ENVIRONMENTAL IMPACT STUDY FOR THE RUMICHACA - PASTO DUAL CARRIAGEWAY ROAD PROJECT, PEDREGAL – CATAMBUCO SECTION, UF 4 AND UF 5.1 CONCESSION CONTRACT UNDER SCHEME NO APP. 15 2015

Géminis Consultores Ambientales
Environmental consultants

Chapter 7. Demand, use, exploitation of and / or effect on natural resources

San Juan de Pasto, March 2017

TABLE OF CONTENTS

INDEX OF TABLES

LIST OF FIGURES

LIST OF PHOTOS

7. DEMAND, USE, EXPLOITATION OF AND / OR EFFECT ON NATURAL RESOURCES

Follows the description of natural resources to be used, exploited or affected by the implementation of the Rumichaca - Pasto dual carriageway road project, Pedregal - Catambuco section, which requires the use and / or intervention of different natural resources due to the interaction of the road project layout with natural resources, the need of supplies and / or construction materials and the importance of properly managing liquid and solid waste generated by the project.

This chapter presents the classification of natural resources that will be demanded by the project, the permits required for their exploitation and in turn the saving and use of water programs developed in Annex 7.a and the savings and energy use program presented in Annex 7.b

The community has been informed in all matters relating to the use and exploitation of resources through impact workshops carried out in the territorial units of the area of influence of the Project, perceiving thereby their expectations and their positive perception towards the road improvement. The following outlines some of the expectations raised by the community related to water sources, discharges and air emissions:

- To highlight that it is necessary to correctly manage watersheds that may be contaminated
- It is suggested to channel some water sources specifically in minor territorial units belonging to the municipality of Pasto
- The community states that polluting water sources (streams, rivers and fountainheads) can harm their crops, their animals and human health.

As for the impact on air quality, communities have a common view when identifying contamination by impurities in the air, by handling building material, material from excavations and machinery polluting gases., They also consider that this contamination will be constant due to increased traffic flow during road operation, reason why noise pollution will also increase from noise during construction and operation of the road.

As for the soil, the communities state potential impacts on soil degradation due to road improvement, also identifying that there will be soil erosion, which can trigger, according to the community, landslides land may become "loose" during construction due to the vibration of heavy vehicles and machinery operation among others, which may also affect houses neighboring the road. The community mentions that the mountains in intervened area may be affected causing landslides.

The community also expressed concern about the effect on sewer systems and in other cases identified road construction as a favorable opportunity to implement sewerage in the county according to the processes advanced by the Community Action Boards.

Considering the aspects raised by the community as well as the impacts identified for the project (See Chapter 8. Impact Assessment), use and resources management will be subject to compliance with provisions of the environmental legislation, which will have control measures will and management plans to prevent and mitigate the impacts.

7.1 Surface water

Activities associated with Project development, the demand and use of water resources are related to the needs of the activities to be developed. The amount of water to be used is described below and is requested by means of the sole uptake formats requesting water concession permission as established in the Natural Resources Code, Decree 1076 of 2015 and Decree 1541 of 1978.

Surface water is required for industrial and domestic use, and for temporary site facilities, such as wetting activities in camps, fronts required work, processing plants, washing, cleaning and irrigation activities.

7.1.1 Requested water flow

Materialization of a second road axis will result in implementing various temporary industrial work fronts, which will have uptake sources and the amount needed to develop industrial and domestic activities.

- Industrial use required flow

To determine the flow required for Project development, the amount of water required for industrial activities such as the process plant (concrete, asphalt and crushing), cleaning and wetting two (2) camps proposed for the Pedregal - Catambuco section activities were taken into account. See Table 7.1

In most cases the activities will be conducted insofar as possible with recirculated water in response to the measures proposed in the savings and efficient use of water program.

The industrial flow calculation use the considered the maximum required for development of the activities in work sites and camps with a loss factor of 25%. On the other hand, otherwise the flow given in concession will be 0.5 to 1.5 l / s that will be available in storage tanks in order to supply the flow required for the various processes of the works that is 6 L / s for aforementioned activities.

Table 7.1 Flow required for industrial use

UF	CAMP- WORK SITES	ACTIVITY	CONSUMPTION (L / s)	LOSS RATE 25%	FLOW IN CONCESSION
4	Tangua camp	Processing plant cleansing and wetting activities	6 L / s	1.5 L / s	0.5 to 1.5 L / s
4	Work sites	Wetting	3 L / s	0.75	0.5 to 1.5 L / s
5	Cebadal camp	Processing plant cleansing and wetting activities	6 L / s	1.5 L / s	0.5 to 1.5 L / s

Source: (Gemini SAS Consultants, 2016)

· Industrial uptake sources

Given described needs, a total of five (5) water bodies were selected to supply the needs of all industrial processes such as: process plant (concrete, asphalt and crushing), cleaning and wetting activities for the two (2) camps proposed for the Pedregal – Catambuco section. See Table 7.1 (See Annex GDB/mapping/PDF/EIADCRP_IP_033). Water demand required for camps such as Cebadal and Tangua and work sites, water sources used for water uptake are shown in Table 7.2 and Figure 7.1. (See Annex GDB / mapping / PDF / EIADCRP_IP_033); water quality was monitored by analyzing the physicochemical and microbiological parameters of the uptake source, (See Chapter 5.1 in section 5.1.6)

Table 7.2 Sources of water uptake Pedregal - Catambuco section

UF	SOURCE	PROPERTY NAME	OWNER	LOCATION UPTAKE POINT	COUNTY	MUNICIPALITY
4	Rio Bobo	528885-00-010008-0087-000	Sarasty Enriquez Jorge Samuel	E: 960614.499 N: 608230.956	Inantas Bajo	Yacuanquer
4	La Magdalena	52788-00-0100000001	-	E: 961,218.70 N: 610773.57	Inantas Alto	Yacuanquer
4	La Chaquita	52788-00-100050503000	-	E: 967138.506 N; 614073.608	Chávez	Tangua

5	La Marquesa	52788-00-01-0006-0131-000	Araujo Yandar Tulio	E: 968222.919 N: 617028.3	El Tambor	Tangua

Source: Gemini Consultants SAS, 2016

Table 7.3 Sources of water uptake Pedregal - Catambuco section

UF	SOURCE	PROPERTY NAME	OWNER	LOCATION UPTAKE POINT	COUNTY	MUNICIPALI TY
5	La Magdalena	52788-00-01000503250 00	-	E: 965242.001 N: 615211.1876 E: 965261.292 N: 615216.731	El Cebadal	Tangua

Source: (Gemini Environmental Consultants, 2016)

Water concession permits to supply the industrial camps are described according to above information. See Annex 7.1.1.a

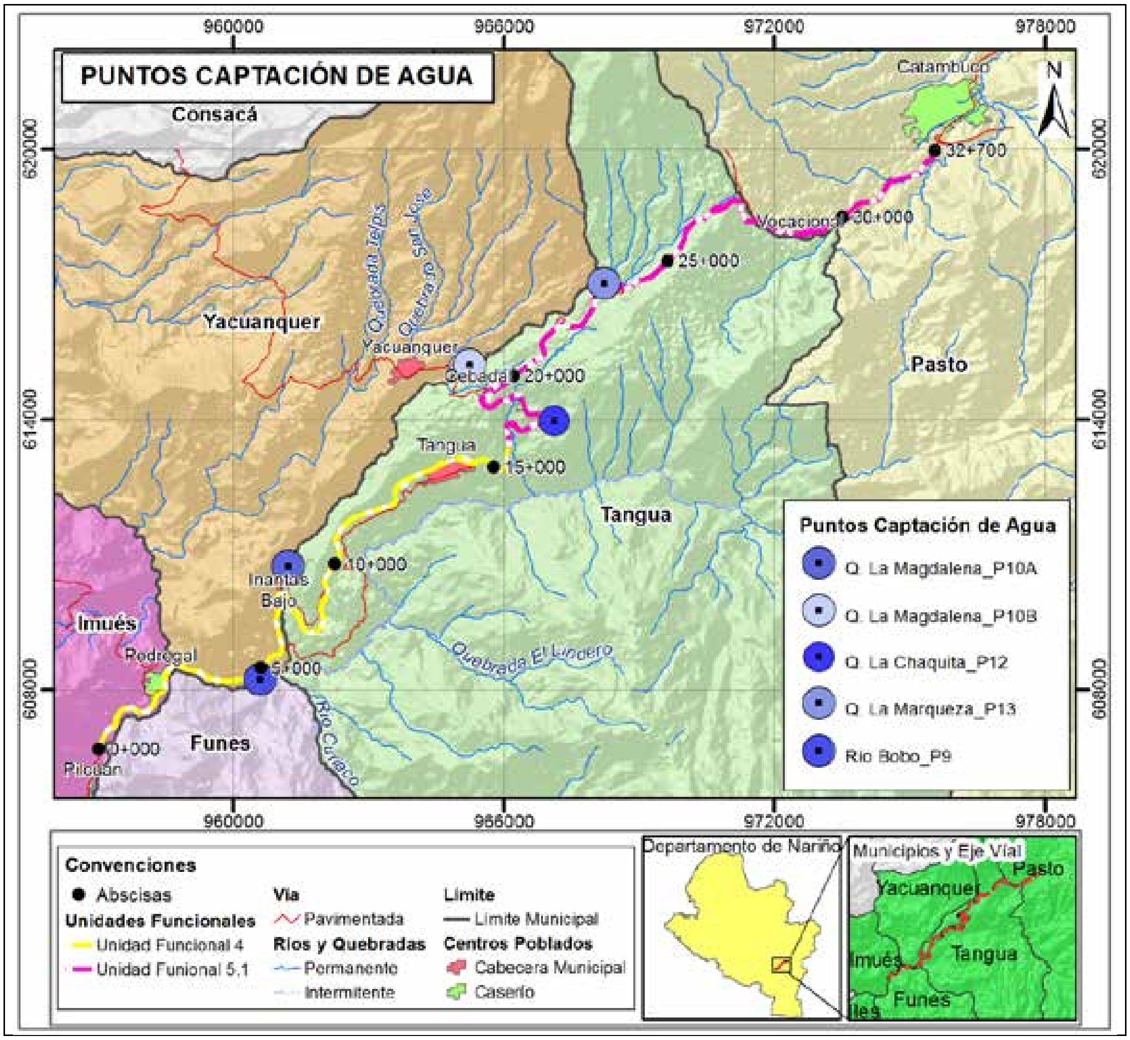


Figure 7.1 Water uptake points, Pedregal - Catambuco section
Source (Gemini SAS Consultants, 2016)

- Household water requirements

The water used in the project is for meeting basic needs such as toiletries, hygiene and human consumption. To calculate required flow, personnel at each camp was taken into account, and net supply was estimated according to information concerning climate changes (with a technical loss of 25%, according to Resolution 2320 of 2009), considering that the project area is located over 1,000 meters above sea level, an estimated supply of 90 l / person / day is estimated. Table 7.4 shows the average daily demand of domestic water use for the Project per camp.

It is noteworthy that domestic use requirements are not included in the request for water concession permit, since this water will be provided by a third party (municipal and county aqueducts). For the Pedregal - Catambuco section, the drinking water service was contracted with the Marquesa Bajo, Los Ajos and Empotanque county aqueduct administration board that will supply the Cebadal and Tangua camps respectively; annexed letters evidence service availability of the aqueducts. See Annex 7.1.1.b. The aforesaid to ensure that the bacteriological and physical chemical quality is fit for human consumption according to Decree 1575 of 2007; the service will be transported in water tanker trucks to the storage point.

Table 7.4 Water demand, household use per camp

ITEM	VALUE	DESCRIPTION
Supply	90 l / inh * day	As provided for in article one of resolution 2320 of 2009, that establishes that for a low complexity level, cold weather, a maximum net supply of 90 l / inh * day
Workers	250	Maximum estimate of workers in proposed camp
Required flow	22500L / day	This is the maximum flow required of drinking water for 250 workers.
	0,260L / sec	
Safety factor	0.065 L / sec	The Surplus and Losses Correction Factor in the supply and transportation systems is 25% of the calculated required flow
Total	**0.325 L / sec**	

Source: (Gemini SAS Consultants, 2016)

7.1.1.1 Estimated consumption flow construction stage

The amount of water for industrial use in the various processes of the works presents great variability in the availability required for each camp in the Pedregal - Ipiales section as observed in Table 7.5 that shows water demand required for different industrial activities.

Table 7.5 Estimated consumption flow for the Project

UF	CAMP	TYPE OF MATERIAL	MATERIAL VOLUME	WATER EMISSIONS	PRODUCTION WATER USE	PLACEMENT WATER USE	PLANT MATERIAL PRODUCTION	WATER AMOUNT
			(M3)	(M3 / hour)	(M3 water / m3 Material)	(M3 water / m3 Material)	(M3 / hour)	(M3)
UF4	TANGUA	CRUSHING	**379035**	1,48	-	-	80	7,012
		BASE and SUB.BASES	160065	-	-	0.08		12,805
		M. ASPHALT	40,665	-	0.01	-		407
		CONCRETE	41062		0.25	-		10,266
								30,490
UF5	CEBADAL	CRUSHING	**390653**	1,48	-	-	80	7,227
		BASE and SUB.BASES	182745	-	-	0.08		14,620
		M. ASPHALT	48367	-	0.01	-		484
		CONCRETE	20,183		0.25	-		5,046
								27,376
		Total						**57866**

It was estimated that total water consumption for the project, with an estimated construction time of five (5) years, is 57,867 m3 / hour, this equates to 16,074.16 L / s distributed in the above mentioned activities.

7.1.2. Uptake systems

Proposals for water sources uptake are the following alternatives can be by the difference of land level or boost pump; the size and characteristics of the headworks should allow flow uptake necessary for the supply. Chosen option in each source will be reported to the ANLA in the first environmental compliance report ICA.

- Uptake via tank truck motor pump

This scheme consists of a motor pump installed on a tank truck, which will join an up to 6 " hose or suction pipe from the water stream. This pipe will have a fitting on the suction end to prevent ingress of drag material (See Figure 7.2).

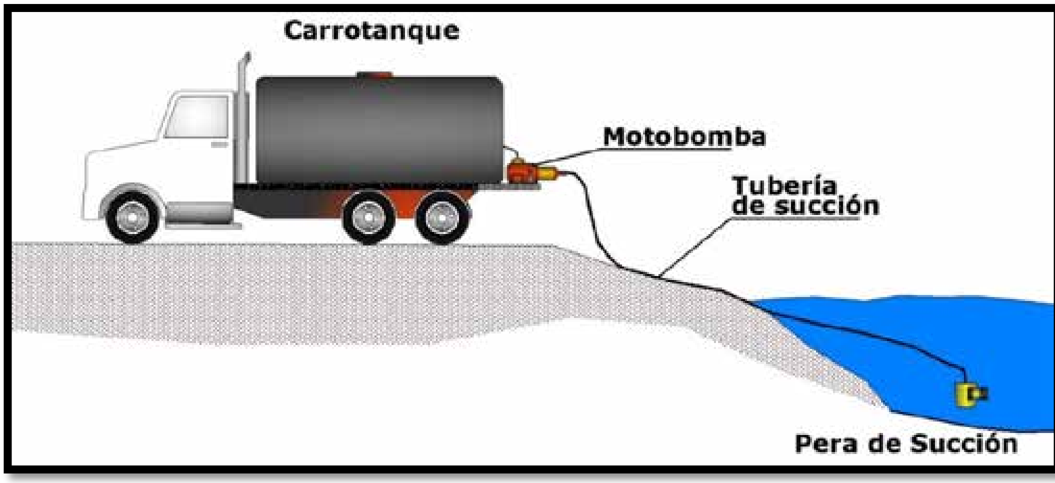


Figure 7.2 Direct uptake system from tank truck
Source Gemini Consulting SAS, 2015

Storage and water distribution tanks will be installed in each location where the collected water is taken.

The following recommendations must be considered when using tank trucks to uptake water:

- The tank truck cannot enter the water body and must keep a safe distance in meters from the water edge to avoid affecting the slope.
- Uptake is made by means of a suitable hose to pump water from the water source and prevent altering the quality of the water body. This in order to avoid generating instability in the banks and erosion and / scouring thereof.
- The tank truck hose to the water body should be laid using an existing access in order to avoid opening trails.
- The end of the suction hose should not be immersed in the water body to prevent suction of sediment and their impact.
- It is suggested to search existing footprints and grazing areas to avoid an impact on the plant component of the area.

· Water transportation

Uptake water will be transported in tank trucks used exclusively for this activity; mobilizing from the uptake point to the point of temporary storage located in camps, workshops, storage areas or plants, depending on the demand for the resource.

The resource will be used for proposed Project activities. The tank truck must be cleaned before starting the uptake activities. Uptake can begin once the tank truck is clean for transportation to the temporary storage.

Tank trucks used to transport water may not load any other substances (chemicals, domestic and non-domestic waste water, fuel, etc.) that could deteriorate the water quality or contaminate it.

Figure 7.3 Tank catruckr for water transport
Source (Gemini SAS Consultants, 2016)

The environmental management plan described in chapter 11.1.1 presents management measures for surface water uptake activities, see Table 11.1.1.8 Uptake Management.

- Restitution of surplus water and distribution

Pretreated water will be returned through underground sources; it should be noted that the water that unused is stored for later use. Water is gravitationally distributed through a hydraulic system for powering various distribution points or stipulated hydrants.

- Temporary storage

Temporary water storage for domestic and industrial use must be separated, so that water storage tanks will be installed (clearly marked in permanent housing camps, plants, storage facilities or other areas requiring the supply).

Temporary storage tanks for drinking water and raw water must meet the general characteristics shown in Table 7.6.

Table 7.6 General characteristics for drinking water and raw water storage tanks

CHARACTERISTIC	DESCRIPTION
Safety	The tank should be located on land not susceptible to landslides or flooding. It must also be stable with respect to soil quality foundation and geotechnical or geological origin faults.
Serviceability	The tank should be such that it can be serviced with minimal disruptions, taking into account the following provisions: 1. For the low complexity level it can have a single compartment 3. The tank must be provided with valves for closing inlet pipes and outlet pipes. 4. The inlet and outlet closing devices must be marked according to the color code for piping and valves. 5. The tank should have the shape and serviceability facility.
Access restriction	Necessary safety measures must be taken using fences, restricted road accesses, monitoring or otherwise to prevent access of strangers.
Tank location	The location of the tanks should consider the following recommendations 1. If the tank is buried or half buried, to be away from any source of contamination, such as septic tanks, garbage dumps, toilets, sinks, etc. and must be covered.
Materials	The tank material must withstand the forces caused by land and floatation pressures for buried or partially buried tanks when empty.
Waterproof	The walls and the bottom should be waterproof and the material exposed to water should be resistant to chemical attacks and corrosion.
Ventilation	The tank must have vents allowing the ingress and egress of an air source, with a 5 mm mesh to prevent the entry of insects; if these are PVC, technical standard NTC 1260 should be used.

Source Gemini Consulting SAS, 2015

Storage tanks for drinking and industrial water use, corresponding to a multipurpose tank allowing constant flow of water, easily cleaned, resistant to sun exposure and impacts; the multipurpose polyethylene tank has storage tank specifications shown in Table 7.7.

Table 7.7 Characteristics of storage tanks

CHARACTERISTICS	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: (Gemini SAS Consultants, 2016)

The water storage tank is white in order to refract sunlight, has an antimicrobial and anti-adhesive layer in order to minimize changes in odor and flavor that could be presented in drinking water.

7.1.2 Analysis of current or potential conflicts over water availability and use

According to the field survey, in the area of influence of the project the main water uses identified were domestic and irrigation where managed pasture and annual crops are the highest water users in the agricultural area and to a lesser extent sheepherding for properties located in the uptake basins used for project water requirements. Industrial and commercial use is associated with car washes, service stations, auto repair shops and dairy processing among others less important.

Water availability is the limiting factor in irrigation development in the basin. An increase in irrigated area could lead to conflict if farmers do not manage their water requests. The current practice is that anyone who wants to use water from a water source just takes it directly. The practice involves a potential future conflict over water.

Beneficiaries downstream of the supply sources suffer water shortages during the dry months. This is caused by the limited capacity of delivery systems. Water shortage problems for users located downstream could be solved greatly if the administration boards of aqueduct and / or communal action boards take corrective measures such as prohibiting the use of water resources for agriculture.

- Uses and water conflicts

From fieldwork and according to secondary information, potential conflicts were identified by use of water resources at the sources related to water uptake of uses and users of sources to intervene. After collecting field information in the area of influence it was identified that the main uses of water resources are domestic, agricultural, livestock and industrial for surface water bodies.

According to field information, tributaries located on the high side are the only major sources that supply population centers, counties and provinces, since the quality and quantity conditions is suitable for human and domestic consumption. Government agencies, organizations (community action boards and / or aqueduct administrative boards) and all users should be in charge of preserving the water sources.

A water conflict found was the relationship of neighbors because those living downstream complain to those living upstream of not letting water move to their boundaries and / or property, of littering or discharging on source. These interests associated with domestic use, agriculture, industry, among others often contradict instead of solving, which makes it even more complicated. See Table 7.8 Water use Pedregal-Catambuco sector.

Table 7.8 Water uses Pedregal-Catambuco sector

SURFACE WATER			
USE	CONCESSIONS	DEMAND l / s	PARTICIPATION
DOMESTIC	8	0.70	45 %
AGRICULTURAL	4	0.35	35%
INDUSTRIAL	3	0.115	20 %

Source: Gemini Consulting SAS

Communities state that the biggest problem is the decline in the quantity and quality of water assets due to depreciation of plant cover and increased consumptive water uses, lack and absence of solidarity and environmental responsibility, lack of technical assistance and training for the use of solid and liquid waste and waste from industrial and agricultural activities and others.

Reduced water sources for water supply to municipal aqueducts is a general concern among inhabitants. With some exceptions, all municipal county aqueducts are suffering from shortage of water resources. Discomfort and health effects by those reporting increasingly frequent pollution of water resources due to deposits and solid waste accumulation and wastewater discharges without any treatment or management are common in the community.

- Domestic use

Properties located within the AI demand water resources for domestic use activities; generally uptake in the area of influence is from water bodies with surface-type pretreatment to supply county aqueducts and independent type supply.

- Livestock use

In the study area there are mostly poultry sheds followed by extensive cattle and swine artisan breeding, which use water from water surface bodies close to the properties to feed and clean the breeding infrastructure used.

- Current uptake points Use

In uptake strips requested in this study, uses and users associated therewith were verified. There are uptakes in the Municipality of Tangua and Yacuanquer, which are used for agricultural and livestock purposes. Table 7.9 shows the characteristics of requested deposits.

Table 7.9 Users and uses uptake points

FU	SOURCE	APPLICATIONS	USERS	FLOW IN CONCESSION l / s
4	LA MAGDALENA	Domestic	782	1.5
4	LA CHAQUITA	-	-	-
4	RIO BOBO	Domestic	24257	47
		Agricultural		40
		Livestock		5
5	MARQUEZA (CUBIJAN)	Domestic	80	1.5

Source: Gemini Consulting SAS

· Ecological flow

The ecological flow is a management tool that allows agreeing on an integrated and sustainable management of water resources, establishing quality, quantity and water flow rate required to maintain the components, functions, processes and resilience of aquatic ecosystems that provide goods and services to society. Given the economic, social and environmental water demands, it is recognized that goods and services from water basins depend on physical, biological and social processes.

The ecological flow seeks to reproduce to some extent the natural hydrological regime preserving the seasonal patterns of minimum and maximum flows – dry and rainy seasons, respectively, the flood regime and exchange rates of special interest to manage the water infrastructure. See Table 7.10 Ecological flow, Pedregal-Catambuco.

Table 7.10 Ecological flow, Pedregal - Catambuco

Source Name	Average flow (L / s)	Ecological flow (30%)	Water demand source (L / s)	Available flow (L / s)	Flow uptake requested (l / s)	Magna Sirgas planar coordinates origin West	
						North	East
Rio Bobo	710	213	92	405	1.5	960614.5	608,230.96
Q. The Magdalena	55	16.5	32,29	6.21	1.0	961218.7	610,773.57
Q. The Chaquita	2.2	0,66	0.3	1,24	0.5	967,138.506	614,973.608
Q. The Marquesa	5.4	1,62	2.3	1,48	0, 5	968,222.92	617028.3

Source: (Gemini SAS Consultants, 2016)

- Flow frequency analysis

The frequency analysis is a method for estimating the frequency occurrence or likelihood of occurrence of past or future extreme events. Thus, the graphical representation of the likelihood is a frequency analysis method.

The maximum and minimum values in hydrology drain (precipitation or flow) should be treated by probabilistic distribution. Although there are many probabilistic distributions for maximum values, it is very common in hydrology to use the Gumbel (European School) and log-Pearson Type III (American School) probabilistic distribution values.

The information on minimum annual flows of each station was processed and adjusted by software to probabilistic functions. Follows the analysis of each one using minimum flows in different frequency periods.

Casanare automatic station

The frequency analysis for maximum and minimum annual flows recorded throughout the recording period of the Casanare Automatic station in the Bobo river, is reported in the following tables and graphs (Table 7.11 Table 7.11 and Figure 7.4 Figure 7.5)

Table 7.11 Frequency analysis Minimum Flow - Casanare Automatic station

RETURN PERIOD	EXPECTED Tr VALUE PER DISTRIBUTION				
	GUMBEL	NORMAL	PEARSON III	LOG PEARSON III	LOG NORMAL
(years)	m3 / s	m3 / s	m3 / s	m3 / s	m3 / s
1.33	0.54692	0.56006	0.55434	0.54701	0.55497
2	0.48705	0.50125	0.49246	0.47817	0.49396

RETURN PERIOD	EXPECTED Tr VALUE PER DISTRIBUTION				
	GUMBEL	NORMAL	PEARSON III	LOG PEARSON III	LOG NORMAL
5	0.43026	0.42851	0.42716	0.42231	0.42769
CHI SQUARE TEST	1.00000	3.00000	---	---	1.00000

Source Gemini Consultores SA, 2016

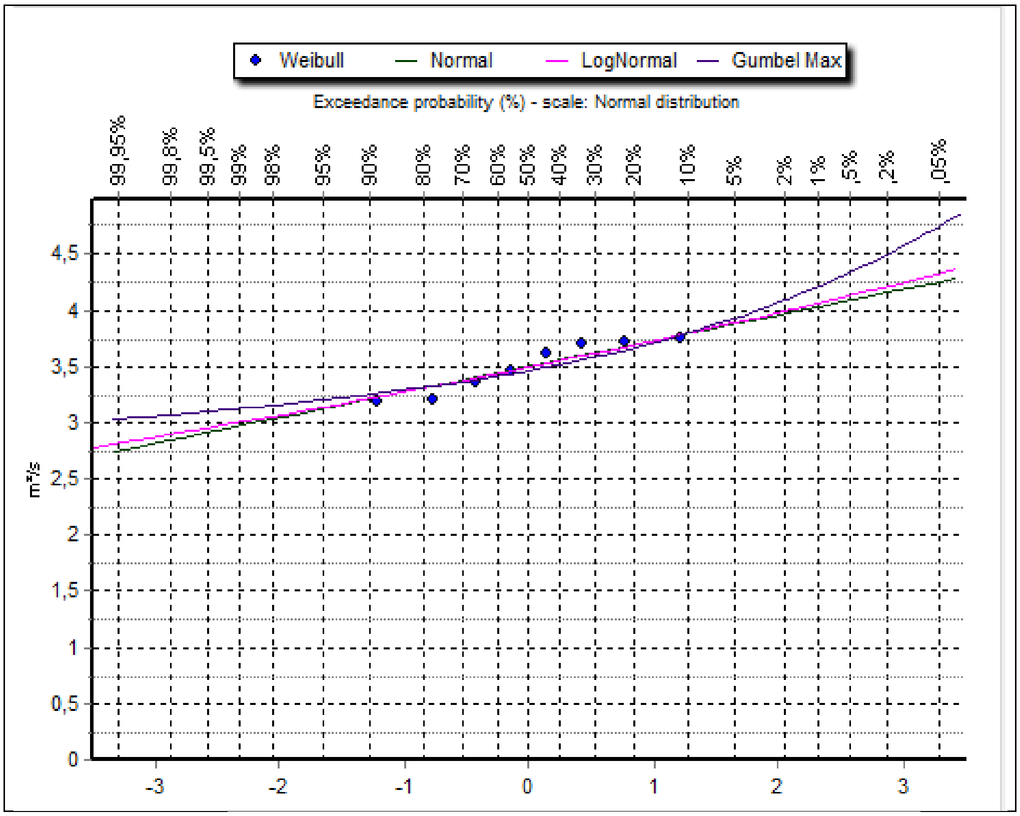


Figure 7.4 Minimum Flow frequencies - Casanare Automatic station

Source Gemini Consulting SAS

Table 7.11 FrequencY analysis Maximum Flow - Casanare Automatic Station

RETURN PERIOD	EXPECTED Tr VALUE PER DISTRIBUTION		
	GUMBEL	NORMAL	LOG NORMAL
(years)	m3 / s	m3 / s	m3 / s
1.33	3.33959	3.34616	3.34262
2	3.46379	3.50125	3.49385
5	3.66530	3.69309	3.69041
CHI SQUARE TEST	1.00000	1.00000	1.00000

Source: Gemini Consulting SAS

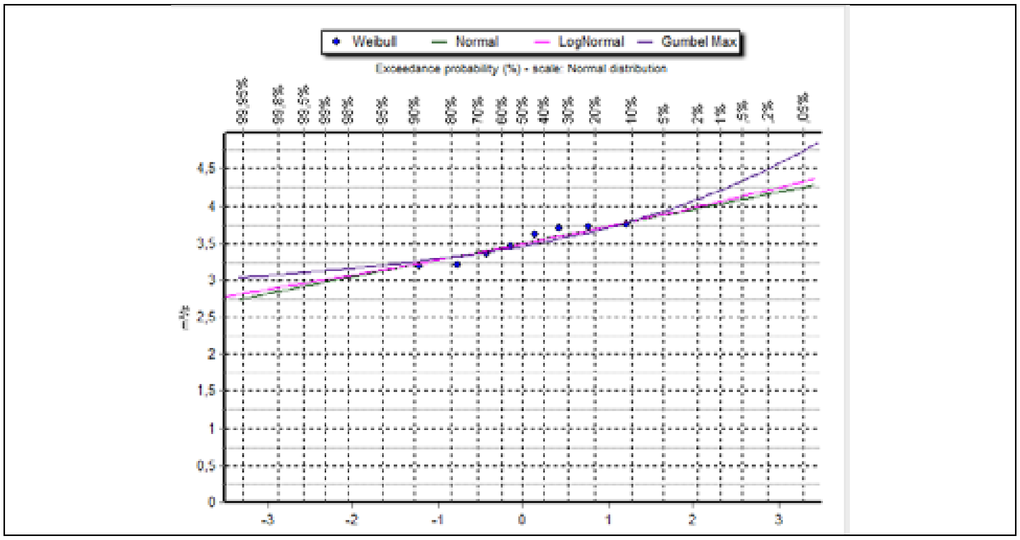


Figure 7.5 Maximum flow frequencies Casanare Automatic Station

Source Gemini Consulting SAS

Juanambú Bridge Station

The frequency analysis for maximum and minimum annual flows reported throughout the recording period of the Juanambú Bridge station on the Juanambú river is reported in the following tables and graphs (Table 7.12 Table 7.13 and Figure 7.6 Figure 7.7)

Table 7.12 Frequency analysis Minimum Flow - Juanambú Bridge Station

RETURN PERIOD	EXPECTED Tr VALUE PER DISTRIBUTION				
	GUMBEL	NORMAL	PEARSON III	LOG PEARSON III	LOG NORMAL
(years)	m3 / s	m3 / s	m3 / s	m3 / s	m3 / s
1.33	21.3119	22.1405	21.5605	21.1710	21.5239
2	17.5357	18.4315	17.6116	17.3680	17.6747
5	13.9540	13.8438	13.7767	13.9522	13.8520
CHI SQUARE TEST	0.33333	2.75758	---	---	1.78788

Source Gemini Consultores SA, 2016

Figure 7.8

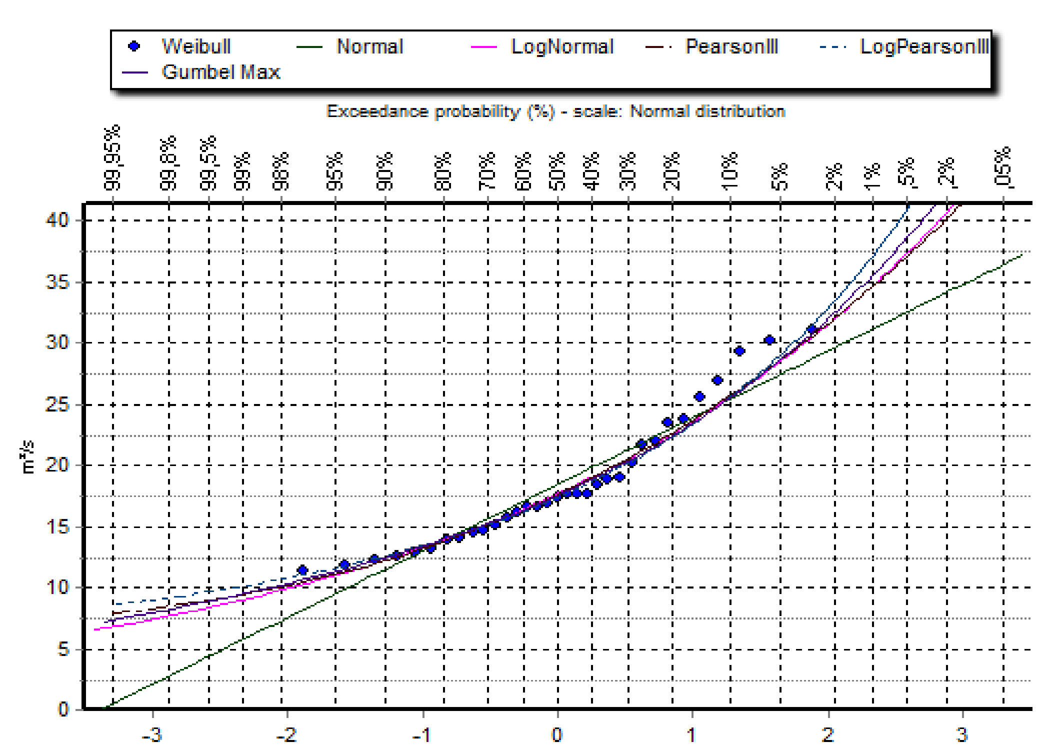


Figure 7.6 Minimum Flow Frequencies - Juanambú Bridge Station

Source Gemini Consulting SAS

Table 7.13 Frequency analysis Maximum Flow - Juanambú Bridge Station

RETURN PERIOD	EXPECTED Tr VALUE PER DISTRIBUTION		
	GUMBEL	**NORMAL**	**LOG NORMAL**
(years)	**m3 / s**	**m3 / s**	**m3 / s**
1.33	82.7644	83.6808	82.4650
2	100.097	105.325	100.827
5	128.220	132.097	129.291
CHI SQUARE TEST	0.31429	0.77143	0.31429

Source Gemini Consulting SAS

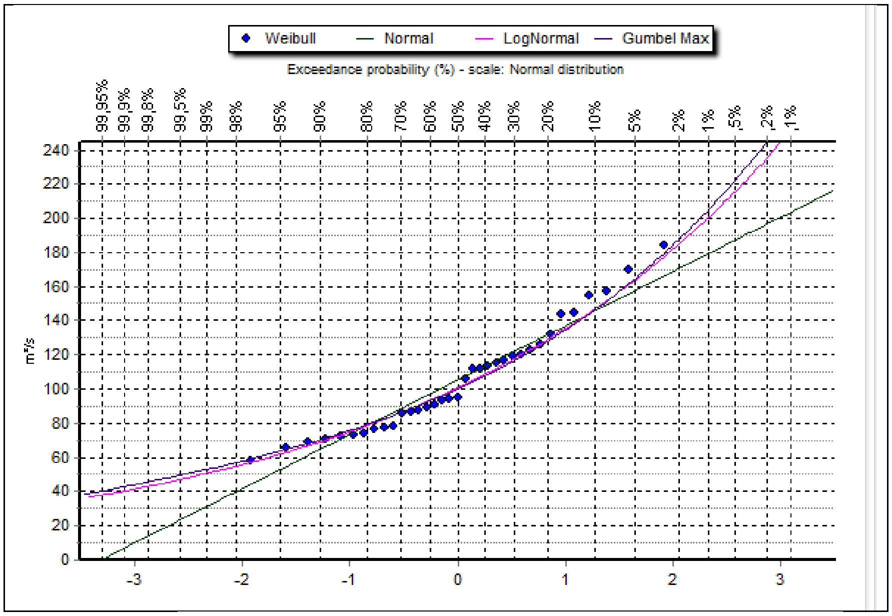


Figure 7.7 Maximum Flow frequencies - Juanambú Bridge Station

Source Gemini Consulting SAS

Centenio Bocatoma Station

The frequency analysis for maximum and minimum annual flows reported throughout the recording period of the Centenario Bocatoma station on the Pasto River, is reported in the following tables and graphs (Table 7.15 Table 7.14 and Figure 7.8 Figure 7.9)

Table 7.15 Frequencies analysis Minimum Flows – Centenario Bocatoma Station

RETURN PERIOD	EXPECTED Tr VALUE PER DISTRIBUTION				
	GUMBEL	NORMAL	PEARSON III	LOG PEARSON III	LOG NORMAL
(years)	m3 / s	m3 / s	m3 / s	m3 / s	m3 / s
1.33	0.86855	0.89856	0.89856	0.86590	0.87964
2	0.73179	0.76423	0.76423	0.70480	0.73994
5	0.60206	0.59807	0.59807	0.57890	0.59744
CHI SQUARE TEST	1.30769	1.30769	1.30769	4.38462	0.92308

Source Gemini Consultores SA, 2016

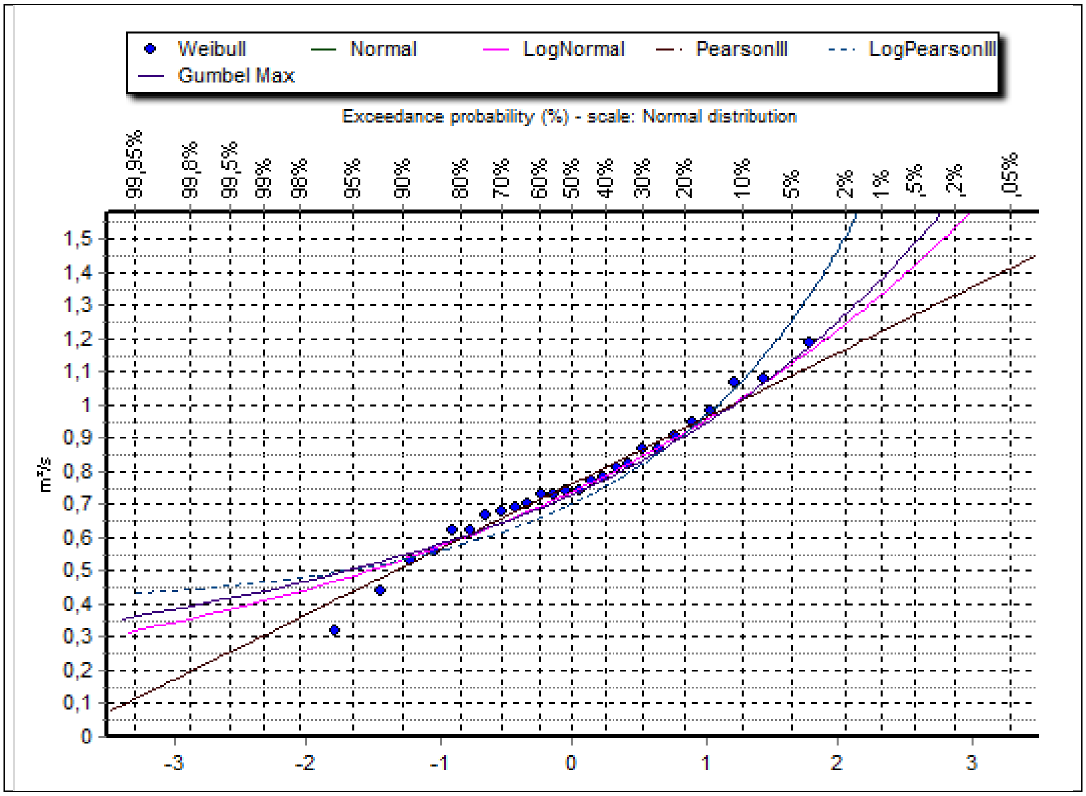


Figure 7.8 Minimum Flow Frequencies - Bocatoma Centenario Station

Source Gemini Consulting SAS

Table 7.14 Frequencies analysis Maximum Flows - Bocatoma Centenario Station

RETURN PERIOD	EXPECTED Tr VALUE PER DISTRIBUTION		
	GUMBEL	**NORMAL**	**LOG NORMAL**
(years)	**m3 / s**	**m3 / s**	**m3 / s**
1.33	6.31677	6.50009	6.44607
2	9.78423	10.8300	9.33738
5	15.4101	16.1857	14.7667
CHI SQUARE TEST	2.04000	2.04000	0.76000

Source Gemini Consulting SAS

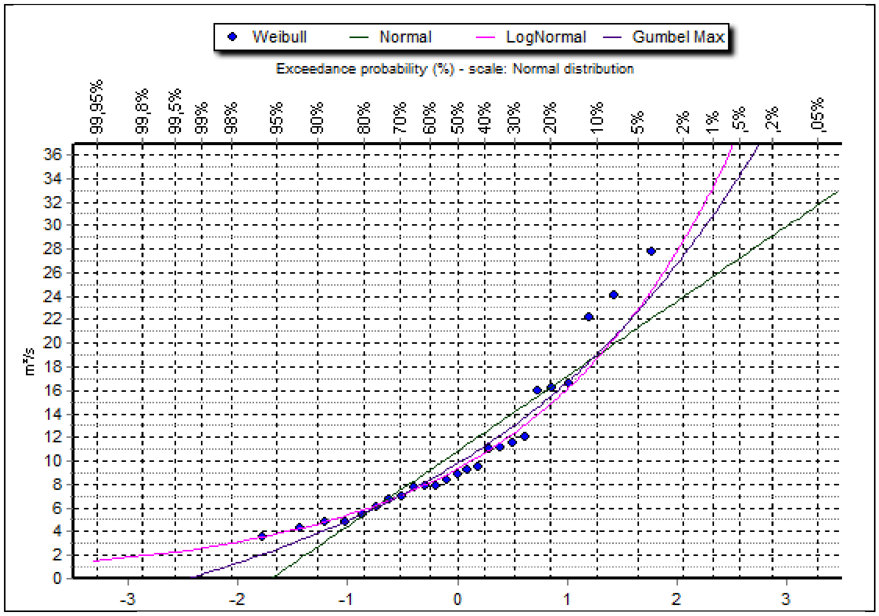


Figure 7.9 Maximum Flow Frequencies - Bocatoma Centenario Station
Source Gemini Consulting SAS

- Flow duration curves

The flow duration curve is the frequency analysis of the historical series of average daily flows. It is estimated that if the historical series is good enough, the duration curve is representative of the rate of average current flows and therefore can be used to predict the behavior of future flow regimes, or the regime presented during the life of the project.

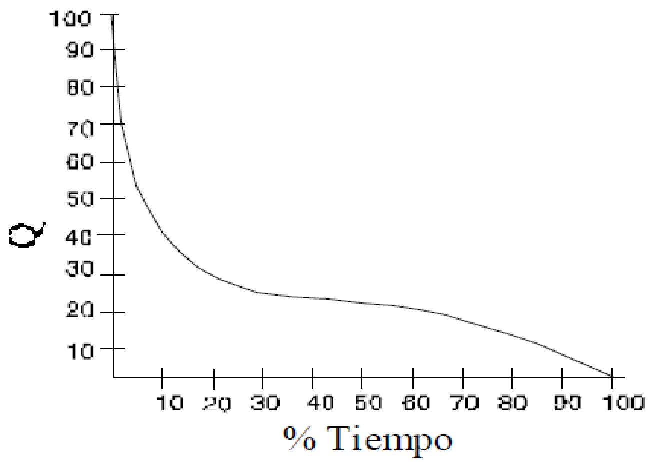
As shown in the following figures, the vertical duration curve scale represents average flow (daily, monthly or annually) and the horizontal scale the likelihood that these flows can be matched or exceeded.

It is a graph with flow, Q. as ordinate and the number of days in the year (usually expressed in % of time) in that flow, Q, is exceeded or equaled, as abscissa. The Q ordinate for any likelihood percentage represents the magnitude of the flow in an average year, expected to be exceeded or equaled by a percentage, P, of time.

The average annual, monthly or daily flow data can be used to construct the curve. The flows are arranged in descending order, using class intervals if the number of values is very large. If N is the number of data, the exceedance likelihood, P, of any discharge (or class value), Q, is:

$$P = \frac{m}{N} \times 100$$

Where m is the number of times the flow occurs at that time. If the flow rate is drawn against percentage of time when it is exceeded or equaled, a graph is obtained as shown in the following figure.



Duration curves have typical forms depending on the characteristics of the watersheds. In mountain basins i.e. the steep slope in the initial section of the curve indicates that high flows are present for short periods, while in lowland rivers the differences are not very noticeable in the slopes of the different sections of the curve.

The typical flow rates are defined as presented at different likelihood of occurrence in a curve flow duration, this is a Q_{10}, representing maximum flow exceeded 10% of the time, while a Q_{90} corresponds to a minimum flow rate exceeded 90% of the time. The main flow characteristic data are:

- Q_{90}: Characteristic dry flow rate exceeded 355 days a year.
- Q_{80}: Low water flow, to define periods of construction works with direct intervention of the channel.

- Q_{75}: Low water flow, exceeded 275 days a year flow or 75% of the time.
- Q_{50}: Average flow, flow exceeded 50% of the time is used for exploitation water distribution and is recommended not fall below this value.
- Q_{25}: High water flow: flow rate exceeded 355 days a year 55% of the time.
- Q_{10}: Maximum flow characteristic: flow exceeded 10 days a year.

