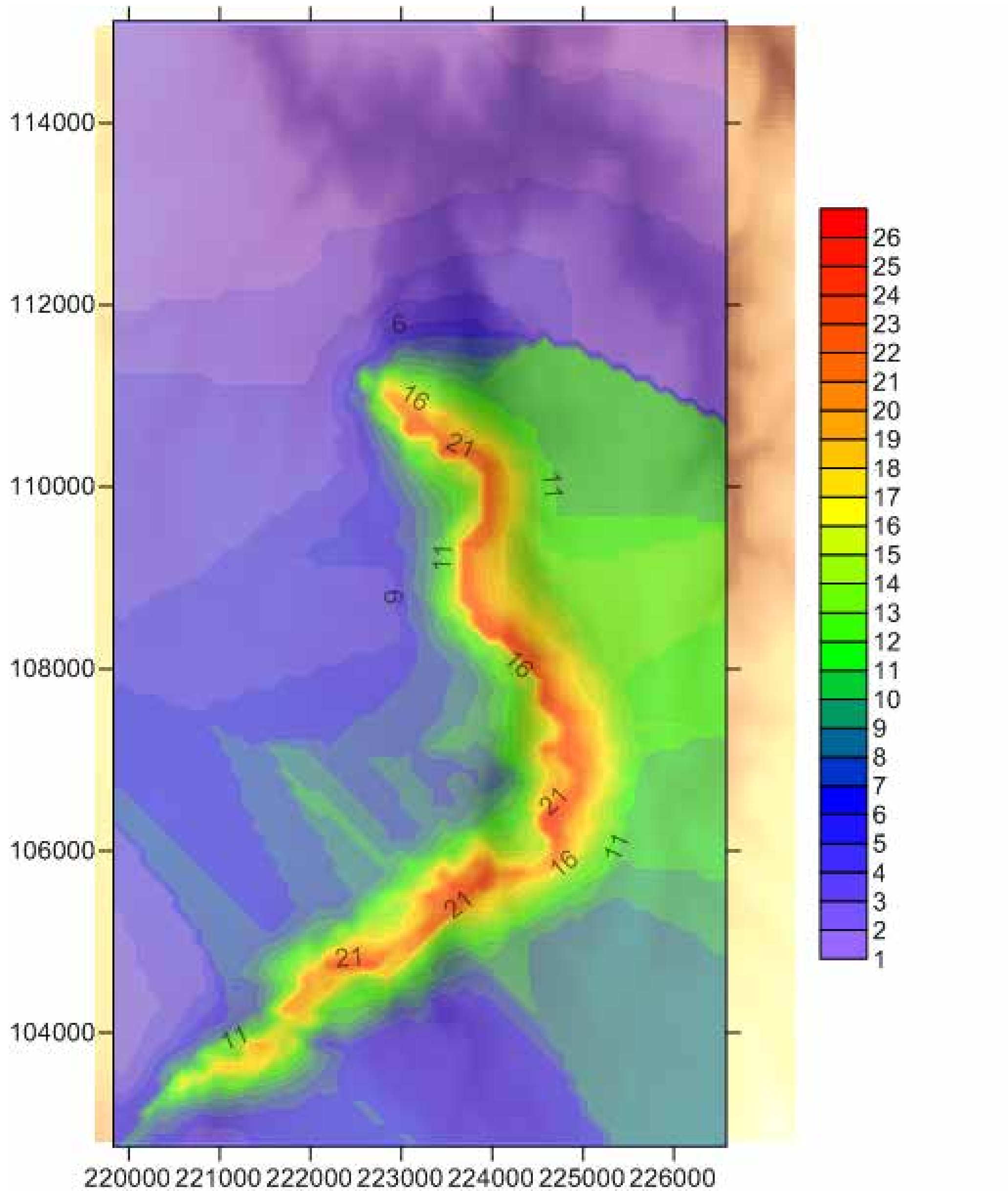
Source: GEOCOL CONSULTORES S.A, 2017

Figure 7.126 Isopleths of SO2 Concentration - 24 h Average



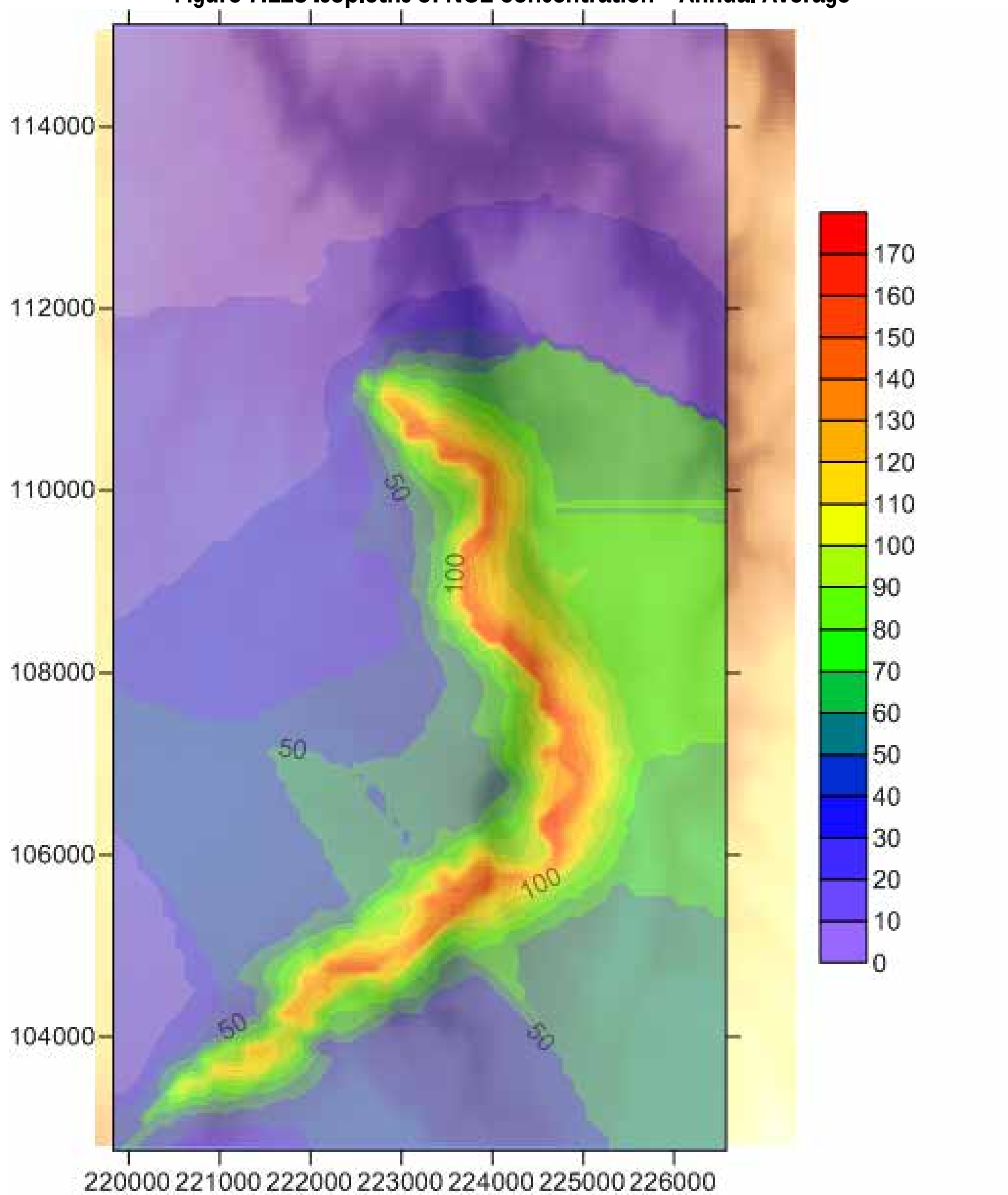
Source: GEOCOL CONSULTORES S.A, 2017