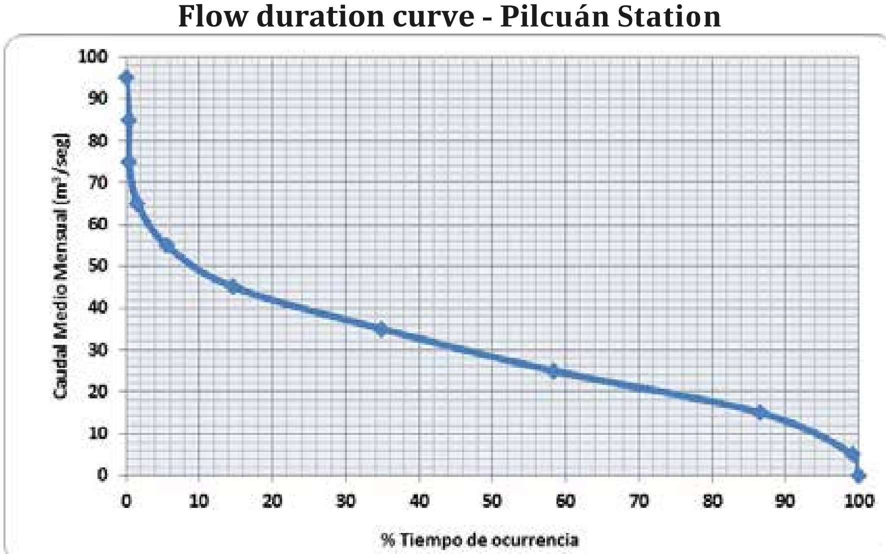
Pilcuán station

The following figure shows the flow duration curve constructed with the average monthly records from the Pilcuán station. In the Guaitara River case, flow characteristics are presented in the following table.

Characteristic Flows - Pilcuán Station

Characteristic flows	Value (m3 / s)
Q10	48
Q25	39
Q50	28
Q75	twenty
Q90	fifteen

Flow duration curve - Pilcuán Station



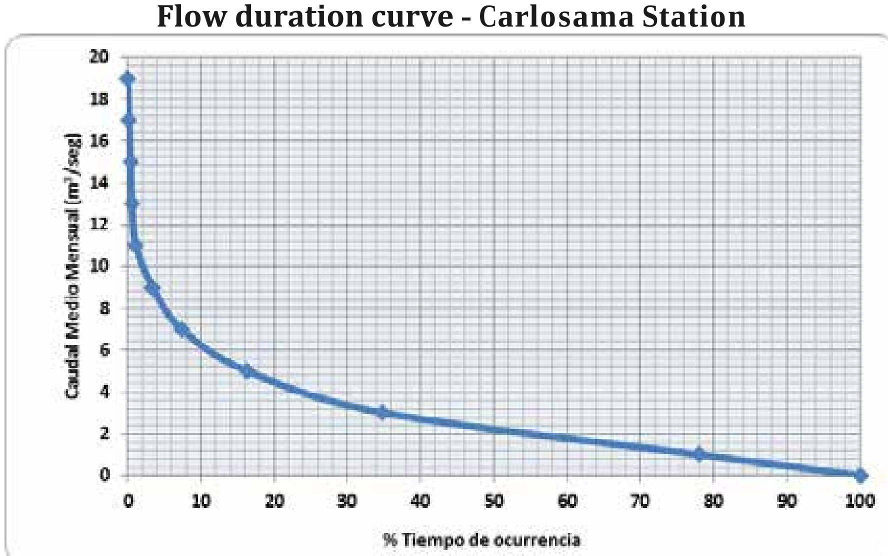
Carlosama Station

The following figure shows the flow duration curve constructed with the average monthly records from the Carlosama station. The typical flow rates are presented in the following table.

Characteristic Flows - Carlosama station

Characteristic flows	Value (m3 / s)
Q10	6.5
Q25	3.8
Q50	2.4
Q75	1.2
Q90	0.5

Flow duration curve - Carlosama Station



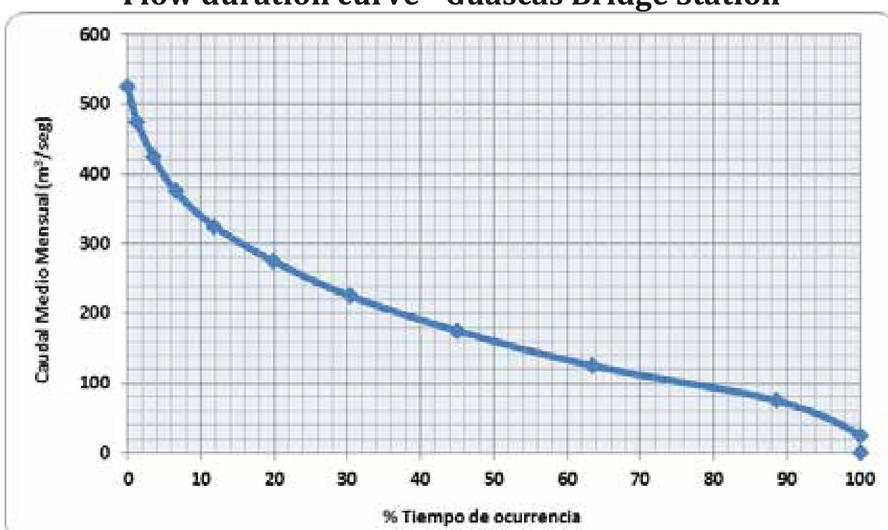
Guascas Bridge Station

The following figure shows the flow duration curve constructed with the average monthly records from the Guascas Bridge station presents. The typical flow rates on the Patia River are presented in the following table.

Characteristic flows - Guascas Bridge Station

Characteristic flows	Value (m3 / s)
Q10	340
Q25	245
Q50	160
Q75	100
Q90	70

Flow duration curve - Guascas Bridge Station



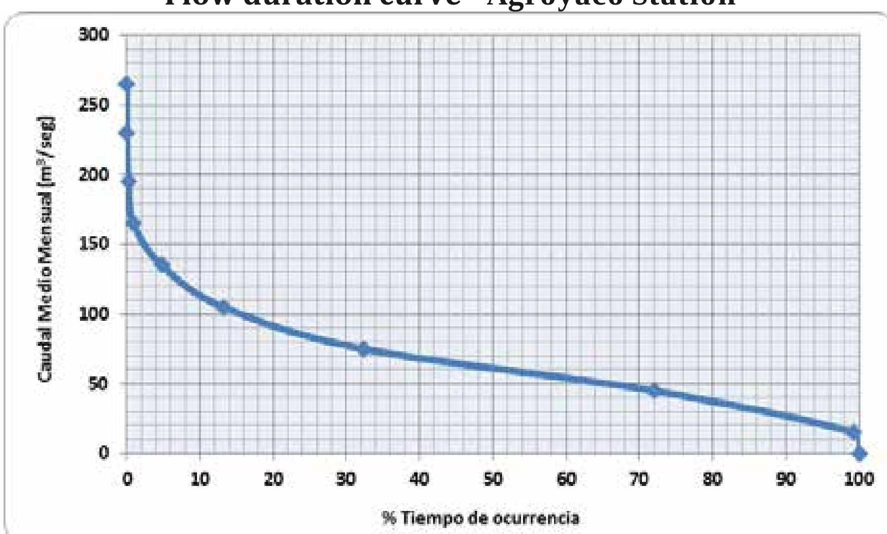
Agroyaco station

The following figure shows the flow duration curve constructed with the average monthly records of the Agroyaco station. The typical flow rates on the river Guaitara are presented in the following table.

Characteristic Flows - Agroyaco Station

Characteristic flows	Value (m3 / s)
Q10	115
Q25	85
Q50	60
Q75	40
Q90	28

Flow duration curve - Agroyaco Station



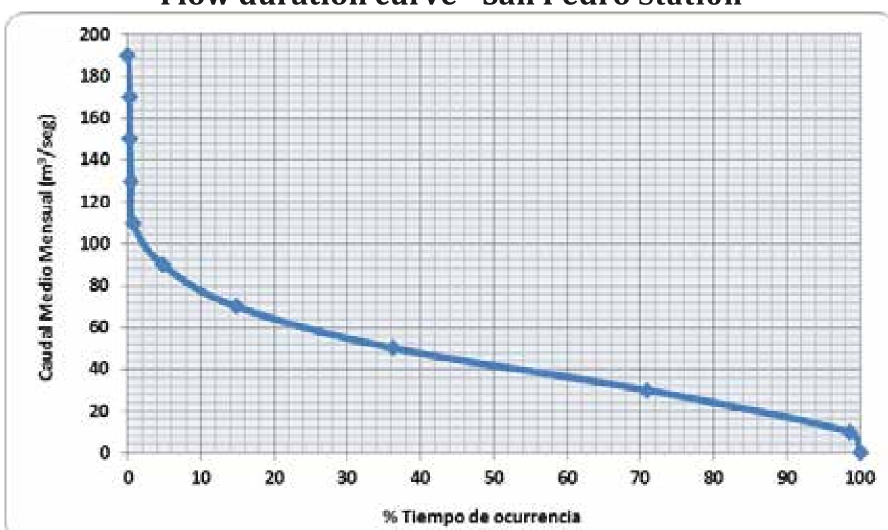
San Pedro Station

The following figure shows the flow duration curve constructed with the average monthly records of the San Pedro station. The typical flow rates on the river Guaitara are presented in the following table.

Flow Characteristic - San Pedro Station

Characteristic flows	Value (m3 / s)
Q10	77
Q25	60
Q50	43
Q75	28
Q90	18

Flow duration curve - San Pedro Station



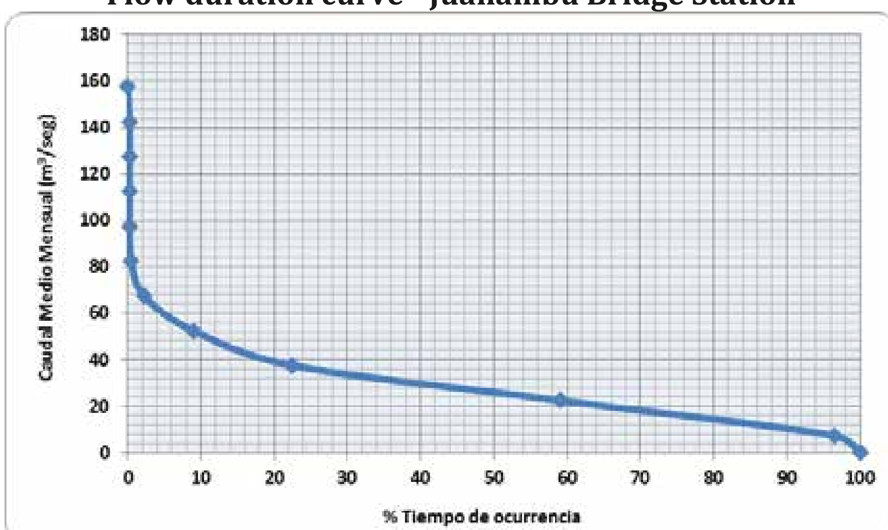
Juanambú Bridge Station

The following figure shows the flow duration curve constructed with the average monthly records of the Juanambú Bridge station. The typical flow rates on the Guaitara River are presented in the following table.

Characteristic flows - Juanambú Bridge Station

Characteristic flows	Value (m3 / s)
Q10	fifty
Q25	38
Q50	27
Q75	17
Q90	10

Flow duration curve - Juanambú Bridge Station



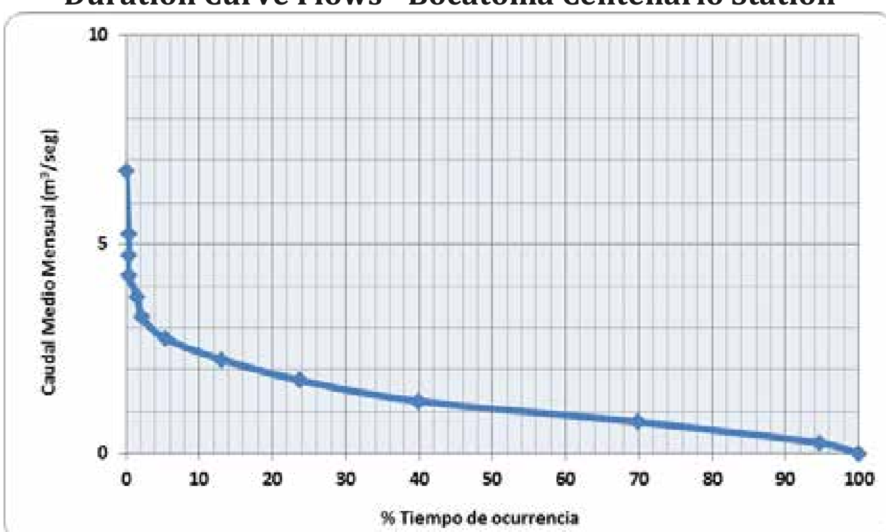
Bocatoma Centenario Station

The following figure shows the flow duration curve constructed with the average monthly records of the Bocatoma Centenario station. The typical flow rates on the Pasto River are presented in the following table.

Characteristic Flows - Bocatoma Centenario Station

Characteristic flows	Value (m3 / s)
Q10	2.4
Q25	1.7
Q50	1
Q75	0.7
Q90	0.4

Duration Curve Flows - Bocatoma Centenario Station



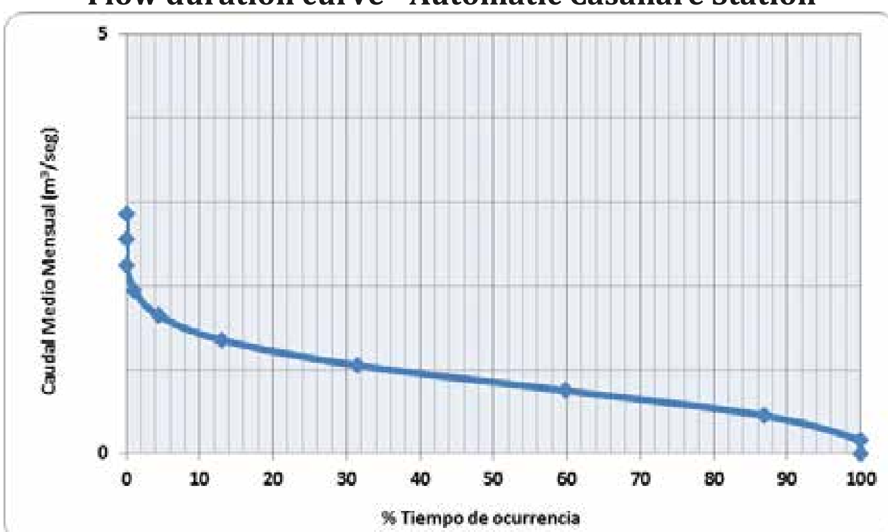
Automatic Casanare Station

The following figure shows the flow duration curve constructed with the average monthly records of the Casanare Automatic station. The typical flow rates on the Bobo River are presented in the following table.

Characteristic Flows - Automatic Casanare Station

Characteristic flows	Value (m3 / s)
Q10	1.4
Q25	1.1
Q50	0.9
Q75	0.6
Q90	0.4

Flow duration curve - Automatic Casanare Station



7.2. Underground water

Execution of the activities foreseen for development of this project does not require using groundwater since the needs of water resources are supplied from surface water uptake and purchase of authorized water resources that provide water with optimal characteristics for human consumption. Therefore a groundwater concession is not requested.

7.3. Discharges

Project discharges is from industrial consumption (processing plant, washing machines and workshop). Wastewater will receive physical and bacteriological treatment before being discharged, this in order to ensure removal of pollutants and improve physicochemical characteristics of the wastewater. Table 7.15 shows the facilities of each of camp.

Table 7.15 Camp facilities

UF	CAMP	PLANAR COORDINATE	PK	ACTIVITY
4	Tangua camp	E: 965241.119 N: 613193.624	14 + 300 14 + 500	Processing asphalt, crushing plant, offices and housing
5	Cebadal camp	E: 967254.322 N: 615985.056	21 + 700	Processing asphalt, crushing plant, offices and housing

Source: (Gemini SAS Consultants, 2016)

Strategies for disposal of liquid waste from camps are distributed as follows, clarifying that viability and importance will be in line as listed below.

- Vactor discharges
- Surface water discharges
- Municipal sewage discharges
- Ground discharges

7.3.3 Vactor discharges

Discharges generated from developing core project activities will be of an industrial and domestic type. According to the aforesaid and giving compliance with the provisions of current environmental regulations, Decree 3930 of 2010 (provisions relating to the uses of water resources, the water resources and discharges to water resources to soil and drainage systems Planning) and Resolution 631, 2015 (whereby the parameters and maximum allowable limit values for specific discharges to surface body water and sewage systems are established); such discharges will be collected, managed and disposed of by third parties through a suction device known as vactor vacuum.

To clarigy that the third party shall have the respective environmental and operational permits allowing them to provide the service. See Annex 7.3.a

7.3.4 Discharges to sewage

The camp located in the El Vergel county, municipality of Tangua will generate both industrial and domestic effluents which will be disposed of in the municipal sewer system managed by the Administración Publica Cooperativa de Agua Potable y Saneamiento Básico de Tangua (EMPOTANGUA) who must meet the requirements stipulated by Article 39 (Liability of the provider of home public sewage services). Similarly, the construction group will assume as part of its responsibility provisions of Article 38 (Obligation of subscribers and / or users of public utility companies).

Similarly, the necessary arrangements went ahead with the Metropolitan Sanitation Company and EMAS Pasto and the Pasto Service Company of Sanitary Works EMPOPASTO, for management and disposal of domestic liquid wastes from the camps, see Annex 7.3.b

7.3.3 Characteristics of wastewater composition

In the works comprising the materialization of the new road axis, discharges associated with processes of the concrete, asphalt and crushing plant and temporary facilities (camps) will be generated, reason why a system to treat wastewater whose characterization described below will be installed.

- Domestic wastewater

Two types of black and gray domestic wastewater are generated from camp operations during the different project stages. Household waste will be handled by the company providing the vactor service that will be responsible for collecting domestic wastewater, the company will have due environmental and operational permits.

During the construction stage, a domestic wastewater discharge (ARD) flow rate was calculated according to consumption per day per camp considering that the number of projected camp workers are two hundred fifty (250) and that area climate can be considered as cold, so the daily water demand per inhabitant is ninety (90) L / s, resulting in a discharge flow of approximately:

$$Q_d = \frac{C * P * R}{86400} = \frac{90 \frac{L}{hab} * 250\ hab * 0.8}{86400} = 0.21 \frac{L}{s}$$

Greywater: coming from the camps (kitchen, bathroom), characterized by having suspended materials and vegetable fats. Their organic pollution index is less than sanitary or black type waters.

Sewage: characterized by a high content of organic load and a high population of total and fecal coliforms; its concentration depends on the flow of wastewater and the number of workers that in this case will be two hundred and fifty (250) employees in each camp. See Table 7.16

Table 7.16 Black wastewater characterization

PARAMETER	UNITY	REPORTED VALUES
Color	CPU	> 150
Chlorides	mg Cl / l	> 150
DBO	mg O2 / l	> 500
COD	mg O2 / l	> 600
Total hardness	mg CaCO3 /	50
pH	Unit	7- 9
Dissolved solids	mg / l	300-800
Suspended solids	mg / l	100-200
Sulfates	SO4 mg / l	40-100
Total coliforms	NMP /	900,000
Fecal coliforms	NMP /	80,000
Fats and oils	mg / l	50- 100

Source (Consorcio Vial Helios, 2008)

- Industrial wastewater

These waters originate from activities as concrete plants with a high amount of dissolved and suspended solids and chemical residues as shown in Table 7.17. Metal concentrations vary according to the needs of the mixture and its disposal; the values shown in the table are the allowable discharge limits.

Table 7.17 Concrete plant wastewater characterization

PARAMETER	UNITS	RESULT
Chlorides	mg Cl / l	58.8
pH	Units	11

PARAMETER	UNITS	RESULT
Total solids	mg / l	499
Sulfates	MgSO4 / l	135
Settled solids	mg / l	332
COD	PPM	216
Turbidity	FTU	50
Hardness	mgCaCO3 / L	4220
Alkalinity	mgCaCO3 / L	3389
Arsenic	mg / l	0.5
Barium	mg / l	1.0
Cadmium	mg / l	0.01
Zinc	mg / l	13
Copper	mg / l	1.0
Mercury	mg / l	0.02
Lead	mg / l	0.05
Selenium	mg / l	0.01

Source (Consorcio Vial Helios, 2008)

To calculate the discharge of non-domestic wastewater (ARnD) during the operation stage, the industrial contribution coefficient considered for an average level of complexity is 0.4 L / sec (Ci) and the calculated water consumption for use in the project's process plants is 1.5 L / sec (Qi), with these data the non-domestic wastewater flow is calculated ($QARnD$) shown in the following equation:

$$Q_{ARnD} = Ci * Qi$$

$$Q_{ARnD} = 0,4\frac{L}{seg} * 1.5\frac{L}{seg} = 0,6\ L/seg$$

Given that concrete plants are equipped with a wastewater recirculation system.

The characteristics of the recirculation system will be presented in the Environmental Compliance Reports - ICA. The following table shows the discharge flow during the construction stage.

The discharge flow rate of industrial water was determined as 0.6 L / s as 85% (0.5 lost by evaporation approximately) of resulting water from the process plants to be recirculated so that only 10% will be disposed of through the vactor.

Table 7.20Discharge flow

NAME	TYPE OF WATER	Water consumption	Wastewater generation
		Requested water flow L / sec	Water discharge L / Sec
Tangua camp	ARD	0.28	0,21
	ARnd	1.5	0.6
Cebadal camp	ARD	0.28	0,21
	ARnd	1.5	0.6

Source. (Gemini SAS Consultants, 2016)

- *Treatment Systems*

The treatment systems designs obey the characteristics of the waste waters to be treated, which vary depending on their origin. Wastewater treatment systems are not only a measure of environmental management for the possible effects from project development, but is currently also assumed as an activity thereof. Because of this, the Concessionary seeks to propose alternative treatment systems which have greater efficiency in removing pollutants, resulting in greater protection to natural resources and the environment. Discharges will be collected after pretreatment in a septic tank (sewage) and grease trap (gray water), clarifiers, etc., through an authorized third party for collection and treatment.

- Greywater treatment system

From camps (showers, sinks, dishwashers and washing machines), are characterized by suspended materials and vegetable fats. The organic contamination index of these waters is less than sanitary or black type water. These waters will be independently routed to a grease trap whose effluent will join the cesspit with a removal efficiency of 80%, to be disposed of in the infiltration field meeting RAS 2000required standard, which specifies a minimum distance of 50 meters from any water body.

The treatment units foreseen before discharging water in the infiltration field are as follows:

ü Grease trap

As a first step a grease trap (physical process) for grease retention will be installed, located at the outlet of the camp housing area in order to prevent clogging, adhesion, bad smell problems, among others. The following established designs parameters will be considered. Table 7.21

Table 7.21 Grease trap design parameters

PARAMETER	CHARACTERISTIC
Storage capacity (kg)	≥ [design flow (l / min)] / 4
Area (m2)	= 0.25 m2 per l / s flow
Width / length	1: 4 - 1:18
Ascending speed	≥ 4 mm / sec
Ø input	≥ 50 mm
Ø output	≥ 100 mm

Source: (Ministry of Economic Development, 2008)

Figure 7.10 and Figure 7.11 respectively show the operation, profile views and a typical grease trap.

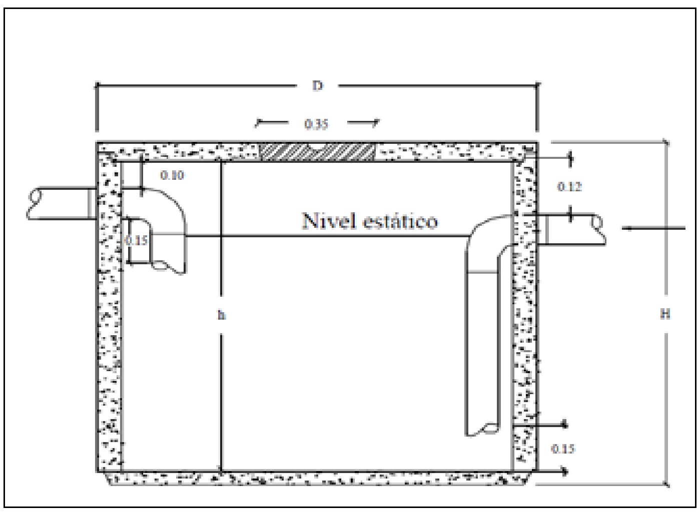


Figure 7.10: Typical grease trap design

Source Fatuvisa, 2013

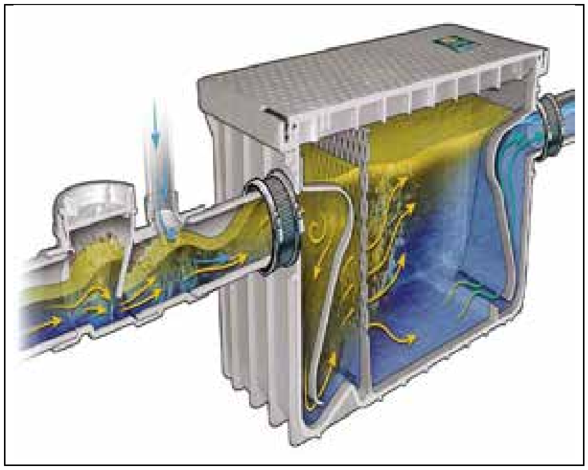


Figure 7.11: Grease trap operation
Source Anveplast, 2013

ü Cesspool

The function of the septic tank is to receive and decontaminate generated wastewater product of tasks such as cooking, washing with detergents containing high grease loading and biological waste. When contaminated water enters the tank the solid waste drops to the bottom in a process called sedimentation where organic matter stabilizes and is transformed into sludge with harmless characteristics.

The tank must be airtight, long lasting and with a stable structure since its contents have very high concentrations of organic matter and pathogens that may be responsible for diseases and infections; it must have a cover allowing inspections and maintenance, and must also have an exhaust pipe as venting mechanism. See Figure 7.11

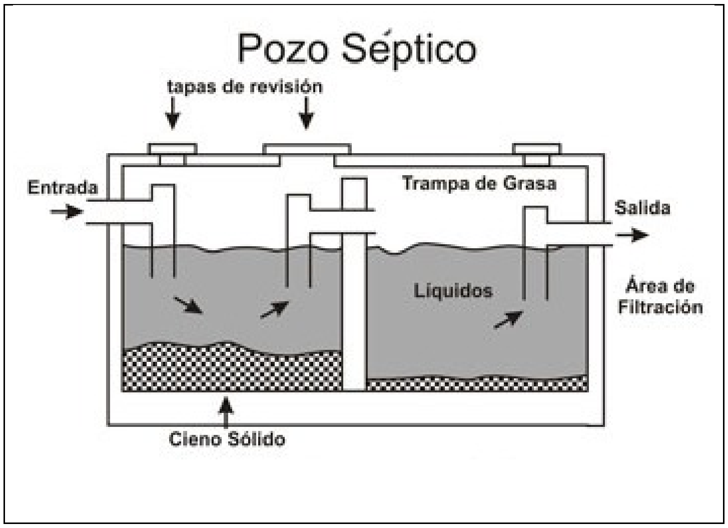


Figure 7.11: Basic treatment operation

Source: (Orientation Guide basic sanitation, 2016)

ü Ascendant Flow Anaerobic Filter - FAFA

It is complementary to the septic system achieving a reduction of 50 to 70% of BOD removal on previously achieved. The FAFA system consists of a closed tank or chamber, made up by a bed of gravel and pebbles where the influent from previous treatments passes upward through the interstices, and the biological film formed on the surface of this granular material works as anaerobic digestion and reduction.

FAFA is an anaerobic bioreactor system having an inert filler material; the bacterial population grows on the filler material degrading the BOD soluble influent resulting in a clarified effluent with reduced organic load. It is an easy to operate system, reducing the likelihood of having a health emergency in the camp.

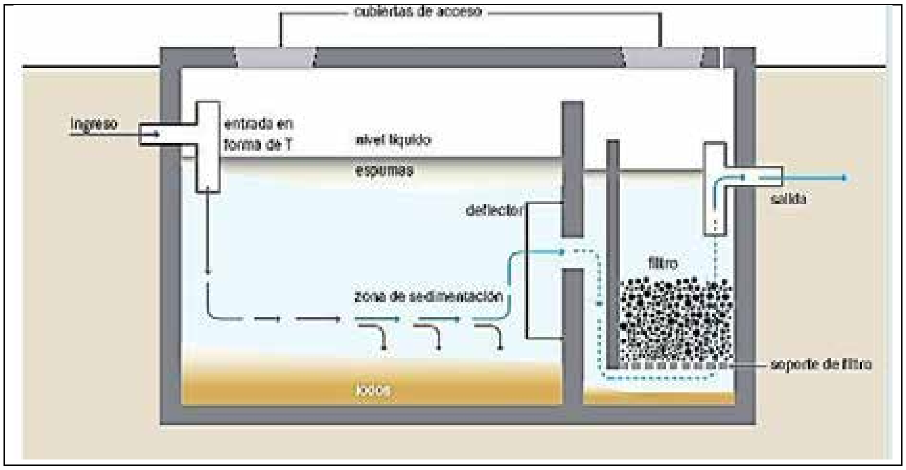


Figure 7.12: FAFA Model
Source: (Alliance for Water, 2016)

With this last phase of treatment a percentage of total removal of 95% of contaminants are expected, which makes this optimal for this use in industrial processes and wetting pathways.

To ensure proposed treatment, its operation and maintenance measures are part of the environmental management plan. See Section 11.1.1.

- Sewage treatment system

The water from all sanitary units is characterized by a high content of organic load and high population of total coliforms and faecal. Its concentration depends on the flow rate and the number of workers whose maximum production peak is estimated to be 250 inhabitants.

Portable sanitary units will be installed in the work fronts and camps that will be hired and will work by vacuum suction. The respective environmental licenses for such activity must be checked and operating capability of the contractor must be considered due to the conditions of project development. Selected company to operate will be informed in the first Environmental Compliance Report ICA.

The contactor providing the service is in charge of installing, operating and servicing the sanitary units. Contractor must have all environmental and operating permits, given that it is responsible for the disposal of waste generated therein. These units are constructed of material highly resistant to weathering and with systems allowing waste removal. See Figure 7.13.

Figure 7.13: Portable Sanitary Unit
Source: (Sale of portable toilets, 2016)

It is recommended to install a portable sanitary unit for every 10-15 workers by gender difference (American National Standards Institute) and no more than 60 meters away from the workplace.

o Industrial wastewater treatment system

Industrial wastewaters are the product of a material process transformation; this wastewater has a high amount of dissolved (sodium and potassium) and high alkalinity suspended (calcium carbonate) solids with high alkalinity characteristics and residual heat, with the characteristics of concrete waste water plants.

ü Grease trap for oily water

As a first step for industrial water treatment there are grease traps for oily water retention; with this trap oil and grease retention from washing and maintenance of equipment is expected.

The contribution of fats and oils basically comes from material spills from the concrete plant. The elements to be removed, which usually occur in this type of wastewater, comprise free and emulsified oils, phenols, nitrogen and sulfur compounds from tank dams and cleaning equipment. Therefore, for effective control thereof, a grease trap that allows retaining these materials must be installed. To clarify that minimization of oils and greases depends on the good behavior of personnel who should be trained.

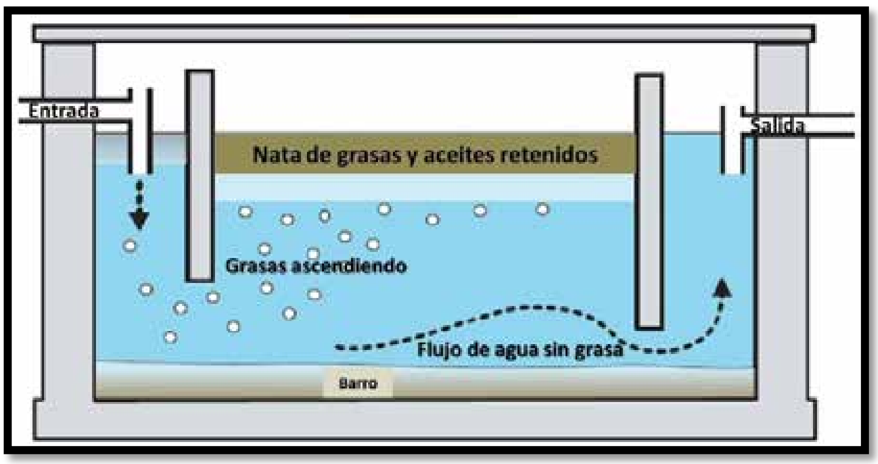


Figure 7.15 Grease trap operation
Source (National University, 2016)

ü Desanders

The purpose of a desander is to separate the sand, coarse particles and sedimentary solids below 1mm and greater than 0.2 mm from the water. The use of the desander prevents deposits in the driveline avoiding overloading in subsequent treatment processes.

The desander unit is a hydraulic structure whose function is to remove particles of a certain size, so a horizontal flow desander was installed to increase the retention time, the longer the retention time the higher the sedimentation of solids.

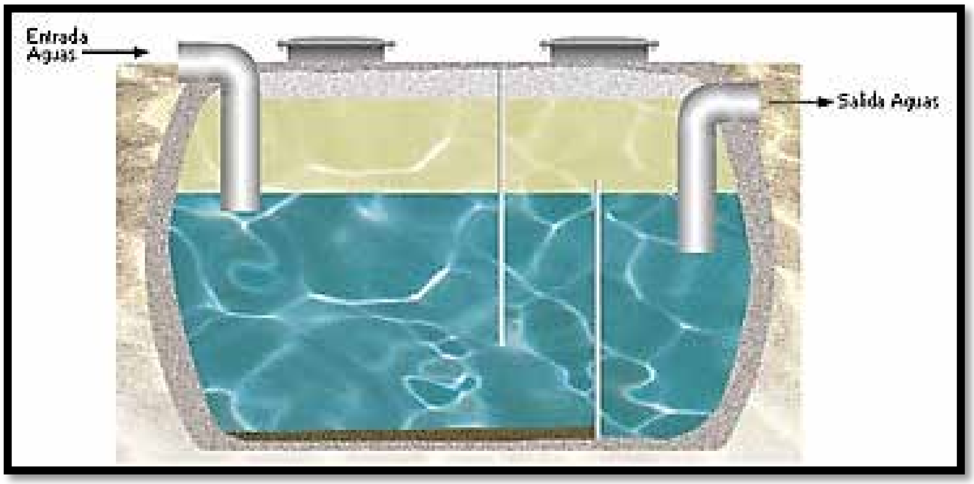


Figure 7.14 Desander tank
Source (Hidritec, 2016)

Water passing through the desander is routed to the sedimentary pit which is the end physical industrial water treatment unit.

ü Sedimentary pit

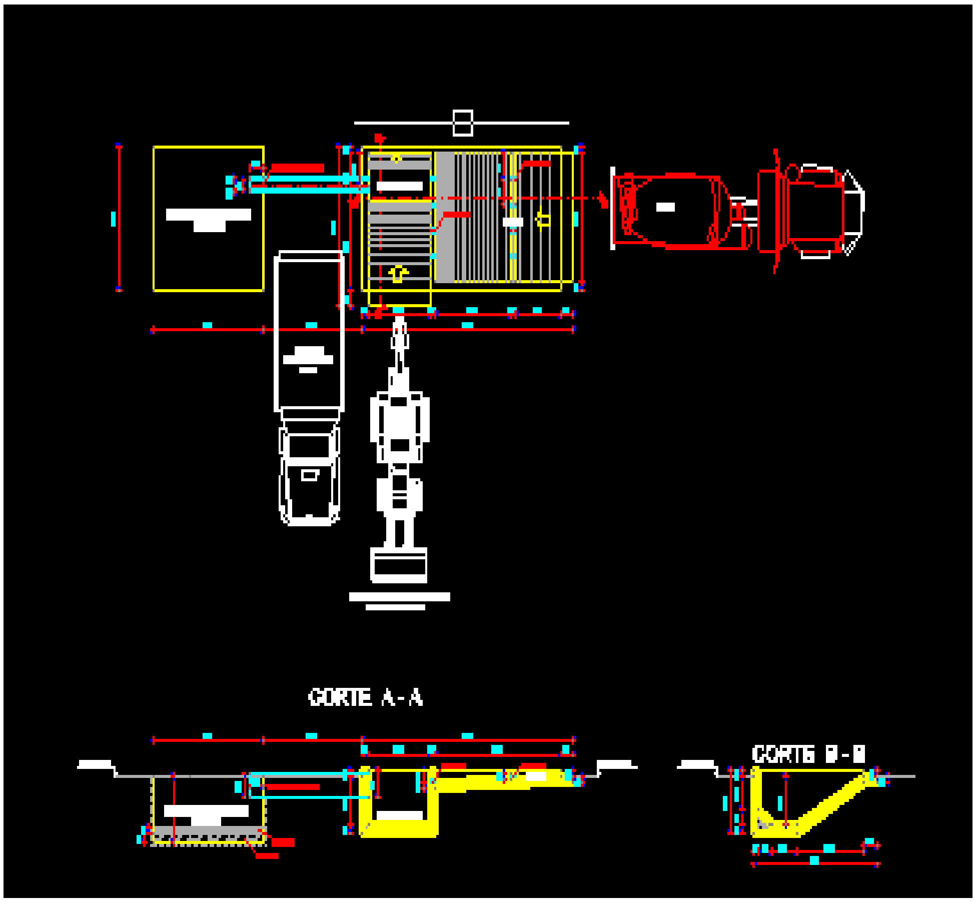
The purpose of using a pit to decant suspended solids in wastewater prior removal of sedimentable solids; the pit must have a geomembrane HDPE waterproofing deck that allows protecting the soil, inhibiting liquid filtration and separating particles below 0.2 mm and greater than 0.5 mm by gravity, reducing 15% BOD and 50% suspended solids.

The pool will be located adjacent to the camp where the water resulting from the treatment and highly clarified with a percentage of 80% removal is considered optimal for recirculation in industrial processes and wetting of roads; in the event of bad odors use odor control products.

Generated sludge product of wastewater treatment will be transported by dump trucks to authorized ZODMEs. It should be noted that as with other proposed systems these will be monitored and management conditions specified in the management plan, see section 11.1.1 of this study.

ü Description of pits for recirculation and reuse in the production plant

CONCRETE PLANT PIT



Water has two uses clearly defined in concrete plants, the first is to produce concretes of different resistance required in the project, and the second is to wash the mixer when exiting the plant after required concrete has been loaded. In the first case there is no waste of water and one hundred percent of the water used in the process is used for mixing the stone aggregates with cement. In the second case, however, the water required for washing the mixer must pass through the sedimentation pit to remove all suspended solids deposited in these structures to then take them to the deposit of unusable materials for the works or ZODME,

The process begins with the dispatch of Concrete required for execution of works in mixer trucks; vehicles once downloaded are moved to the equipment washing area, this area is located in the industrial area, with hard floor, minimum slope, perimeter gutters and equipped with grids that carry water only to wash pit. The vehicle is parked so that the mixing "pear" will be inside the area intended for washing and is washed with pressure hoses, which are part of the equipment. During the process, to guarantee removal of all adhered materials preventing corrosion of the equipment parts. The wash water passes to a settling pit where the solids are separated by gravity by differences in size, here sedimentable solids are deposited in the bottom of the pit for subsequent removal during maintenance days, and decanted water passes through an open concrete channel to a storage tank for subsequent reuse during project execution in activities such as wetting or artwork construction activities.

Generated sludge is removed with backhoe type equipment and arranged in the ZODME.

7.3.1. Discharges into water bodies

Surface water discharges whether industrial and household type is pretreatment to ensure concentrations of contaminants are within the ranges established by environmental control entities. For Tangua and Cebadal camps the discharge points are distributed to the following water sources: Magdalena Stream as shown in Table 7.18

Table 7.18 Surface water discharges Line Type

Camp	Water source	Magna plane coordinates origin SIRGAS West			
		START		END	
		EAST	NORTH	EAST	NORTH
Tangua	Magdalena Stream	961066.8191	610,387.184	961,089.663	610,426.273
Cebadal	Magdalena Stream	966934.5958	616,232.133	966,941.983	616,259.754

Annex 7.3.1 shows show formats to allow discharges into surface waters.

- <u>Low flows</u>

The Bobo River has the Casanare Automatic hydrometric station operated by the IDEAM with a record of 24 years since 1989 to 2012, which allowed direct characterization of the hydrological regime. Figure 7.15 shows the multi-annual temporal distribution of average, maximum and minimum flows. These figures show that flow regime is monomodal type.

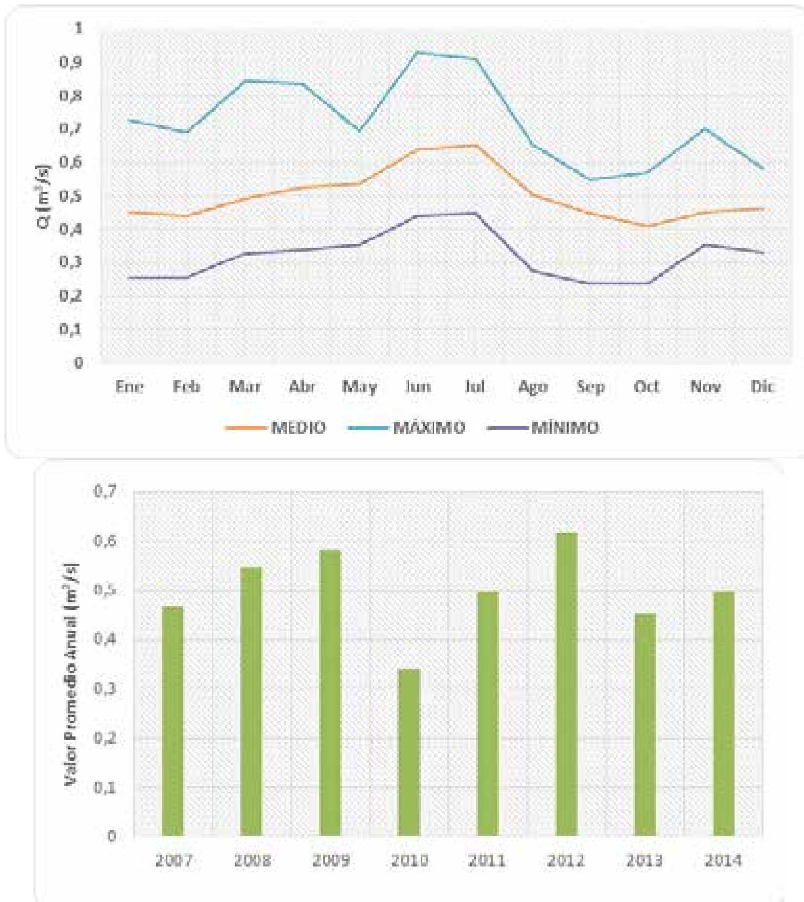


Figure 7.15 Minimum flow distribution - Casanare Automatic Station(Bobo River)
Source: **(Gemini Environmental Consultants, 2016)**

The minimum flow rate is 0.23 m3 / s. The low flow period occurs during the months of September to March, October being the month in which the lowest flows are recorded. Finally,Figure 7.15 presents a graphic summary of the series boxplots using the minimum flow values of the multiyear average monthly records of the Automatic Casanare station (Bobo River), concluding that:

- <u>Water quality discharge points</u>

Monitored points for water quality are presented in Table 7.19 where the source name, coordinates, city and monitored point (upstream and downstream) are specified.

Table 7.19 Line Type Points monitoring surface water bodies, Pedregal - Catambuco section

MUNICIPALITY	SOURCE NAME	MAGNA SIRGAS COORDINATE ORIGIN WEST			
		START		END	
		EAST	NORTH	EAST	NORTH
Tangua	Magdalena	961066.8191	610,387.184	961,089.663	610,426.273
Cebadal	Magdalena	966934.5958	616,232.133	966,941.983	616,259.754

Source: (Gemini Environmental Consultants, 2016)

- *Physical-chemical and bacteriological characterization*

Water quality was determined measuring physicochemical and bacteriological parameters of the Bobo river sources and the Magdalena stream. This procedure is followed to determine whether the values of these parameters are within the range set out in the legislation. Physicochemical analysis was performed taking into account the PO-PSM-45 water sampling and techniques of the Standard Methods 1060 edition 22 guidelines.

Follows the results of measured parameters for characterization of water sources intervened directly by the project, see Table 7.20

Table 7.20 Water quality analysis results discharge projected points

Parameters	Bobo River	La Magdalena Stream
pH (units)	7.21	7.04
Temperature ° C	19	10.7
Dissolved Oxygen (mg / L)	4,32	7.9
Conductivity (uS / cm)	451	116.7
BOD mg / L	13.1	5
COD mg / L	24.8	20
Total Suspended Solids mg / L	<20	<10
Fats and Oils mg / L	<9.0	<10
Alkalinity mg / L	20.7	42.82
Total Hardness mg / L	68	52.16
Total Coliforms NMP / mL	11000	3500
Thermotolerant coliforms NPM / ml	4900	330

E. coli	**Presence**	**Presence**
Turbidity NTU	2,22	2.5
UPC True Color	<5.00	38
Total nitrogen mg / L	<3.00	0,68
Total phosphorus mg / L	<0.062	<0.06
Total Phenols mg / L	<0,002	-
Zinc mg / L	<0.014	<0.05
Barium Total mg / L	<0.141	<0.50
Total Cadmium mg / L	<0.0048	<0.003
Total Copper mg / L	<0.0088	<0.10
Total chromium mg / L	<0.0046	-
Mercury Total mg / L	0.0007	<1.00
Nickel Total mg / L	<0.0045	<0.02
Total silver mg / L	<0.007	<0.04
Lead Total mg / L	<0.0054	<0.01
Total Selenium mg / L	<0.0055	<0.01
Arsenic mg / L	<0.010	<10

Source: (ASOAMSAS, 2016)

For clarity with respect to water quality monitors that were developed in the Rumichaca – Pasto project, Pedregal - Catambuco Section, refer to Chapter 5.1 of this study and see Annex 5.1.6

7.3.2 Ground discharges

One option for discharging waste water from industrial activities of the camps is through two infiltration fields in the soil located one in each camp area (Tangua and Cebadal). Figure 7.16 shows the location of proposed sites for wastewater discharges.

The respective discharge permit was requested for each infiltration field using the national discharges sole formats (see Annex 7.3.2)

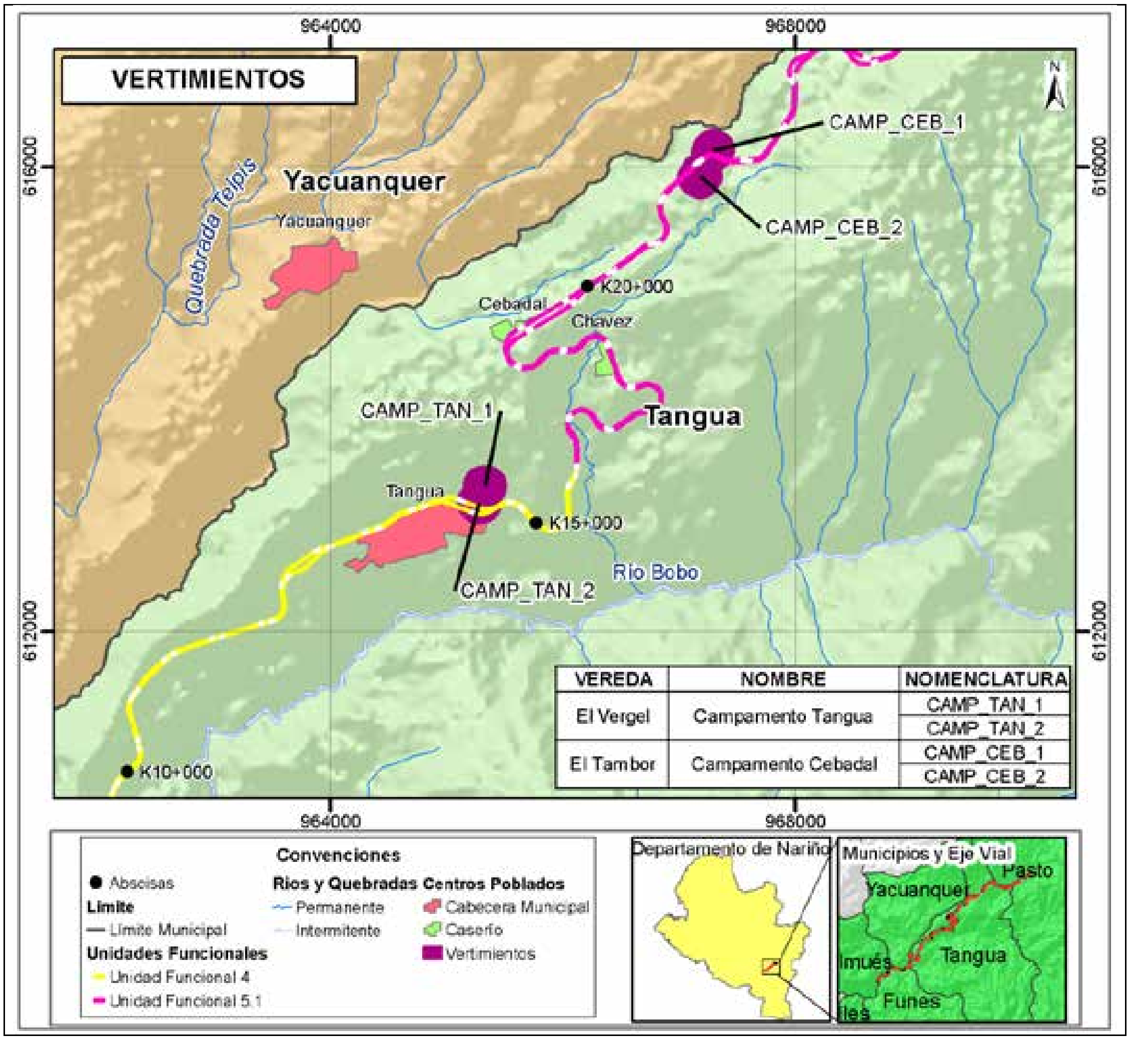


Figure 7.16: Location of discharges
Source: (Gemini Consultants SAS)

- <u>Disposal areas of infiltration fields</u>

To determine each possible infiltration field area, ground units and topography were considered resulting in the following areas (See Table 7.21). (See Annex GDB / cartography / pdf / EIADCRP_IP_033)

Table 7.21 Areas of infiltration fields

UF	CAMP	PLANAR COORDINATES (Colombia magna west)	IMAGE
4	Tangua	E: 965336.87 N: 613267.72 E: 965355.43 N: 613256.06 E: 965339.24 N: 613235.35 E: 965306.41 N: 613263.71 E: 965336.87 N: 613267.72 E: 965292.35 N: 613120.07 E: 965302.65 N: 613098.18 E: 965269.97 N: 613093.1 E: 965258.41 N: 613115.88 E: 965292.35 N: 613120.07	

UF	CAMP	PLANAR COORDINATES (Colombia magna west)	IMAGE
5	Cebadal	E: 967208.99 N: 615931.12 E: 967185.7 N: 615893.47 E: 967153.08 N: 615915.05 E: 967177.44 N: 615952.88 E: 967208.99 N: 615931.12 E: 967316.42 N: 616154.25 E: 967293.84 N: 616125.17 E: 967271.92 N: 616135.05 E: 967295.96 N: 616164.12 E: 967316.42 N: 616154.25	

Source: (Gemini SAS Consultants, 2016)

- <u>Percolation tests</u>

To determine the ability of soil infiltration a hole 40 x 40 cm and 1 meter deep was opened; integrated samples at different depths (0 – 30; 30 - 70 cm and 70 - 1 meter) were taken. Soil samples collected were taken to the laboratory where the rate of infiltration is determined. Photography 7.1 shows soil survey execution in proposed camp areas.

Given the preliminary analyzes, infiltration capacities average 2.5 cm / hour are expected; 0.5cm / hr to 7 cm / hr range; with good in average capacities observed to process the discharge permit.

Photography 7.1 Definition sampling point
Coordinates magna sigma origin west X 967,252.79 - 616,114.11 Y
Source (Gemini SAS Consultants, 2016)

- Soil sampling

To select the sampling site, a prior area visit to the surface to be sampled was made, in order to know the type of soil, topography, visual assessment, climate, surface soil color, vegetation, soil texture, sample area, amount and size of the grid.

Table 7.22 shows the location of each sample point and the camp to which it belongs. Soil studies are presented in Annex 7.3.2.a

Table 7.22 Location of the sampled points

Point	Camp	Magna SIRGAS Planar Coordinates Origin West	
		EAST	NORTH
1	Tangua-1	965,210.42	613,114.93
2	Tangua-2	965,340.36	613,251.03
3	El Tambor-1	967,252.78	616,114.11
4	El Tambor -2	967,232.37	615,987.56

Source: (Gemini SAS Consultants, 2016)

Photograph 7.2 and Photograph 7.3 show the photographic record of the soil sampling in the area of the Tangua camp.

Photograph 7.2: Opening hole soil study
Coordinates magna sigma origin west X 965,026.64 - 611,765.93 Y
Source (Gemini SAS Consultants, 2016)

Photograph 7.3 Soil sample collection
Coordinates magna sigma origin west X 965,026.64 - 611,765.93 Y
Source (Gemini SAS Consultants, 2016)

- *General sample description*

The table describes sample conditions for the four points of interest

Table 7.23 Identification test pit points

Point	Depth (M)	Description
Tangua-1	0.00 to 1.50	Silty sand brown
Tangua-2	0.00 to 1.50	Brown sandy loam
El Tambor-1	0.00 to 1.50	Brown sandy loam
El Tambor-2	0.00 to 1.50	Brown sandy loam

Source: (ASOAM, 2016)

- *Field humidity*

Humidity is responsible for allowing biological processes, as a result, are presence of water is essential in soils not abundant but sufficiently because hummidity in soils can generate microbial activity resulting in plant fertilizers. The results of sampled points are shown in the following Table 7.24

Table 7.24 Depths and humidity

Point	Depth (M)	Humidity (%)
Tangua-1	0.00 to 1.50	25.9
Tangua-2	0.00 to 1.50	24.8
El Tambor-1	0.00 to 1.50	26.5
El Tambor-2	0.00 to 1.50	27.2

Source: (ASOAM, 2016)

Data presented in analyzed samples have an average of 26.12% of natural humidity, being a normal value for soils with clay loam characteristics. The maximum humidity value was obtained in El Tambor-2 and the minimum in the point located in Tangua-2.

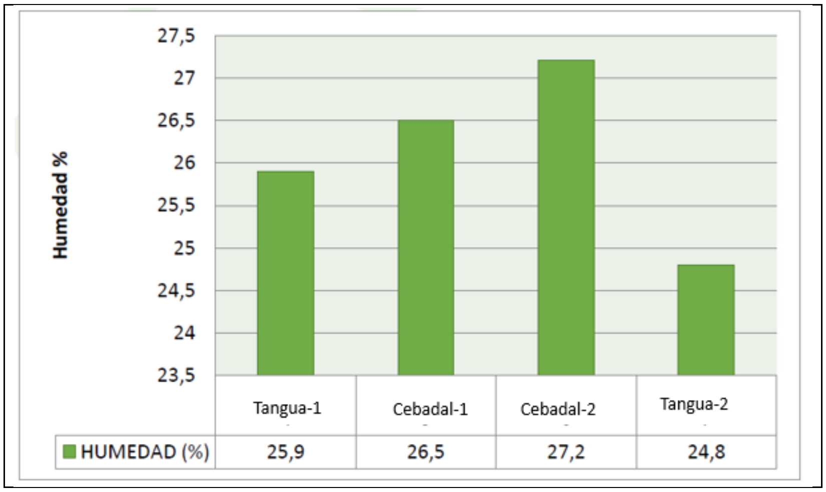


Figure 7.17 Percentage of activities

Source (ASOAM, 2016)

- *Granulometry*

Granulometry is the determination of the proportion of sizes in which different sizes of particle are present in the soil.

Table 7.25 Granulometry point Tangua-1

P 1 =	303.5		P 2 =	96.9	
T amiz		R eten	%	% R et	%
P ulg.	mm		R eten	A cum	Pass
3	75, 0				
2 ½	63, 0	0.0	0.0	0.0	100.0
2	50, 0	0.0	0.0	0.0	100.0
1 ½	38, 1	0.0	0.0	0.0	100.0
1	25, 0	0.0	0.0	0.0	100.0
3. 4	19, 0	0.0	0.0	0.0	100.0
1/2	12, 5	0.0	0.0	0.0	100.0
3/8	9, 5	2.1	0.7	0.7	99.3
No . 4	4, 75	0.9	0.3	1.0	99.0
No. 10	200	5.5	1.8	2.8	97.2
No. 40	0, 43	33.4	11.0	13.8	86.2
No. 10 0	0, 15	32.1	10.6	24.4	75.6
No. 0.200	0, 075	22.9	7.5	31.9	68.1

BACKGROUND	206.6	68.1	100.0	0.0

Source: (ASOAM, 2016)

Table 7.26 Granulometry point Tangua-2

P 1 =	241.1		P 2 =	52.7	
T amiz		R eten	%	% R et	%
P ulg.	mm		R eten	A cum	Pass
3	75, 0				
2 ½	63, 0	0.0	0.0	0.0	100.0
2	50, 0	0.0	0.0	0.0	100.0
1 ½	38, 1	0.0	0.0	0.0	100.0
1	25, 0	0.0	0.0	0.0	100.0
3. 4	19, 0	0.0	0.0	0.0	100.0
1/2	12, 5	0.0	0.0	0.0	100.0
3/8	9, 5	0.0	0.0	0.0	100.0
No . 4	4, 75	0.3	0.1	0.1	99.9
No. 10	200	1.6	0.7	0.8	99.2
No. 40	0, 43	12.4	5.1	5.9	94.1
No . 10 0	0, 15	21.3	8.8	14.8	85.2
No. 0.200	0, 075	17.1	7.1	21.9	78.1
BACKGROUND		188.4	78.1	100.0	0.0

Source: (ASOAM, 2016)

Table 7.27 Granulometry point Cebadal - 1

P 1 =	241.1		P 2 =	52.7	
T amiz		R eten	%	% R et	%
P ulg.	mm		R eten	A cum	Pass
3	75, 0				
2 ½	63, 0	0.0	0.0	0.0	100.0
2	50, 0	0.0	0.0	0.0	100.0
1 ½	38, 1	0.0	0.0	0.0	100.0
1	25, 0	0.0	0.0	0.0	100.0
3. 4	19, 0	0.0	0.0	0.0	100.0
1/2	12, 5	0.0	0.0	0.0	100.0
3/8	9, 5	0.0	0.0	0.0	100.0
No . 4	4, 75	0.3	0.1	0.1	99.9
No. 10	200	1.6	0.7	0.8	99.2
No. 40	0, 43	12.4	5.1	5.9	94.1
No . 10 0	0, 15	21.3	8.8	14.8	85.2

No. 0.200	**0, 075**	17.1	7.1	21.9	78.1
BACKGROUND		188.4	78.1	100.0	0.0

Source: (ASOAM, 2016)

Table 7.28 Granulometry point Cebadal - 2

P 1 =	348.0		**P 2 =**	210.1	
T amiz		**R eten**	**%**	**% R et**	**%**
P ulg.	**mm**		**R eten**	**A cum**	**Pass**
3	**75, 0**				
2 ½	**63, 0**	0.0	0.0	0.0	100.0
2	**50, 0**	0.0	0.0	0.0	100.0
1 ½	**38, 1**	0.0	0.0	0.0	100.0
1	**25, 0**	0.0	0.0	0.0	100.0
3. 4	**19, 0**	0.0	0.0	0.0	100.0
1/2	**12, 5**	0.0	0.0	0.0	100.0
3/8	**9, 5**	0.0	0.0	0.0	100.0
No . 4	**4, 75**	0.3	0.1	0.1	99.9
No. 10	**200**	4.8	1.4	1.5	98.5
No. 40	**0, 43**	81.4	23.4	24.9	75.1
No. 10 0	**0, 15**	94.6	27.2	52.0	48.0
No .200	**0, 075**	29.0	8.3	60.4	39.6
BACKGROUND		137.9	39.6	100.0	0.0

Source: (ASOAM, 2016)

- Granulometry curves

After sieving, the amount that passes through each mesh is determined; this is obtained by plotting on a semilogarithmic scale, the logarithm of the opening of sieve in mm in the abscissa, and the percentage passing through each mesh, in ordinates.

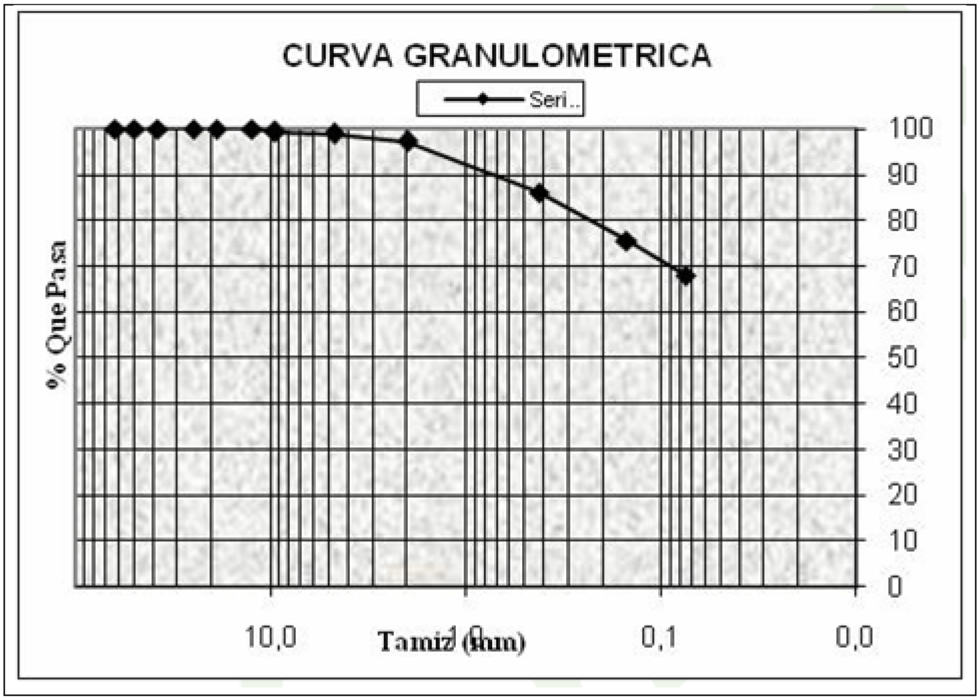


Figure 7.20 Granulometric curve Tangua-1 point

Source (ASOAM, 2016)

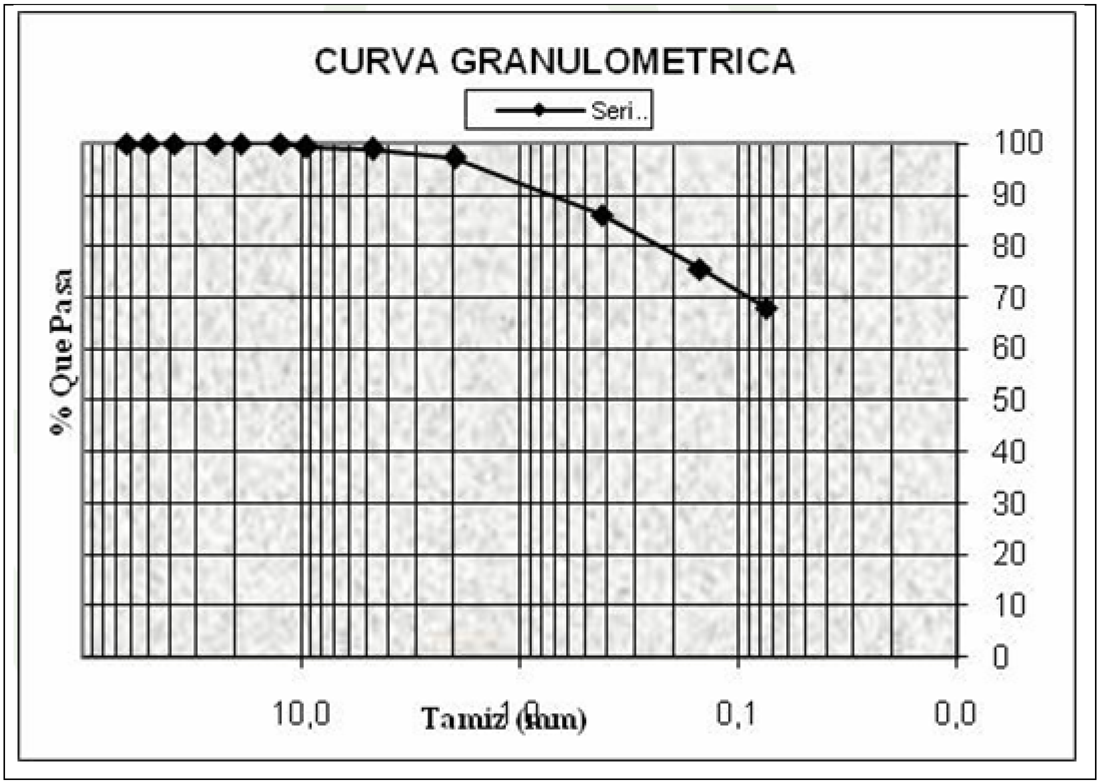


Figure 7.18 Granulometric curve Tangua-2 point

Source (ASOAM, 2016)

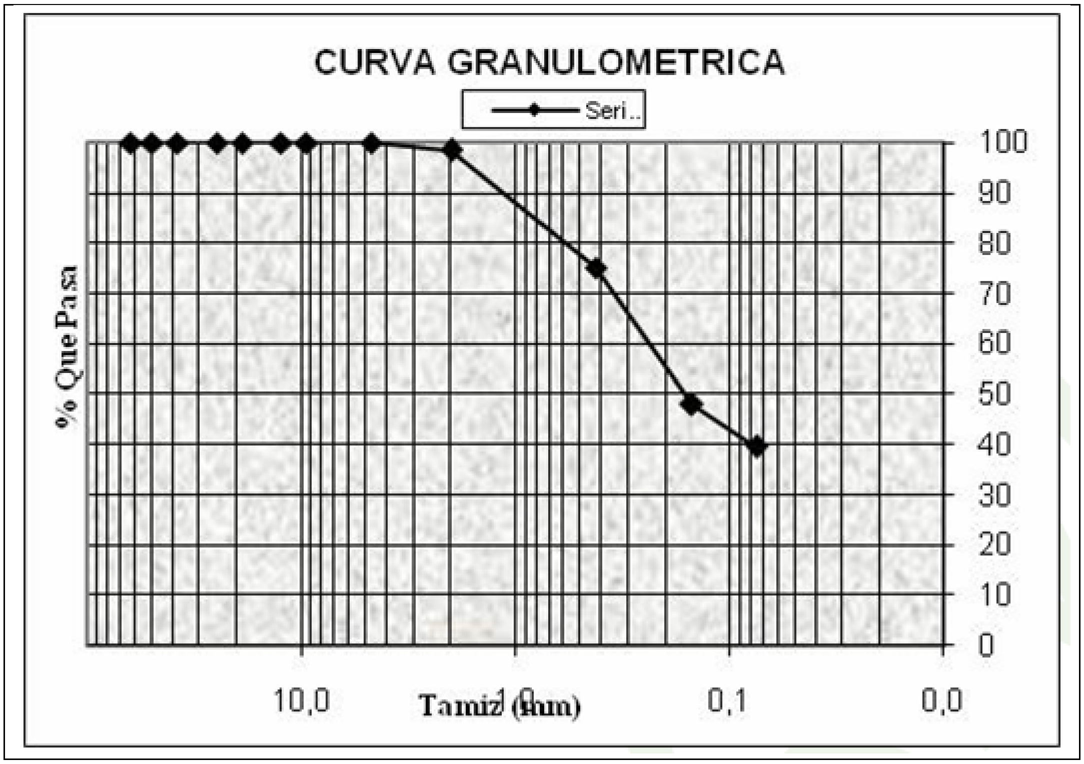


Figure 7.19 Granulometric curve Cebadal-1 point

Source (ASOAM, 2016)

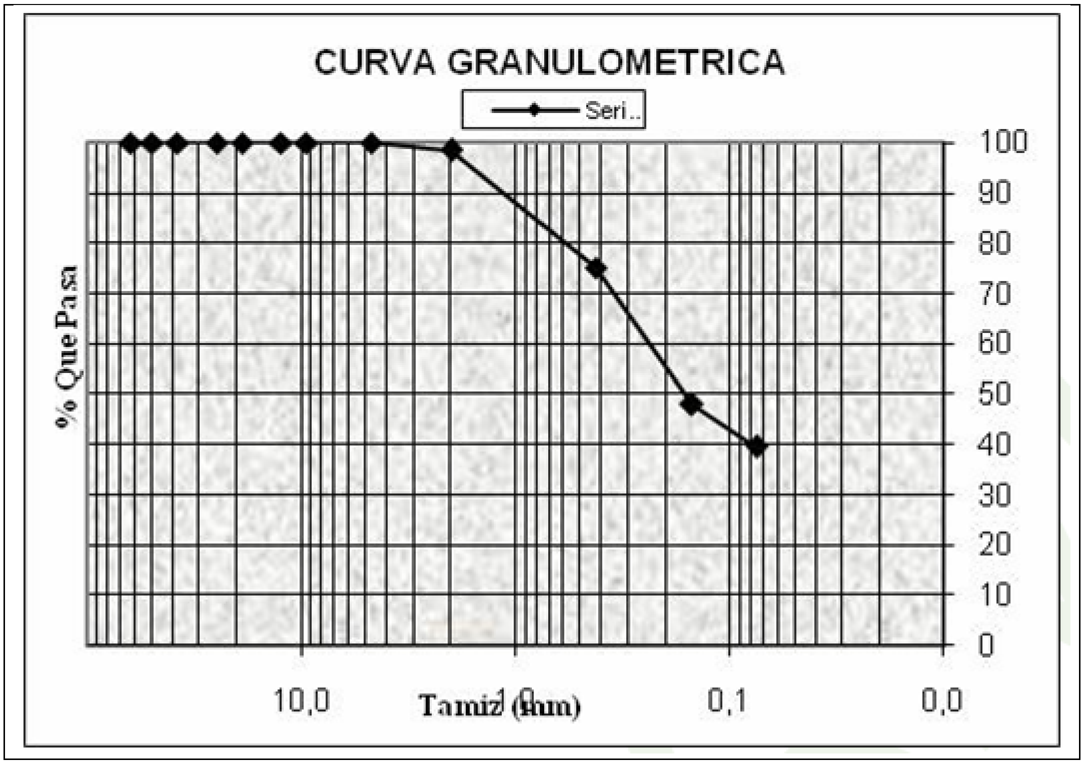


Figura 7.20 Granulometric curve Cebadal-1 point

Source (ASOAM, 2016)

- *Permeability or hydraulic conductivity*

Permeability is a characteristic associated with porosity, defined as the ease with which soil allows penetration by fluids.

Absolute porosity values are sufficient to estimate soil permeability but some other factors like pore system geometry. Thus, a leafy structure leaves a high porosity but considerably hinders the water flow, as happens when there is a good interconnection between macroporosity components.

Permeability or hydraulic conductivity is a property that depends on fluid characteristics and permeability of the porous medium through which it circulates and of the force of gravity (g).

So some fluid properties such as specific weight, dynamic viscosity and temperature affect the K value, as well as the average size through the open spaces (d), stratification, packing, grain distribution, available sizes considered through the form factor (C) and porosity.

For example, with regard to variations in the physical properties of the water, salt water flows faster than sweet water, being more dense and hot water flows faster than the cold, being less viscous.

Table 7.29 Permeability results

Point	Depth (M)	D10 (MM)	PERMEABILITY (M / S)
Tangua-1	0.00 to 1.50	0,021	5.11×10^{-6}
Tangua-2	0.00 to 1.50	0,015	2.61×10^{-6}
El Tambor-1	0.00 to 1.50	0,001	1,16 x10-8
El Tambor -2	0.00 to 1.50	0,023	6.14 x 10-6

Source: (ASOAM, 2016)

The average permeability or hydraulic conductivity values are 2.33 x 10-6 m / sec equivalent to 0.201 m / day respectively, these values show low permeability soils with very high fines content.

- *Analysis of metals in soils*

Metals considered in the soil characterization analysis in the area of influence, as part of the Environmental Impact Study, refer to arsenic, barium, calcium, cadmium, cobalt, chromium, total, magnesium, mercury, potassium, selenium and sodium, which are in varying proportions but in low concentrations that may be attributed to the characteristics of the soil under study. Values recorded for each metal in the four (4) evaluated points are given below.

Table 7.30 Total metals results

METALS	UND	Tangua-1	Tangua-2	Drum-1	Drum-1
Total arsenic	mg / kg	2.5	2.8	3.5	1.8
Total barium	mg / kg	230.3	235.5	328.7	236.6

METALS	UND	Tangua-1	Tangua-2	Drum-1	Drum-1
Total calcium	mg / kg	3279.9	1740.9	3287.3	2764.6
Cadmium	mg / kg	<1.8	<1.8	<1.8	<1.8
Total cobalt	mg / kg	7.4	5.1	4	2.3
Chrome	mg / kg	<1.8	<1.8	<1.8	<1.8
Total magnesium	mg / kg	586.9	1294	1195.4	1625.9
Total mercury	mg / kg	<0.1	<0.1	<0.1	<0.1
Total potassium	mg / kg	1479.6	2145.9	1778.1	1998.1
Selenium	mg / kg	<1.8	<1.8	<1.8	<1.8
Total sodium	mg / kg	345.2	233.2	602.7	279.5

Source: (ASOAM, 2016)

Figure 7.21 Total Arsenic Variation shows arsenic variation contained in soil samples taken at four (4) points, presenting a greater concentration at Tangua-1 sampling point with a value of 5 mg / kg, this establishes the reducing soil conditions and is strongly bound to soil minerals, particularly the colloidal metal oxides and hydroxides, by ionic bonds.

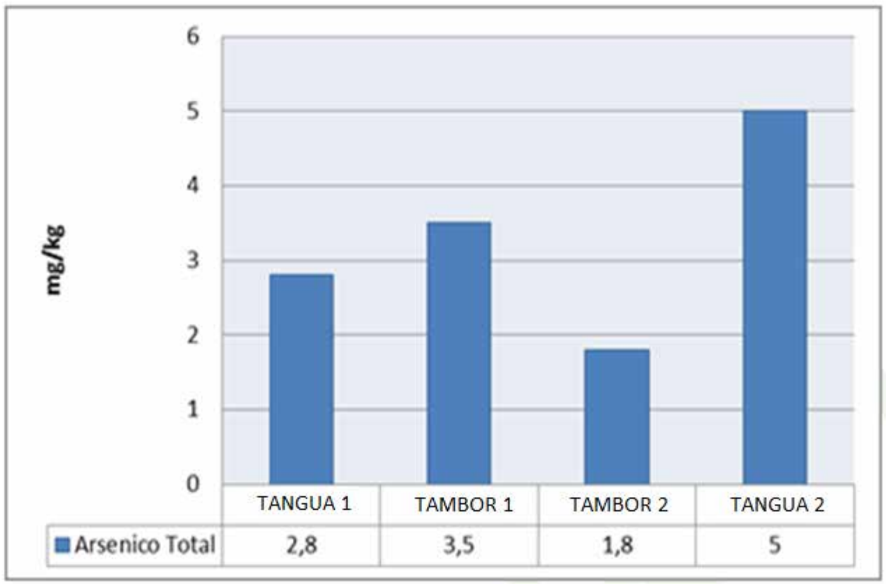


Figure 7.21 Total Arsenic Variation

Source (ASOAM, 2016)

Figure 7.22 shows barium concentration variations recorded in the four (4) sampling points. The highest value was obtained in Tangua 1 point with 328.7 mg / kg and a lower value at the sampling point with a value of 203.3 mg / kg.

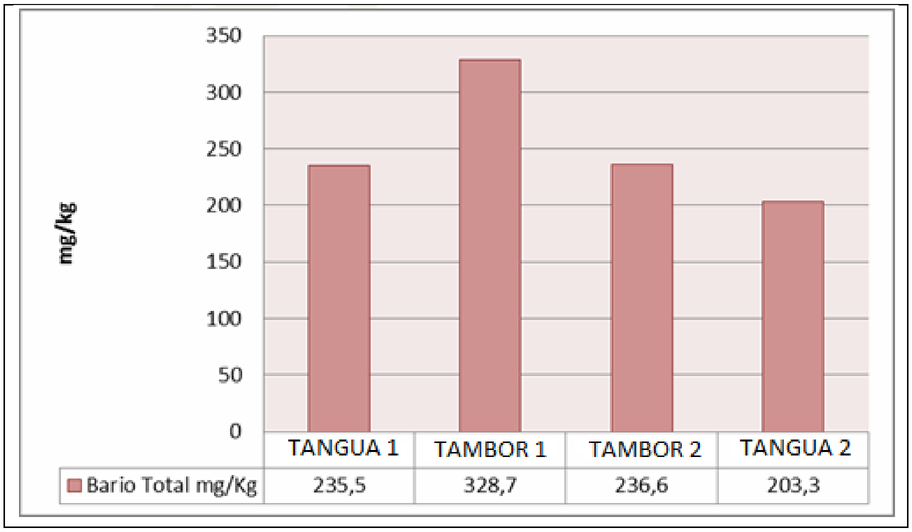


Figure 7.22 Total Barium Variation

Source (ASOAM, 2016)

Total calcium at sampling points, Figure 7.23 show a positive effect as clay flocculants and widely contributes to the organization of the soil structure and stability thereof with a high value at sampling point Test pit No. 7 with 3880.8 mg / kg and a minimum value of 1740 mg / kg for Tangua -1 point.

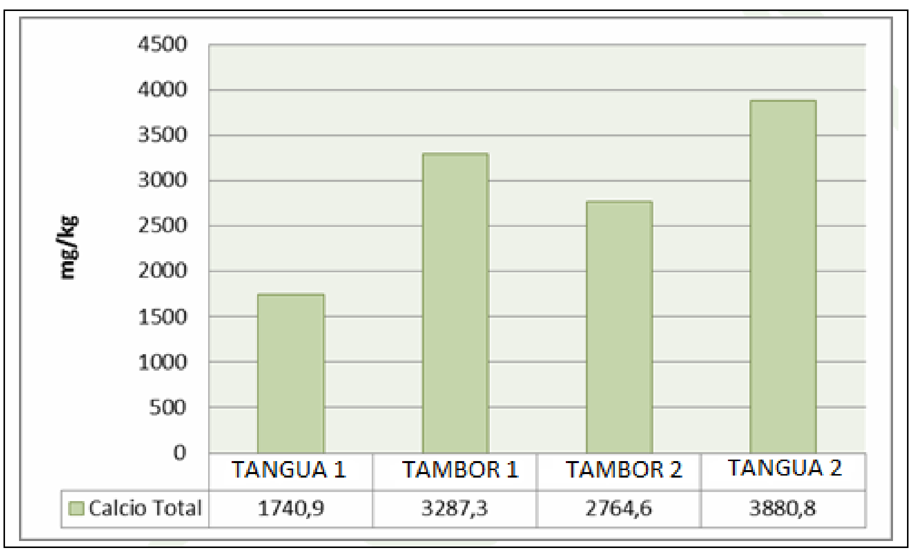


Figure 7.23 **Total Calcium Variation.**

Source (ASOAM, 2016)

Magnesium variation in the sampling points show high concentrations in Tangua 2 point and low values in El Tambor 1 point, showing heavy and light soils respectively at these two points. However not cause magnesium induced deficiency.

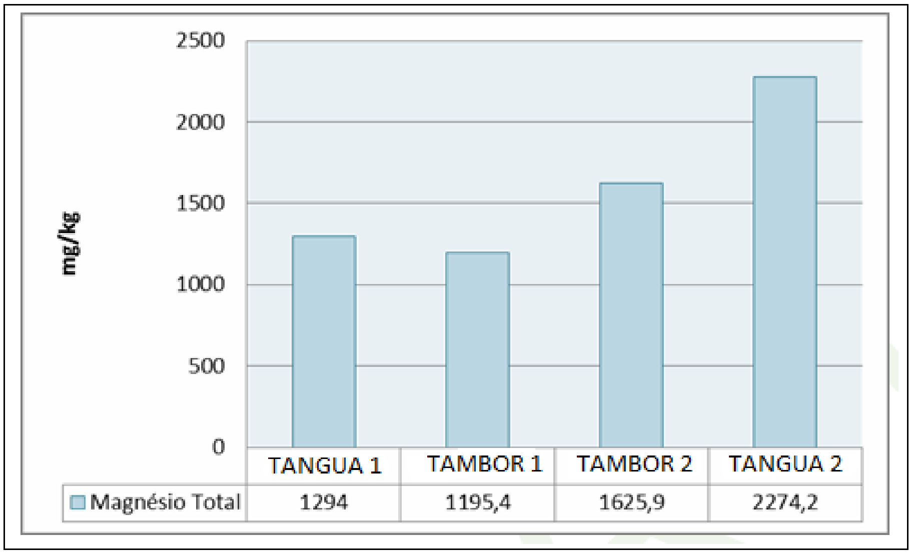


Figure 7.24 Total Magnesium Variation.
Source (ASOAM, 2016)

Figure 7.25 shows cobalt variation obtained from the sampling results, observing a reduction in Tangua 1 point respectively to El Tambor 2 point. This variation point is linked mainly to oxides of manganese and iron, so that only a small part of the cobalt remains free and, therefore, mobile, showing sampling sites with low soil acidification.

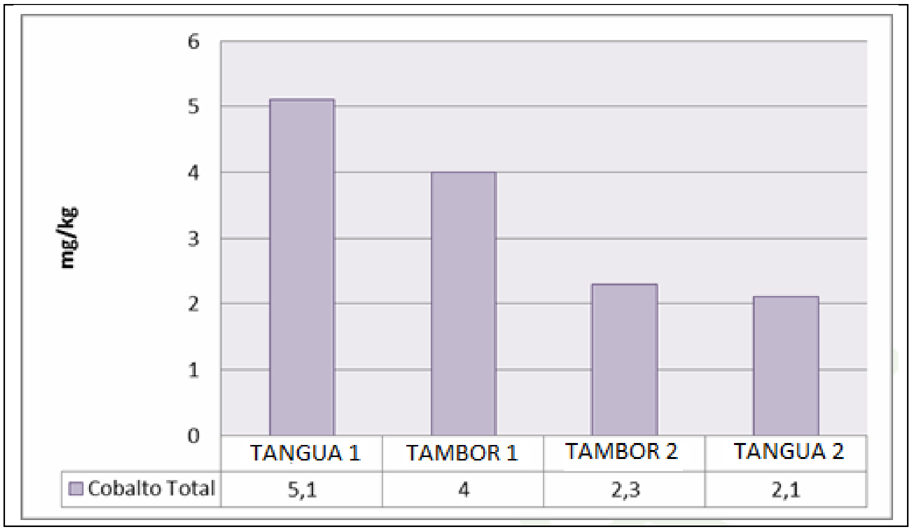


Figure 7.25 Total Cobalt Variation

Source (ASOAM, 2016)

Figure 7.26 shows potassium variations with Tangua 2 point a lower value with 587.4 mg / kg, this is possibly due to washing and erosion. It can also be fixed by clay minerals, slowly becoming available.

This loss arising from washing depends on the weather and the nature of the soil: soils with plenty of change have lower losses than sandy soils. In rainy climates and soils with little changing capacity, potassium losses can be large; however, in general, potassium concentration is constant for a depth of 90cm.

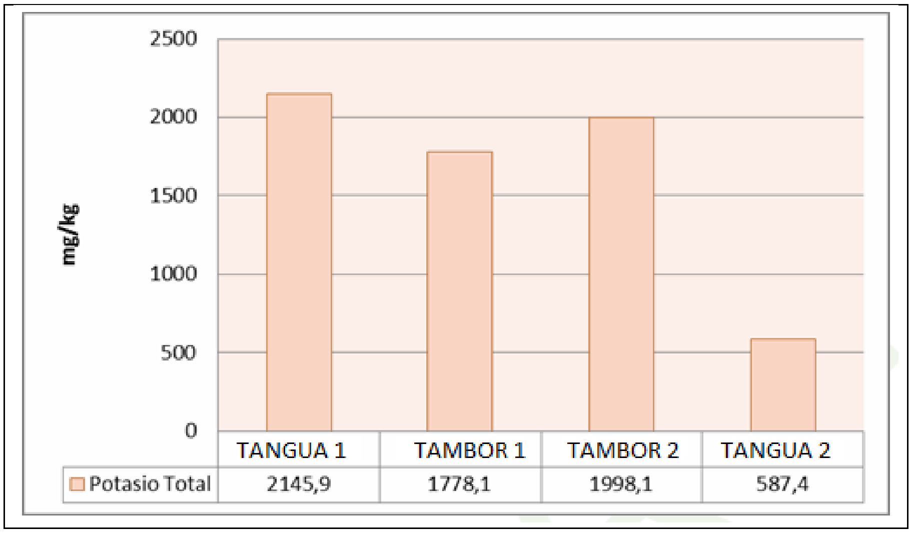


Figure 7.26 **Total Potassium variation**.

Source (ASOAM, 2016)

At high concentrations sodium directly affects soil properties related to retention and availability of water to existing vegetation. Soil samples taken in Tangua 2 contain the highest concentration values with 1055.3 mg / kg and Tangua 1 the higher concentrations with a range of 233.2 mg / kg.

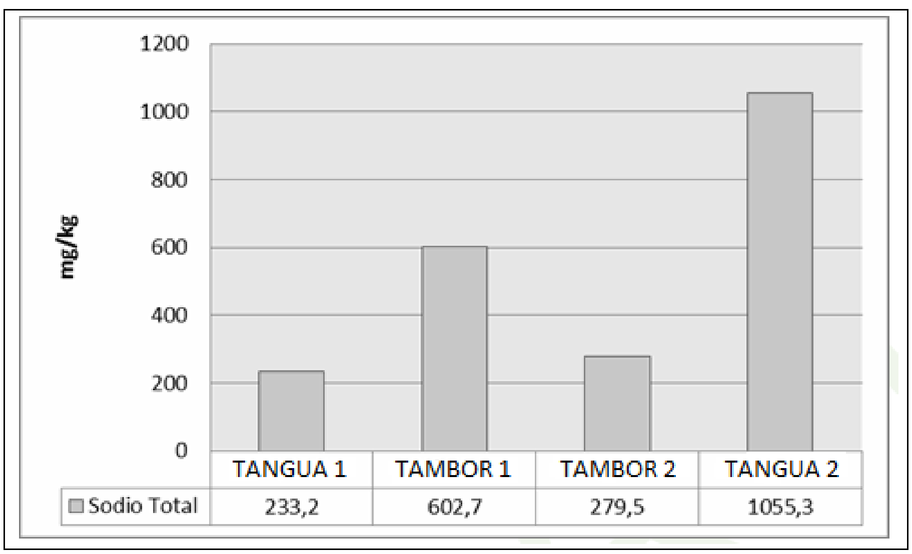


Figure 7.27 Sodium Total variation.

Source (ASOAM, 2016)

- *Cation exchange capacity*

In the cation exchange capacity, the load of soil particles should be balanced by cations in the adsorbed surface phase. The ion can be exchanged with another to balance the load in the colloidal phase and the reaction is rapid, primarily stoichiometry and of electrostatic nature.

In general the higher the cationic exchange capacity the greater the ability of the soil to fix metals. The adsorption power of various heavy metals depends on their valence and hydrated ionic radius, the higher the value and smaller valence, is less strongly they are retained.

Table 7.31 Cation Exchange Capacity Results

Analysis date	Parameter	Method	Analytical technique	Method quantification limit	UND	Tangua 1	Tambor 1	Tambor 2	Tangua 2
28/09 / 2016-10/14/2016	CIC	NTC 5268	Ammonium acetate extraction 1N Ph 7.0 Titrimetry	0.1	cmol (+) / kg ss	27.6	28.7	12.1	11.1

The Cation Exchange Capacity records values of 11.1 cmol (+) / kg ss in Tangua 2 point and 28.7 cmol (+) / kg ss in El Tambor point 2 according to the aforsaid one can say that analyzed samples show good retention of ions and macronutrients necessary for development of vegetation.

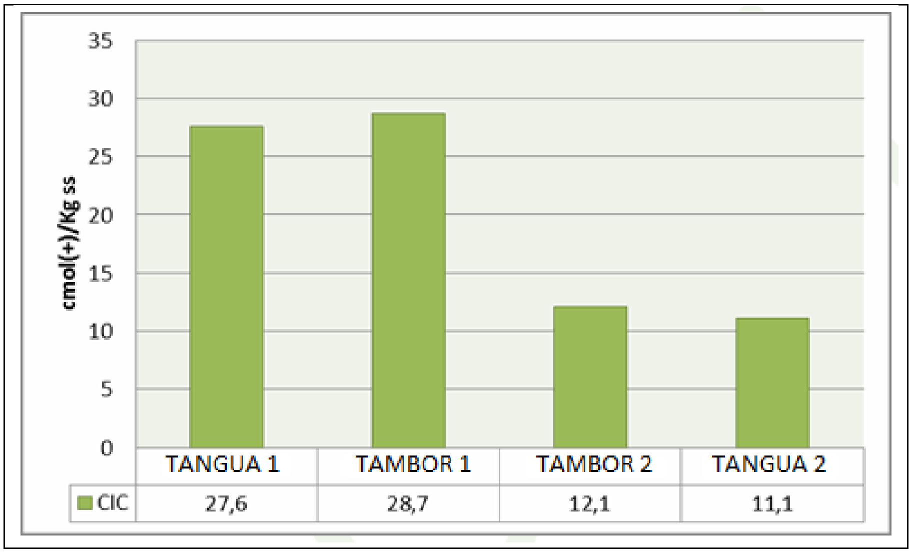


Figure 7.28 Cation Exchange Capacity Variation

Source (ASOAM, 2016)

- *TPH*

The determination of total petroleum hydrocarbons (TPH) is used to evaluate oil-contaminated sites. The use of maximum TPH concentration to establish cleaning levels of soil samples contaminated with hydrocarbons is a common approach implemented by regulatory authorities.

Gas chromatography (GC) is a technique to observe the profile of sample contamination, and can differentiate those compounds that come from the organic matter of the soil or metabolic products generated during treatment. For methods based on GC, the HTPs are defined as any compound removable by a solvent or purge gas, and detected by gas chromatography / flame ionization detector (GC / FID) with a specific range of carbons. The main advantage of this method is that it provides information about the type of oil in the sample, as well as its quantification, although identifying the type of product is not always easy (Weisman, 1998).

Table 7.32 TPH Results

Parameter	UND	Tangua 1	Tambor 1	Tambor 2	Tangua 2
GRO	mg / kg	<2.5	<2.5	<2.5	<2.5
DRO	mg / kg	<2.5	<2.5	<2.5	<2.5

Source (ASOAM, 2016)

In the following figures we can see that the chromatograms corresponding to the target process and do not show characteristic DRO and GRO profiles. Also, the chromatographic profiles of the four (4) samples do not match the standard GRO and DRO profiles; the quantification result is reported in Table 14. The chromatograms of the sample shows chromatographic peaks with different tR to the standard, these peaks correspond to compounds which are sensitive to the ionization detector (FID). However, these compounds do not belong to the TPH group of and cannot be identified or quantified because of the extent of the analytical method.