Figure 7.127 Isopleths of SO2 Concentration – Annual Average



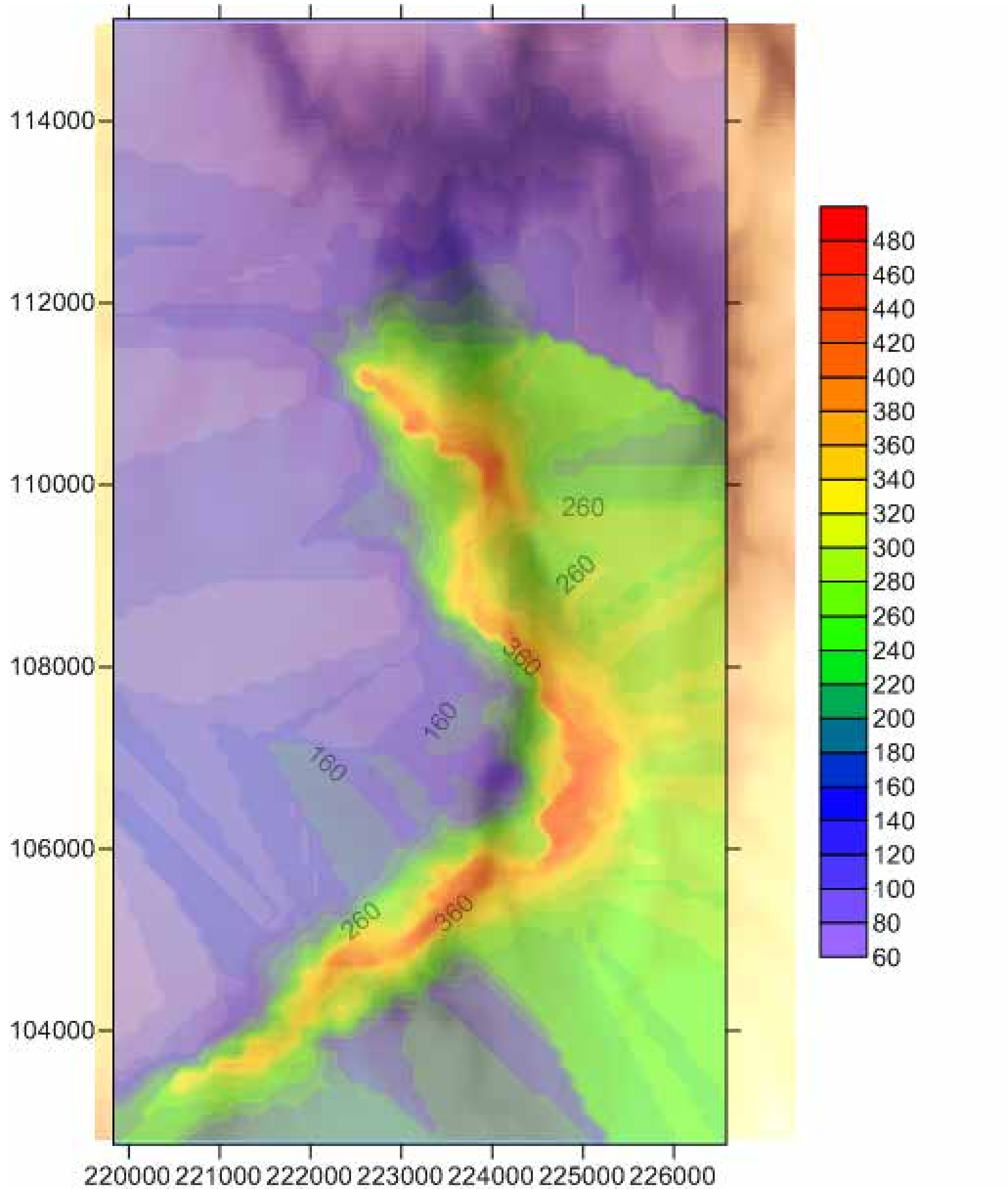
Source: GEOCOL CONSULTORES S.A, 2017

Figure 7.128 Isopleths of NO2 Concentration – Annual Average