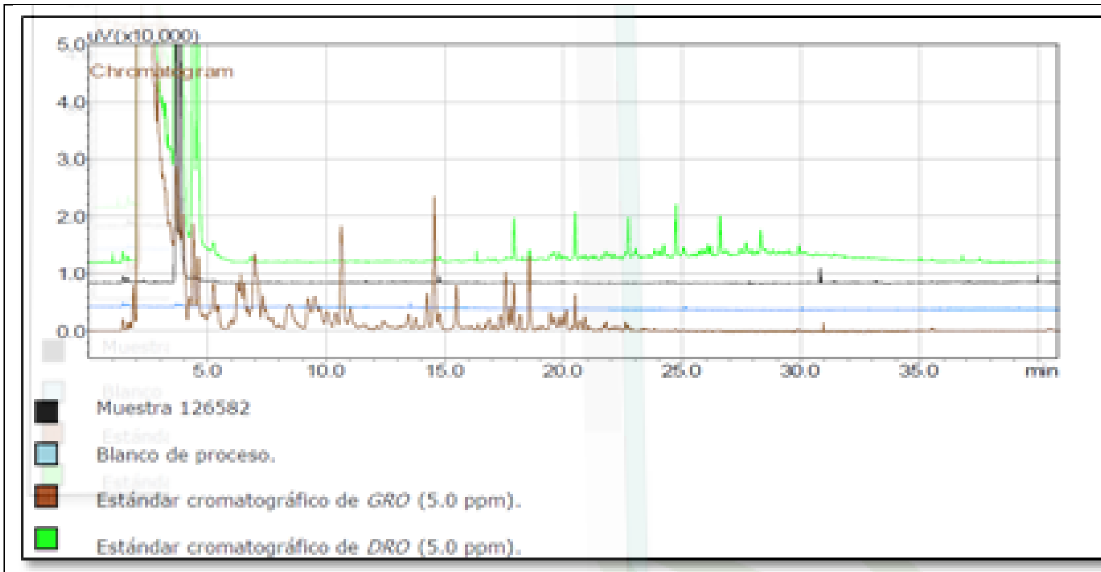


Figure 7.29 Comparative chromatogram: white sample and standard point Tangua 1

Source (ASOAM, 2016)

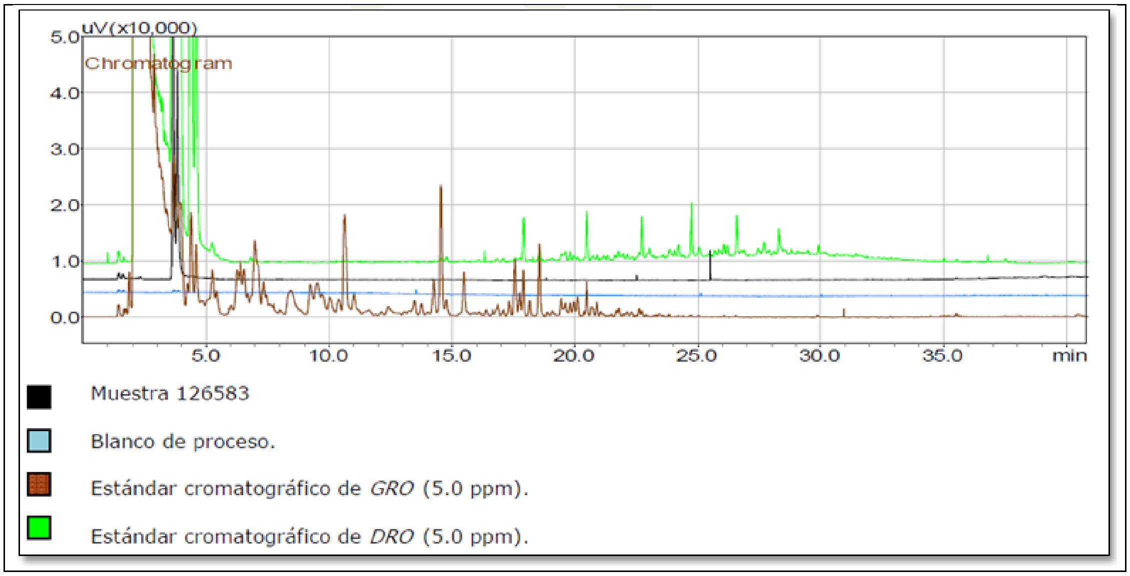


Figure 7.30 Comparative chromatogram: white, sample and standard point Tambor 1

Source (ASOAM, 2016)

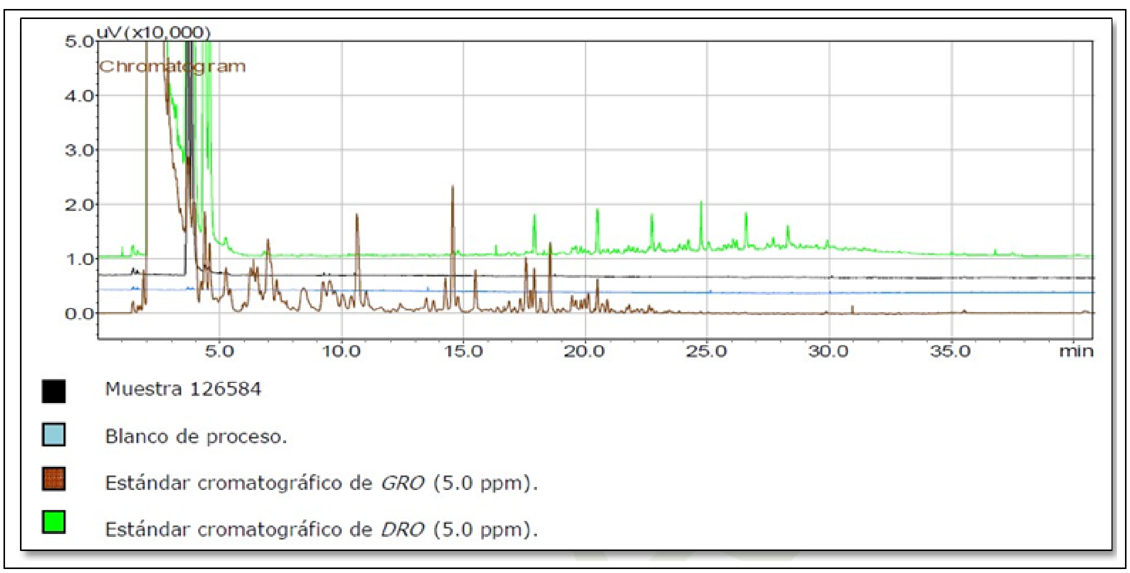


Figure 7.31 Comparative chromatogram: white, sample and standard point Tambor 2

Source (ASOAM, 2016)

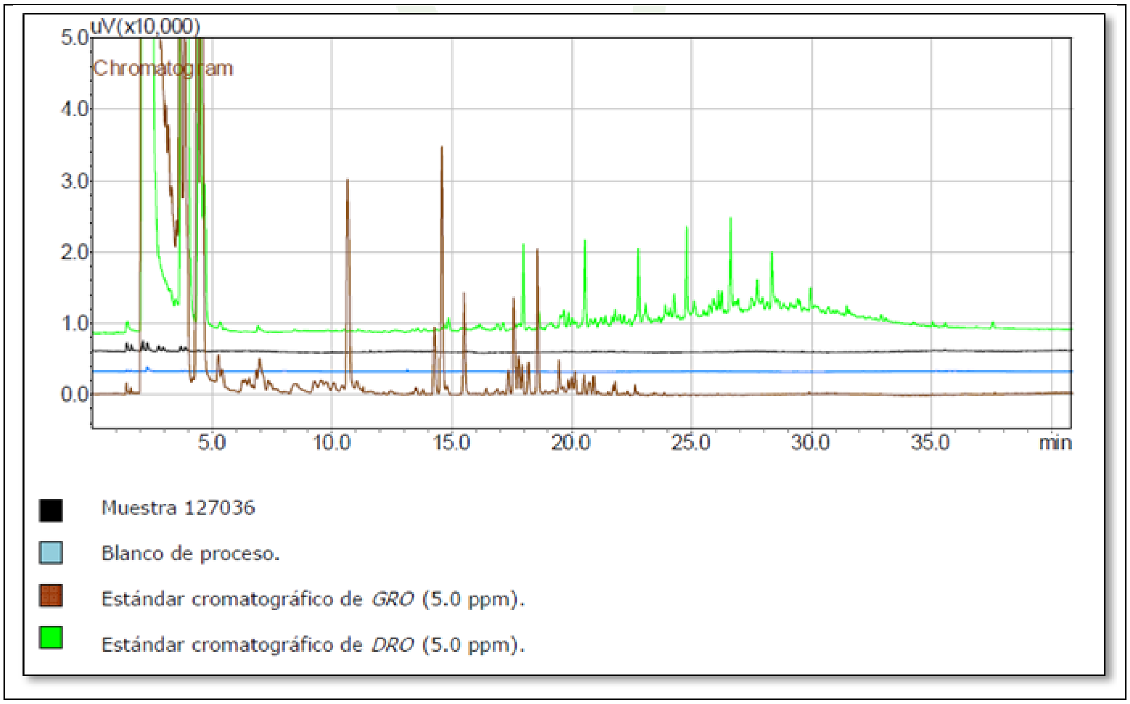


Figure 7.32 Comparative chromatogram: white, sample and standards Tangua 2
Source (ASOAM, 2016)

The results of the physicochemical characterization carried out on soil samples from the project area as part of the Environmental Impact Study on the road Pedregal- Pasto section, support the conclusion that:

Regarding sampling points evaluated in total metals; the different ranges of concentration of each determined element do not have significant variations; i.e. that the physicochemical soil conditions are not factors punctually intervening on the accumulation of these elements.

The Cation Exchange Capacity CIC in samples analyzed shows good retention of ions and macronutrients, inferring from this good condition to sustain vegetation in these soils,

Humidity recorded values associated with the availability and water retention in the soil, describing at all points suitable conditions for sustaining plant species. The highest value was recorded in El Tambor 2 and the lowest at Tangua 2 point, behavior given by the physical, chemical and land geographical conditions.

The total petroleum hydrocarbons in the four (4) samples do not match the DRO and GRO standard profiles and could not be identified or quantified because of the extent of the analytical method.

Additionally, Tangua 1 and Tambor 1 report a value in the range of 27 to 29 cmol (+) / kg ss, indicating good exchange of utilizable compounds

· Meteorology

- *Weather*

Given the location and geomorphology characteristics, the municipality of Ipiales has a tropical high mountain climate with a temperature which fluctuates very little, because there is a high relative humidity and precipitation constituting a contribution to vegetation and soils in the area.

Humidity is affected by two dynamics that are: the Amazon landmass that has an incidence in the Easter foothills and slope; and occasionally the El Niño phenomenon influencing the western department of Nariño.

Currently, the development of agriculture and indiscriminate logging is affected by the changes observed in the atmosphere as precipitation, temperature, relative humidity, sunshine and air currents. These phenomena become elements that determine the climate of Ipiales.

- *Temperature*

Temperature behavior is related to the relief expressed in altitude. The intertropical situation does not generate large variations in monthly mean values throughout the year, whose variation does not exceed 5 ° C.

Usually the hottest periods are divided into two semesters of the year and correspond to periods of lower rainfall. The annual average is 10.8%, which allows establishing that in the months of June, July and August temperatures are low. These climatic aspects are vital to determine the biological cycle of crops. In the month of July 1985 the lowest temperature of 8.3 ° C was recorded and the highest temperature in the months of October 1941 an in May 1995 with 14.4 ° C.

- *Precipitation*

Precipitation originates from the condensation of atmospheric moisture. The study area is of orographic origin because condensation and cooling of warm air masses from the ocean produce the rising of the air up the slope of the mountain range. On the moor, precipitation is higher and decreases in eastern foothills and the Andean highlands.

To have information on precipitation in the area of the municipality of Ipiales, data from the San Luis Airport weather station were used from 1941 to 1995.

Records indicate that during the months of March and April rainfall is heavier, decreasing midyear i.e. during the months of July and August and increasing again towards the months of October, November and December with an average of 970.8 mm, presenting a maximum value of 1230.4 mm in 1970 and a minimum of 211.2 mm in 1946; the monthly average is 72.57 mm. The maximum monthly value reported corresponds to February 1963 with 270.0 mm and 2.0 mm minimum in August of the same year.

The above phenomenon can be explained because the municipality has a bimodal rainfall regime, characterized by registering two periods of increased rainfall (March-April) and (October-December) with a period of less rainfall in the middle of the year (July and August)

- Relative humidity

The relative humidity values over the past ten years have been 85% and according to San Luis Station records, the annual average of the period 1941 to 1995 was 83% concluding that there is a large fluctuation between 63% minimum and 91% maximum values.

- *Brightness and solar radiation*

Given situation of Ipiales in the equatorial belt and its altitude, it can almost never be free of clouds, which has been a key development of the landscape especially the cloud forest, however data analyzed from the San Luis station shows a fluctuation ranging from 51.1 to 199 hours per month with an annual average in the period 1941 to 1995 of 1.434.3 hours.

- *Evaporation*

During the past five years there was less evaporation due to low area temperature equivalent to 892 mm area.

- *Winds*

Air currents acting on the municipality of Ipiales exert great influence in determining the climate. Southeast winds (trade winds) blowing from the Tropic towards the Ecuador come loaded with moisture, which is deposited on the Central Eastern Cordillera thus modifying the rainfall regime during the months of July and August.

Another air stream is the dynamic exerted by the Amazon landmass which give rise to moisture laden currents, which when hitting high mountains, precipitate causing drastic temperature changes in the surrounding slopes of La Victoria, Cultún and the Pun and Cultún valleys.

Local winds also occur because of physical-spatial dynamics, these change the temperature and are perceived more strongly in the afternoon and are called mountain breezes, valley breezes. This phenomenon is explained by the heating experienced by mountainsides during the daytime explained, which produces an air flow from valley towards the mountain, due to existing relationship between temperature and atmospheric pressure. During the night the phenomenon is reversed and is perceived in the highlands of Túquerres and Ipiales and on the slopes of the Central Easter Cordillera.

Regarding the wind speed, it is important to note that in 1982 the average wind speed value was 3.23 m / sec, varying between 5.53 m / s (maximum) in August and 2.03 m / sec (minimum) registered in December.

This allows establishing that the wind blows stronger during the months of July and August and slows down at the end of the year, i.e. during the months of November and December.

The presence of mountain ranges act as a modifying radiation factor (insolation and irradiation), pressure and cloud cover, manifested in thermal modifications according to altitudinal levels designated thermal floors.

- *Hydrology*

Consists of three major watersheds:

- Guaitara River Basin and its tributaries: constituted by the Boqueron River that in the high part is the Doña Juana Stream; Blanco and Carchi Rivers, Morro Stream, Teques or Pulcas, Orejuela, El Rosario, Cutuaquer.
  The Guaytara or GuaitaraRriver namecome from the Quechua language meaning blue river. It is characterized by its spectacular chasms, its spectacular canyon and beautiful landscapes in its 135 km journey to its mouth in the Patia River.
- Chingual river basin, which in its upper part is called the Pun or Chúnquer creek and its tributaries are the rivers San Francisco, Green, Yamués, El Cultún.
- The San Miguel River basin and its tributaries formed by the Churuyaco, Sapoyaco, Rumiyaco, Kerosén, Lora and Ranchería rivers.

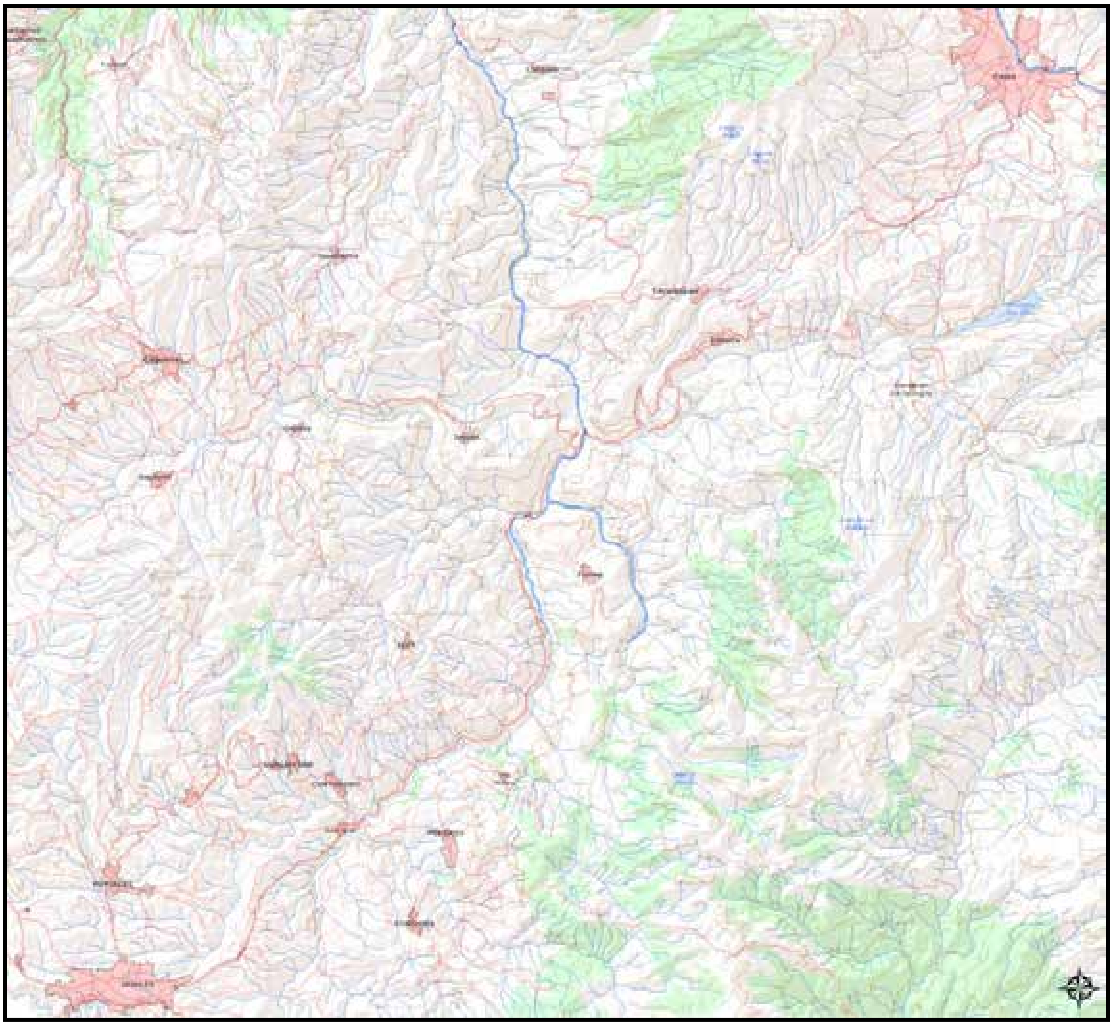


Figure7.33 Surface runoff from the study area

Fuente IGAC

- *Geology*

The geology of the area is comprised of tertiary sedimentary rocks and deposits little or unconsolidated from the quaternary.

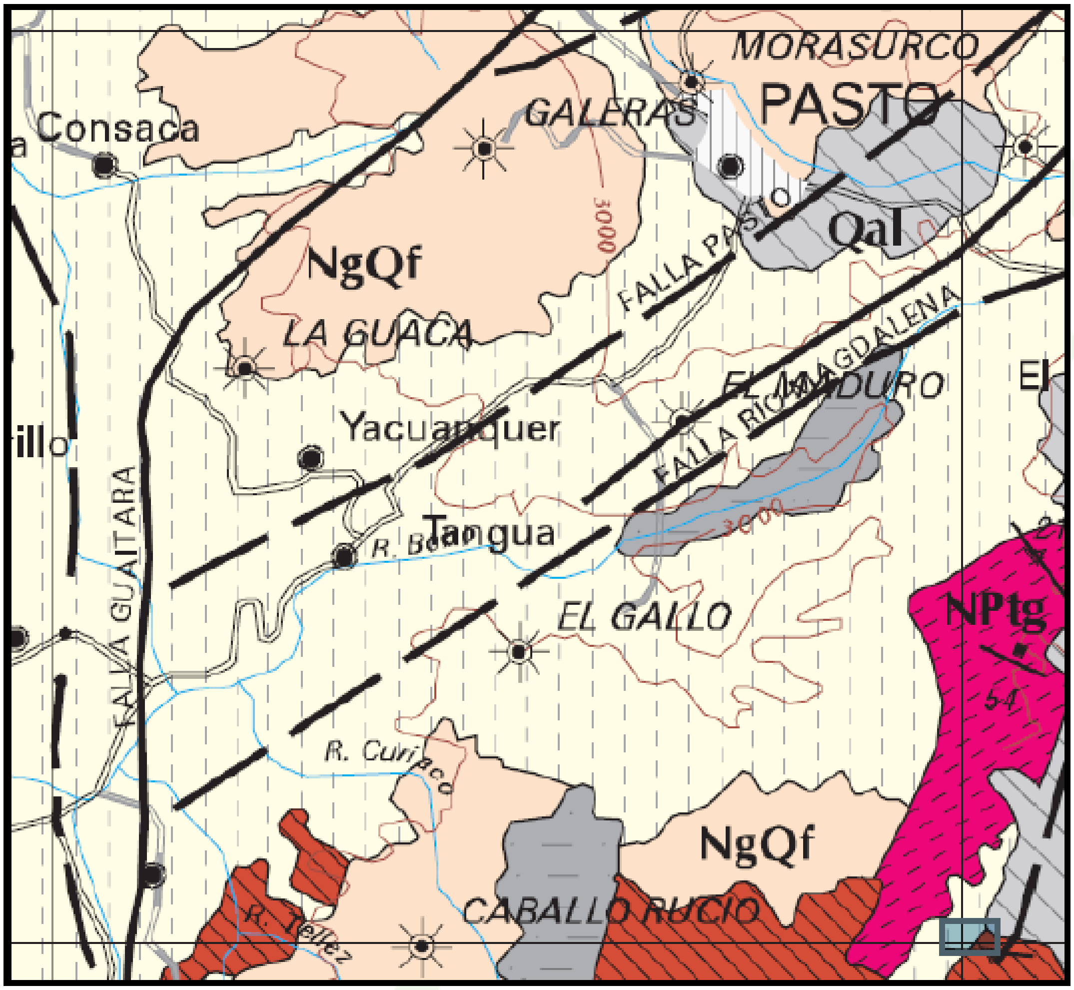


Figure 7.34 General geology of the study area

Source IGAC

Description of geological formations present in the study area:

- Qal: alluvial, lacustrine deposits and quaternary glaciers located east and west of the area of interest.
- NgQp: pyroclastic rocks intercalated locally with mudflows and alluvial deposits, are of neotenic age and outcrops along the entire Troncal de Occidente highway.

- NgQf: lavas interbedded with occasional pyroclastic, outcropping in the northern, southeastern and southwestern part of the study area and are of neotenic age.
- Nptg: intrusive Precambrian formations formed by migmatites, granites and syenites and outcropping to the southeast of the area of interest.
- MPtG: metamorphic rocks of Precambrian age, shaped by granulites, migmatites, amphibolites and biotite gneisses and outcropping to the southeast of the area of interest.

o Measures to prevent soil contamination

Proposed measures are part of a physical bacteriological treatment system to allow removing the contaminant load taking into account the estimated discharge composition in order to improve the characteristics of the resulting wastewater from industrial and domestic processes. Annex 7.3.2.b presents the management plan is presented for discharges.

7.4. Riverbed occupation

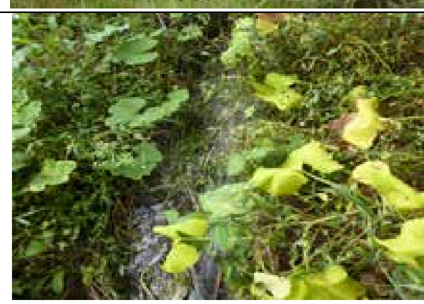
This section refers to each riverbed intervention needed by the project to enable the structures and operation of the road corridor or any associated infrastructure, as described in Chapter 3 of this EIA.

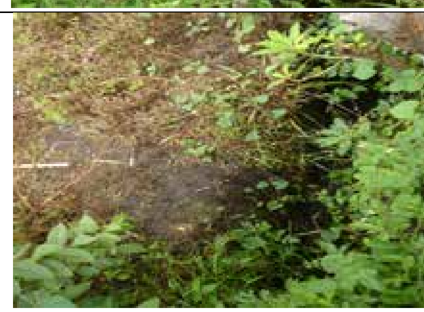
The necessary structures in riverbed sites can be viaducts, bridges, canals, dikes, culvert and box culverts, among others, which have been discussed in Chapter 3 and also in the annexes as Annex GDB / cartography / PDF / EIADCRP_IP_034.

Crossings of surface water bodies consist of engineering works designed and planned to give way and properly manage runoffs in each sites. Works for a total of (65) bodies of water in UF-4 and UF-5 are foreseen as listed in Table 7.37 (Annex 7.4).

Table 7.33: Riverbed Occupations

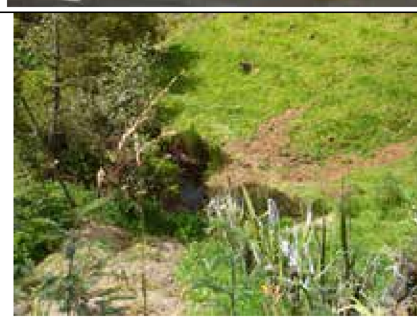
UF	SOURCE NAME	TYPE	WORK SPECIFICATION	PLANAR COORDINATES		PHOTOGRAPHIC RECORDS
				EAST	NORTH	
4	NAMELESS 1	SEWER 0+993	NOT RECORDED	957447,30	607459,31	
4	NAMELESS 2	SEWER 1+193	NOT RECORDED	957656,89	607587,23	
4	NAMELESS 3	SEWER 4+673	NOT RECORDED	960309,21	608351,84	
4	NAMELESS 4	SEWER 5+300	NOT RECORDED	960802,12	608702,69	

U	SOURCE	TYPE	WORK	PLANAR COORDINATES		PHOTOGRAPHIC RECORDS
4	NAMELESS 5	SEWER 5+915	NOT RECORDED	961022,95	609139,77	
4	NAMELESS 6	SEWER 8+212	NOT RECORDED	961762,85	609272,40	
4	NAMELESS 8	SEWER 8+420	NOT RECORDED	961925,48	609395,96	
4	NAMELESS 9	SEWER 7+952	NOT RECORDED	961539.97	609370.06	

U	SOURCE	TYPE	WORK	PLANAR COORDINATES		PHOTOGRAPHIC RECORDS
4	NAMELESS 10	SDN-1	NOT RECORDED	960945,11	609578,11	
4	NAMELESS 11	SEWER 7+593	NOT RECORDED	961384.18	609687,67	
4	NAMELESS 12	SEWER 7+425	NOT RECORDED	961266.95	609818.61	
4	NAMELESS 13	SEWER 8+843	NOT RECORDED	961933,68	609772,62	

U	SOURCE	TYPE	WORK	PLANAR COORDINATES		PHOTOGRAPHIC RECORDS
4	NAMELESS 14	SEWER 6+659	NOT RECORDED	960962.53	609864,85	
4	NAMELESS 15	SDN-2	NOT RECORDED	961219,79	609953,13	
4	NAMELESS 16	SDN-3	NOT RECORDED	960942.03	610060.10	
4	QUEBRADA LA MAGDALENA	DRAINAGE 2	NOT RECORDED	961055,98	610135.72	

U	SOURCE	TYPE	WORK	PLANAR COORDINATES		PHOTOGRAPHIC RECORDS
4	NAMELESS 17	SEWER 9+473	NOT RECORDED	962041,06	610310.03	
4	NAMELESS 18	SEWER 9+522	NOT RECORDED	962012.10	610390.13	
4	NAMELESS 19	SEWER 9+647	NOT RECORDED	962055,15	610503.21	
4	NAMELESS 20	SEWER 13+038	NOT RECORDED	963995,74	612730.24	

U	SOURCE	TYPE	WORK	PLANAR COORDINATES		PHOTOGRAPHIC RECORDS
4	NAMELESS 21	SEWER 13+421	NOT RECORDED	964354,29	612873,85	
4	NAMELESS 22	SEWER 13+862	NOT RECORDED	964746.31	613063,84	
4	NAMELESS 23	SDN-4	NOT RECORDED	964812,34	613086,11	
4	NAMELESS 24	SEWER 14+026	NOT RECORDED	964901,36	613116,88	

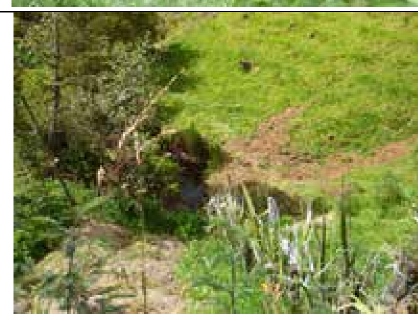
U	SOURCE	TYPE	WORK	PLANAR COORDINATES		PHOTOGRAPHIC RECORDS
4	NAMELESS 25	SEWER 14+234	NOT RECORDED	965097.95	613119.39	
4	NAMELESS 26	BOX CULVERT - 3	NOT RECORDED	957048,31	606818,50	
4	NAMELESS 27	SEWER 0+232	NOT RECORDED	957087.60	606898,26	
4	NAMELESS 28	SEWER 0+518	NOT RECORDED	957244,55	607135,06	

U	SOURCE	TYPE	WORK	PLANAR COORDINATES		PHOTOGRAPHIC RECORDS
4	GUAITARA RIVER	VIADUCT	NOT RECORDED	958736,48	608557,67	
5	NAMELESS 29	BOX CULVERT - 1	NOT RECORDED	966054,29	613847,89	
5	NAMELESS 30	SEWER 16+948	NOT RECORDED	966628,23	613872,95	
5	NAMELESS 31	DRAINAGE 3	NOT RECORDED	966804,19	614104,07	

U	SOURCE	TYPE	WORK	PLANAR COORDINATES		PHOTOGRAPHIC RECORDS
5	NAMELESS 32	BOX CULVERT - 8	NOT RECORDED	966463,97	614224,22	
5	NAMELESS 33	SEWER 18+873	NOT RECORDED	965650,28	614271,26	
5	NAMELESS 34	SEWER 19+037	NOT RECORDED	965523,92	614365,54	
5	NAMELESS 35	SDN 6	NOT RECORDED	965545,78	614480,87	

U	SOURCE	TYPE	WORK	PLANAR COORDINATES		PHOTOGRAPHIC RECORDS
5	NAMELESS 36	SDN 36	NOT RECORDED	965512,57	614491,46	
5	EL QUELAL STREAM	BOX CULVERT -2	NOT RECORDED	966316,92	614532,46	
5	NAMELESS 37	SDN-11	NOT RECORDED	966391,90	615078,53	
5	NAMELESS 38	SEWER 22+232	NOT RECORDED	967757,43	616132,46	

U	SOURCE	TYPE	WORK	PLANAR COORDINATES		PHOTOGRAPHIC RECORDS
5	NAMELESS 39	SDN-12	NOT RECORDED	967956,17	616411,06	
5	NAMELESS 40	SEWER 23+031	NOT RECORDED	968021,64	616858,83	
5	NAMELESS 41	SDN-8	NOT RECORDED	967963,74	616866,44	
5	LA MARQUEZA STREAM	DRENAJE 11	NOT RECORDED	968447,19	617016,49	

U	SOURCE	TYPE	WORK	PLANAR COORDINATES		PHOTOGRAPHIC RECORDS
5	LOS AJOS STREAM	BOX CULVERT - 4	NOT RECORDED	968211,90	617051,11	
5	LOS AJOS STREAM	BOX CULVERT - 5	NOT RECORDED	968401,55	617052,44	
5	PIQUISIQUI STREAM	BOX CULVERT - 6	NOT RECORDED	971538,78	618399,85	
5	NAMELESS 42	SEWER 27+459	NOT RECORDED	971265,67	618605,51	

U	SOURCE	TYPE	WORK	PLANAR COORDINATES		PHOTOGRAPHIC RECORDS
5	NAMELESS 43	SDN-9	NOT RECORDED	970742,94	618707,21	
5	CUBIJAN STREAM	BOX CULVERT - 7	NOT RECORDED	974562,53	619262,35	
5	NAMELESS 44	SEWER 31+790	NOT RECORDED	974942,98	619381,41	
5	NAMELESS 45	SDN-10	NOT RECORDED	968460,03	617023,78	

U	SOURCE	TYPE	WORK	PLANAR COORDINATES		PHOTOGRAPHIC RECORDS
4	NAMELESS 46	SEWER 14+234	NOT RECORDED	965070,94	613083,41	

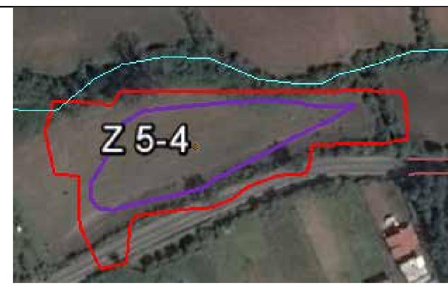
Source Géminis Consultores S.A.S

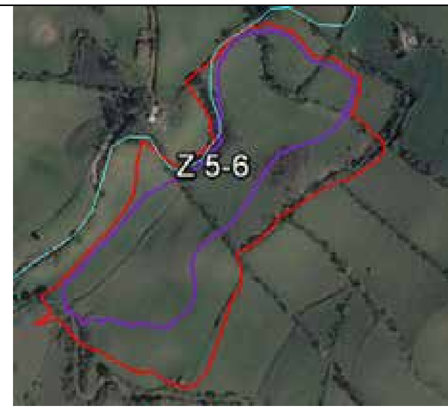
· Riverbed occupation for drains

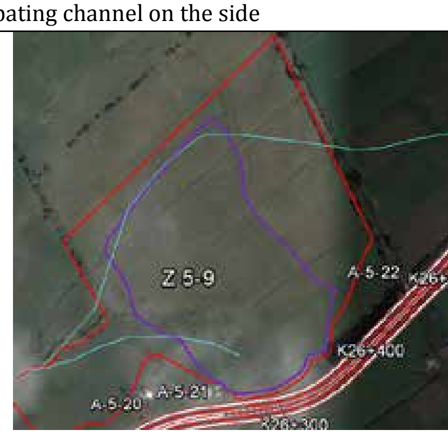
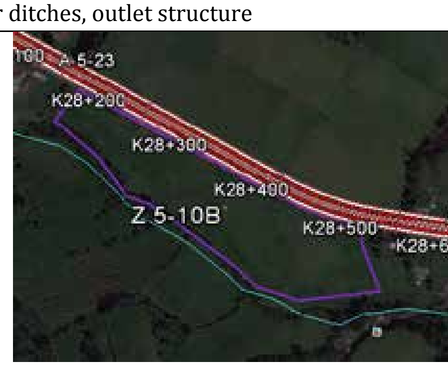
Drainage occupations are foreseen in the Project in order to maintain their morphological and physical with respective management measures. Ver Tabla 7.38

Table 7.34 Riverbed occupation for drains

UF	SOURCE NAME	ZODME	COOR X	COOR Y	PHOTOGRAPHIC RECORD
4	**Nameless 47**	**ZR4-2**	962015,46	609351,57	
Management measures are filters, retaining walls, perimeter ditches, outlet structure					

5	**Nameless 48**	**Z5- 1A**	966922.095	614183.361	
Management measures are filters, retaining walls, perimeter ditches, outlet structure					
5	El Cebadal Stream	Z5-4	965452,173	614710,126	
Management measures are filters, retaining walls, perimeter ditches, outlet structure salida					
5	El Cebadal Stream	Z5-5	965641,521	614799,297	
Management measures are filters, retaining walls, perimeter ditches, outlet structure					
5	El Cebadal Stream	ZR5-1	966192,508	615125,672	
Management measures are filters, retaining walls, perimeter ditches, outlet structure					

5	El Cebadal Stream	ZR5-2	966457,206	615301,222	
Management measures are filters, retaining walls, perimeter ditches, outlet structure					
5	El Quelal Stream	Z5- 6	967153,256	615406,352	
Management measures are filters, retaining walls, perimeter ditches, outlet structure					
5	Nameless 49	ZR5- 3	967738.808	616222.181	
Management measures are filters, perimeter ditches, outlet structure					

5	Nameless	Z5-6B	967940.122	616697.946	
Management measures are filters, outlet structure, and dissipating channel on the side					
5	El Establo Stream	Z5-9	970308,908	618527,763	
Management measures are filters, retaining walls, perimeter ditches, outlet structure					
5	El Establo Stream	Z5-10	970904,009	618856,601	
Management measures are filters, retaining walls, perimeter ditches, outlet structure					

5	Cubijan Stream (Piedra Pintada Stream)	Z5- 13	974878,476	619293,950	

Intervening channels for the works described in the above table require environmental authority approval that is requested by riverbed occupancy permits whose forms are in Annex 7. 4.

- *Special crossings*

There are two special crossings of great hydric importance which are the Guáitara River and the La Magdalena Stream (see Table 7.39). Chapter 3 of this study shows the hydraulic works designs.

Tabla 7.35 Cruces especiales

UF	SOURCE NAME	TYPE	TEMPORAL	COOR_X	COOR_Y
4	Magdalena Stream	Box	Permanente	961059,5957	610155,9585
4	Magdalena Stream a	Box	Permanente	961059,5957	610155,9585

7.4.1 Frequency Analysis for flows

Maximum flows for afferent drainage area of each hydraulic work were calculated using the Rational Method for those basins with drainage areas less than 2.5 square kilometers. For larger basins flows were calculated using the unit hydrograph method.

- Rational method

This is a methodology commonly used in hydrology to generate peak flows in small or smaller basins with no hydrometric information; this consists of estimating the maximum flow assuming uniform intensity of precipitation during the time of concentration of the basin. The assumption of uniform precipitation during the time of concentration is an approximation done considering that in reality a rainfall event is uniform during the time of concentration of the basin. Thus, the flow at a given point of the basin gradually grows to a maximum value when the entire basin is contributing to the runoff at the site of water concentration. The "Rational Method" is expressed by the ratio:

$$Q = \frac{C \cdot I \cdot A}{360}$$

Where:
Q: Maximum flow in m^3 / s.
C: Runoff coefficient, dimensionless.
I: Rainfall intensity in mm / h.
A: Drainage area in ha.

- Runoff coefficient

The runoff coefficient relates the maximum flow generated produced after discounting storage losses, retention and infiltration, with generating precipitation intensity inherent in each basin and mainly depending on the soil type, vegetation cover and the slope of the basin.

Maximum flows for different return periods were estimated. Table 7.40 shows the summary of parameters used to calculate maximum flows in streams with an area exceeding 2.5 sq km. For the remaining basins the parameters used are summarized in Table 7.41

Table 7.36 Summary of modeling parameters to estimate maximum flow in basins over 2,5 km²

Site	Area (km²)	Tc (min)	Tlag (min)	CN	Histogram	Reduction factor per area	Rainfall duration (hours)
La Magdalena	36,6	154	92	81	SCS tipo II	0,75	2,5

Source: Consorcio SH

Table 7.41 Design intensity for different return periods, right basin banks

Basin	Area(Km²)	Tc (min)	Intensity (mm/h)						
			2,33	5	10	20	25	50	100
1	0.0557	15	73.05	84.4	96.3	109.	114.	130.	149.
2	0.6715	17.38	66.33	76.6	87.4	99.7	104.	118.	135.
3	0.1331	15	73.05	84.4	96.3	109.	114.	130.	149.
4	0.1331	15	73.05	84.4	96.3	109.	114.	130.	149.
5	0.7259	18.08	64.69	74.7	85.3	97.3	101.	115.	132.
6	0.0068	15	73.05	84.4	96.3	109.	114.	130.	149.
7	0.0247	15	73.05	84.4	96.3	109.	114.	130.	149.
8	0.1805	15	73.05	84.4	96.3	109.	114.	130.	149.
9	0.1226	15	73.05	84.4	96.3	109.	114.	130.	149.
10	0.0466	15	73.05	84.4	96.3	109.	114.	130.	149.
11	0.0531	15	73.05	84.4	96.3	109.	114.	130.	149.
12	0.0395	15	73.05	84.4	96.3	109.	114.	130.	149.
13	0.0382	15	73.05	84.4	96.3	109.	114.	130.	149.
15	0.0289	15	73.05	84.4	96.3	109.	114.	130.	149.
17	0.9751	20.06	60.59	70.0	79.9	91.1	95.1	108.	123.
18	0.0126	15	73.05	84.4	96.3	109.	114.	130.	149.
19	0.1484	15	73.05	84.4	96.3	109.	114.	130.	149.
20	0.0044	15	73.05	84.4	96.3	109.	114.	130.	149.
21	0.1458	15	73.05	84.4	96.3	109.	114.	130.	149.
22	0.1474	15	73.05	84.4	96.3	109.	114.	130.	149.
23	0.0678	15	73.05	84.4	96.3	109.	114.	130.	149.
24	0.0304	15	73.05	84.4	96.3	109.	114.	130.	149.

Source: Consorcio SH

Determination of design flows considering aforesaid paragraphs are shown in Table 7.38 and Table 7.42

Table 7.37 La Magdalena Stream flows

Tr	Basin	Area (km²)	Tc (min)	C N	Q (m³/s)

Tr	Basin	Area (km^2)	Tc (min)	CN	Q (m^3/s)
5	Q. La Magdalena	36,5	154	81	26,2
10					35,3
20					44,9
25					48,15
50					58,4
100					69,3

Source: Consorcio SH

Table 7.38 Design flow for different return periods for efferent basins to the drainage waters

Basin	Area (Km^2)	Q m^3/s						
		Q 2	Q 5	Q 10	Q 20	Q 25	Q 50	Q 100
1	0.0557	0.42	0.52	0.63	0.76	0.82	0.99	1.22
2	0.6715	4.65	5.81	6.96	8.50	9.07	11.02	13.60
3	0.0732	0.55	0.69	0.82	1.00	1.07	1.30	1.61
4	0.1643	1.23	1.54	1.85	2.26	2.41	2.92	3.61
5	0.0437	0.33	0.41	0.49	0.60	0.64	0.78	0.96
6	0.6633	4.42	5.53	6.62	8.09	8.63	10.49	12.94
7	0.0068	0.05	0.06	0.08	0.09	0.10	0.12	0.15
8	0.0366	0.28	0.34	0.41	0.50	0.54	0.65	0.80
9	0.2139	1.61	2.01	2.40	2.94	3.13	3.81	4.70
10	0.1226	0.92	1.15	1.38	1.68	1.80	2.18	2.69
11	0.0466	0.35	0.44	0.52	0.64	0.68	0.83	1.02
12	0.0670	0.50	0.63	0.75	0.92	0.98	1.19	1.47
13	0.0251	0.19	0.24	0.28	0.34	0.37	0.45	0.55
14	0.0165	0.12	0.16	0.19	0.23	0.24	0.29	0.36
15	0.0175	0.13	0.16	0.20	0.24	0.26	0.31	0.38
16	0.0923	0.69	0.87	1.04	1.27	1.35	1.64	2.03
17	0.4338	3.00	3.75	4.49	5.49	5.86	7.12	8.78
18	0.1992	1.38	1.72	2.06	2.52	2.69	3.27	4.03
19	0.1484	1.11	1.39	1.67	2.04	2.17	2.64	3.26
20	0.0044	0.03	0.04	0.05	0.06	0.06	0.08	0.10

Basin	Area (Km²)	Q m³/s						
		Q 2	Q 5	Q 10	Q 20	Q 25	Q 50	Q 100
21	0.1458	1.09	1.37	1.64	2.00	2.14	2.60	3.20
22	0.1474	1.11	1.38	1.66	2.03	2.16	2.62	3.24
23	0.0678	0.51	0.64	0.76	0.93	0.99	1.21	1.49
24	0.0304	0.23	0.29	0.34	0.42	0.45	0.54	0.67
25	0.0977	0.73	0.92	1.10	1.34	1.43	1.74	2.15
26	0.0618	0.46	0.58	0.69	0.85	0.91	1.10	1.36
27	0.0189	0.12	0.15	0.18	0.22	0.24	0.29	0.36
28	0.3521	2.02	2.53	3.03	3.70	3.95	4.80	5.92
29	0.1756	1.14	1.43	1.71	2.09	2.23	2.71	3.34
30	0.2076	1.24	1.56	1.86	2.28	2.43	2.95	3.64
31	0.0696	0.45	0.57	0.68	0.83	0.88	1.07	1.32
32	0.4690	2.63	3.29	3.94	4.82	5.14	6.25	7.71
33	0.0607	0.39	0.49	0.59	0.72	0.77	0.94	1.15
34	0.0302	0.20	0.25	0.29	0.36	0.38	0.47	0.58
35	0.0384	0.25	0.31	0.37	0.46	0.49	0.59	0.73
36	0.2830	1.84	2.30	2.76	3.37	3.59	4.36	5.38
37	0.1407	0.91	1.14	1.37	1.67	1.79	2.17	2.68
38	0.1893	1.23	1.54	1.84	2.25	2.40	2.92	3.60
40	0.0548	0.36	0.45	0.53	0.65	0.69	0.84	1.04
41	0.0795	0.52	0.65	0.77	0.95	1.01	1.23	1.51
42	0.0263	0.17	0.21	0.26	0.31	0.33	0.40	0.50
43	0.0170	0.11	0.14	0.17	0.20	0.22	0.26	0.32
44	0.0858	0.56	0.70	0.83	1.02	1.09	1.32	1.63
45	0.0997	0.65	0.81	0.97	1.19	1.26	1.54	1.90
46	0.0169	0.11	0.14	0.16	0.20	0.21	0.26	0.32
47	0.0312	0.20	0.25	0.30	0.37	0.40	0.48	0.59
48	0.0830	0.54	0.67	0.81	0.99	1.05	1.28	1.58
49	0.0295	0.19	0.24	0.29	0.35	0.37	0.45	0.56
50	0.0400	0.26	0.32	0.39	0.48	0.51	0.62	0.76
51	0.0403	0.26	0.33	0.39	0.48	0.51	0.62	0.77
52	0.0231	0.15	0.19	0.23	0.28	0.29	0.36	0.44
53	0.0821	0.53	0.67	0.80	0.98	1.04	1.27	1.56

Basin	Area (Km^2)	Q m^3/s						
		Q 2	Q 5	Q 10	Q 20	Q 25	Q 50	Q 100
54	0.0546	0.35	0.44	0.53	0.65	0.69	0.84	1.04
55	0.0407	0.26	0.33	0.40	0.48	0.52	0.63	0.77
56	0.0449	0.29	0.37	0.44	0.53	0.57	0.69	0.85
57	0.0200	0.13	0.16	0.19	0.24	0.25	0.31	0.38
58	0.0219	0.14	0.18	0.21	0.26	0.28	0.34	0.42
59	0.0299	0.19	0.24	0.29	0.36	0.38	0.46	0.57
60	0.0355	0.23	0.29	0.35	0.42	0.45	0.55	0.68
61	0.0275	0.18	0.22	0.27	0.33	0.35	0.42	0.52
62	0.1695	1.10	1.38	1.65	2.02	2.15	2.61	3.23
63	0.0061	0.04	0.05	0.06	0.07	0.08	0.09	0.12
64	0.0156	0.10	0.13	0.15	0.19	0.20	0.24	0.30
65	0.0955	0.62	0.78	0.93	1.14	1.21	1.47	1.82
66	0.2055	1.34	1.67	2.00	2.45	2.61	3.17	3.91
67	0.1142	0.74	0.93	1.11	1.36	1.45	1.76	2.17
68	0.2219	1.44	1.80	2.16	2.64	2.82	3.42	4.22
69	0.2057	1.34	1.67	2.00	2.45	2.61	3.17	3.91
70	0.2123	1.27	1.59	1.91	2.33	2.48	3.02	3.72
71	0.3350	1.93	2.42	2.90	3.54	3.78	4.59	5.66
72	0.1698	1.10	1.38	1.65	2.02	2.16	2.62	3.23
73	0.3297	2.14	2.68	3.21	3.92	4.18	5.08	6.27
74	0.0128	0.08	0.10	0.12	0.15	0.16	0.20	0.24
75	0.0298	0.19	0.24	0.29	0.36	0.38	0.46	0.57
76	0.0626	0.41	0.51	0.61	0.75	0.79	0.97	1.19

Source: Consorcio SH

7.4.2. Subsidence calculations

Subsidence studies have been conducted in accordance with provisions of Maza Alvarez (Alvarez Maza J, 1970) and Ocampo Monforte (Monforte, 1986) publications.

Rising river water levels lead to changes in the bottom and the banks of the waterway. These changes in channel shape are due to greater current drag, which by transporting a higher number of particles in suspension from the bottom, makes the river level drop.

The methodology used to calculate general subsidence corresponds to the proposal by Maza AJA (Maza J Alvarez, 1970). In this methodology, the calculation criteria proposed by Lichtvan - Lebedev and for the implementation thereof it is necessary to distinguish the cohesiveness and homogeneity characteristics of soils present in the riverbed.