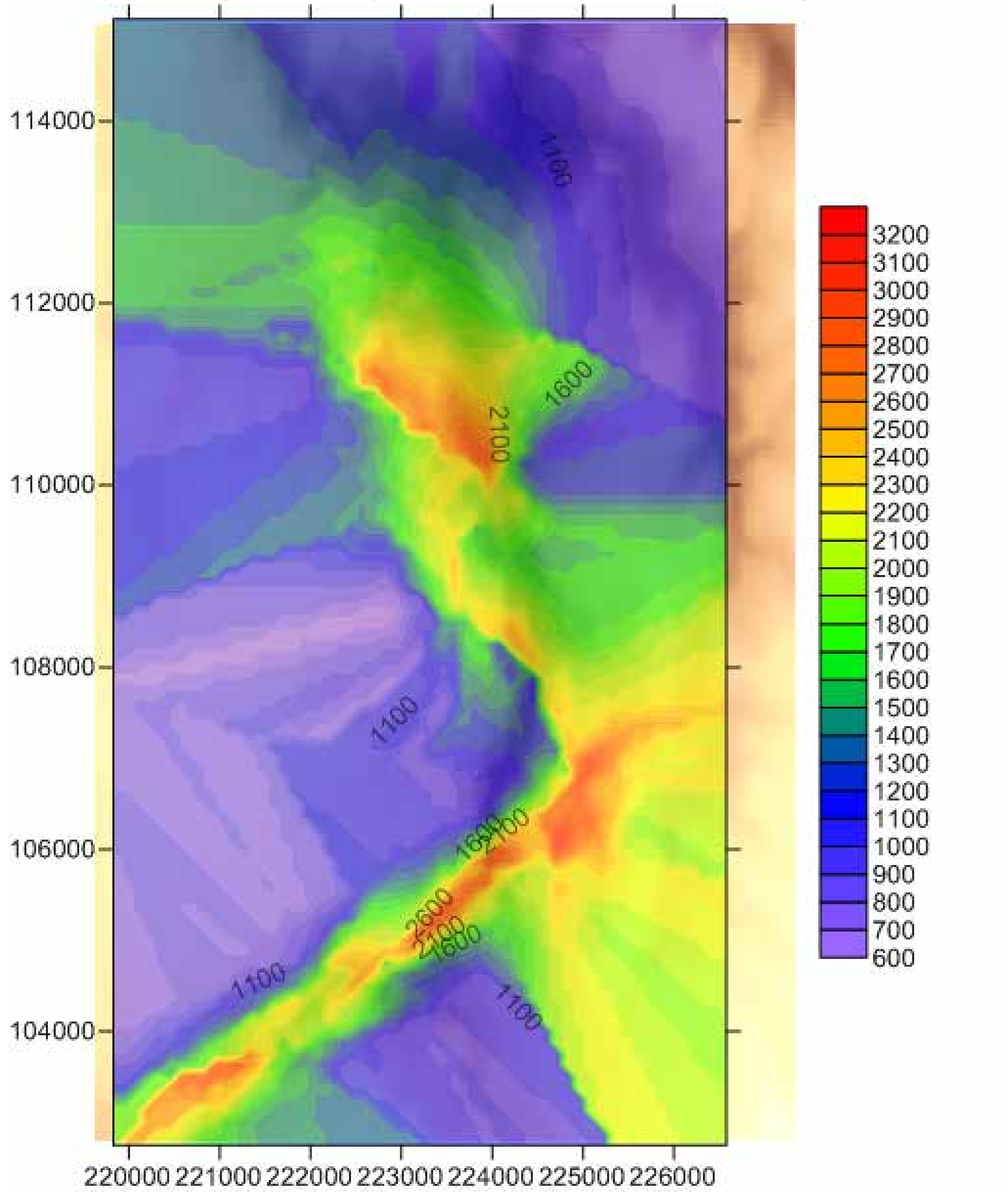
Source: GEOCOL CONSULTORES S.A, 2017

Figure 7.129 Isopleths of NO2 Concentration - 24 h Average



Source: GEOCOL CONSULTORES S.A, 2017

Figure 7.130 Isopleths of NO2 Concentration - 1h Average



Source: GEOCOL CONSULTORES S.A, 2017

7.7 BUILDING MATERIALS

7.7.1 Exploitation of Quarry Material

The activities of the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment do not include exploitation of quarry material.