The maximum expected subsidence depth expected by the passage of higher water levels is given by the following expressions:

Equation 7-1

$$H_s = \left[\frac{\alpha H_0{}^{5/3}}{0{,}68\ d_m{}^{0{,}28}\beta}\right]^{\frac{1}{1+z}}$$

Equation 7-2

$$H_s = \left[\frac{\alpha H_0{}^{5/3}}{0{,}60\ \gamma_s{}^{1{,}18}\beta}\right]^{\frac{1}{1+x}}$$

Equation 7-1 is used for granular soils and Equation 7-2 for cohesive soils.

Follows a description of parameters involved in the general subsidence equations:

Hs = is the height between the water surface (when the high water level is passing) and the erosive background (m).

α = Coefficient of expenditure distribution, calculated by Equation 7-3.

Equation 7-3

$$\alpha = \frac{Q_d}{H_0^{5/3} B_e}$$

Where,

Qd = design flow rate for the return period considered (m3 / s).
HO = is the depth of the cross section for flow design consideration (m).
Be = is the width of the section for the design flow level (m). It is important to clarify that if the current runs parallel to the axis of the basins, that length will be the section considered less the thickness of the basins that are inside it. When there is a fleet angle of the current, the effective width can be calculated by plotting lines indicating the direction of flow, tangential to the basins and measuring the resulting clearings.

dm = average diameter of bottom particles (mm). This parameter is calculated by Equation 4.4.

Equation 7-4 $$d_m = 0{,}001 \sum_{i=1}^{n} d_i p_i$$

Where,

- di = Average diameter of a fraction of the granulometric curve of the total sample being analyzed (mm).
- pi = Percentage of the weight of the same portion, compared to the total weight of the sample.
- β = coefficient related to the return period of the design flow, which is obtained with the values of Table 7.43

Table 7.39 Coefficient β.

TR	β.	% Likelihood
1	0,77	100
2	0,82	50
5	0,86	20
10	0,9	10
20	0,94	5
50	0,97	2
100	1	1
300	1,03	0,3
500	1,05	0,2
1000	1,07	0,1

Source Géminis Consultores S.A.S

Z= Coefficient used only for granular soils calculated by Equation 7-5

Equation 7-5 $$Z = 0{,}394557 - 0{,}04136 \log(d_m) - 0{,}00891 \left(\log[d_m]\right)^2$$

Where,

- d_m= Average diameter of bottom particles (mm). See Equation 7-6

X= Coefficient used only for cohesive soils, calculated by Equation 4.6.

Ecuación 7-6 $$X = 0{,}892619 - 0{,}58073\,\gamma_s + 0{,}136275\,\gamma_s^2$$

Where,

- Υ_s= Specific soil weight (Ton/m3).

To determine subsidence from the Graphic Method in a P point, as schematically shown in Figure 7.38, the following described variables intervene:

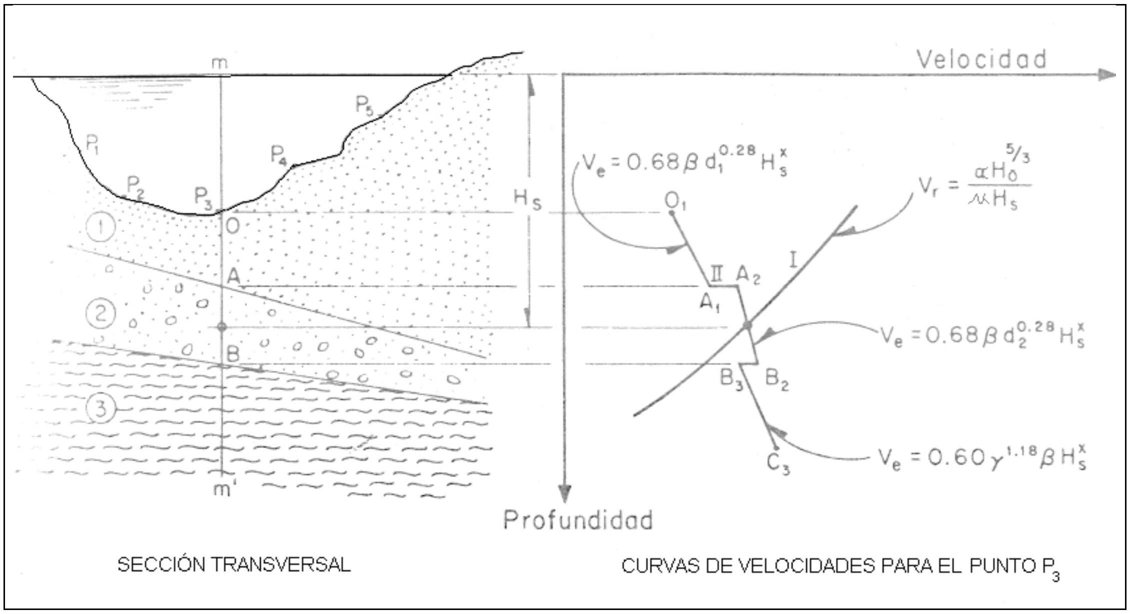


Figure 7.35 Subsidence calculation by the graphic method
Source: Consorcio SH

μ= Contraction coefficient that depends on the distance between the batteries and the average section velocity, calculated by Equation 7-7.

Equation 7-7 $$\mu = 1 - 0{,}387\frac{\bar{v}}{L}$$

Where,

- ṽ= Mean velocity of the cross section for design flow (m/s).
- L= Length between two batteries (m).

d_s = Subsidence depth, calculated by Equation 7-8

Equation 7-8

$d_s = H_S - H_O$

Where

H_s = the height between the water surface (when the high level of water is passing) and the erosive bottom (m).

H_O = is the depth of the cross section for flow design consideration (m).

Given the sizing of the works where water currents intersect the road layout projected on the Pedregal – Pasto section, and considering the density results shown in table 7.45, the general subsidence has been calculated.

Table 7.45 Density of transported material.

Abscissa	Density (KN / m3)
K0 + 000-K2 + 550	13.7
K2-K5 + 550 + 930	13.4
K5-K12 + 930 + 620	13.9
K12 + K15 + 750 620	13.7
K15 + 722 - K18 + 876	14.42
K18 + 876 - K24 + 018	8,25
K24 + 018 - K30 + 030	9.14
K30 + 030 - K37 + 948	10.25

Source: Consorcio SH

In order to determine structure subsidence, a rectangular geometry section has been designed, with a variable width according to the diameter of the sewer. Table 7.46 shows the width of the outlet structure in relation to the diameter of the sewer.

Table 7.40 Structure outlet geometry

Sewer diameter (m)	Structure output base (m)
0.9	4.5
1	5,05
1.2	5.9
1.3	6.3
1.5	7,15
1.6	7.6
1.8	8.5

Source: Consorcio SH

For structures Culvert Box type, the outlet section was calculated as the width of the structure plus an additional width of one meter on each side; when there is more than one cell it is estimated as the case of a cell, adding one meter, simulating this as the separation between cells.

Subsidence was calculated from the Lichtvan - Lebedev formula for cohesive soils, whereby the laboratory results by zoning were taken into account. Subsidence results have been grouped according to size and type of work as shown in Table 7.47 for sewers and in Table 7.49 for Box Culverts.

Table 7.41 Sewers subsidence Functional Unit 4

Homogeneous area / Diameter	0.9 m	1.2 m	1.5 m
K0 + 000 - K2 + 550	0.80	0.80	-
K2 + 550 - 930 + K5	0,79	-	-
K5 + 930-12 + 620	0,81	0,82	0,86
K12 + 620 - 750 + K15	0.80	0,82	0.85

Source: Consorcio SH

Table 7.42 Sewers subsidence Functional Unit 5

Homogeneous area / Diameter	0.9 m	1.2 m	1.5 m
K15 + 722 - K18 + 876	0.20	0.30	0.45
K18 + 876 - K24 + 018	0.35	0.60	0.75
K24 + 018 - K30 + 030	0.30	0.50	0.60

Source: Consorcio SH

Table 7.43 Box Culvert subsidence

Abscissa	Base (m)	Height (m)	Subsidence (m)
K0 + 136.95	2.50	2.50	0.90
K0 + 602.88	2.50	2.50	0.89
K16 + 200.46	3.50	3.50	1.0
K17 + 746	2.00	2.00	0.75
K18 + 122	2.00	2.00	1.5
K23 + 309.72	3.00	3.00	1.5
K23 + 479,90	3.00	3.00	1.5
K27 + 854.54	3.00	3.00	1.5
K31 + 403.37	3.50	3.50	1.75

Source: Consorcio SH

· Hydraulic analysis of surface drainage

There are several parameters and criteria used to design and / or analyze the hydraulic capacity of cross drainage works included in document "HYDROLOGY, HYDRAULICS AND SUBSIDENCE DESIGN CRITERIA (PEPA-CDI-HID-UFS-007-R 0); follows a description of each one thereof.

· Cross drainage, sewers and Box Culverts works

- *Location of cross drainage works*

Drainage works were located taking into account the natural condition of the various drains, creeks and rivers to be intercepted with the road, preferably looking for intersections to maintain their alignment, however, for topographical reasons there are minor derivations to their alignments, which are corrected with short channeling so as to maintain the natural conditions of drains in the shortest length.

The separation between drainage works obeys to natural topographical conditions of the sector, generation of low points in the project's road geometry, the longitudinal drainage capacity and the continuity of existing drainage. In particular, development of many urban and industrial areas of the project area have had the road as a hub, generating service needs of all types like restaurants, gas stations, parking, etc. that have changed the natural drainage pattern considering new structures and separation of the drainage works.

Two types of inlet structures to the drainage works were considered, depending on the location of the slope with respect to the natural drainage: when the road is in cut the projected inlet structure is box-like in reinforced concrete and when the road is in fill the projected inlet structure is head type with fins. In some cases under the cut condition, energy dissipation structures that allow routing the water down the slopes were projected.

· Hydraulic operation

A sewer flow is not uniform; it has areas with gradually varied flow and areas with rapidly varied flow, so their theoretical analysis is complex. Its capacity and operation depends on where the hydraulic control section of the sewer is located, so that the flow can be controlled at the inlet with control at the outlet. Flow conditions have been classified by different authors as Bodhaine (Chow, 1994).

The design of the project´s drainage works was limited to flow conditions corresponding to case A with control at the inlet, and case E with control at the outlet, where the height of the water lamina downstream of the TW work outlet is not greater than diameter "d" or the height of the work, i.e. there is no submergence at the outlet, and the flow discharges freely. The design is based on the analysis for the two hydraulic control conditions, adopting as a design the largest HW.

In the ducts with hydraulic control with the inlet, sizing of projected sewer is calculated by the criteria given in the Hydraulic Design Series Number 5 (United States Department of Transportation, 2001), using the following equations:

Where:

D = Pipe diameter in m

Q = Flow in m3 / s

A = Duct section area in m2

Ec Critical energy = Yc + (VC2 / 2g)

Where:

C = Critical depth

VC =Critical speed

g = Gravity

k, m = Loss coefficients for Hydraulic Control at the inlet

Z = Correction factor of slope of the power line at the inlet (0.7 * S) for perpendicular inlets, and (0.5 * S) for other types of inlets, where S is the slope of the work in m / m.

If the hydraulic control is located at the outlet, subcritical flow occurs in the sewer and sizing should consider the backwater originated therein as a result of the roughness of the pipe and hydraulic losses at the inlet and outlet of the work, so Manning's formula is used in order to determine the losses in the barrel or channel. The equation used to determine the diameter or height of the work is:

Where:

YT = Inlet, friction and outlet losses

Y0 = Maximum between TW and the value of (D + YC) / 2

TW = Downstream level.

S = Slope of the work

L= Length of the work

Taking into account natural terrain conditions, it is evident that for hydraulic structures of the project will have a flow with hydraulic control in the inlet, however, conditions are verified.

Sizing of these drainage works was made by complementing a commercial standardization of pipe diameters, for that reason the design limited the flow to a HW level just before the inlet to a value of the relation between this HW level and the diameter or height of the rectangular section (D) between 0.8 and 1.0 using commercial pipe diameters and greater standardization of heights and widths in Box Culverts.

- *Minimum diameter*

The minimum diameter of all new sewers will be 0.90 m, the existing 0.6 diameter sewers located under the existing roadway will be kept if the following conditions are met:

- No structural damage that could potentially affect the stability of the work.

- With hydraulic capacity required under the design criteria established in the document "HYDROLOGY, HYDRAULICS AND SUBSIDENCE DESIGN CRITERIA (PEPA-CDI-HID-UFS-007-R0) and this design.

- The work is located on the existing road and this road will be kept in the final layout of the new project (with reference to the suggestion of the geometric design manual that states that the existing road will be used as much as possible).

Estimate of drainage areas

The definition of drainage areas or basins contributing to each drainage work was defined considering the existing drainage on the road and its lows points. From the location of these sites, the layout plan of the project and existing mapping, the divisions of basins and drainage areas to the location of implanted drainage work were drawn. Drawings CSH-4-PL-OD-G-7001-0-H1 - CSH-4-PL-OD-G-7001-0-H2 - CSH-4-PL-OD-G-7001-0-H3 show basin delimitations.

- Existing drainage

In the initial stage of the project a field inventory of existing roadway was made, identifying the quantity and type of existing works.

From this procedure, it the existence of concrete pipes with diameters of 0.25 m, 0.60 m, 0.70 m and 0.90 m were identified, mainly 0.60 m diameter; Box culvert type sections of up to 3.0 m by 4.0 m base high were identified; Table 7.50 shows the summary of the number of existing works by diameter and type of work.

Table 7.44 Summary of existing works

UF	TYPE OF WORK	DIAMETER / BASE (m)	HEIGHT (m)	# PIPES	AMOUNT
4	Sewer	0.25	-	1	1
	Sewer	0,6	-	2	2
	Sewer	0,6	-	1	152
	Sewer	0,9	-	1	2
	Box Culvert	0,66	0,6	-	1
	Box Culvert	1,3	2,2	-	2
	Box Culvert	3	4	-	1
5	Sewer	0,6	-	2	4
	Sewer	0,6	-	1	352
	Sewer	0,7	-	1	3
	Sewer	0,9	-	1	7
	Sewer	0,9	-	2	1
	Box Culvert	0,66	0,6	-	1
	Box Culvert	0,9	0,95	-	1
	Box Culvert	0,9	0,58	-	1
	Box Culvert	1	1	-	1
	Box Culvert	1,3	2,2	-	1
	Box Culvert	1,6	2	-	1
	Box Culvert	1,7	1,9	-	1
	Box Culvert	1,7	2	-	1

UF	TYPE OF	DIAMETER/	HEIGHT	# PIPES	AMOUNT
	Box Culvert	3	4	-	1

Source: Consorcio SH

- <u>Hydraulic Analysis of existing cross drainage works</u>

This stage consisted of analyzing the hydraulic capacity of identified existing sewers and characterized in the inventory of field works in accordance with the parameters set out in the document "HYDROLOGY, HYDRAULICS AND SUBSIDENCE DESIGN CRITERIA (CSH-4-VD-G-G-7000-0, CSH-5-VD-G-G-7000-1).

Based on this modeling, the structures with sufficient hydraulic capacity were identified and that given their location may be retained and the structures that must be replaced, according to the afferent flow associated with established return periods.

The analysis showed that for functional units 4 and 5, drainage works will be kept on one of the road sides and will be connected to the new ones using a box with drainage works defined for the projected lane as presented in the Table 7.50

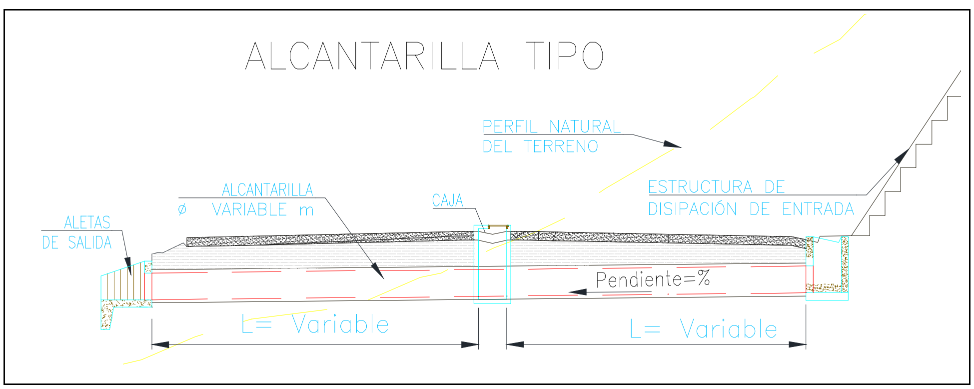


Figure 7.36 Sewer type

Source (Géminis Consultores Ambientales, 2016)

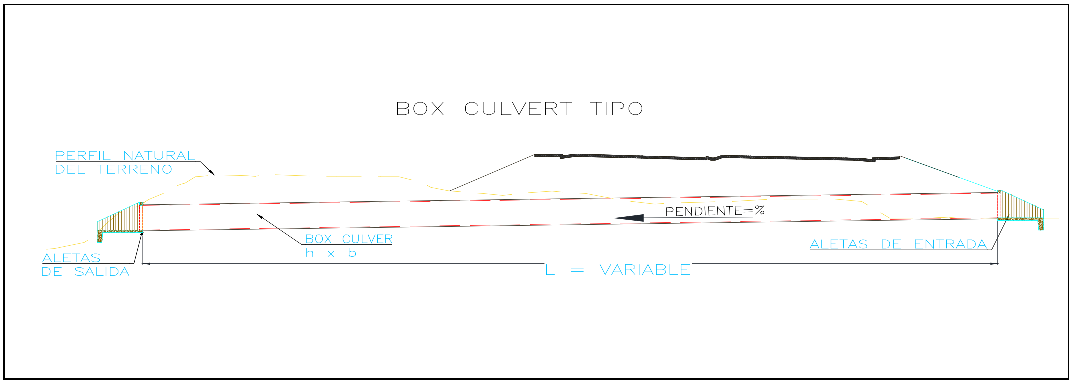


Figure 7.37 Box type

Source (Géminis Consultores Ambientales, 2016)

Table 7.451 Existing works that will be kept in existing lane and will extend in projected lane

UF	Basin	Abscissa	Work type	Existing lane (kept work)		Projected lane (new work)	
				Margin	Diameter (m)	Margin	Diameter (m)
4	30	4+770.03	Sewer	Left	0.6	Right	0.9
	62	10+844.28	Sewer	Left	0.6	Right	0.9
	63	10+938.58	Sewer	Left	0.6	Right	0.9
	64	11+038.24	Sewer	Left	0.6	Right	0.9
	65	11+169.28	Sewer	Left	0.6	Right	0.9
	66	11+274.59	Sewer	Left	0.6	Right	0.9
	67	11+357.37	Sewer	Left	0.6	Right	0.9
	68	11+436.90	Sewer	Left	0.6	Right	0.9
	69	11+516.07	Sewer	Left	0.6	Right	0.9

UF	Basin	Abscissa	Work type	Existing lane (kept work)		Projected lane (new work)	
	71	11+854 .32	Sewer	Left	0.6	Right	0.9
5	50	22+332 ,47	Sewer	Right	0,6	Right	0,9
	97	27+991 ,18	Sewer	Left	0,6	Right	0,9

Source: Consorcio SH

In addition, and due to the roadway projected, in the sections between the abscissas 12+630 to 14+200 UF4 and 19+036.20 to 19+864.19 UF 5, is located an encased section, drainage will be handled with crown ditches, the road ditch and the central ditch; to manage the drainage of the lane over the existing road, the drainage works that are presented in Table 7.52 and the Table 7.52 will be kept.

Table 7.462 Existing drainage works that will be kept on the existing lane and will not be extended to projected UF4 lane

Abscissa	Work type	Existing lane (kept work)	
		Margin	Diameter (m)
K12+630	Sewer	Left	0,6
K12+692	Sewer	Right	0,6
K12+771	Sewer	Right	0,6
K14+102	Sewer	Right	0,6
K14+200	Sewer	Right	0,6

Source: Consorcio SH

Table 7.53 Existing drainage works that will be kept on the existing lane and will not be extended to projected UF5 lane

Work number per inventory	Work type	Diameter (m)	Abscissa	Abscissa axis
197	Sewer	0.6	K19+43	Auxiliary
198	Sewer	0.6	K19+52	Auxiliary
200	Sewer	0.6	K19+67	Auxiliary

201	Sewer	0.6	K19+79	Auxiliary
306	Sewer	0.6	K28+87	Main
307	Sewer	0.6	K28+94	Main
308	Sewer	0.6	K29+07	Main
309	Sewer	0.6	K29+15	Main
310	Sewer	0.6	K29+24	Main
311	Sewer	0.6	K29+32	Main

Source: Consorcio SH

7.4.3 Preliminary designs of works

The designs of the works to build, temporality, construction procedures, hydraulic design of transit and the feasibility stage of the free edges and additional protection works were established for each of the riverbed occupation works, these can be analyzed in Annex 7. 4.2

- Projected Drainage

Hydraulic Analysis and sizing of new works

On the basis of the activities presented in the design criteria set out in document "HYDROLOGY, HYDRAULICS AND SUBSIDENCE DESIGN CRITERIA (CSH--VD-G-G-7000-0, CSH--VD-G-G-7000-1) and in the previous paragraphs, the sizing of drainage works was calculated. For the design a spreadsheet was used developed by INGETEC, which contains the recommendations, formulas, parameters and criteria presented in the technical paper Hydraulic Design Series Number 5 of the "United States Department of Transportation Services", the design is based on the analysis for the 2 of hydraulic control conditions (control at the inlet and control at the outlet), adopting as design diameter or height the highest HW result determine. This was done for sewers of up to 1.80 m.

Hydraulic analysis and sizing of major works

Works with dimension above diameter of 1.5 m and 1.8 m were designed using the free access software HY-8 Culvert hydraulic analysis, program developed by the *Federal Highway Administration of U.S. Department of Transportation*, taking into account that these sections due to flow conditions, may have high speeds inside and outside of the barrel; follows the results obtained for the major works that are projected in the functional units 4 and 5.

Table 7.53 and **Table 7.54** show the dissipation structures located on the cut slopes that deliver to a drainage work box per functional unit.

Table 7.474 Dissipation structures delivering to UF 4 box

BASIN	ABSSICISA
1	K0+035.26
3	K0+276.46
6	K0+807.11
7	K0+932.85
8	K1+112.92
9	K1+210.12
10	K1+334.56
11	K1+410.40
12	K1+496.11
13	K1+863.83
16	K2+264.10
17	K2+479.64
18	K2+680.64
22	K3+631.60
23	K3+837.20
24	K4+054.04
25	K4+232.90
27	K4+560.12
32	K5+189.11
33	K5+300.41
34	K5+486.83
35	K5+731.53
36	K5+922.81
42	K7+278.64
43	K7+417.95
44	K7+561.71

BASIN	ABSSICISA
45	K7+794.71
46	K7+952.26
47	K8+212.39
50	K8+843.38
52	K9+437.34
53	K9+522.83
54	K9+644.19
55	K9+767.18
56	K9+917.35
57	K9+967.92
73	K12+324.77
74	K12+508.01
75	K13+040.01
76	K13+284.01
77	K13+421.35
78	K13+862.38
79	K14+025.87
80	K14+234.35
81	K14+545.55
82	K14+628.45
83	K14+970.81
84	K15+132.25
85	K15+465.07
86	K15+642.87
87	K15+736.78

Source: Consorcio SH

Table 7.55 Dissipation structures delivering to UF 5 Box

BASIN	ABSSICISA	BASIN	ABSSICISA
1	K15+862.97	49	K25+017.77
2	K15+913.26	50	K25+153.57
3	K16+139.09	51	K25+278.75
5	K16+512.06	52	K25+374.73
7	K16+725.41	53	K25+476.87
9	K16+948.00	54	K25+594.87
10	K17+013.13	55	K25+738.61
15	K18+317.79	56	K25+819.02
16	K18+546.41	57	K25+996.51
17	K18+636.22	58	K26+078.42
19	K18+873.57	62	K26+456.45
23	K20+443.27	65	K27+015.86
24	K21+036.58	66	K27+255.95
25	K21+128.16	69	K27+669.79
26	K21+200.22	70	K27+729.29
27	K27+279.11	72	K27+989.69
28	K21+397.91	73	K28+070.41
29	K21+488.43	76	K28+424.47
30	K21+573.76	77	K28+559.21
31	K21+942.08	78	K28+676.63
32	K22+109.23	79	K28+777.45
34	K22+577.00	80	K29+683.03
36	K22+912.16	81	K29+898.39
40	K23+963.00	82	K30+059.53
41	K24+043.26	84	K30+304.14
42	K24+171.12	85	K30+476.40
43	K24+335.46	86	K30+617.71
44	K24+490.29	87	K30+685.57
45	K24+568.74	99	K32+161.33
46	K24+678.71	101	K32+353.72

BASIN	ABSSICISA	BASIN	ABSSICISA
47	K24+787.47	102	K32+433.45
48	K24+932.54	103	K32+525.91

Source: Consorcio SH

· Subdrainage

The objective of the subdrainage is to eliminate infiltrated water that could affect the road, in order to ensure the stability of the platform, the pavement structure and the slope of the road. The specific objectives are:

- Facilitate implementing the explanations during the construction phase of the road, since appropriate drainage allows circulation and the work of the machines and favors the possibility of using the excavated soils to construct embankments.
- Prevent saturation of the subgrade and pavement layers, increasing the carrying capacity, improving its response capacity and reducing the required pavement thickness
- Contribute to the stability of the slopes by the favorable orientation of the groundwater flow, the reduction of interstitial pressures and, consequently, the improvement of their geotechnical properties.

Basic Subdrainge functions

Subdrenaje systems must meet the following basic functions to minimize the impacts of internal water in highway projects:

- Lower the water table in the area of the road, on the slopes of the cuts and fills and in the foundations of the embankments and road structures.
- Intercept underground leaks to prevent water outcrops on the pavement.
- Drain the surface water that infiltrates pavement and containment structures.
- Collect the discharge from the different subdrainage systems.

- *Classes of subdrainages*

The subdrainage system elements are classified into two categories: 1) those that control infiltration and 2) those that control groundwater. The first are designed and built to intercept and remove water that enters the crown due to precipitation or surface flow, while the second is intended to lower the water table level and reduce the movement of water in the subgrade and pavement layers.

Longitudinal

This is placed in an essentially parallel direction to the road axis both horizontal and vertical. Formed by a trench of a certain depth, protection filter and, eventually, a manifold. The installation, specifically, water evacuation infiltrating into the pavement, is called side base drain or longitudinal drains, see Figure 7.38

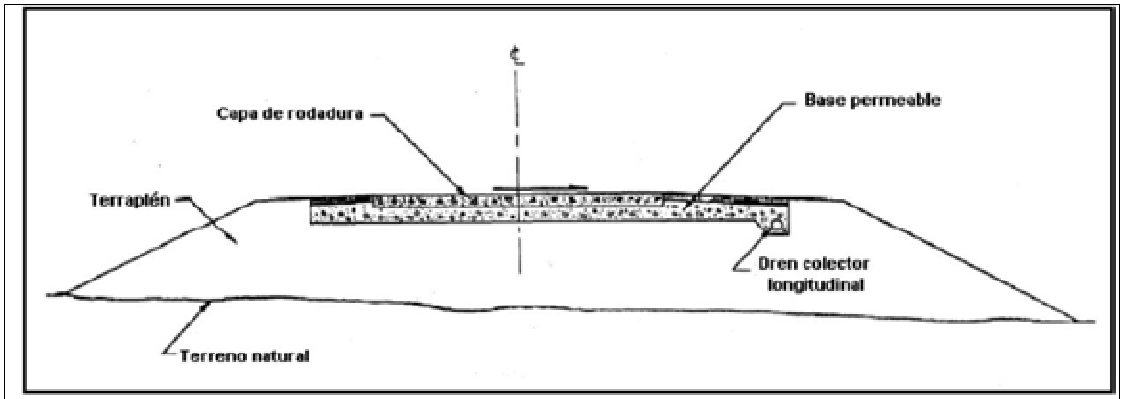


Figure 7.41 Longitudinal drain scheme
Source: Consorcio SH

- Transverse

These subdrains are those that cross the road from one side to the other. Usually the crossing is perpendicular, but it can be done transversally or even in a herringbone shape. The constitution of such drains is similar to the longitudinal drains: trench, manifold and protective filter. Transverse drains are used in pavement joints to drain groundwater infiltration and bases and sub-bases, see Figure 7.39

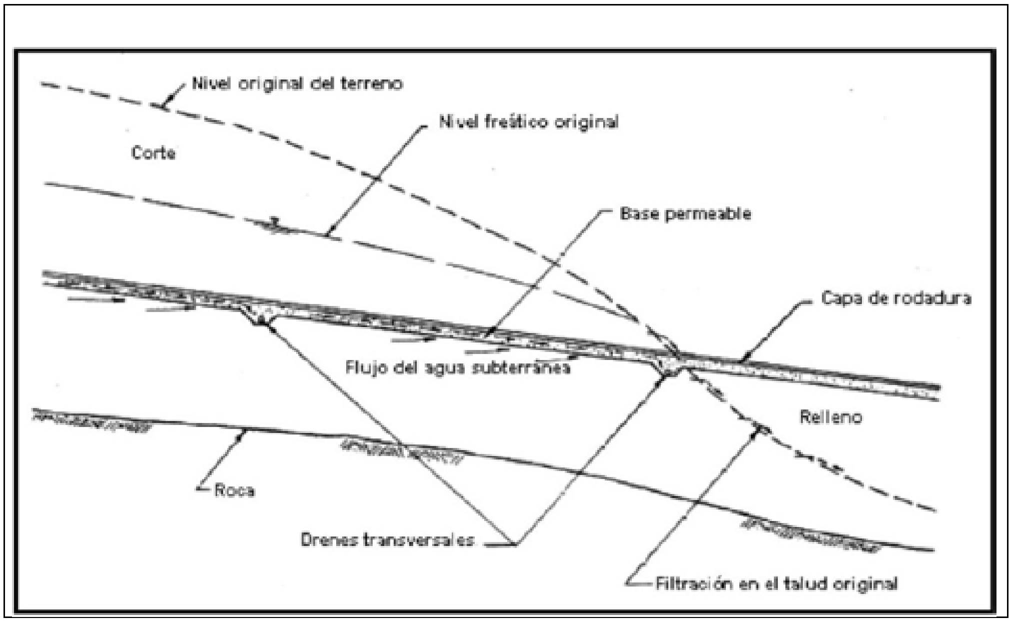


Figure7.42 Transvers drain on road in cut with perpendicular alignment to existing contour (profile)

Source: Consorcio SH

- Horizontal

Horizontal drains consist of small diameter pipes with small holes, which are installed with a slight upward tilt on cut slopes or embankments to drain water and relieve internal pressure from pores, looking for increased stability. One of the advantages of horizontal drains is their ability to drain water and / or abate pore pressures at depths inaccessible for other more conventional underdrain elements, see Figure 7.40

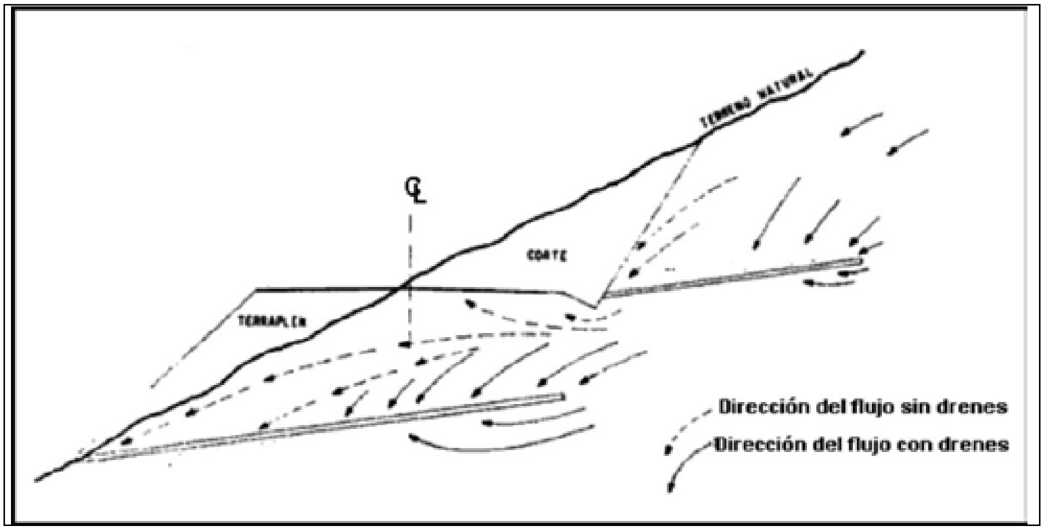


Figure 7.38 Horizontal drain in hillside cut
Source: Consorcio SH

Required information for subdrain designs

The data needed for the analysis and design of subdrains can be placed into four categories:

1. The geometry of the flow domain.
2. The properties of existing materials.
3. Climatological data.
4. Additional Information.

The geometry of the flow domain involves both the geometric design of the road and the prevailing subsurface conditions. She helps define the various problems associated with internal drainage and provides the boundary conditions governing their solution. The fundamental properties of materials allow their classification helps predict their behavior, particularly in relation to their water flow transmission capacity (permeability).

Climatological data offers the designer an idea of possible sources of subsurface water affecting the road. Given the latitude there the Republic of Colombia is, rainfall is the only climate aspect that is of interest when designing subsurface drainage.

The designer must consider other aspects that may have some impact on the subdrainage system design. For example, the impact the system can have on the prevailing groundwater regime and other design aspects, and the influence of the underdrain or lack of it on the sequence of road construction operations, etc.

In order to manage water infiltration and groundwater level in the pavement structure, longitudinal drains are used in road areas that are in box or in areas with mixed geometry on the cut side where needed; filters should be designed at the base of the slopes and the central separator. Proposed longitudinal drains are 0.50 x 0.70 m, underdrains with geotextile and granular material, covered with a NT2000 PAVCO or equivalent geotextile.

- Longitudinal drainage elements

Crown ditches are presented to handle the longitudinal drainage of the road, ditches located on the cu and, lateral berms and central separator, as shown in the typical section Figure 7.41

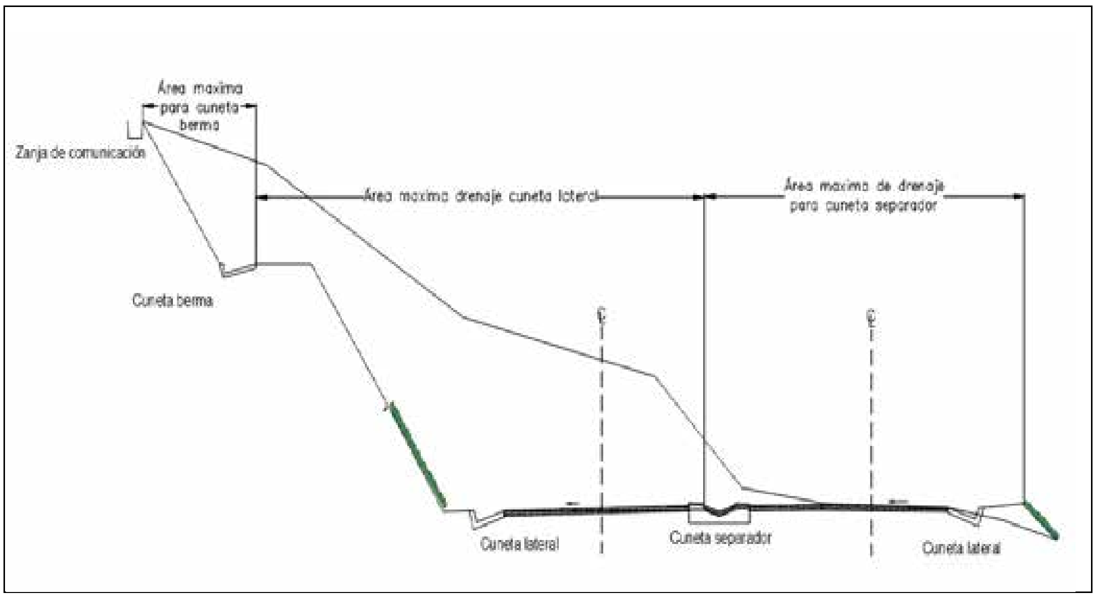


Figure 7.39 Longitudinal drainage elements
Source: Consorcio SH

- Ditches

Ditches are drainage structures that capture runoff water from the road platform and cut slopes, leading them longitudinally to ensure proper disposal. Ditches built on embankment areas also protect the edges of the berm and fill slopes from erosion caused by rain water.

For ditches in cut areas, the points are sewer collecting boxes and side exits to the natural terrain in a change of cut to embankment. In embankment ditches, water is disposed on natural ground through downcomers or relieves and in the central separator ditches, the waters are also conducted to the hopper of a sewer.

Ditches should be located in essentially all cuts, in those embankments susceptible to erosion and in all internal margin of a separator receiving rainwater from the roads.

- Crown ditches

Crown ditches are runoff interceptors in the upper cut slope or near the base of the slope, respectively. Crown ditches are used to intercept rainwater, preventing its passage through the slope, and must be located at least 3m from the edge of the cut slope.

It is usually recommended that crown ditches be fully waterproofed to prevent infiltrations that may affect the slope of the road. Crown ditches can be trapezoidal or rectangular and like ditches, the flow rate and size are estimated with the Manning method and rational expression for a section and a selected coating and a given topography.

Hydraulic operation

It is to verify that the hydraulic capacity of the structure, calculated with Manning's equation is higher than the design flow.

Equation 7-8 –

$$Q = \frac{1}{n}\left(AR^{2/3}S^{1/2}\right)$$

Where:

Q = Design flow rate in cubic meters per second (m3 / s), the design flow is calculated using the rational method.

n = Manning's roughness coefficient.

A = Wet area in square meters (m2). R: Hydraulic radius, in meters (m).

S = Slope, in meters per meter (m / m).

From Equation 7-9 the water surface and the speed in the section for the design flow can be obtained. The water layer should be less than or equal to the depth of the ditch and the speed should be, in turn, less than the maximum allowable for the material of the ditch, but greater than the rate that favors sedimentation and plant growth .

The maximum flow rate depends on the type of coating of the channel or ditch, for which the maximum speed recommendations (Chow, 2004) were adopted.

The definition of hydraulic capacity of ditches was performed, taking into account the areas of afferent drain; a design flow was established per meter for each type of structure and then the maximum length of ditch according to the longitudinal slopes defined.

- <u>Side ditch</u>

The ditch will be 0.20 m high, a surface width of 1.00 m; 0.9 m wide on the side of the road and a slope of 4.5 H: 1.0 V and o the cut slope the width will be 0.10 m and a slope of 1.0H: 2, 0V.

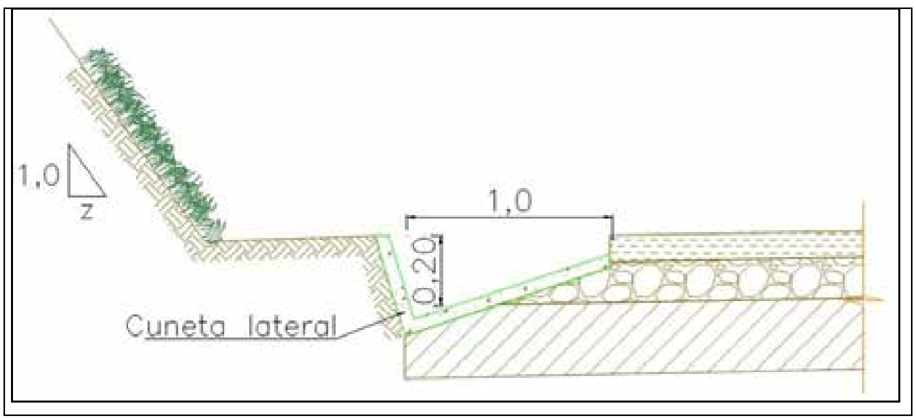


Figure 7.40 Side ditch
Source: Consorcio SH

To calculate the flow coefficients for runoffs of 0.9 and for the road and 0.5 for the cut area, the intensity was taken from the Imués and Sindagua stations for a return period of 10 years. Table 7.55 shows the variables used and the results of estimating the flow rate per linear meter.

Table 7.48 Design flow per lineal meter of side ditch

UF	Road C.	Cut C.	I Tr 10 (Mm / h)	Road A (m / m)	Cut A (m / m)	Qroad (m^3 / s / m)	Qcut (m^3 / s / m)	Qtotal (m^3 / s / m)
4	0.9	0.5	96.34	12.3	14	0.000296241	0.00018732	0.000483566
	0.9	0.5	72.31	12.3	14	0.00022235	0.00014060	0.00036295

Source: Consorcio SH

After obtaining the contribution flow rate per linear meter, the capacity of the concrete ditch for a range of longitudinal gradients of the road, ranging between 0.5% and 5% was estimated as shown in Table 7.57

Tabla 7.49 Maximum length in function of road slope

UF	Flow (m^3/s)	Slope (m/m)	Z1 1V :Z1H	Z2 1V :Z2H	n -	Yn (m)	Vel. (m/s)	Ditch length (m)
4	0.0992	0,0050	4,500	0,50	0,014	0,20	0.993	205.16
	0.1400	0,0100	4,500	0,50	0,014	0,20	1.404	289.53
	0.1712	0,0150	4,500	0,50	0,014	0,20	1.719	353.96
	0.1973	0,0200	4,500	0,50	0,014	0,20	1.984	408.05
	0.2410	0,0300	4,500	0,50	0,014	0,20	2.428	498.38
	0.2776	0,0400	4,500	0,50	0,014	0,20	2.802	574.09
	0.3141	0,0500	4,500	0,50	0,014	0,20	3.143	649.56
5	0,0993	0,0050	4,500	0,50	0,014	0,20	0,994	274
	0,1404	0,0100	4,500	0,50	0,014	0,20	1,405	387
	0,1720	0,0150	4,500	0,50	0,014	0,20	1,721	474
	0,1985	0,0200	4,500	0,50	0,014	0,20	1,987	547
	0,2431	0,0300	4,500	0,50	0,014	0,20	2,434	670
	0,2808	0,0400	4,500	0,50	0,014	0,20	2,810	774
	0,3139	0,0500	4,500	0,50	0,014	0,20	3,142	865

Source: Consorcio SH

The lengths obtained are more than 200 m, considering therefore that selected ditch is suitable for handling surface waters.

- *Central separator and berm ditch*

To size the gutters, the central spacer (Figure 7.46) and cut berms, the same analysis performed in the preceding paragraph was carried out, the size of these ditches were standardized with a height of 0.15 m, a surface width of 1.00 m and slope side 1, 0H: 3,33V. For purposes hydraulic verification, the analysis made for the central ditch separator is presented, considering that surface draining thereto is almost impermeable and therefore will have a higher amount of flow contribution.

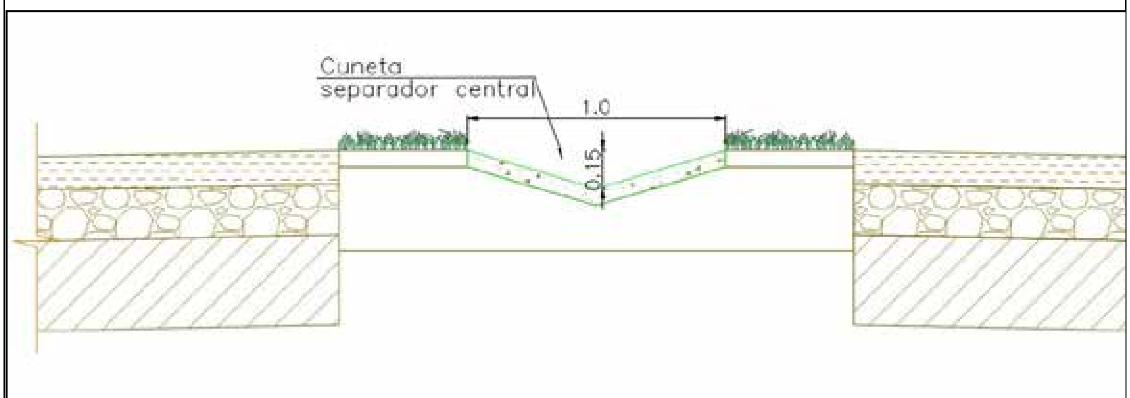


Figure 7.41 Central separator ditch
Source: Consorcio SH

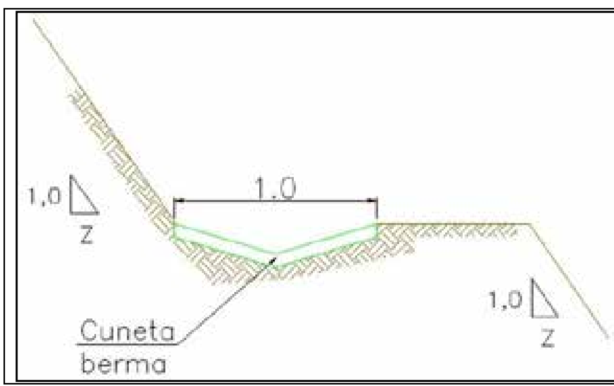


Figure 7.42 Cut berm ditch

Source: Consorcio SH

A runoff coefficient of 0.9 was used to calculate the flow and the intensity was taken from the Imues and Sindagua stations and for a return period of 10 years. Table 7.50 shows the variables used and the results of the flow estimation per linear meter.

Table 7.51 Design flow rate per central separator linear meter of ditch

UF	C Road	I Tr 10 (Mm/h)	Road A (m/m)	Road Q (m^3/s)
4	0.9	5.47	12.3	0.000296
5	0.9	72.3	12.3	0.0002224

After obtaining the contribution flow rate per linear meter, the capacity of the ditch was estimated in particular for a range of longitudinal road gradients, which vary between 0.5% and 5% as shown in Table 7.60

Table 7.52 Maximum ditch length in function of road slope

UF	Flow (m^3/s)	Slope (m/m)	Z1 1V : Z1H	Z2 1V : Z2H	N -	Yn (m)	V(m/s)	Ditch length ta (m)
4	0,0651	0,0050	3,330	3,33	0,014	0,15	0,86	216.37
	0,0920	0,0100	3,330	3,33	0,014	0,15	1,23	310.22
	0,1127	0,0150	3,330	3,33	0,014	0,15	1,51	379.58
	0,1302	0,0200	3,330	3,33	0,014	0,15	1,74	437.91
	0,1594	0,0300	3,330	3,33	0,014	0,15	2,13	535.44
	0,1841	0,0400	3,330	3,33	0,014	0,15	2,46	617.37
	0,2058	0,0500	3,330	3,33	0,014	0,15	2,75	689.32
5	0,0651	0,0050	3,330	3,33	0,014	0,15	0,87	179
	0,0920	0,0100	3,330	3,33	0,014	0,15	1,23	254
	0,1127	0,0150	3,330	3,33	0,014	0,15	1,51	311
	0,1302	0,0200	3,330	3,33	0,014	0,15	1,74	359
	0,1594	0,0300	3,330	3,33	0,014	0,15	2,13	439

U F	Flow (m^3/s)	Slope (m/m)	Z1 1V : Z1H	Z2 1V : Z2H	N -	Yn (m)	V(m /s)	Ditch length ta (m)
	0,1841	0,0400	3,330	3,33	0,014	0,15	2,46	507
	0,2058	0,0500	3,330	3,33	0,014	0,15	2,75	567

Source: Consorcio SH

The lengths obtained are more than 170 m, which is considered that selected ditch is suitable for handling both the separator's surface water and that of the cut slopes.

3.3.1.1 Crown ditches

Concrete crown ditches will have a base of 0.40 m, a height of 0.50 m and a surface width of 1.00 m; 0 and slopes on the side walls of 0.6H: 1.0V. See Figure 7.48.

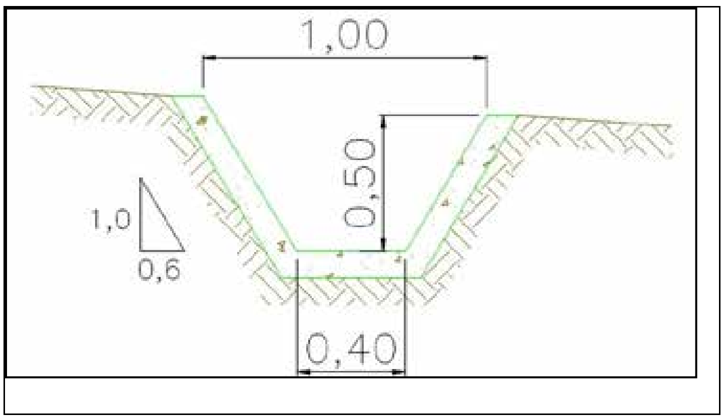


Figure 7.43 Crown ditches
Source: Consorcio SH

The function of proposed longitudinal slope (range 0.5 to 5%), material and geometry was estimated the hydraulic capacity of the crown ditch as shown in Table 7.61

Table 7.53 Hydraulic capacity of crown ditches.

UF	Flow (m3 / s)	Slope (m /	Base (m)	Z 1 1V:	Z 2 1V:	n -	Y (m)	V (M /
4	.6514	0.0050	0.40	0.60	0.60	0,014	0.50	1,860

	.9191	0.0100	0.40	0.60	0.60	0,014	0.50	2,629
	1.1270	0.0150	0.40	0.60	0.60	0,014	0.50	3,221
	1.3014	0.0200	0.40	0.60	0.60	0,014	0.50	3,720
	1.5932	0.0300	0.40	0.60	0.60	0,014	0.50	4,555
	1.8411	0.0400	0.40	0.60	0.60	0,014	0.50	5,261
	2.0567	0.0500	0.40	0.60	0.60	0,014	0.50	5,880
5	.6511	0.0050	0,400	0,600	0.60	0,014	0.50	1,860
	.9206	0.0100	0,400	0,600	0.60	0,014	0.50	2,630
	1.1275	0.0150	0,400	0,600	0.60	0,014	0.50	3,222
	1.3019	0.0200	0,400	0,600	0.60	0,014	0.50	3,720
	1.5945	0.0300	0,400	0,600	0.60	0,014	0.50	4,556
	1.8412	0.0400	0,400	0,600	0.60	0,014	0.50	5,261
	2.0585	0.0500	0,400	0,600	0.60	0,014	0.50	5,882

Source: Consorcio SH

Having obtained the hydraulic capacity for each slope and applied the rational method, the afferent drainage area that the crown ditch can evacuate was estimated, as presented in the drainage areas of crown ditches. See Table 7.62

Table 7.54 Drainage areas of crown ditches

UF	Slope (m / m)	Runoff coef.	Intensity (mm / h)	Drainage area (hec)	Flow (m3 / s)
4	0.0050	0,42	96.34	5.80	0.65
	0.0100	0,42	96.34	8.18	0,92
	0.0150	0,42	96.34	10.03	1,13
	0.0200	0,42	96.34	11.58	1.30
	0.0300	0,42	96.34	14.18	1,59
	0.0400	0,42	96.34	16.38	1,84
	0.0500	0,42	96.34	18.30	2,06
5	0.0050	0,42	72.31	7.72	0.65
	0.0100	0,42	72.31	10.91	0,92

	0.0150	0,42	72.31	13.36	1,13
	0.0200	0,42	72.31	15.43	1.30
	0.0300	0,42	72.31	18,90	1,59
	0.0400	0,42	72.31	21,82	1,84
	0.0500	0,42	72.31	24,40	2,06

Source: Consorcio SH

· <u>Additional works</u>

- *Dissipation structures*

The purpose of such work is to protect cut slopes and embankments against erosion, for this purpose three types of dissipation structures in the cuts were designed; the first in cases where the delivery is made to sewers inlet (Figure 7.44), the second when delivery is made directly to the side of the road, as shown in Figure 7.50 and the third when the dissipation structure is in the outlet see Figure 3-13.

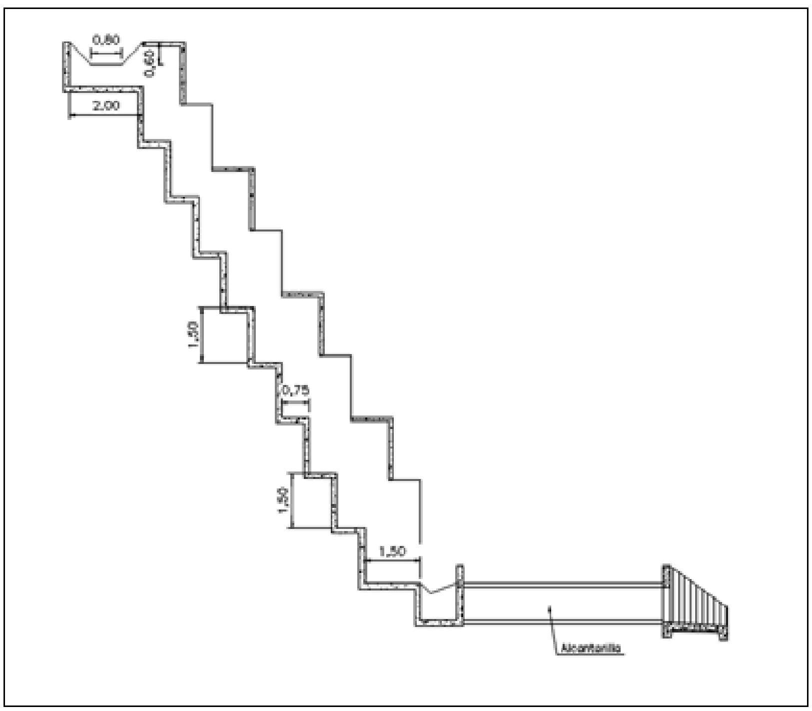


Figure 7.50 Dissipation structure with inlet box culvert
Source: Consorcio SH

Figure 7.51 shows dissipation structures located on cut slopes and delivered to the drainage work box per functional unit.

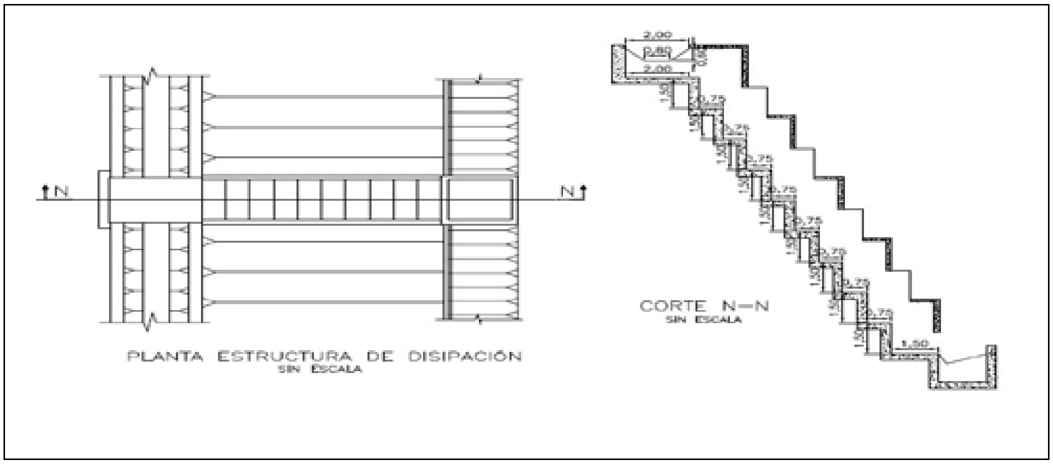


Figure 7.45 Dissipation structure delivering to ditch

Source: Consorcio SH

Table 7.63 shows dissipation structures located in cut slopes and delivering to side ditch.

Table 7.55 Dissipation structures delivering to ditch

UF	BASIN	ABSCISSA
4	3	K0 + 180.00
	3	K0 + 400.00
	8	K1 + 157.00
	35	K5 + 774.00
	50	K8 + 890.00
	57	K10 + 060.00
	74	K12 + 563.00
5	1	K15 + 800.00
	81	K29 + 514.00

Source: Consorcio SH

To protect embankments a dissipation structure similar to that of the cuts was projected but with a different geometry due to the difference in slope. Figure 7.52 shows this type of structure.

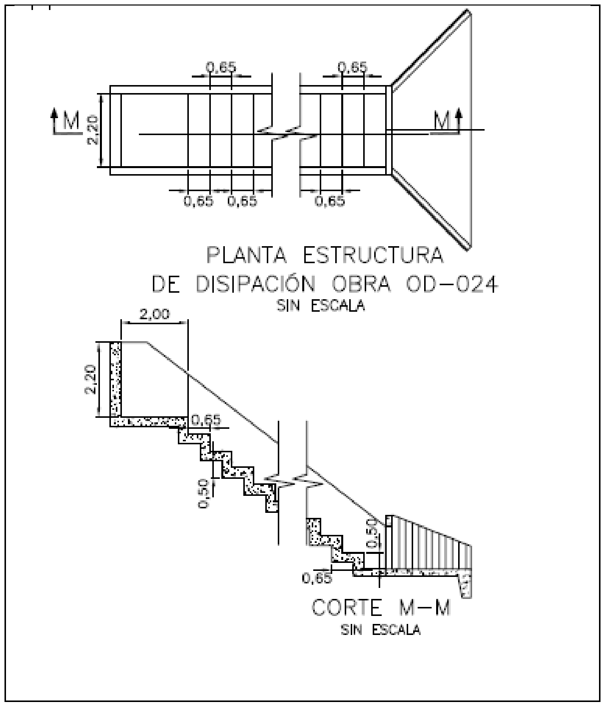


Figure 7.46 Dissipation structure to outlet
Source: Consorcio SH

Table 7.64 shows dissipation structures located over the fills.

Table 7.56 Dissipation structures delivering to the outlet

UF	BASIN	ABSCISSA
4	14	K1 + 863.83
	20	K3 + 094.55
	22	K3 + 416.27

UF	BASIN	ABSCISSA
	50	K8 + 651.84
	51	K8 + 843.38
	52	K9 + 079.36
	53	K9 + 437.34
	54	K9 + 522.67
	55	K9 + 644.19
	57	K9 + 917.35
	58	K9 + 967.92
	70	K11 + 595.18
	75	K12 + 508.01
5	4	K16 + 237.50
	21	K19 + 938.92
	36	K22 + 912.16
	40	K23 + 962.46
	41	K24 + 043.26
	42	K24 + 171.12

UF	BASIN	ABSCISSA
	85	K30 + 476.40

Source: Consorcio SH

The geometry and configuration of dissipation structures at the inlet and outlet of the drainage works presented in drawings CSH-4-PL-OD-G-7002 and CSH-5-PL-OD-G-7007 - Typical Drainage Details - Sizing.

7.5. Forestry use

In line with Decree 1791 of 1996 and Decree 1076 of 2015 "Whereby the Single Regulatory Decree of the Environment and Sustainable Development Sector is issued", the environmental authority is the entity that issues the authorization to use a forest isolated or trees located on private land or public property, either planted forest or natural forest by three types of logging: unique, persistent and domestic.

In this order of ideas, the proposed Rumichaca-Pasto the dual carriageway construction project, Pedregal-Catambuco section, requires a sole forestry use, which will take place only once for areas where forest type vegetation was identified.

Accordingly, the logging permit is requested for forestry individuals located within the line of chamfers and right of way (which comprises the area forming the roadway, construction sites of bridges, viaducts, returns, separators, ditches, toll, CCO), ZODME locations and their access, camps and plants and surface water uptake points.

Quantity and surface works and / or constructive project activities related to forestry.

The total project intervention area includes 485,48ha related to specific road construction sites, right of way, and associated infrastructure. In this area, 123,69ha correspond to 33 ZODME excavation material storage areas and 6.76 ha to 2 camp areas.

As shown in Table 7.65, the highest percentage is occupied by Zodme areas (24 of the 33 have tree vegetation) with 50.42% of the area to be used, followed by road areas with 46.82% of the total area and finally the camp areas, which are only two in the Pedregal-Catambuco section. See map EIADCRP_PC_035 (scale 1: 25,000).

Table 7.575 Forestry related infrastructure works

Type of infrastructure	Total area (ha)	Occupied percent (%)
ZODME areas	123.69	50.42
* Associated infrastructure	6.76	2.76
Roads **	114.87	46.82
Total	245.32	100

* Camps. ** Includes the area inside the chamfers line and punctual infrastructure (occupation of rivers, bridges, viaducts, returns, separators, ditches, toll, CCO) and roads associated with the second road to be built (right of way, access to: Zodmes, camps, uptake points, worksites)
Source: Gemini Environmental Consultants, 2016.

To calculate forest volume to be used, only the area located in ecosystems with total or partial presence of tree stands and / or trees was taken into account. For mosaics, crops and grazing cover areas only the effective area, i.e., only the areas with presence of trees were considered.

The estimated cartographically areas with presence of grouped trees or woodlands and individual trees are:

Table 7.58 Areas by ecosystem

Ecosystem		Area occupied by woodlands or grouped forest (ha)	Area occupied by scattered trees (ha)
Code	Cover (Level 3)		
202.4.2	Mosaic of pasture and crops of the high Andes orobioma environment	14.86	0.23
202.2.4	Agroforestry crops of the high Andes orobioma environment	7.23	0.13
		1.27	0.02
	Agroforestry crops of the high Andes orobioma environment	2,51	0.05
212.4.2	Mosaic of pasture and crops of the high Andes orobioma environment	15,99	0.33
203.1.4	Riparian forest of the middle Andes orobioma environment	2.07	-
203.1.5	Plantations of the middle Andes orobioma environment	2,14	-
213.1.4	Riparian forest of the high Andes orobioma	0.11	-

	environment		
213.1.5	Plantations of the high Andes orobioma environment	0,34	-
Total		**46.518**	**0,76**

Source: Gemini Environmental Consultants, 2016.

From the area indicated in above table, calculations and estimates of forest harvesting on ecosystems where sampling was performed were made.

Moreover, it should be noted that for the ZODME, 100% inventories and respective calculations of the sites with timberline are included. Those located where there is presence of forest elements are not included in this logging request.

7.5.1 Type of sampling

Resolution 0751 of 2015 whereby the terms of reference for preparation of the EIA are adopted, states in paragraph 7.5 logging, when a sole forestry use permit is requested the following information must be submitted:

> *Forest inventory of individuals present in each vegetation cover, using a statistical sampling to meet a sampling error not exceeding 15% and a likelihood of 95%.*

- Methodology

The forest use calculation was performed by sampling and a 100%inventory whose scope is shown below. This methodology is detailed in section 2.3.2.2 of Chapter 2 in the section entitled "Methodology for calculating Forest Use".

The number of sample plots was defined based on a pre-sampling that used as a reference a minimum of two plots per cover (Annex 7.5.8).

Given that in the intervention area the forestry component is not only present in natural and planted forests as a unit of cover, but also planted trees that are part of agricultural and livestock areas; the latter was sampled in order to characterize the vegetation, the pre-sampling for this particular case was made taking as forest area the sum of the woodlands. This process is carried out within the area of intervention.

Moreover, scattered trees and grasses in crops were estimated, calculating the area through satellite images (sum of total area occupied by scattered trees and grasses in the Mosaic cover of crops and grasses (2.4.2), grasses and trees planted (2.2.4.1) and crops and trees planted (2.2.4.2) and summing these volumes to the total ecosystem.

The volume obtained was extrapolated to the entire area of the ecosystem in regard the percentage of existing vegetation, taking into account the guidelines of this Corine Land Cover methodology adapted to Colombia.

According to the aforesaid, a stratified random sampling was made with samples taken by vegetation cover susceptible to intervention and their location was randomly selected within the area delimited by chamfers.

Calculation of forest use of accesses to ZODMES, camps, uptakes and occupation of channels, is included within the sampling area evaluated.

Meanwhile, for ZODMES and camp sites, a 100% inventory was made, given that these are smaller areas where the presence of scattered and dispersed forest elements facilitated obtaining the information for all of them. ((See Annex 7.5.1 *Inventory intervention Pedregal-Catambuco*) See Annex 7.5.2 *Inventory Zodme at 100% Pedregal-Catambuco* and 7.5.3 *inventory camps at 100% Pedregal - Catambuco*)

All information gathered in the field was recorded in the flora sampling formats (Annex 7.5.5a and 7.5.5b inventory by plots, 7.5.6 inventory at 100% in ZODMES).

- Results

According to the pre-sampling results included in Annex 7.5.8 (that also includes the sampling error estimate), the information gathering of sample plots was carried out at the sites listed in Table 7.65.

Table 7.59. Plots by ecosystem, Rumichaca-Pasto road Project, Pedregal- Catambuco section intervention area

COVER	ID	Sector	PK	Magna Sirgas planar coordinates Origen West	
				X	Y
Orobioma medio de los andes					
Mosaic grasses and crops	4- 2.4.2-PP2	Inantas bajo (Yacuanquer)	4+600	960310,763	608304,167
	5- 2.4.2-PP1	Chávez (Tangua)	18+200	966212,29	614562,16
Grasses and planted trees	4-2.2.4.1-PP1	El tablón (Tangua)	7+700	961401,68	609630,965
	4-2.2.4.1-PP2	San Pedro (Tangua)	10+500	962282,377	611288,299
Crops and planted trees	4-2.2.4.2-PP1	El Pedregal (Imués)	0+800	957403,1945	607415,582
	4- 2.2.4.2-PP2	Inantas bajo (Yacuanquer)	3+800	959464,8592	608293,2075
Riparian Forest	4- 3.1.4-PP3	Inantas bajo (Yacuanquer)	6+300	961012,108	609509,374
	4- 3.1.4-PP4	Inantas bajo (Yacuanquer)	6+500	961012,131	609708,412
Forest plantation	4-3.1.5-PP1	El Vergel (Tangua)	12+700	963639,1673	612527,8236
	4-3.1.5-PP2	El Cebadal	15+600	966065,6034	613235,2568
High Andes Orobioma					
Mosaic of grasses and crops	5-2.4.2-PP4	Vocational (Grass)	29+300	972933,8695	618176,75
	5- 2.4.2-PP5	Vocational (Grass)	29+600	973193,5797	618318,02
	5-2.4.2-PP6	La Merced (Grass)	30+970	974334,445	618886,1457
	5- 2.4.2-PP7	La Merced (Grass)	31+150	974417,9201	619042,8001
Grasses and planted trees	2.2.4.1-PP2	El Tambor (Tangua)	22+100	967606,7802	616088,5799
	2.2.4.1-PP3	La Palizada (Tangua)	27+200	970961,4328	618809,6963
	2.2.4.1-PP4	Catambuco (Grass)	31+800	974968,2494	619359,13
Forest plantation	3.1.5-PP1	El Páramo (Tangua)	26+700	969393,8648	617226,73
	3.1.5-PP2	El Páramo (Tangua)	24+800	969371,6071	617248,83

COVER	ID	Sector	PK	Magna Sirgas planar coordinates Origen West	
				X	Y
Riparian Forest	5-323-PP1-AI	Vocational (Grass)	29+500	973200,816	618257,906
	5-323-PP2-AI	Vocational (Grass)	29+600	973212,553	618268,822
	5-323-PP3-AI	Vocational (Grass)	29+700	973279,825	618314,391

Source: Géminis Consultores Ambientales, 2016.

Follows the list of the sampling results by vegetation and ecosystem, according to the data obtained in aforementioned plots (See Annex 7.5.5b 7.5.5a and field formats medium and high Andes orobioma).

7.5.2. Total and commercial volume

The formula used to determine the total and commercial volume of established plots, corresponds to the following: V = AB (m ^ 2) * H (m) * Ff * N

Where:
AB = π / 4 * (DAP) ^ 2
H = Total height or commercial Height
Ff = Form Factor (0.7)
N = Number of stemwood

Applying this parameter is very important to obtain the forest use volume requested, where the diameter, height and form factor (0.7 in this case) values determine the results.

7.5.2.1 Inventory by cover and ecosystem in the intervention area.

To obtain the volume of wood to be requested for forest use, only the individuals recognized as timber were recognized, i.e., fruit trees were excluded.

This in accordance with Article 72 of Decree 1791 of 1996 (Forestry use request), which quotes verbatim: "*agricultural crops or fruit trees with woody characteristics may be used to obtain forest products, in which case only a safe conduct is required to mobilize* them. "

Fruit tree species not included in the inventory are Persea americana Mill. (Avocado), Citrus sinensis (L.) Osbeck (orange), Citrus reticulata Blanco (Mandarin), Psidium guajava L. (guava), Citrus limon (L.) Osbeck (Lemon), Inga spectabilis (Vahl) Willd. (Guabo), loquat (Thunb.) Lindl. (Loquat), Annona cherimola (Chirimoya) and Spondias mombin L. (Ovo).

In the area of project intervention, nine (9) ecosystems were identified that have the tree component, five of which correspond to mosaics or agroforestry crops for the latter two, the calculation was performed taking into account only the area of the patches occupied by timberline, as mentioned above in the pre-sampling and sampling calculation procedure.

In the sum of the volumes of the area called "Roads" used to calculate total and commercial volume, the grassland woodlands medium Andes orobioma ecosystem was not considered since this was only found in the Zodme (area Z4- 4) whose volume is listed in separate document of these areas. (See Annex 7.5.2. Zodme 100% Inventory)

- Mosaic of grasses and crops middle Andes orobioma (20242)

The species representing the highest volume in comparison is the Eucalyptus globulus Labill (Eucalyptus) with 6,70m3 (Total volume) because this is the most abundant species in fustal state in the ecosystem. In most cases it was observed that this species is located mainly in live fences to delimit land and pastures.

Table 7.66 and its figure show the volumes for the fustal stratum of the mosaic grasses and crops ecosystem middle Andes orobioma for a total of 7,512m3, of which 5,087m3 correspond to the commercial volume in the sampled area.

Table 7.608. Total and commercial forest volume in mosaic grass and crops middle Andes orobioma ecosystem

No.	Common name	Scientific name	Total volume (m3)	Commercial volume (m3)
1	Eucalyptus	*Eucalyptus globulus*Labill.	6,699	4,453
2	Maco	*oblongifoliola Cabralea*C.DC.	0.419	0.350
3	Quillotocto	*Tecoma stans (*L.) Juss. ex Kunth	0.248	0.163
4	Urapan	*Fraxinus chinensis*Roxb.	0.147	0.120
Total			**7,512**	**5,087**

Source: Gemini Environmental Consultants, 2016.

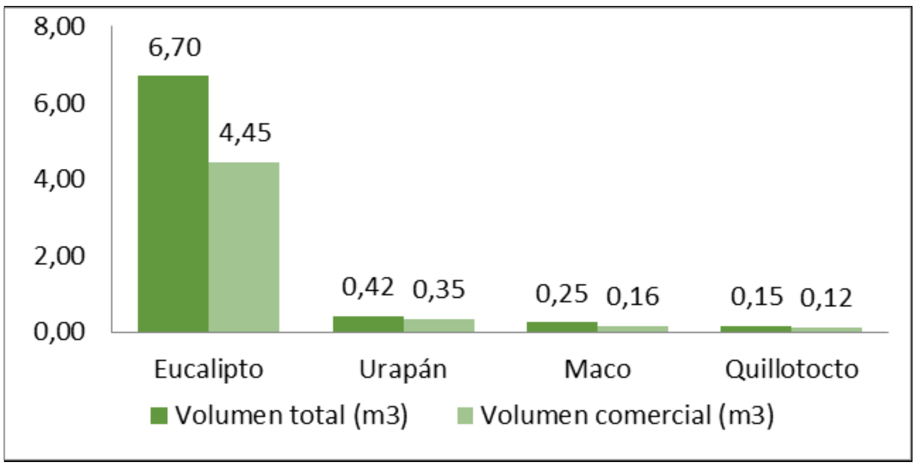


Figure 7.47. Total and commercial forest volume in mosaic grass and crops middle Andes orobioma ecosystem

Source: Gemini Environmental Consultants, 2016.

Given the above, an average total volume of 37,561m3 per hectare and an average commercial volume of 25,434 m3 per hectare were estimated.

- Grasses and trees planted from the middle Andes orobioma (202241)

The total sample volume for each species for the grasses and trees planted of the middle Andes orobioma ecosystem was determined as shown in Table 7.67; the species with the highest total and commercial volume was globulus Labill Eucalyptus (Eucalyptus) with 4,289m3 (Total) and 2,962m3 (commercial), other species found showed volumes below 1 m3.

For the total species, a total volume of 9,224m3 was determined, of which 6,040m3 correspond to leverage trade volume. As observed, the values of volume in these mosaics are not very high, this is because the tree species found in pastures and planted trees in the middle Andes orobioma ecosystem, are mostly planted not for commercial purposes but to be used as living fences, ornamental and domestic use, reason why there is no proper forestry management that allows optimal development of forest species for forestry use.

Table 7.61. Forest volume by species in grasses and trees planted middle Andes orobioma (202241) ecosystem

No.	Common name	Scientific name	Total volume (m3)	Commercial volume (m3)
1	Eucalyptus	*Eucalyptus globulus*	4,289	2,962
2	Guayacán	*Lafoensia speciosa*	2,676	1,731
3	Caspirosario	*Llagunoa nitida*Ruiz & Pav	0.079	0.056
4	Cucharo	*Myrsine guianensis*	0.603	0.331
6	Pichuelo	*Senna spectabilis*	1,465	0.904
7	Quillotocto	*Tecoma stans*	0.111	0.056
Total			**9,224**	**6,040**

Source: Gemini Environmental Consultants, 2016.

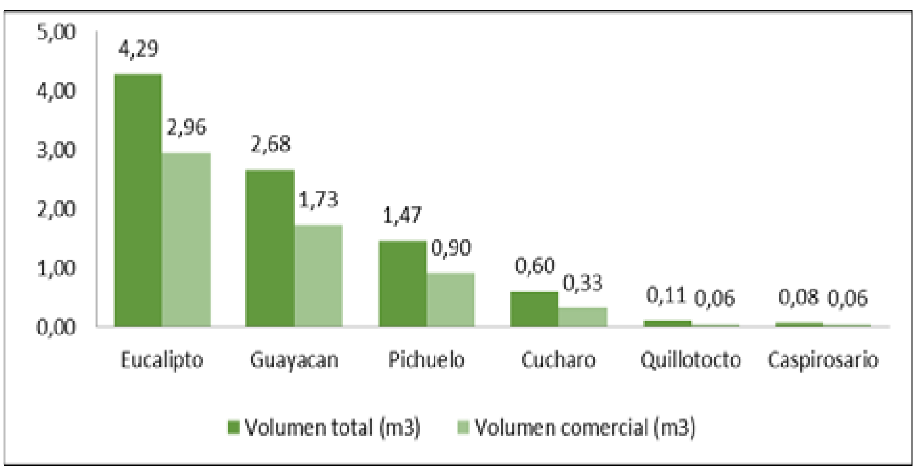


Figure 7.48. Forest volume by species in grasses and trees planted middle Andes orobioma ecosystem

Source. Gemini Environmental Consultants, 2016

Given the above an average total volume of 46.120 m3 per hectare and an average commercial volume per hectare of 30,2199m3 were estimated.

- Crops and trees planted of the middle Andes orobioma (202,242)

Sampled fustals in the crops and trees planted of the middle Andes orobioma ecosystem, add up to a total of 1,107m3 of harvestable timber and 2,632m3 of total volume (Table 7.70), this low volume is because this cover has crops as productive activity, growth of the species is controlled and there is also a number of fruit species, which do not add to requested volume use.

Table 7.70. Forest volume by species in crops and trees planted middle Andes orobioma ecosystem

No.	Common name	Scientific name	Total volume (m3)	Trade volume (m3)
1	Carbonero	*Albizia carbonaria Britton*	0.103	0.039
2	Casco de vaca	*Bauhinia Pictish*(Kunth) DC	0.040	0.011
3	Cedar	*Cedrela odorata L.*	0.541	0.203
4	Gualanday	*Jacaranda cuspidifolia*Mart.	0.239	0.106
5	Guayacan	*Lafoensia acuminata (Ruiz & Pav.) DC.*	0.939	0.262
6	Higuerilla	*Ricinus communis L.*	0.035	0,005
7	Pichuelo	*Senna spectabilis* (DC.) H.S.Irwin & Barneby	0.040	0.010
8	Urapan	*Fraxinus chinensis*Roxb.	0.696	0.471
Total			**2,632**	**1,107**

Source. Gemini Environmental Consultants, 2016

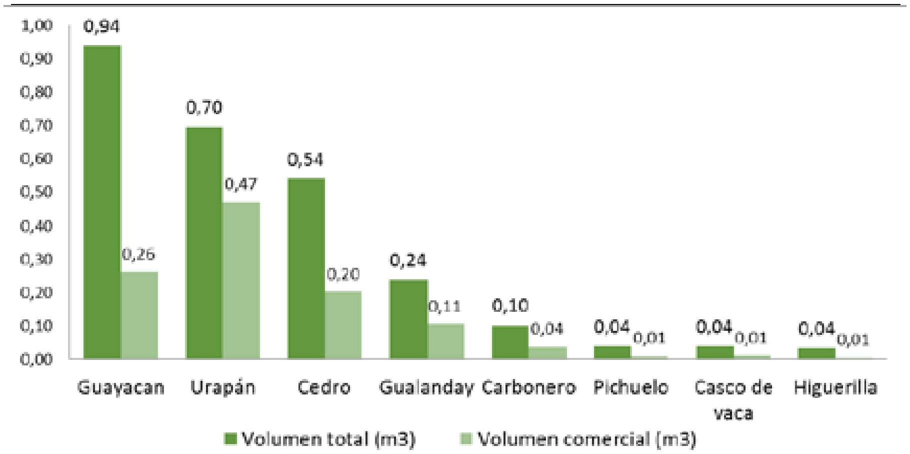


Figure 7.49. Forest volume by species, in gallery and riparian forests middle Andes orobioma ecosystem

Source: Gemini Environmental Consultants, 2016.

Given the above an average total volume of 13,160 m3 per hectare and an average commercial volume per hectare of 5,535m3 were estimated.

- Riparian and gallery forest from the middle Andes orobioma (20314)

As shown in Table 7.69, the only species with input volume for the sample taken in the gallery or riparian forest ecosystem of the middle Andes orobioma, is the *Fraxinus chinensis*Roxb (Urapan) with 24,34m3 total volume and 10,76m3 of commercial volume, reflecting a possible enrichment of the forest with planted species, since this is an introduced species that is not representative of natural forests in the area.

The species listed in forest use of this ecosystem differ from those found in area of influence characterization, this is because the characterization sampling was carried out taking into account the characteristic vegetation of this ecosystem in the area, therefore samples were taken in places that explain the natural ecosystem associated with water bodies located in the area of influence of the project. However, by placing the samples to calculate logging inside the intervention area, the predominance of sectors encompassed by orchards and foreign timber and / or introduced from farms neighboring the road was found.

Table 7.71. Forest volume by species in the forest and riparian gallery middle orobioma Andes ecosystem

No.	Common name	Scientific name	Total volume (m3)	Commercial volume (m3)
1	Urapan	*Fraxinus chinensis*Roxb.	24.34	10.76
Total			**24.34**	**10.76**

Source. Gemini Environmental Consultants, 2016.

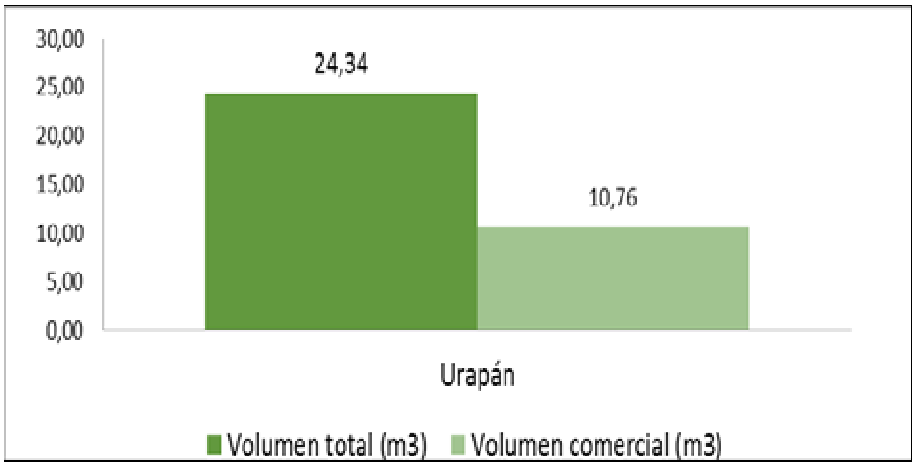


Figure 7.506 Forest volume by species in the forest and riparian gallery orobioma middle Andes ecosystem

Source: Gemini Environmental Consultants, 2016.

Given the above, the average total volume per hectare of 121,70m3 and an average commercial volume per hectare it 53,80m3 were estimated.

- Forest plantation of the middle Andes orobioma (20315)

It was determined that the highest volume timber in the sample taken was contributed by *Eucalyptus globulus* Labill (Eucalyptus) with a total volume of 23,24m3 and a commercial volume of 14,89m3 and Pinus patula Schiede ex Schltdl. & Cham (Pino) with a total volume of 1,29m3 and 0,82m3 commercial.

For the study a total volume of 24,529m3 and a commercial volume of 15,716m3 were obtained. The potentially useful net volume of roundwood, with respect to the total volume, shows a wide difference, mainly because in the intervention area most trees found they did not have proper forestry management making them harvestable timber, but are mostly in unproductive land without great care by the farmer. (See Table 7.72)

Table 7.622 Forest volume by species in the forest plantation middle Andes orobioma ecosystem

No	Common name	Scientific name	Total volume (m3)	Commercial volume (m3)
1	Eucalyptus	*Eucalyptus globulus*Labill.	23,238	14,893
2	Pine tree	*Pinus patula*Schiede ex Schltdl. & Cham.	1,291	0.823
Total			**24.53**	**15.71**

Source: Gemini Environmental Consultants, 2016.

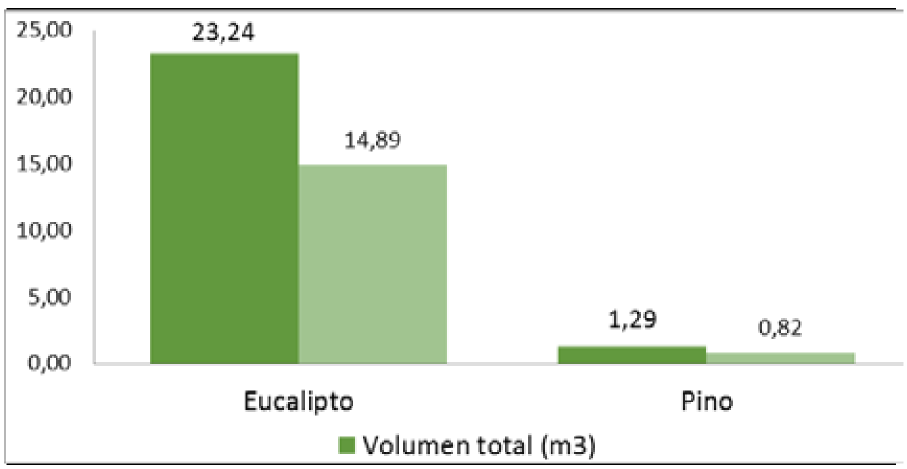


Figure 7.517. Forest volume by species in the forest plantation middle Andes orobioma ecosystem

Source: Gemini Environmental Consultants, 2016.

Given the above the average total volume per hectare of 122,647m3 and an average commercial volume of 78.582 m3 per hectare were estimated.

- Mosaic grasses and crops high Andes orobioma (21242)

As indicated by Figure 7.58 the species with the greatest volume contribution in this ecosystem is the Eucalyptus globulus Labil. (Eucalyptus) with 5,622m3 of harvestable timber, and the species with the lowest value is *Baccharis latifolia (Ruiz & Pav.)*

Pers.(Chilca) with 0,092m3, that, although not a timber species, individuals with CAP established for fustals were found, this high contrast is because the first is an introduced species of rapid growth and characteristics of timber, while the second is a smaller size kind.

Table 7.71 shows for the sample taken in the intervention area mosaic grasses and crops ecosystem from the high Andes orobioma; the commercial volume corresponds to 9,19m3, being a low value compared to the total volume of 19.68m3. This is presumably because most fustals found in the study area have been planted for dendrological harvesting, hedgerows, or have grown by natural propagation; and therefore they have not undergone technical management to avoid growth, inclined, without low and / or bifurcated branches.

Table 7.63 Volume per species in the mosaic pastures and crops high Andes orobioma ecosystem

No,	Common name	Scientific name	Total volume (m3)	Commercial volume (m3)
1	Japanese Acacia	*Acacia melanoxylon*R.Br.	3,088	1,487
2	Chilca	*Baccharis latifolia*(Ruiz & Pav.) Pers.	0.186	0.092
3	Cipré	*Cupressus lusitanica*Mill.	0.261	0.145
4	Eucalyptus	*Eucalyptus globulus*Labill.	10,841	5,622
5	Jazmin huesito	*Pittosporum undulatum*Vent.	0.239	0.107
6	Moquillo	*Saurauia ursina*Triana & Planch.	0.284	0.118
7	Mote	*Saurauia bullosa*Wawra	0.243	0.096
8	Pino	*Pinus patula*Schiede ex Schltdl. & Cham.	4,539	1,525
Total			**19.681**	**9,192**

Source: Gemini Environmental Consultants, 2016.

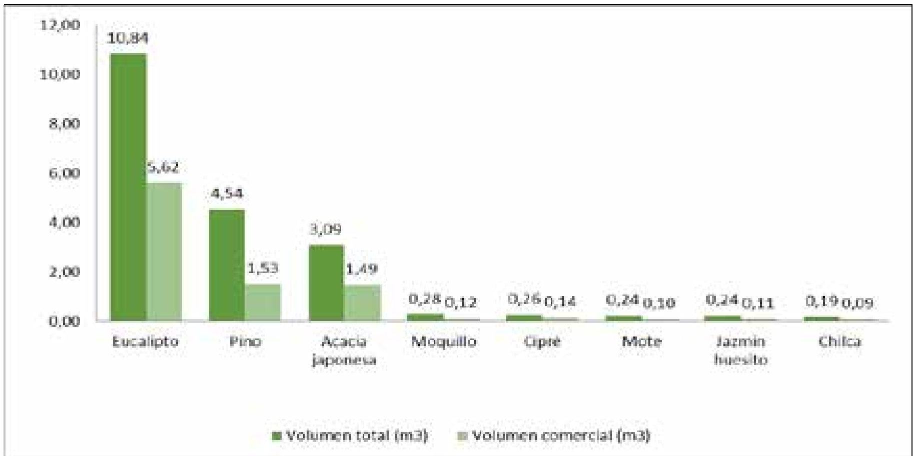


Figure 7.528. Volume per species in the mosaic pastures and crops high Andes orobioma ecosystem

Source: Gemini Environmental Consultants, 2016.

Given the above an average total volume of 49,202m3 per hectare and an average commercial volume per hectare of 22,980m3 were estimated

- Grasses and trees planted from the high Andes orobioma (212241)

The total volume for each species for Pastures and trees planted from the high Andes orobioma ecosystem was determined, as shown in Figure 7.56 the species *Cupressus lusitanica* (Cipro) is the species with the larges exploitable volume with a total volume of 19,875m3 and a trade volume of 4,923m3.

For the study a total volume of 19,68m3 and a commercial volume of 9,19m3 were obtained (Table 7.72). The net volume potentially useful of round wood, with commercial volume, with respect to the total volume shows a wide difference, mainly because in the intervention area most trees found did not have proper forestry management to make them harvestable timber but are found mostly in live fences and around houses.

Table 7.64 Forest volume by species in the pastures and planted trees high Andes orobioma ecosystem

No.	Common name	Scientific name	Total volume (m3)	Commercial volume (m3)
1	Japanese Acacia	*Acacia melanoxylon*	0.719	0.347

No.	Common name	Scientific name	Total volume (m3)	Commercial volume (m3)
2	Alder	*Alnus acuminata*	0.545	0.336
3	Yellow	*Miconia nodosa*	0260	0.125
4	Cedrillo	*Phyllanthus salviifolius*	0.348	0.278
5	Cipré	Cupressus lusitanica	19,875	4,923
6	Colla	*dendrophorbium lloense*	0.456	0.232
7	Cujaco	*Solanum ovalifolium*	0.257	0.143
8	Eucalyptus	Eucalyptus globulus	6,568	4,339
9	Lechero	*Euphorbia laurifolia*	0.535	0.321
10	Majua	*Palicoureasp*	0.172	0.095
11	Moquillo	*Saurauia ursina*Triana & Planch.	0.662	0.404
12	Roso	*Miconia thaezans*	0.046	0.029
13	Elder	*Sambucus nigra*	0.080	0.037
14	Urapan	*Fraxinus chinensis*	0.499	0.294
15	Uvilan	*Monnina aestuans*	0,025	0,000
Total			**31.047**	**11,902**

Source: Gemini Environmental Consultants, 2016.

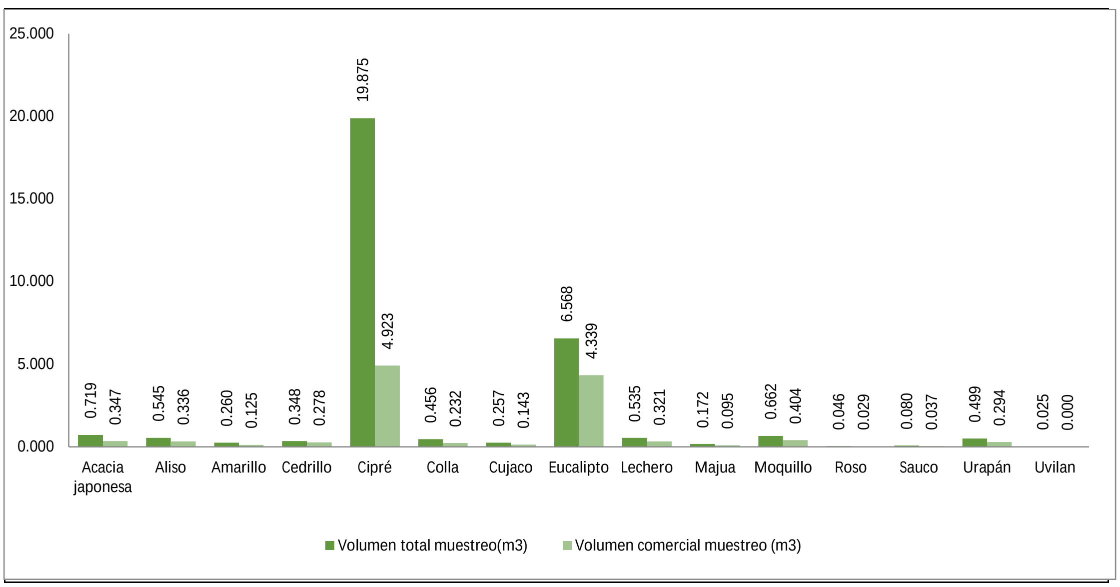


Figure 7.53. Forest volume by species in the pastures and planted trees high Andes orobioma ecosystem

Source: Gemini Environmental Consultants, 2016.

Given the above the average total volume per hectare of 103,489m3 and an average commercial volume per hectare 39,674m3 were estimated.

o Forest plantation of the high Andes orobioma (21315)

Sampling of this ecosystem presents a commercial volume of timber 14,005m3 corresponding to a 19,293m3 total volume. (Table 7.73 and Figure 7.57)

Table 7.65. Total commercial volume in the forest plantation high Andes orobioma ecosystem

No	Common name	Scientific name	Total volume (m3)	Commercial volume (m3)
1	Eucalyptus	*Eucalyptus globulus*Labill.	19,293	14,005
Total			**19,293**	**14,005**

Source: Gemini Environmental Consultants, 2016.

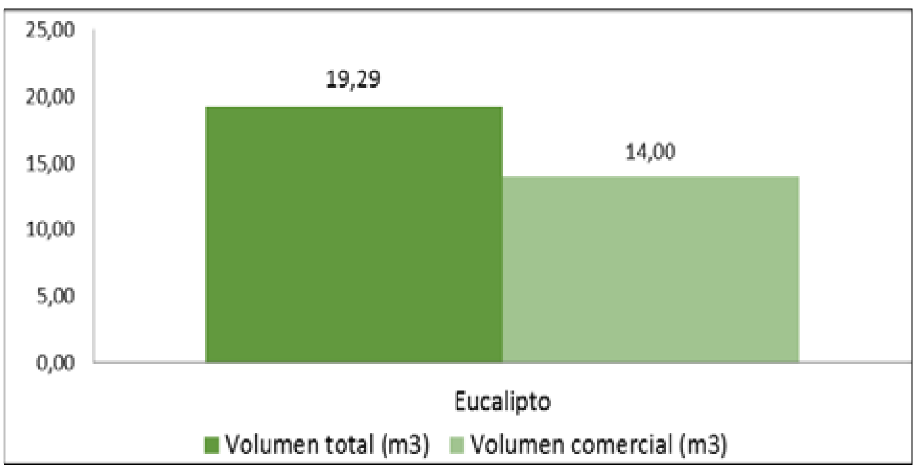


Figure 7.60 Total commercial volume in the forest plantation high Andes orobioma ecosystem

Source: Gemini Environmental Consultants, 2016.

Given the above an average total volume of 96,465 m3 per hectare and an average commercial volume of 70.023 m3 per hectare were estimated.