7.7.2 Exploitation of Dragging Materials of Courses or Beds of Currents or Water Deposits

The activities of the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment do not include exploitation of dragging materials of courses or beds of currents or water deposits.

7.7.3 Acquisition of Materials in Existing Sources

7.7.3.1 Mining Titles

Table 7.93 shows the list of mining titles of the areas from which the materials for execution of the building activities of the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment shall be extracted.

Table 7.93 Mining Title of Quarries

NAME OF THE SOURCE OF MATERIALS	LOCATION	MINING TITLE
Madeko - El Juncal	PK28+800	Not reported
Capulí - Panavías	Iles	Exploitation License No. 00342-52
Mina Rosapamba	PK34+400 Road Catambuco	Resolution No. 004059 dated September 29 2014 (Extension of Exploitation License)"
Mina La Victoria	Km 8 Road Occidente Pasto	Concession Contract for the Exploration-Exploitation of a Deposit of Building Materials No. JDB-14011
Mina Mikel	PK 38+000	Resolution No. GTRC-0105-09 Extension Special Exploitation License No. 17271
Agresur	District El Porvenir, Municipality of Iles	Concession Contract for the Exploration-Exploitation of a Deposit of Building Materials No. EIM-142
Panavias	Téllez River	Resolution 004059 dated September 29 2014 (Extension of Exploitation License No. 00342-52) (Contract with Panavias)

Source: Consorcio SH, 2017.

7.7.3.2 Environmental Authorization

Table 7.94 contains the list of environmental licenses issued by the competent environmental authority allowing exploitation of the materials to be acquired for execution of the building activities of the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment.

Table 7.94 Environmental Licenses of the Quarries

NAME OF THE SOURCE OF MATERIALS	LOCATION	ENVIRONMENTAL LICENSE
Madeko - El Juncal	PK28+800	Not reported
Capulí - Panavías	Iles	File No. 2201 Resolution 273 of July 23 2002
Mina Rosapamba	PK34+400 Road Catambuco	File LSC-014-10 Resolution 737 of September 07 2010
Mina La Victoria	Km 8 Road Occidente Pasto	File 163 Resolution 226 of July 02 1996
Mina Mikel	PK 38+000	File LSC-007-09 Resolution 964 of November 23 2009
Agresur	District El Porvenir, Municipality of Iles	File No. 2403 Resolution 981 of December 28 2006 (Contract with Panavias)
Panavias	Téllez River	File No. 2403 Resolution 981 of December 28 2006

Source: Consorcio SH, 2017.

7.7.3.3 List of Materials

Table 7.95 contains the list of materials available in each source of materials.

Table 7.95 Volume of Material Available and Required in Quarries

NAME OF THE SOURCE OF MATERIALS	LOCATION	ESTIMATED RESERVES (m^3)	USES OF MATERIALS
Madeko - El Juncal	PK28+800	480,000	Granular bases and subbases
Capulí - Panavías	Iles	250,000	Granular bases and subbases
Mina Rosapamba	PK34+400 Road Catambuco	280,000	Granular bases and subbases
Mina La Victoria	Km 8 Road Occidente Pasto	2,942,730	Granular bases and subbases and concrete-asphalt aggregates
Mina Mikel	PK 38+000	225,000	Concrete-asphalt and hydraulic aggregates
Agresur	District El Porvenir, Municipality de Iles	180,000	Subbase and surfacing
Panavias	Téllez River	150,000	Granular bases

Source: Consorcio SH, 2017.

Annex 2. Civil. XI Project Infrastructure contains the general location of the sources of material to be used with the corresponding access roads between the project site and such sources.

It is clarified that the company may work with other material extraction and commercialization companies other than the ones previously indicated, provided that they have valid mining-environmental permits. This information shall be attached to the environmental compliance reports - ICA.

7.7.4 Extraction of Materials on Mining Titles in the Right of Way

The activities of the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment do not include extraction of material son mining titles in the right of way.