- Riparian forest from the High Andes orobioma (2.1.3.1.4)

Sampling of this ecosystem shows a commercial timber volume of 24,862m3 corresponding to 38,122m3 total volume. (and Figure 7.58)

Table 7.666. Total and commercial volume in the riparian forest high Andes orobioma ecosystem

No.	Common name	Scientific name	Total volume (m3)	Commercial volume (m3)
1	Alder	*Alnus acuminata*	1,465	1,001
2	Cipré	*Cupressus lusitanica*	0.148	0.098
3	Eucalyptus	Eucalyptus globulus Labill.	34,329	22619
4	Amarillo	*Miconia nodosa*	0.280	0.118
5	Pine tree	Pinus patula	1,240	0.681
6	Moquillo	*Saurauia*sp.	0.599	0.303
7	Cujaco	*Solanum hazenii*Britton	0.030	0.020
8	Encino	*Weinmannia tomentosa*	0.032	0.021
Total			**38.122**	**24.862**

Source: Gemini Environmental Consultants, 2016.

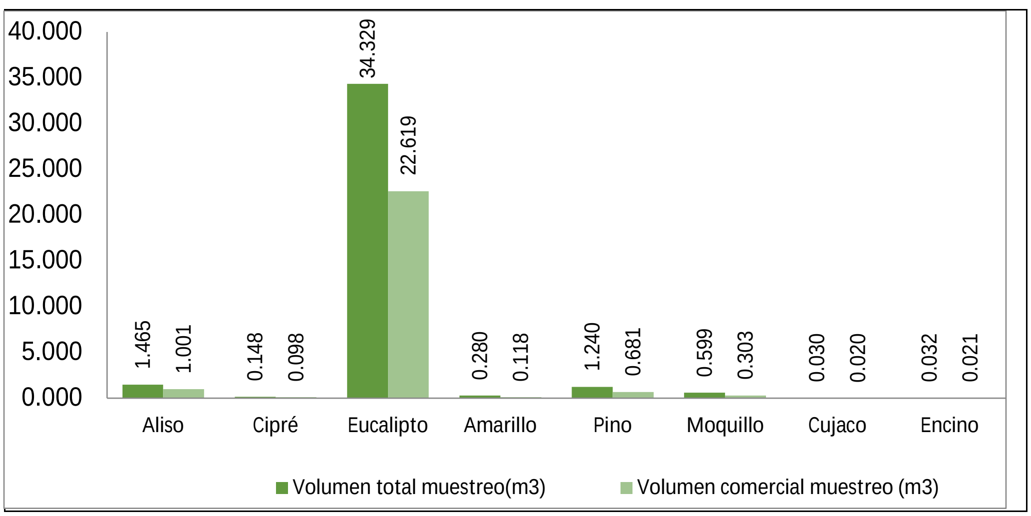


Figure 7.61. Total and commercial volume in the riparian forest high Andes orobioma ecosystem

Source: Gemini Environmental Consultants, 2016.

Given the above an average total volume of 127.075 m3 per hectare and an average commercial volume of 82.874 m3 per hectare were estimated.

7.5.2.2. Calculation of total and commercial volume per vegetal cover to be intervene in road areas - Sampling Results

The estimate of the total timber volume is obtained from distributing natural areas inventoried inside different ecosystems; considering the fact that in covers associated with mosaics, land occupation for the tree component is less than the surface occupied by pasture or crops because species planted predominantly with foreign or introduced wood were found. While in wooded areas there is an occupation of total coverage space where introduced species not native to the area were also found.

The percentage of natural areas is listed in the heterogeneous coverage tables are equivalent to land occupation by natural areas with respect to the total area of each ecosystem.

This process was done with the help of satellite imagery, where, after obtaining the value and the average volume per hectare, the total area values of the ecosystem were extrapolated.

This determination was made taking into account the Corine Land Cover methodology adapted for Colombia that establishes (for this case) that the heterogeneous agricultural areas are occupied by natural spaces between 30 and 70% of total coverage.

Total volume

As shown in Table 7.75 the calculations for mosaic areas (Heterogeneous agricultural areas) with woody vegetation areas, results in total volume of 1991.062m3, including woody patches between crops and pastures and dispersed in the same areas.

Table 7.677. Total volume Pedregal-Catambuco section heterogeneous cover dual carriageway

Wooded patches						Scattered trees			
Ecosystem	$\bar{X}$ Vol Tot/ha (m^3/ha)	Cover area (ha)*	Percentage forest occupation **	Forest occupied area (ha)	Estimated cover volume (m3)	% occupation disperse trees	Natural spaces area (ha)	Estimated cover volume (m3)	Sum by ecosystem (m3)
1	2	3	4	5 (3x4) /100	6 (5x2)	7	8	9 (8x2)	10 (6+9)
202.4.2	37.561	33.373	44.531	14.861	**558.213**	0.69	0.23	8.689	**566.902**
202.2.4.1	46.120	19.248	37.551	7.228	**333.338**	0.69	0.13	6.153	**339.492**
202.2.4.2	13.160	2.990	42.351	1.266	**16.667**	0.69	0.02	0.273	**16.940**
212.4.2	49.202	47.885	33.400	15.994	**786.920**	0.69	0.33	16.332	**803.251**
212.2.4.1	103.489	6.707	37.410	2.509	**259.665**	0.69	0.05	4.811	**264.477**
Total	**249.533**	**110.204**		**41.858**	**1954.803**			**36.259**	**1991.062**
				Total	**(1954.803+36.259) =1991.06**				

Mosaic pastures and crops middle Andes orobioma [202.4.2] Grasses and trees planted middle Andes orobioma [202.2.4.1], crops and trees planted middle Andes orobioma [202.2.4.2], Mosaic pastures and crops high Andes orobioma [212.4.2] grasses and trees planted high Andes orobioma [212.2.4.1].
* Area occupied by each cover inside the area of intervention (calculated cartographically)
** Percentage occupied by forest elements in each cartographically cover (calculated)
(3x4) /100: Box 3 multiplied by 4/100; (5x2) Box 5 multiplied by the box 2
Source: Gemini Environmental Consultants, 2016.

The Table 7.78 presents the estimated total volume in ecosystem composed of homogeneous cover, i.e. where trees are continuously present throughout the extent of the cover unit; as explained before, these calculations were performed separately since in the other ecosystems there is only an occupancy percentage of forest areas with respect to the total cover area. Their sum yielded a total volume of 561,32m3.

Table 7.688. Total volume Pedregal- Catambuco section homogeneous coverage dual carriageway

Ecosystem	$\bar{X}$ Vol Tot / ha (m3)	Coverage Area (ha)	Total estimated coverage volume (m3)
203.1.4	121,700	2.07	**251.51**
203.1.5	122647	2.14	**262.44**

213.1.4	127075	0.11	**14.39**
213.1.5	96465	0.34	**32.97**
Total	**467.89**	**4.66**	**561.32**

Riparian forest middle Andes orobioma, [203.1.4], forest plantation middle Andes orobioma [20.3.1.5], riparian forest high Andes orobioma [213.1.4], forest plantations high Andes orobioma [21.3.1.5]
Source: Gemini Environmental Consultants, 2016.

Commercial volume

Estimated timber volume of heterogeneous vegetation cover in the Pedregal-Catambuco section intervention area is 1089,836m3 (See Table 7.79).

Table 7.699. Pedregal- Catambuco sector commercial volume heterogeneous cover dual carriageway

Wooded patches						Scattered trees			
Ecosystem	**X̄ Vol Tot/ha (m^3/ha)**	**Cover area (ha)***	**Percentage forest occupation ****	**Forest occupied area (ha)**	**Estimated cover volume (m3)**	**% occupation disperse trees**	**Natural spaces area (ha)**	**Estimated cover volume (m3)**	**Sum by ecosystem (m3)**
1	**2**	**3**	**4**	**5 (3x4) / 100**	**6 (5x2)**	**7**	**8**	**9 (8x2)**	**10 (6 + 9)**
202.4.2	25,434	33373	44,531	14,861	**377983**	0.69	0.23	5,884	**383866**
202.2.4.1	30199	19.248	37551	7,228	**218270**	0.69	0.13	4,029	**222299**
202.2.4.2	5,535	2,990	42351	1,266	**7,010**	0.69	0.02	0.115	**7,125**
212.4.2	22,980	47,885	33,400	15,994	**367527**	0.69	0.33	7,628	**375155**
212.2.4.1	39674	6,707	37,410	2,509	**99546**	0.69	0.05	1,845	**101391**
Total	**123822**	**110204**		**41,858**	**1070.336**		**0.76**	**19,500**	**1089.836**
				Total	**(1070.336 + 19,500) = 1089.84**				

Mosaic pastures and crops middle Andes orobioma [202.4.2] Grasses and trees planted middle Andes orobioma [202.2.4.1], crops and trees planted middle Andes orobioma [202.2.4.2], Mosaic pastures and crops high Andes orobioma [212.4.2] grasses and trees planted high Andes orobioma [212.2.4.1].
* Area occupied by each cover inside the area of intervention (calculated cartographically)
** Percentage occupied by forest elements in each cartographically cover (calculated)
(3x4) /100: Box 3 multiplied by 4/100; (5x2) Box 5 multiplied by the box 2
Source: Gemini Environmental Consultants, 2016.
Source: Gemini Environmental Consultants, 2016.

Homogeneous cover found in the Pedregal- Catambuco section intervention area were Riparian forests [3.1.4], forest plantations [3.1.5], middle and high Andes orobioma, which showed a commercial volume of 312,66m3 (Table 7.80):

Table 7.80. Commercial volume Pedregal- Catambuco sector, homogeneous cover dual carriageway.

Ecosystem	$\bar{X}$ Vol Com / ha (m3 / ha)	Cover Area (ha)	Estimated commercial volume per cover (m3)
203.1.4	53,800	2.07	**111.19**
203.1.5	78,582	2.14	**168.15**
213.1.4	82874	0.11	**9.38**
213.1.5	70023	0.34	**23.94**
Total	**285.28**	**4.66**	**312.66**

Riparian forest orobioma middle of the Andes [203.1.4], forest plantation middle of the Andes orobioma [203.1.5], riparian forest high Andes orobioma [213.1.4], forest plantation high Andes orobioma [213.1.5]
Source: Gemini Environmental Consultants, 2016.

According to Table 7.81 the estimated total volume for the construction area second lane Pedregal-Catambuco section is 2552,38m3 sector, i.e., from the existing vegetation along functional units 4 and 5 this amount corresponds to 1402,49m3 of harvestable timber (commercial volume).

Table 7.81. Sum total and commercial value Pedregal-Catambuco section dual carriageway

Ecosystem	Commercial estimated volume (m3)	Total estimated volume (m3)	Location
202.4.2	383.87	566.90	0 + 000-0 + 300 4 + 400-5 + 100, 13 + 00-13 + 500, 15 + 100-15 + 400.
202.2.4.1	222.30	339.49	4 + 850-5 + 100, 100 + 5 + 800-6, 600-7 + 7 + 800, 10 + 200-10 + 850, 12 + 800-13 + 000, 13 + 500-14 + 000,
202.2.4.2	7.13	16.94	0 + 600-0 + 900, 8 + 500-3 + 850
203.1.4	111.19	251.51	8 + 820-9 + 050
203.1.5	168.15	262.44	6 + 050-6 + 150, 6 + 260-6 + 320, 6 + 400-6 + 600, 6 + 700-6 + 750, 6 + 850-7 + 000.
212.4.2	375.15	803.25	0 + 900-1 + 200
212.2.4.1	101.39	264.48	16 + 000-16 + 400, 18 + 200-19 + 200, 20 + 200-20 + 400, 21 + 100-21 + 500, 21 + 800-22 + 400, 22 + 650-22 + 900,

Ecosystem	Commercial estimated volume (m3)	Total estimated volume (m3)	Location
			23+ 280-24 + 050, 24 + 660-25 + 600, 28 + 600-30 + 600, 30 + 750-31 + 200, 32 + 000-32 + 450.
213.1.4	9.38	14.39	32 + 000-32 + 100
213.1.5	23.94	32.97	16 + 300-16 + 650, 18 + 400-18 + 450, 20 + 550-20 + 700, 20 + 850-21 + 000, 21 + 800-22 + 650, 22 + 800-22 + 900, 26+ 700-27 + 600, 27 + 700-27 + 900, 31 + 700-32 + 000, 32 + 450-32 + 780.
Total	**1402.49**	**2552.38**	

Mosaic pastures and crops middle Andes orobioma [202.4.2] Grasses and trees planted middle Andes orobioma [202.2.4.1], crops and trees planted middle Andes orobioma [202.2.4.2], Mosaic pastures and crops high Andes orobioma [212.4.2] grasses and trees planted high Andes orobioma [212.2.4.1].

* Area occupied by each cover inside the area of intervention (calculated cartographically)

** Percentage occupied by forest elements in each cartographically cover (calculated)

(3x4) /100: Box 3 multiplied by 4/100; (5x2) Box 5 multiplied by the box 2

Source: Gemini Environmental Consultants, 2016.

7.5.2.3 Rubble Materials and Excavation Materials Disposal Areas - ZODME

These areas were chosen for disposal according to the environmental zoning criteria for the road project, following the technical survey control specifications for the final road layout.

These areas were designed considering surplus material volume, the physical characteristics of each place, the most convenient location for the project, as well as geological, topographic and drainage features; preventing failures from sliding of deposited materials.

An estimated commercial volume of 265,331m3 and a total 476,535m3 volume is estimated for the ZODME areas.

This volume is relatively low given the characteristics of the individuals, i.e. the number of trees existing in fustal sate is low; in some ZODME areas only vegetation bush type can be seen, with no presence of trees with CAP ≥10 cm.

Table 7.82 lists the number of identified individuals per ZODME inventoried according to the functional unit. (See Annex 7.5.2. 100% Zodme areas inventory)

Table 7.70. Total and commercial value of ZODME located in the Pedregal-Catambuco section

NOMENCLATURE	NAME	COUNTY	MUNICIPALITY	AREA (ha)	Number of individuals	Volume	
						Total Vol.	Commercial Vol.
Z 4-1	Z 4-1 PK 0 + 000	Pilcuán	Imués	2.68	5	0.382	0.243
Z 4-2	Z 0 + 400 04.02 PK	Pilcuán	Imués	0.47	8	3,285	1,664
Z 03/04	Z 03/04 PK 2 + 000	El Pedregal	Imués	0.79	eleven	0.991	0.440
Z 4-4	Z 4-4 PK 5 + 200	Inantas Bajo	Yacuanquer	6.75	51	23586	13,547
Z 4-5	Z 4-5 PK 5 + 200	Inantas Bajo	Yacuanquer	5.05	66	7,015	3,392
Z4-6	PK 4-2 ZR 8 + 600	Cocha Verde	Tangua	6.43	97	64281	35243
Z 4-7	Z 4-7 PK 10 + 400	San Pedro Obraje	Tangua	10.65	16	5,655	3,236
Z 4-9	Z 4-9 PK 14 + 560	El Vergel	Tangua	3.74	2	0.206	0.082
R 4-2	PK 4-2 ZR 8 + 600	Cocha Verde	Tangua	2.67	9	4,589	2,385
Z 5-1b	Z 5-1b PK 17 + 350	Chávez	Tangua	1.44	2	0.107	0.043
Z 5-3	Z 5-3 PK 18 + 900	El Cebadal	Tangua	15.76	74	48485	20,626
Z 5-6	Z 5-6 PK 20 + 900	El Tambor	Tangua	3.26	36	51502	33,021
Z 5-6B	Z 5-10C PK 29 + 000	El Tambor	Tangua	2.21	64	63,630	36874
Z 5-7	Z 5-7 PK 24 + 500	El Paramo	Tangua	0.78	3	0.192	0.078
Z 5-8	Z 5-8 PK 25 + 000	Marqueza Bajo	Tangua	6.59	44	34099	17,224
Z 5-9	Z 5-9 PK 26 + 280	Marqueza Bajo	Tangua	3.85	13	2,034	1,071
Z 5-10	Z 5-10 PK 26 + 900	La Palizada	Tangua	0.51	2	0.640	0.169
Z 5-10B	Z 5-10B PK 28 + 400	Vocacional	Grass	3.24	6	12,474	6,153

NOMENCLATURE	NAME	COUNTY	MUNICIPALITY	AREA (ha)	Number of individuals	Volume	
						Total Vol.	Commercial Vol.
Z 11/05	Z 30 + 700 5/12 PK	Vocacional	Grass	1.19	5	1,003	0.446
Z 12/05	Z 12/05 PK 30 + 780	Vocacional	Grass	2.16	37	21,396	11,663
Z 5-13	Z 5-13 PK 31 + 600	Huertecillas	Grass	7.27	1	0.036	0.018
R 5-2	ZR 5-2 PK 20 + 520	El Tambor	Tangua	7.82	4	1,351	0.668
R 5-3	ZR 5-3 PK 22 + 450	El Tambor	Tangua	3.95	46	18,949	11,308
R 5-4	ZR 04/05 PK 30 + 950	La Merced	Grass	4.49	121	110,645	65,740
Total				**103.72**	**723**	**476535**	**265331**

Source: Gemini Environmental Consultants, 2016.

The following fruit trees were excluded from the 100% inventory in the ZODME areas: Chilacuan (Carica pubescens), Capulí (Prunus serotina), Chirimoya (Annona cherimola), orange (Citrus sinensis), guava (Psidium guajava) Guabo (Inga spectabilis), Avocado (Persea americana), loquat (Eriobotrya japonica), papaya (Carica papaya); the tree species Yucca (Yucca filifera) was also excluded from the inventory.

7.5.2.4 Camps and plants

These sites are arranged to locate temporary buildings that will serve to meet the needs of the project such as plants, offices, shops, mess hall, shops, housing staff, work fronts, contractors, site supervisors, workers.

In areas projected for the Pedregal-Catambuco sector camps, the forest inventory yielded a total volume of 40,673m3 and a volume of 14,832m3 of usable timber (Table 7.83). (See Annex 7.5.3. 100% camp inventory)

Table 7.713. Total and commercial value Camps and plants for the Pedregal-Catambuco sector

Functional unit	LOCATION			Sector	Area	Number of individuals	Volume	
	PK.	Planar coordinates *					Total Vol. (M3)	Commercial Vol. (M3)
		x	Y					
UF4	14 + 200	965,305.526	613,190.773	Tangua	3,25	63	10,638	3,879
UF5	21 + 800	967,300.773	616,135.877	El Cebadal	3,51	81	30.035	10,953
Total					**6.76**	**144**	**40.673**	**14,832**

* Planar Coordinate Magna SIRGAS origin West

Source: Gemini Environmental Consultants, 2016.

It is noteworthy that in 100% inventory results made in the areas of camps and plants, fruit were excluded, in accordance with provisions of the standard. Excluded Species: Loquat (loquat), Avocado (Persea americana), peach (Prunus persica), Capulí (Prunus serotina) Lemon (Citrus limon). Additionally tree species Yucca (Yucca filifera) was excluded.

7.5.3. Requested volume

As shown in Table 7.82, the estimated use total volume for the entire Pedregal-Catambuco section project is 3069,59m3 and 1682,66m3 for commercial volume, mostly concentrated in the dual carriageway "roads" construction areas. See Annex 7.5.4. Volume estimate calculations reports).

Table 7.724. Forest use volumes for the entire project, Pedregal- Catambuco sector

Activity	Sales volume (m3)	Total Volume (m3)
Roads	1,402.49	2,552.38
Zodme areas	265.331	476.535
Associated infrastructure	14,832	40.673
Total	**1,682.66**	**3,069.59**

Source: Gemini Environmental Consultants, 2016.

7.5.4 *Forest species in threatened Category: Endangered and Prohibited*

In order to identify individuals of species in both Fustal and Brinzal stages in threated categories at a national and regional level inside the area of intervention of the road project, the road corridor was traveled in the areas comprising chamfers and right of way.

Thus, seven individuals from *Juglans neotropica* (Walnut) in fustal state, listed in the category of "endangered" (EN) according to resolution 0192 of 2014 and prohibited under resolution 316 of 1974, were identified whereby some timber forest species are prohibited in Colombia, three (3) individuals in functional unit 5 and four (4) in functional unit 4.

Moreover, in functional unit 4 6 subjects in fustal state Cedrela odorata L. (cedar) were identified in the crops and trees planted medium Andes orobioma ecosystem, classified as vulnerable according to IUCN and endangered as per the resolution 0192 of 2014.

Follows the list of threat categories to forest species listed above.

Table 7.733. Species classification by category of threat.

No.	Common name	Scientific name	Res. 0192/2014	CITES	IUCN	RED BOOK OF TIMBER PLANTS OF COLOMBIA
1	Walnut	*Juglans neotropica*	*Endangered (EN)*	*III*	*Endangered (EN) **	*Endangered (EN)*
2	Cedar	*Cedrela odorataL.*	*Endangered (EN)*	*III*	*Vulnerable (VU) ***	*Endangered (EN)*
	TOTAL					

*http://www.iucnredlist.org/details/32078/0 ** http: //www.iucnredlist.org/details/32292/0

Source: Gemini Environmental Consultants, 2016.

Table 7.86 lists forest species prohibited and endangered identified in forest inventory of functional units 4 and 5.

Table 7.746. Endangered species identified in the Pedregal-Catambuco sector, intervention area

No.	Common name	Scientific name	Functional unit	County	IUCN threat category	Type of Coverage	Coordinates *	DAP (m)	Height (m)		Volume (m3)	
									T	C	Commercial	Total
1	Walnut	*Juglans neotropica*	4	El Placer (Tangua)	IN	2.4.2	X 963,717.26	0.07	7	3	0,003	0.01

No.	Common name	Scientific name	Functional unit	County	IUCN threat category	Type of Coverage	Coordinates *	DAP (m)	Height (m)		Volume (m3)	
									T	C	Commercial	Total
			14 + 500				Y 612,169.88					
2	Walnut	*Juglans neotropica*	4 14 + 500	El Placer (Tangua)	IN	2.4.2	X 963,717.27 Y 612,169.89	0.17	11	3	0.05	0.11
3	Walnut	*Juglans neotropica*	4 14 + 500	El Placer (Tangua)	IN	2.4.2	X 963,717.28 Y 612,169.90	0.32	5	1	0.17	0,61
4	Walnut	*Juglans neotropica*	4 43 + 100	Pilcuan Viejo (Imués)	IN	2.4.2	X 954,931.73 Y 605,106.37	0.18	9	3	0,017	0.08
5	Walnut	*Juglans neotropica*	5 20 + 900	Cebadal (Tangua)	IN	2.2.4.1	X 9669445.1 And 615,501.98	0.35	11	4	0.27	0,74
6	Walnut	*Juglans neotropica*	5 17 + 900	San Antonio (Tangua)	IN	1.1.2	X966390,16 Y614379,91	0,21	9	3	.63	1,89
7	Walnut	*Juglans neotropica*	5 17 + 900	San Antonio (Tangua)	IN	1.1.2	X966389,60 Y614378,14	0.25	9	2.5	0,625	2.25
8	Cedar	*Cedrela odorata*L	4 PK. 0 + 800	La Lima (Imués)	VU	2.2.4.2	X 957375.25 Y 607,356.98	0,19	10	3	0.06	0.2
10	Cedar	*Cedrela odorata*L	4 PK 0 + 800	La Lima (Imués)	VU	2.2.4.2	X 957,368.13 Y 607,348.47	0,19	10	4	0.08	0.2
11	Cedar	*Cedrela odorata*L	4 PK 0 + 800	La Lima (Imués)	VU	2.2.4.2	X 957,368.80 Y 607,343.16	0.16	10	5	0.07	0.14
12	Cedar	*Cedrela odorata*L	4 PK 0 + 800	La Lima (Imués)	VU	2.2.4.2	X 957,368.23 Y 607,337.85	0.11	10	3	0.02	0.06
13	Cedar	*Cedrela odorata*L	4 PK 0 + 800	La Lima (Imués)	VU	2.2.4.2	X 957,369.79 Y 607,338.85	0.13	9	2	0.02	0.08
TOTAL											**2,029**	**6.43**

Mosaic of crops and pastures [2.4.2], *Crops and trees planted [2.2.4.2], Pastures and planted trees [2.2.4.1], Discontinuous urban fabric [1.1.2]*
* Planar Coordinates Magna SIRGAS origin West.
Source: Gemini Environmental Consultants, 2016.

According to the procedure for requesting the lifting of prohibition in the ministry of environment and sustainable rural development, a document corresponding to identification of prohibited epiphytic, litófita and forest vegetation was filed with the forestry direction in the intervention area of the project, writ of commencement No. 391 of August 9, 2016, file ID ATV 0451.

7.5.5 Technical forestry use aspects

The harvesting works of will be done based on technical procedures, ensuring minimal loss of forest products and avoiding damage to surrounding forest individuals.

This procedure is listed in Chapter 11.1.1 of this study, "wildlife management program", which includes timber harvesting.

7.5.6 Destination of forest products

Timber products generated from logging will be used both in construction tasks related to project development as wells as donated to the community. The latter after signing minutes, where the volume of timber donated is specified and possible uses given thereto, stating that under no circumstances will it be commercialized.

7.6 Atmospheric emissions

The project intends to operate crushing, asphalt and concrete plants in the areas of the camps; therefore it is necessary to apply for the respective emission permits to develop these activities.

7.6.1 Emission sources

Emission sources found in the area of influence are classified according to the nature of emitting source and how pollutants are emitted; the sources are anthropogenic and classified as fixed and mobile as described below.

· Identification of existing sources

Identification was made from the following classification: fixed, mobile and area.

- *Mobile sources*

Vehicles traveling in the study area are cars, trucks, tractors trucks, motorcycles and buses designed to operate on public roads. In most urban areas motor vehicles contribute a large amount of CO, NOx, SOx particulates, and air toxics compounds species that reduce visibility.

The inventory of mobile sources traveling on the corridor was extracted from the Traffic, Capacity and Service Levels Corridor 3: Rumichaca- Pasto Study. (See Table 7.85)

Table 7.75 Inventory of mobile sources

SECTOR	VEHICLES / DAY	VEHICLE TYPE	CATEGORY
Pedregal - Catambuco	177	Buses	Category II
	1,526	Cars	Category I
	409	Trucks	Category II

Source: Adapted Traffic Study capacity and service levels Rumichaca -Pasto

- *Fixed sources*

Inherent to generation and activities productive found in the study area, which mostly lack of technology and infrastructure, and therefore have no control systems to prevent contamination. See Table 7.86

Table 7.76: Stationary Sources Pedregal - Catambuco section

SOURCE TYPE	INDUSTRIAL ACTIVITY	CAMP	PLANAR COORDINATES	
			Y	X
Fixed source	Concrete plant	Tangua	965,219.348	613,254.729
	Crusher	Tangua	965227.6	613244.2
	Asphalt producer	Tangua	965,263.64	613,169.322
	Concrete plant	Cebadal	967,335.125	616,017.756
	Crusher	Cebadal	967202.2	615913.9
	Asphalt producer	Cebadal	967,284.589	616,036.012

Source: Gemini Consultants SAS 2016

- Chircales

In the area of influence Chircales or artisan brickworks were identified, as seen in Photograph 7.4.

Follows the description of the brick manufacturing process.

- Storage of raw materials: consists of storing piles of clay for brick making.
- Grinding and mixing: Given that the manufacturing process is artisan, a wet type grinder with rolling mills and rollers is used to be trampled repeatedly by horses. Clay, once ground can be mixed with various additives (sand, barium carbonate etc.) according to quality requirements of the final product.
- Forming: The forming is the brick pattern, the clay passes through a perforated mold pushed by a rotating propeller, and this clay extorts the profile of the incorporated nozzle being able to change depending on the type of piece produced.
- Drying: This is naturally done by storing the shaped brick indoors which reduces the moisture by wind and sun effects.
- Cooking: It is the stage where all the moisture of the brick, which is done in a rustic kiln inn masonry with opencast emissions (see Figure 7.1) The energetic material for cooking is firewood or wood that fires for about 30 hours, until about 1000 ° C temperature is reached producing carbon dioxide (CO_2), smoke, ash and particulate matter.

Photograph 7.4: Rustic oven for baking brick Coordinates magna sirga origin west (E5982.96-N614821.70)

Source: (Gemini SAS Consultants, 2016)

o – Cremation furnace

A single oven serving the Nariño department located in the Pedregal Catambuco sector, the crematorium furnace (see Photograph 7.5) has two chambers: a primary loading, combustion and ignition of waste with a minimum temperature of 850 ° C and a secondary post-combustion where the flue gases are burned with a minimum temperature of 1200oC. The waste is fed only when the chambers have reached and maintained these temperatures.

- The residence time of the gases in the afterburner chamber are of minimum two 2 seconds.
- Each of the chambers operates with its own independent burner and automatic temperature control.
- The incinerator must automatically register the operating temperature in both chambers.

Regarding atmospheric emissions emitted by the crematorium, a concentration of carbon monoxide (CO), articulated material (MP), total hydrocarbons (THC) and benzopyrene and Dibenzo are established.

Photograph 7.5: Crematorium Cristo Rey Coordinates magna sigma origin west (976047.12X - 620671.47)
Source: (Gemini SAS Consultants, 2016)

· Location of projected emission sources

Projected emissions sources come from installation of the asphalt plant and crushing plant, located in the two camps to be located in the Pedregal - Catambuco section. See Table 7.89 and Figure 7.72

Table 7.77: Fixed emission sources Pedregal Catambuco section

CAMP	ABSCISSA	PLANAR COORDINATES MAGNA SIRGAS ORIGIN WEST		MACHINERY
		EAST	NORTH	
CAMP TANGUA	K 14 + 600	965,263.64	613,169.32	Asphalt Plant
		965,219.348	613,254.729	Concrete plant
		965227.6	613244.2	Crushing plant
CAMP CEBADAL	K21 + 700	967,284.58	616,036.012	Asphalt Plant
		967,335.125	616,017.756	Concrete plant
		967202.2	615913.9	Crushing plant

Source: Gemini Consultants SAS 2016

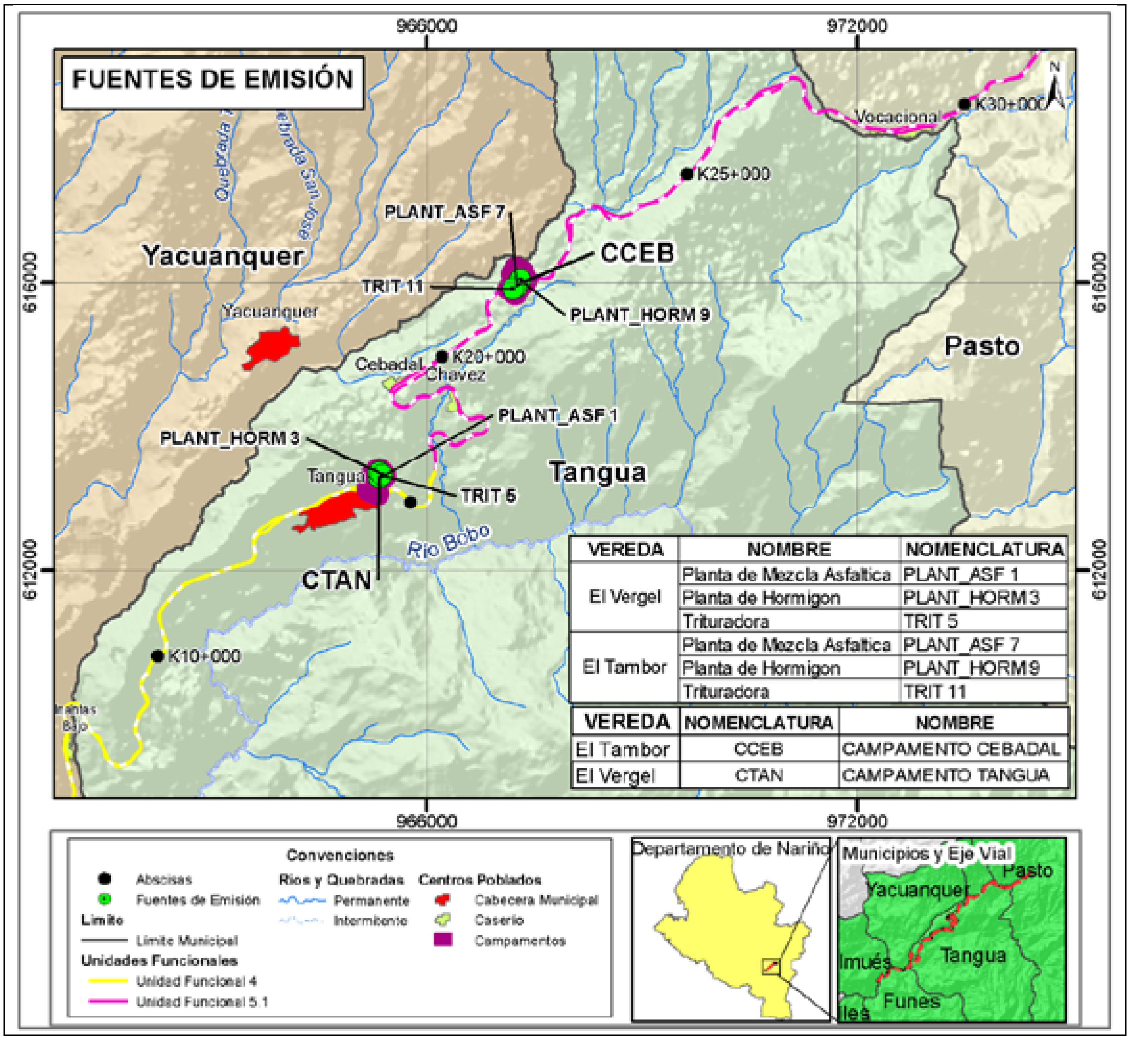


Figure 7.62: Atmospheric emissions foreseen for the Pedregal - Catambuco section

Fuente (Géminis Consultores S.A.S, 2016)

- Estimated air pollutants

To estimate the concentrations of potential contaminants that can contribute to the atmosphere during project implementation, the type of plants used and the pollutants that can generate air emissions were taken into account as well as the asphalt and crushing plants which due to their processes can generate emissions. To note that the machinery to be used has perimeter sprinklers, bag filters and hoods that allow concentration of PM10; see Figure 7.62. It estimated that emissions are minimal because the use of hoods and filters allow the recirculation of such materials in the processes, in addition to ensure the effectiveness of the measures taken, the filters will be regularly serviced.

Application forms allow air emissions for the crushing and asphalt plants are found in Appendix 7. 6. 1

- Asphalt plant

The type of plants that will be used in the project are continuous type which entails generating less waste and are more efficient in their processes, with counterflow drying where aggregates enter the dryer drum at the opposite end to the flame and flow in opposite direction of the gas system, this allows drying at a lower temperature, using less fuel and thus lower emissions.

The emissions from the asphalt plant have two main sources:

- Conducted sources: Those whose fumes exit to the atmosphere through vents, ducts or chimneys.
- Fugitive Sources: Those not channeled in ducts or respirators but are issued directly from the source into the atmosphere.

The main source of conducted emission occurs in the dryer drum where in addition to generating water vapor, combustion products and MP, small amounts of organic compounds are generated which are both incomplete combustion such as heating and mixing asphaltic cement.

The main emissions from asphalt plants are:

- Carbon monoxide CO
- Sulfur S
- Nitrogen oxides (NOX)
- Polycyclic aromatic hydrocarbons
- Phenol
- Toluene
- Xylene
- Naphtha
- Styrene
- Formaldehyde
- Benzene
- Arsenic
- Cadmium

The release of these pollutants into the atmosphere is of the following processes:

- The reaction of nitrogen and oxygen in the dryer generates emissions nitrogen oxide NOx in the combustion zone.
- Emissions of sulfur dioxide SO2 are produced by oxidation of sulfur compounds contained in the fuel.
- Particulate emissions result from volatilization of materials that are then condensed and manipulation thereof.
- Emissions of volatile organic compounds VOC are the byproduct of incomplete combustion.
- The amount of fine material determines the amount of dust emitted into the atmosphere and the amount of asphalt cement consumed per unit volume of asphalt consumed per unit volume of produced asphalt.

Table 7.90: Estimated Emissions from Asphalt Plants

Estimated annual emissions continuous plants			
POLLUTANT	EMISSIONS lb / year		
	Gasoline dryer	Natural gas dryer	Eemissions generated in the process
PM-10	4600	4600	104
COV	6,400	6,400	780
CO	26000	26000	270
SO2	2200	680	
NOX	11000	5200	

Source: (States, 2000)

-Crusher

4 stages: feeder, crusher, sorter and conveyors.

The main source of contamination of the crushers is PM emissions due to the crushing process and the displacement thereof by the conveyor belts, since these are exposed outdoors. It should also be noted that during the transport and storage of materials previously crushed in batteries, a release of volatile organic compounds and particulate matter occurs; all the aforesaid generate a negative impact on the environment and health.

- Reduce the height of fall of the material during movement thereof (loading and unloading)
- Crusher plant cover with geotextile

- Encapsulation of the conveyor belts reducing by 90% the index of total suspended particles
- Using water irrigators to maintain the material moist in order to prevent dust emissions. To have special care curing established irrigation times and the amount of water used, avoiding excessive wetting of the material.

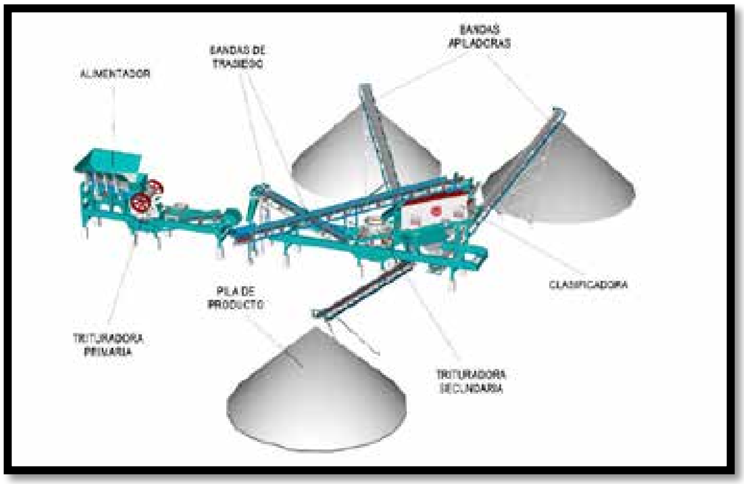


Figure 7.54 Crushing Plant Model
Source: (CYBER, sf)

- Description of transmitting equipment

Follows a description of plants to be used for development of project activities:

- *Asphalt Plant*

The process starts in the pre-dosage feed silos, aggregates are conveyed to the dryer. After the moist enters, bucket elevators carries warm and dry materials to the top of the tower. The dosage tower of the, which is the main center of a plant, consists of vibrating shakers (sieves or strainers) with different openings for granulometric classification that sorts and separates the aggregates of different sizes. The plant system, fully computerized, allows the balance of aggregate to control the floodgates to integrate the necessary quantities of materials temporarily stored in hot silos. The silos have a sealing system to prevent dust escaping into the environment and access covers for maintenance, and a sample collector in each compartment. Downloaded into the mixer, aggregates receive the precise amount of gent, as measured by the balance of bitumen. The system controls the mixing time. After the process, the discharge gates release the material directly onto the transport truck.

The asphalt plant is composed of the aggregates feed system, dryness system, hot aggregates elevator system, vibrating screen, aggregates store, metering and mixing system, bitumen delivery system, powder filter system, finished product warehouse, control system, among others.

The type of plants that will be used in the project are continuous type with a counterflow drying where aggregates enter the dryer drum at the opposite end of the flame and flow countersense of the gas system leading to generate less waste and be more efficient in their processes. (See Figure 7.64)

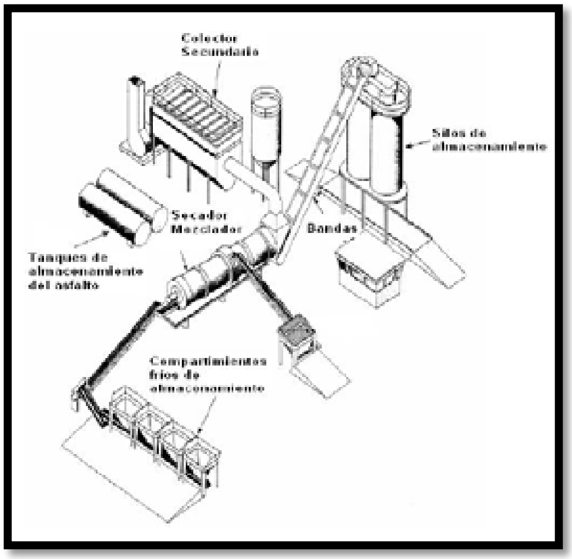


Figure 7.554: Asphalt plant continuous production scheme
Source: (States, 2000)

- *Crushing plant*

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

Receiving hopper: tank where the raw material is poured in the exploitation area.

Primary crushing: the first fragmentation is performed, reducing the size of the pieces of ore to a desired size.

Sieve: the products are screened on a shale shaker in order to segregate those particles whose size is fine enough and, with a consequent increase in the capacity of the secondary crusher.

Generally the primary crushing is carried out using a jaw crusher, which consists of two steel plates (jaws), placed one in front of another, one is fixed and the other is mobile and can rotate around an axis located in its top or bottom by a suitable device moving back and forth in short stokes. The ore is loaded in the space comprised between the jaws and in its forward stroke, crushes the pieces against the fixed plate, when rolling back the movable jaw pushes the crushed ore through the opening formed in the bottom jaws.

Regrind: in the secondary crushing the particle size from the primary crushing is reduced to a range between 3 "and 2 '', leaving it suitable for further milling operations or preliminary concentration considerations.

Conveyors: these collect the material fragmented by primary crushing or from further processing material, it lifts it and transports it to the stockyards or new process steps, the system uses rubber bands and closed canvas rotating cyclically on rollers with electric traction.

- *Power plants*

The type of power plant that needs the project depends on the energy requirements from the asphalt, concrete and crushing plants; on where it will be located and whether it will operate continuously or only when there are power outages. See Figure 7.65

Figure 7.565: Model type power plant

Source (CATERPILLAR, 2016)

Therefore, for power generation one KAT reference C13 plant with the following specifications is proposed. See Table 7.91

Table 7.91: Power plant technical characteristics

OBSERVATION	CHARACTERISTIC
Minimum rating	320 ekW (350 kVA)
Maximum ranking	400 ekW (450 kVA)
Voltage	380-415 volts
Frequency	50 or 60 Hz
Speed	1,500 or 1,800 RPM

Source: (CATERPILLAR, 2016)

Some of the benefits of the plant is that it has a reliable, rugged, durable design, a diesel four-stroke cycle engine, combines consistent performance and excellent fuel economy with minimum weight. Additionally it is under emission standards Stage IIIA of the European Union for off-road emission standards for off-road III China

Diesel engines are an invaluable contribution in achieving environmental protection objectives. Unlike gasoline engines, thanks to its low fuel consumption they produce approximately 20% less carbon dioxide. However, for many years it has become clear that the soot particles generated by diesel engines contribute to environmental pollution and are a health risk.

It has been found that some of the hazardous gases in Diesel exhausts (for example, nitrogen oxides, benzene, sulfur dioxide and formaldehyde) can cause cancer. According to the World Health Organization, these particles are carcinogenic.

Exhaust gases can be eliminated from the power plant using local exhaust ventilation. Local exhaust ventilation requires both supply and extraction fans to extract gas from the diesel power plant where they occur.

- <u>Devices or emission control systems</u>

The asphalt plant has immersed in its systems baghouse filters, which consist of a filtering textile pipeline where the air stream with particulate product of the grinding process and the production of asphalt enters. The pipeline is closed at the top so that the air passes through the duct walls thus having a similar strainer effect. The particles are trapped in the filter and clean air exits the system.

Systems baghouses are constituted by compartments (baghouse or fourth bags) in which a large number of filters are located. To clean the filters, a shaker or counterflow air injection system is used, processes where these materials are reintegrated into the production process thus reducing the negative impacts caused by the generation of PM10. Since it is not possible to service while the system is operations, it is necessary to have parallel compartments for recirculation of particulate matter for systems with continuous flow.

- Smooth filter sleeves

Uses high capacity flat or folded sleeves, enabling the production of asphalt without risk of environmental pollution. The sleeves filter the particles smaller not captured by the static separator, through the passage of the gases through a filter fabric. See Figure 7.66.

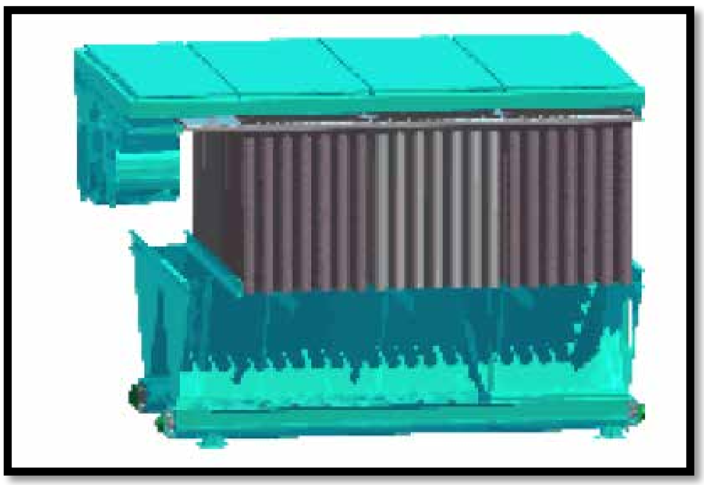


Figure 7.576: Smooth filter sleeves
Source (SAS, sf)

- Folding filter sleeves

The folded sleeves use the filtering surface guaranteeing a lower risk of impregnation, better cleaning efficiency and increased life. See Figure 7.67.

Their characteristics are:

- Surface filtering
- Washable sleeves
- Filtering area 5 times greater than in the smooth sleeves
- Total filtration efficiency
- Fine collector

Figure 7.587: Folding sleeves filter
Source: (CYBER, sf)

- Cyclones

Their proper operation is associated to the pressure drop of gas flow through the system; (Figure 7.68) shows their classification.

- High capacity cyclones: They are able to capture large amounts of particles but not the finest.
- High efficiency cyclones: They retain very fine particles but small capacity

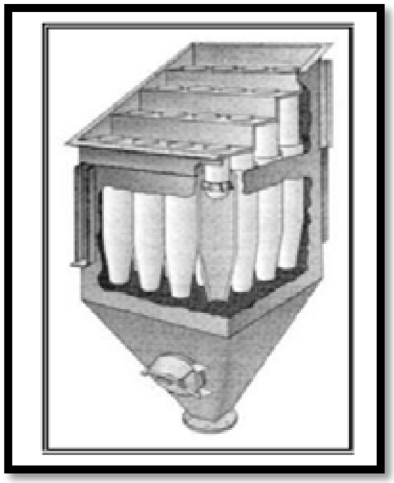


Figure 7.598 Filter cycle model
Source: (CYBER, sf)

- *Wet scrubbers:*

It is a system where the gases, prior to exiting into the atmosphere, are subjected scrubbed so that the atomized water recovers the particles floating in the gases and conveyed them to a sedimentation basin (sludge pit), where heavier particles are decanted and the water and the less dense particles flow.

- *The gas filtering process and fine recovery is divided into two stages:*

PES ESPs

They are characterized by their high efficiency in PM removal, especially when the volume of exhaust gases is high and it is necessary to recover valuable materials without physical modifications. It uses an electric field to move the particles out of the gas stream and on the collector plates.

Emissions containing MP pass through an electric field where particles are negatively charged and attracted to a collector electrode of opposite charge; through a tapping system the electrode is cleaned and particles are collected in a hopper located at the bottom of the precipitator.

Pre-particle collector

The high efficiency pre-dust collector retains particles with size up to 75 um and returns them continuously and directly to the hot aggregates elevator.

Control measures established:

- Plantar curtains of trees around the plant
- Raise the height of chimneys
- Wetting of materials to be crushed to avoid particulate emission

7.6.2 Dispersion model

· Dispersion models applied

AERMOD model, version 15181 30 June 2015, which describes the dispersion of pollutants by parameterizations of the emission sources, weather, terrain, land cover and receivers was used.

It is the US regulatory model for situations where there is no predominance of coastal areas and includes the concepts of state of the art in modeling pollutants.

It is applicable to both rural and urban areas, flat and complex terrain, surface and high emissions and multiple types of sources, including point, line, area and volume (US EPA, 2004). A major innovation of AERMOD is the ability to characterize the planetary boundary layer (PBL) from the surface to the mixing height, building vertical profiles of speed and wind direction, turbulence, temperature and thermal gradient, using ratios of similarity from meteorological observations.

For such end, it only requires surface measurements of wind speed and direction, temperature and cloud cover, the latter may be replaced by two temperature observations at different heights (in situ observations) or by solar radiation. Figure 7.69 shows the flowchart for processing information of an AERMOD dispersion model. This consists of a main module (AERMOD) and two preprocessors (AERMET and AERMAP).

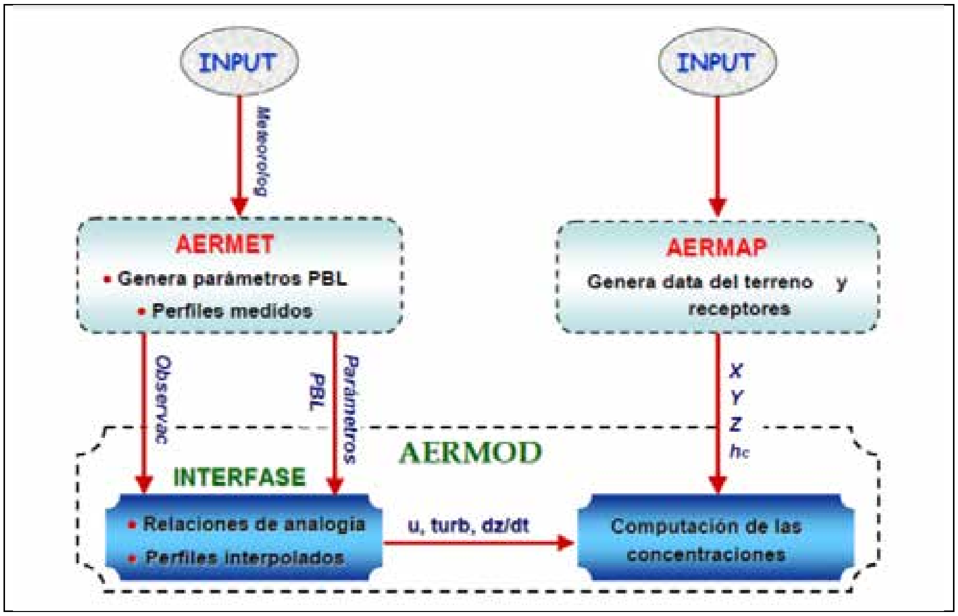


Figure 7.60 AERMOD modeling system scheme
Source (Vivas, 2008)

The AERMOD system consists of three programs: the main AERMOD program, which is supported on the AERMET and AERMAP preprocessors.

AERMET generates the convective boundary layer parameters. It receives as input the terrain characteristics (surface roughness, albedo and Bowen ratio) and surface weather observations (direction and wind speed, temperature and cloudiness). With these CLP calculated parameters: friction velocity (u *), Monin - Obukhov (L), convective velocity (w *) scale, temperature scale (θ *), mixing height (zi) and surface heat flux (H) and organizes weather data for the main program (USEPA, 2004).

AERMAP receives a defined grid in a digital elevation model (DEM) for computing a height representing the influence of the field, known as scale terrain height (hc). hc is used to calculate the aerodynamic boundary height. It also calculates the height of each receiver over sea level (Zr) and passes the coordinates of each receiver to AERMOD, hc and Zr (USEPA, 2004).

AERMOD receives the parameters calculated by AERMET together with atmospheric measurements and using similarity relationships interpolates vertical profiles of wind speed (u), the vertical and lateral turbulent fluctuations (σv, σw), the potential temperature gradient (dθ / dz) and potential temperature (θ). Along with calculates values generated by AERMAP it calculates the concentrations (USEPA, 2004).

- *Input data for the model*

Follows mentioned data and variables feeding the modeling of the Pedregal- Catambuco section.

o Emission sources inventory

Table 7.92 presents the information with projected emission sources during the execution of construction activities of the road project, where the presence of processing plants located in different additional camps are observed, in addition we found the sources of emissions such as brickworks and crematorium furnace located in the project area.

Table 7.782 Location of emission sources Pedregal - Catambuco

UF	CAMP	PLANAR COORDINATES MAGNA SIRGAS ORIGIN WEST	ACTIVITY
4	TANGUA CAMPAMENTO	E: 965300 N: 613253	Concrete Plant Asphalt Plant Crushing plant
5	CEBADAL CAMPAMENTO	E: 967268 N: 616101	Asphalt Plant Concrete plant Crushing plant
5	Fixed source	Jardines Cristo Rey Crematorium furnace	620,671.47
5	Fixed source	Brickworks	614,741.21
5	Fixed source	Brickworks	614,821.70

Source: (Gemini SAS Consultants, 2016)

Follows the site where the monitoring station for analysis and data collection required input is placed to feed the selected AERMOD model.

In the area of influence which are fixed, mobile and area. (See annex GDB / mapping / PDF / EIADCRP_IP_021)

Table 7.979 Location of air quality monitoring stations

AIR QUALITY POINT	COUNTY	MUNICIPALITY	PLANAR COORDINATES MAGNA SIRGAS ORIGIN WEST	
			EAST	NORTH
1	Pedregal	Imués	958,439.945	608,235.425
2	County seat	Tangua	964,268.717	612,785.492
3	Chávez	Tangua	966,837.78	614,411.568
4	El Tambor	Tangua	967,320.276	616,111.612
5	Catambuco	Pasto	975,477.928	620,217.086

Source: Gemini Consultants SAS 2016

- *Weather information*

To select the most representative station, the meteorological behavior of the study area and surface stations with available data obtained from the IDEAM (IDEAM, 2016) list were analyzed. In the study area two stations with sufficient and available information to upload to AERMOD were identified, which are:

· Sindagua station - main climatological

· Botana - Agro meteorological

· Obonuco - Agro meteorological

ü Wind behavior and relief

Considering records of wind behavior at stations available, it appears that the wind direction suffers a turn, passing from winds from the east to south of the project to prevailing winds from the south and southwest north of the project. In turn, the relief marks several different sectors, one to the first southern half of EIA 2, characterized by less pronounced mountain accidents, and another from the middle to the north located along the Guáitara River Valley, a factor that may cause the presence of valley breezes that modify wind behavior. Figure 7.70 shows IDEAM's wind roses and three-dimensional relief representation.

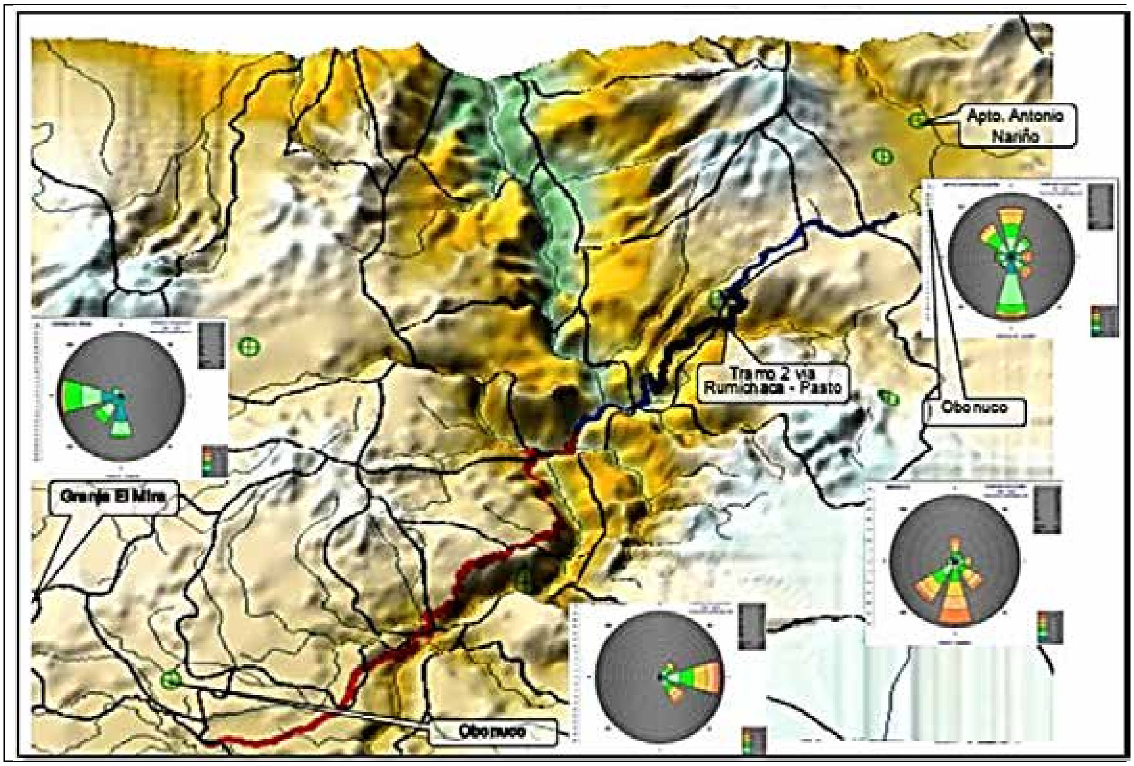


Figure 7.70 Wind behavior and relief in the study area
Source (IDEAM, 2015)

- Selecting the station surface

In consultation with the IDEAM, it was determined that the Sindagua and Botana stations do not contain regular information. However, based on the behavior of the variables described above it is concluded that the Obonuco station in the town of Pasto is sufficient to meet the objectives of the modeling representation.

Data from the surface weather station were purged by preprocessor AERMET, fed with a file SAMSON format (Surface Meteorological Observation Network and Solar US).

Since in the study area there is no elevated station close by that can be considered representative in the simulated zone, the height parameters were calculated using the IDEAM methodology specified in the Protocol for Monitoring and Tracking Air Quality (MAVDT, 2010).

The information from 1 January 2011 and 30 June 2015 was used. The AERMET model validated the data and extrapolation was performed according to the specifications established by US EPA.

Obonuco's station hour meteorology for twelve months was used. No weather information calculated by mesoscale models like WRF was used as the USEPA recommends its application to modeling scales exceeding 50 km, which is higher than that used in this project.

- *Behavior of meteorological variables*

With meteorological records monthly and hourly averages of analyzed variables were obtained, which are presented below.

ü Annual wind rose

The wind rose shown in Figure 7.71 for the Obonuco station show a strongly directional behavior with predominating south wind, with speeds over 3 m / s during most of the time. This behavior is explained by the presence of trade winds from the south.

Comparing this rose wind that reported by IDEAM shown in Figure 7.70 for the same station, a great similarity is observed, confirming the representativeness of data used.

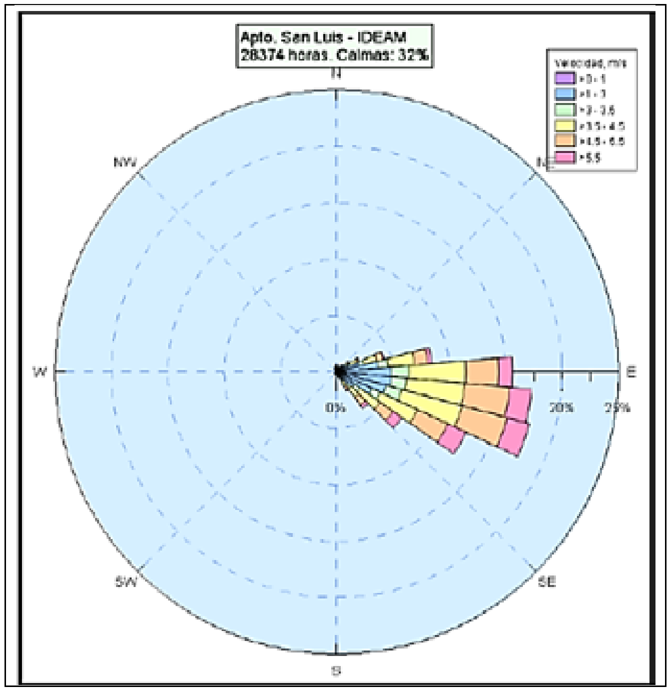
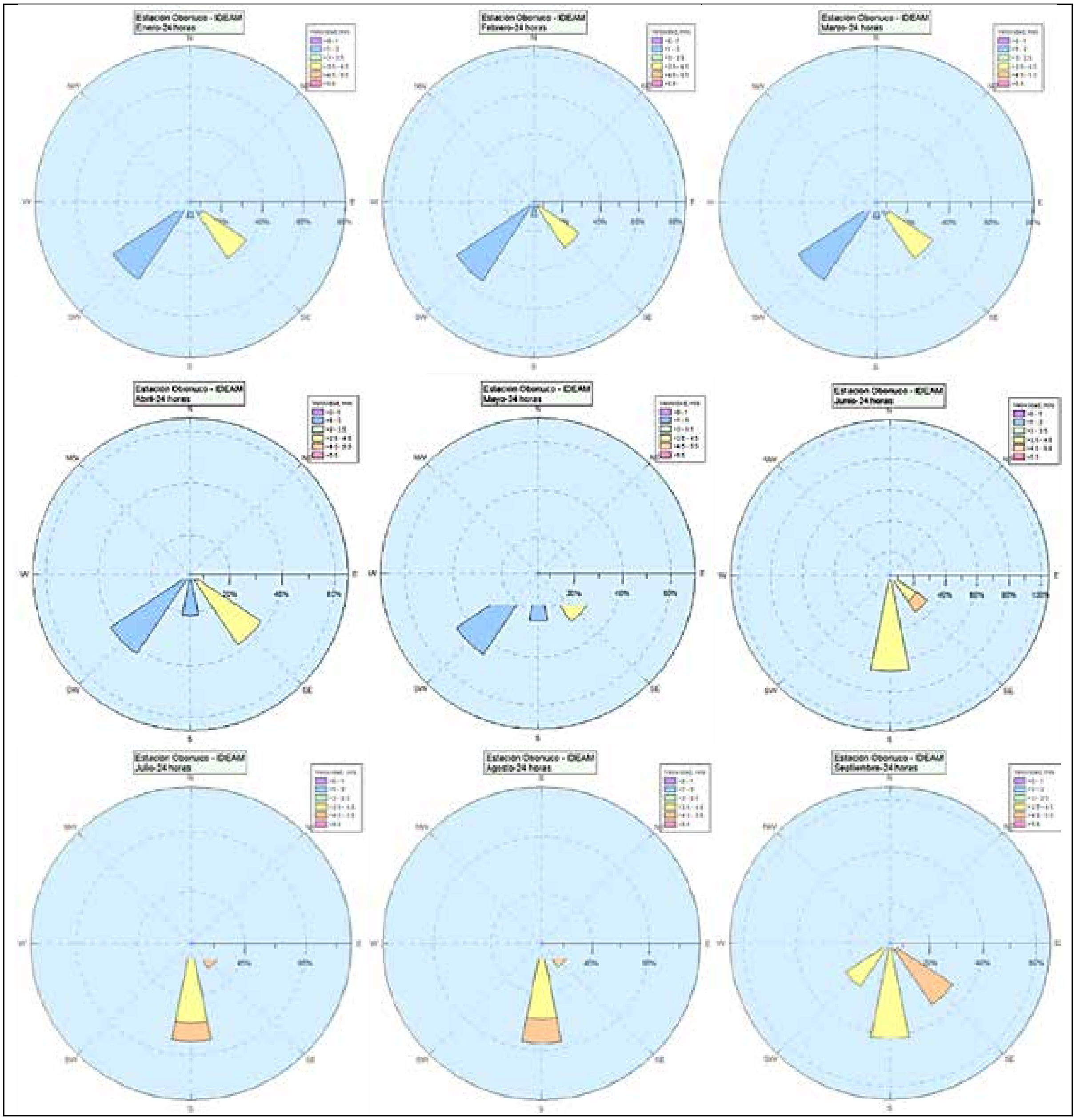


Figure 7.71 Hourly winds rose, Obonuco Station IDEAM
Source (IDEAM, 2015)

- Monthly rose wind

Figure 7.69 shows monthly roses, characterized by the same dynamics of air currents with moderate variations in wind speed. During the months of June to August higher velocities are obtained, due to the remoteness of the intertropical convergence zone (ITCZ), which is the region where the north and south trade winds meet.


Estación Obonuco - IDEAM
Enero-24 horas
Estación Obonuco - IDEAM
Febrero-24 horas
Estación Obonuco - IDEAM
Marzo-24 horas
Estación Obonuco - IDEAM
Abril-24 horas
Estación Obonuco - IDEAM
Mayo-24 horas
Estación Obonuco - IDEAM
Junio-24 horas
Estación Obonuco - IDEAM
Julio-24 horas
Estación Obonuco - IDEAM
Agosto-24 horas
Estación Obonuco - IDEAM
Septiembre-24 horas

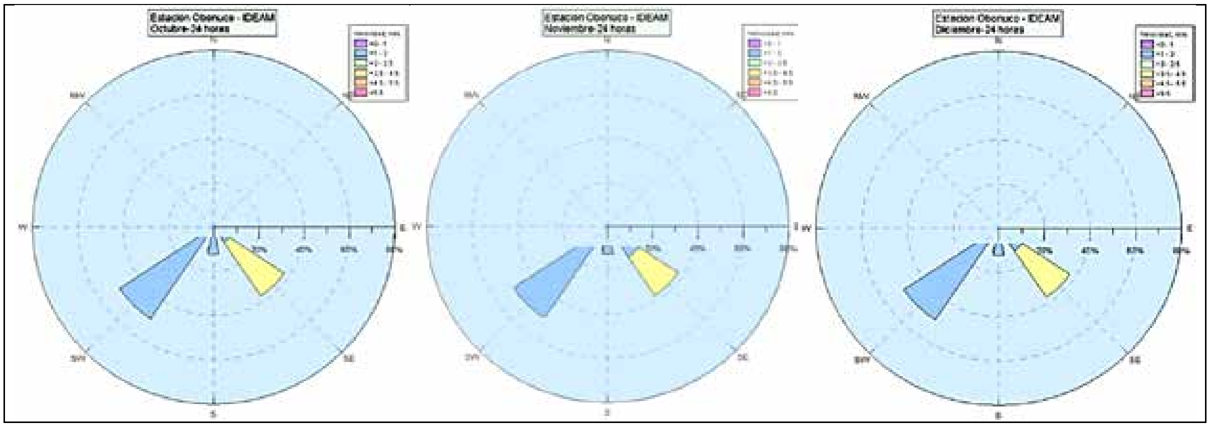


Figure 7.72 Hourly wind rose for each month, Obonuco Station IDEAM
Fuente (IDEAM, 2015)

ü Wind Direction

Figure 7.73 shows wind direction behavior depending on the month and the hour, characterized by predominance of the wind from the south throughout the year and throughout the day, with a difference in the direction between October and April when during the night the wind blows from the northwest. This behavior is due to, as explained above, the marked influence of the south trade winds.

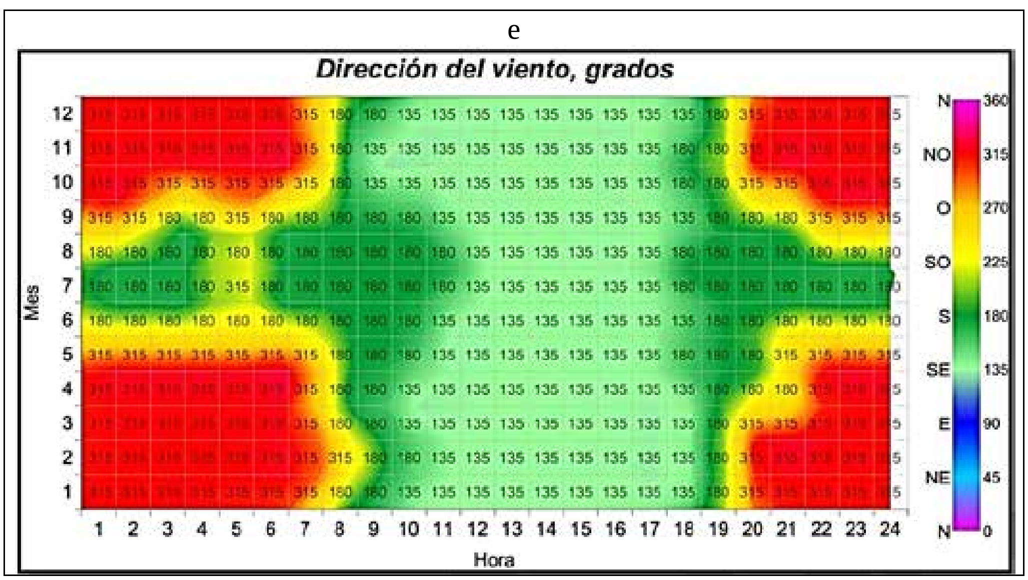


Figure 7.61 Wind direction, Obonuco station IDEAM
Fuente (IDEAM, 2015)

ü Wind speed

Figure 7.74 shows the behavior of the wind speed depending on the month and time. In shows that the increased speed occurs between June and September when reaching up to 5 m / s between 8 am and 4 pm, while the rest of the time the rate is between 3 and 5 m / s except November and December when the velocity is below 2 m / s.

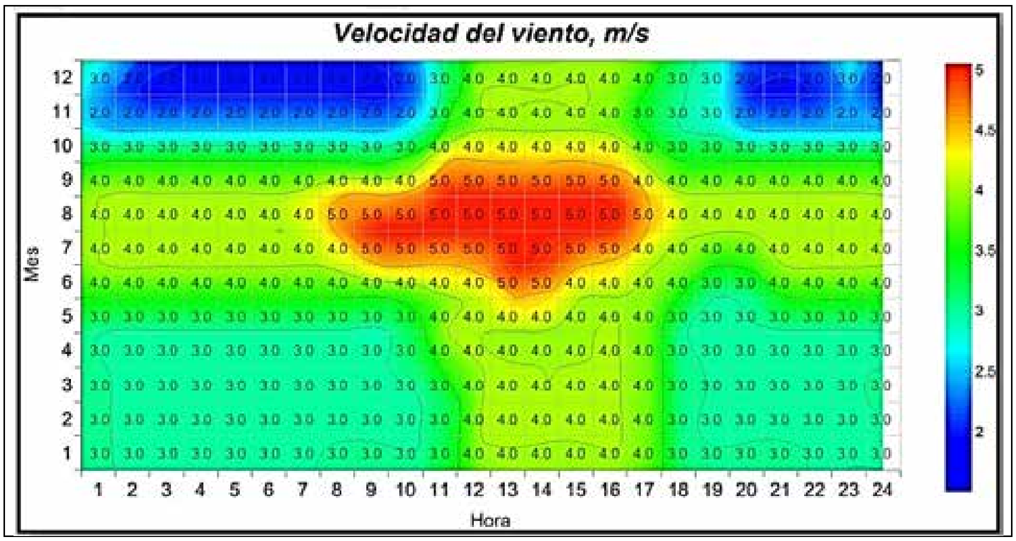


Figure 7.62 Wind speed depending on the month and time, Obonuco station IDEAM
Source (IDEAM, 2015)

ü Ambient temperature

Figure 7.75 shows the behavior of the ambient temperature depending on the time of day and year. The average hour temperature is 12.9 ° C, the minimum 9.4 ° C and maximum 17.0 ° C. Throughout the year the temperature remains stable with a 1.2 ° C difference between the coldest month (August) and the warmest (May), which is explained by the intertropical situation.

Higher temperatures are recorded between 12 noon and 3 pm, time after which it starts to drop until 6am then goes up again with increasing solar radiation.

Noon high temperatures favor the updrafts and thus the dispersion of pollutants, while at night the opposite phenomenon contributes to increasing the concentration of pollutants.

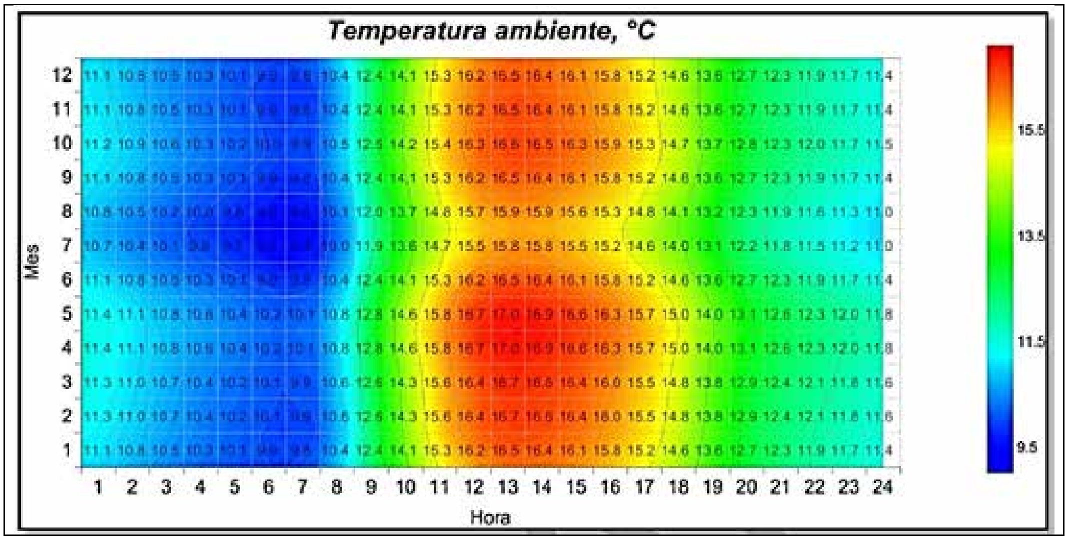


Figure 7.63 Ambient temperature, Obonuco station IDEAM
Source (IDEAM, 2015)

ü Cloudiness

Figure 7.76 shows cloudiness behavior, which always corresponds to a partly cloudy sky and between 3 and 8 oktas. Lower cloudiness occurs between 5am and 12 m, time after which it starts to increase until midnight. The months with higher cloudiness are June and July.

This cloudiness is related to precipitation, which is determined by the topography of this area, which produces the condensation of moisture from the Amazon front.

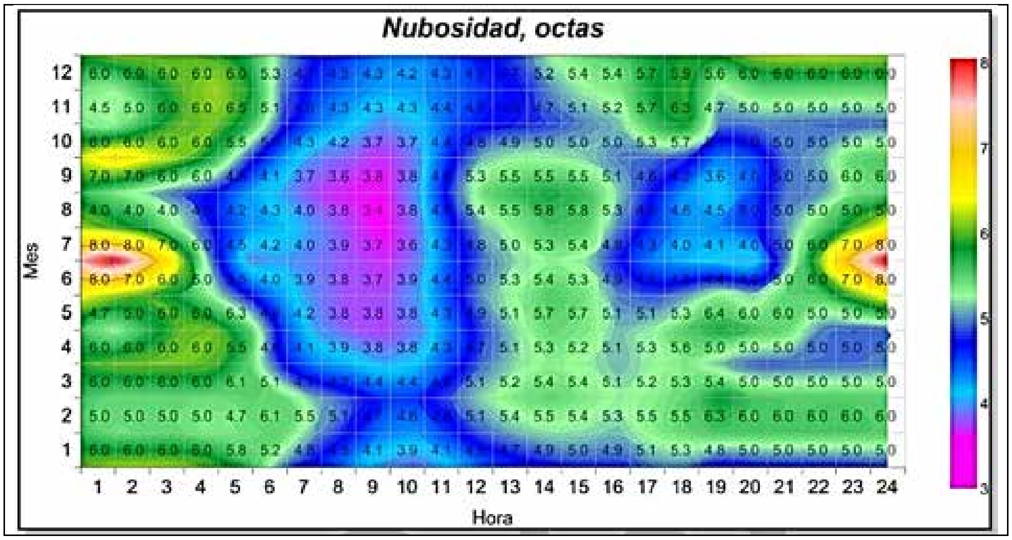


Figure 7.64 Cloudiness, Obonuco station IDEAM
Source (IDEAM, 2015)

ü RH

Figure 7.77 shows the relative humidity behavior. This evidences that humidity remains approximately constant throughout the year, varying by 6% at noon from the period of maximum humidity in March and April, to the minimum between July and September.

During the day humidity varies significantly from 57% -62% to 97% at noon at 7 am. The highest humidity during the night is evidenced of the mixture layer and thereby increasing contamination during this period of the day.

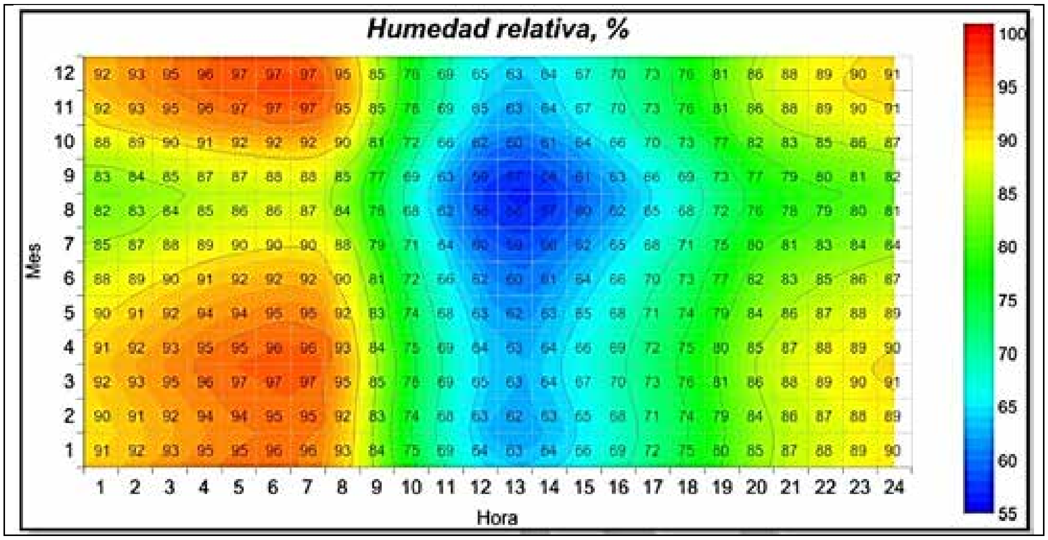


Figure 7.65 Relative humidity, Obonuco station IDEAM
Source (IDEAM, 2015)

ü Mixture height

The mixture height can be interpreted as the available vertical space of contaminants to disperse. At higher mixture height less pollution. The mixture height was calculated with the procedure included in the Protocol for Monitoring and Monitoring Air Quality (MAVDT, 2010).

Figure 7.78 shows the average hourly mixture height. Overnight the mixture drops height, close to 200 due to the absence of solar radiation and circulation wind, but from 5 hours it gradually increases with wind speed. From 7 am it rises faster because the incidence of solar radiation.

From 9 am the contribution of mechanical height associated with wind speed is reduced while the convective processes promoted by solar radiation dominates, reaching its peak at 5 pm to almost 1000 meters, when it abruptly drops with sunset reaching a height close to 0 during the night.

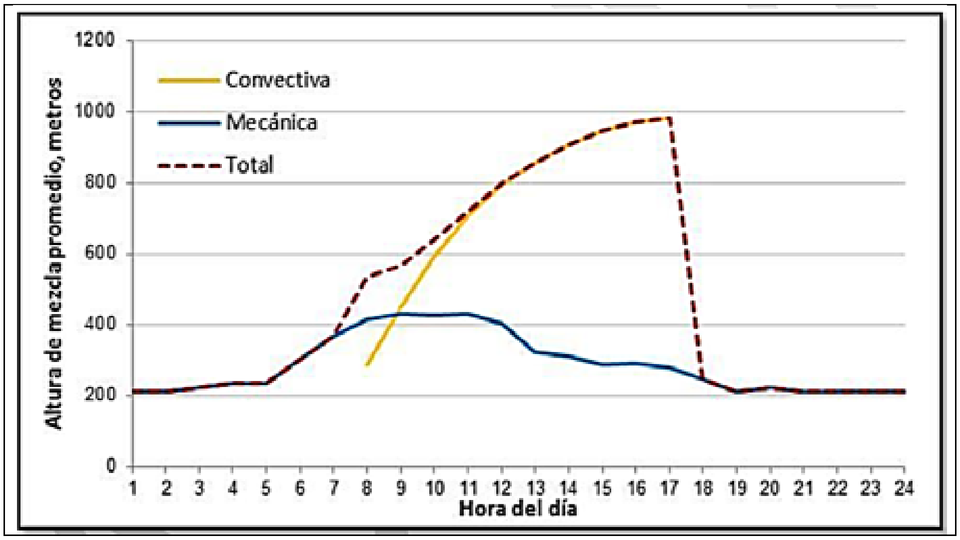


Figure 7.66 Calculated mixture height
Source (IDEAM, 2015)

ü Atmospheric stability

This indicates the degree of air turbulence. An unstable atmosphere promotes mixing of pollutants. The following is the stability category according to Pasquill - Gifford:

A: Very unstable conditions
B: Moderately unstable conditions
C: Slightly Unstable conditions
D: Neutral conditions
E: Slightly stable conditions
F: Moderately stable conditions

This parameter was calculated as indicated in annex 7.6.2. According to the results shown in Figure 7.79, during the day neutral conditions predominate whereas at night the highest frequency occurs for moderately stable conditions. This behavior leads to greater difficulty in the dispersion of pollutants.

Categoria de estabilidad Pasquill Gifford				
Hora	D	E	F	Total
0		3,8%	0,3%	4,2%
1		3,5%	0,7%	4,2%
2		3,5%	0,7%	4,2%
3		3,5%	0,7%	4,2%
4		3,5%	0,7%	4,2%
5		3,5%	0,7%	4,2%
6	4,2%			4,2%
7	4,2%			4,2%
8	4,2%			4,2%
9	4,2%			4,2%
10	4,2%			4,2%
11	4,2%			4,2%
12	4,2%			4,2%
13	4,2%			4,2%
14	4,2%			4,2%
15	4,2%			4,2%
16	4,2%			4,2%
17	4,2%			4,2%
18		4,2%		4,2%
19		3,5%	0,7%	4,2%
20		3,5%	0,7%	4,2%
21		3,5%	0,7%	4,2%
22		3,8%	0,3%	4,2%
23		3,5%	0,7%	4,2%
Total Resultado	50,0%	43,1%	6,9%	100,0%

Figure 7.679 Atmospheric stability behavior with the hour
Source (ASOAM SAS, 2016)

Figure 7.80 shows that atmospheric stability behaves evenly throughout the year, being slightly more stable in the months of December and January.

Hora	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic	Promedio
0	E	E	E	E	E	E	E	E	E	E	F	E	E
1	E	E	E	E	E	E	E	E	E	E	F	F	E
2	E	E	E	E	E	E	E	E	E	E	F	F	E
3	E	E	E	E	E	E	E	E	E	E	F	F	E
4	E	E	E	E	E	E	E	E	E	E	F	F	E
5	E	E	E	E	E	E	E	E	E	E	F	F	E
6	D	D	D	D	D	D	D	D	D	D	D	D	D
7	D	D	D	D	D	D	D	D	D	D	D	D	D
8	D	D	D	D	D	D	D	D	D	D	D	D	D
9	D	D	D	D	D	D	D	D	D	D	D	D	D
10	D	D	D	D	D	D	D	D	D	D	D	D	D
11	D	D	D	D	D	D	D	D	D	D	D	D	D
12	D	D	D	D	D	D	D	D	D	D	D	D	D
13	D	D	D	D	D	D	D	D	D	D	D	D	D
14	D	D	D	D	D	D	D	D	D	D	D	D	D
15	D	D	D	D	D	D	D	D	D	D	D	D	D
16	D	D	D	D	D	D	D	D	D	D	D	D	D
17	D	D	D	D	D	D	D	D	D	D	D	D	D
18	E	E	E	E	E	E	E	E	E	E	E	E	E
19	E	E	E	E	E	E	E	E	E	E	F	F	E
20	E	E	E	E	E	E	E	E	E	E	F	F	E
21	E	E	E	E	E	E	E	E	E	E	F	F	E
22	E	E	E	E	E	E	E	E	E	E	F	E	E
23	E	E	E	E	E	E	E	E	E	E	F	F	E

Figure 7.80 Average atmospheric stability depending on the month and hour

Source

- *Characteristics of the station*

In consultation with the IDEAM, it was determined that the Sindagua and Botana stations do not have enough regular information. However, based on the behavior of the variables above described it is concluded that the Obonuco station in the town of Pasto is sufficient to meet the objectives of the modeling representation. Based on available information, average hours and monthly averages of the station were obtained.

Data from the surface weather station were purged by the preprocessor AERMET, fed with a SAMSON file format (Surface Meteorological Observation Network and US Solar).

ü High station

As noted in the study area there is no high station that can be considered representative of the simulated zone. Therefore, the height parameters were calculated using the

IDEAM methodology specified in the Monitoring and Monitoring Air Quality Protocol (MAVDT, 2010).

Figure 7.81 Location of available high stations

Source NOAA Satellite Image information

- Period of data used

The information for the period from 1 January 2011 and 30 June 2015 was used. The AERMET model validated the data and extrapolation was performed according to the specifications established by US EPA.

Obonuco's station hour meteorology for twelve months was used. No weather information calculated by mesoscale models like WRF was used as the USEPA recommends its application to modeling scales exceeding 50 km, which is higher than that used in this project,

o Topography

The project area is characterized by the presence of mountain formations that modify air flow and thus the dispersion of pollutants.

The AERMOD model takes this effect into account and to that end elevations are introduced by a file containing, for each grid point of receptors, terrain elevation and scale of terrain height, hc, i.e. the greater height of the point within the area of interest for which the slope with respect to the receiver exceeds 10%.

This file is generated by the AERMAP program, which reads topographic files produced by the "Geological Compendium of the United States." However, in Colombia no files are generated with these formats so it was necessary to convert the files available in Colombia to the appropriate format.

Terrain elevations were obtained from satellite soundings with three arc-seconds resolution (90 meters) provided by the IGAC from the Endeavor spacecraft mission of February 2000.

This information was converted to a digital elevation model (DEM) and fed to the AERMAP program. Figure 14 shows a three-dimensional representation of the information in the file, while Figure 15 shows a detail of the topography of the project.

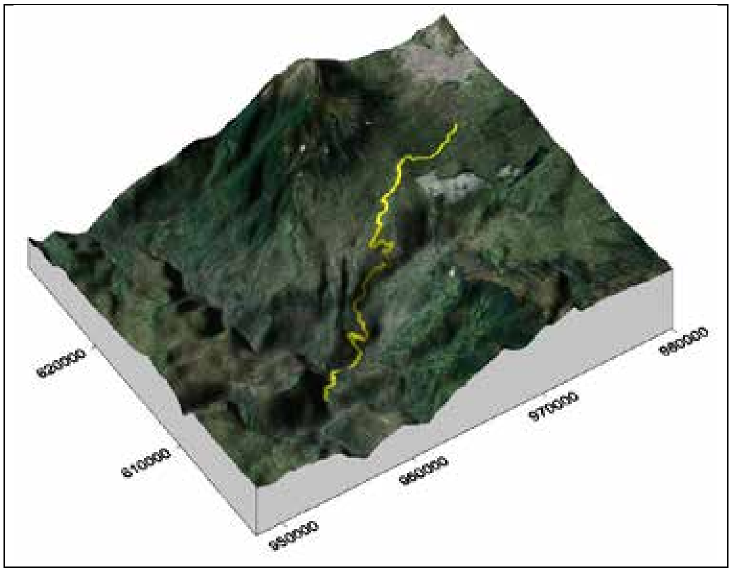


Figure 7.68 Dimensional representation of terrain elevations.

Source (ASOAM SAS, 2016)

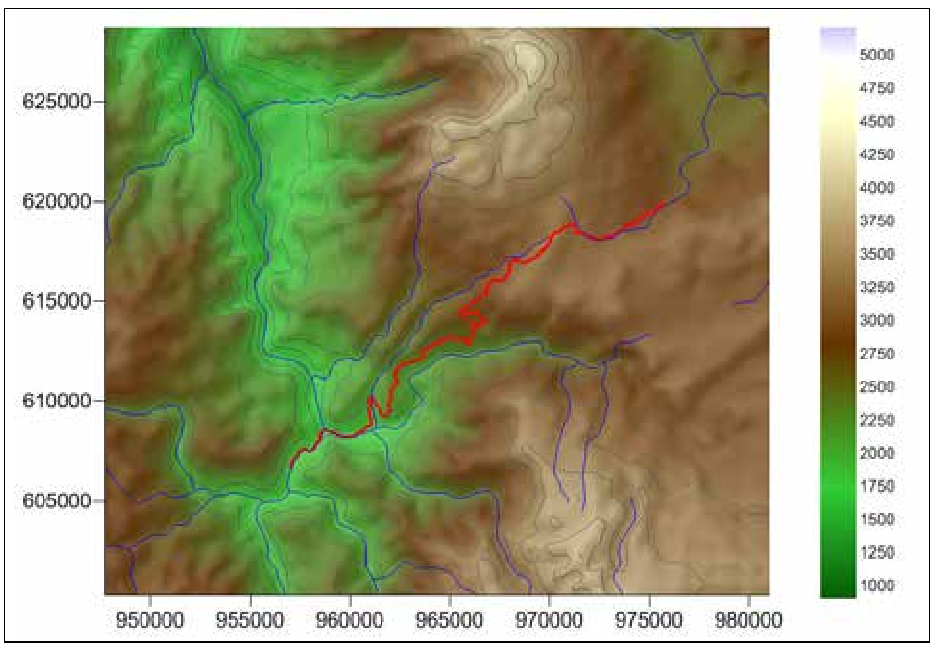


Figure 7.69 Contour plot of ground elevations

Source (ASOAM SAS, 2016)

- Surface parameters

The ground surface characteristics affect the dispersion of pollutants. The model was fed by dividing the road into several sections which were compartmentalized into 12 sectors 30 degrees divisions, covering a distance of three kilometers around as shown in Figure 16 and 17. The model was fed albedo values, surface roughness and averaged Bowen ratio for each sector.

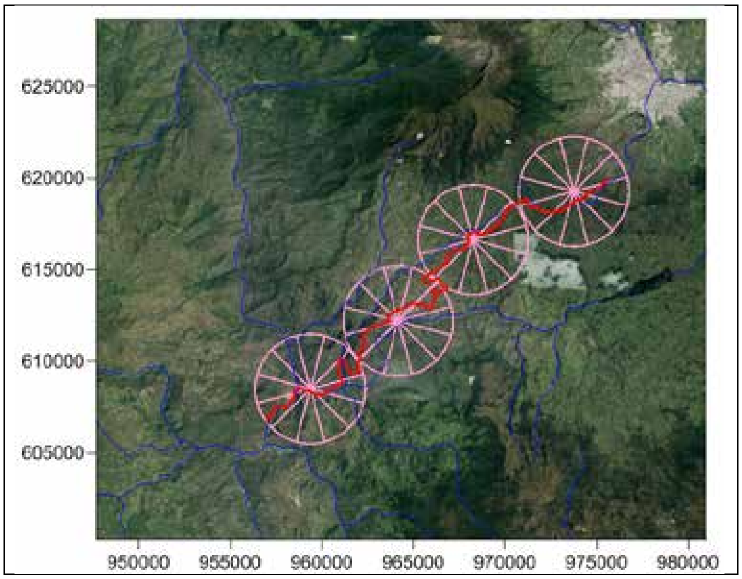


Figure 7.70 Compartmentalizing the road to determine surface parameters.
Source (ASOAM, 2016)

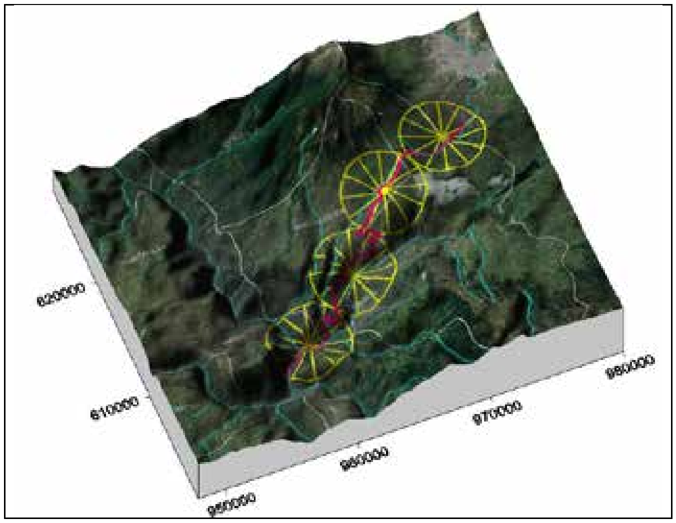


Figure 7.71 Perspective view model
Fuente (ASOAM, 2016)

- Albeldo

Albedo is a measure of the amount of radiation reflected by the Earth's surface. It reaches values from 0.1 for dense forests to 0.9 for fresh snow. It depends on the time of day, cloud cover and the soil surface.

The predominant land for the albedo is the corresponding area with vegetation and crops, urban area is also found.

- Superficial roughness

The length of surface roughness is related to the height of obstacles to the passage of wind and in principle is the height at which the wind speed is zero. The surface roughness was determined for each sector and the average was fed

- Bowen ratio

This value is an indicator of surface soil moisture and is defined as the sensible heat (which is used to heat the air) and latent heat (the time spent evaporating the water) ratio. The US EP-A1 values were used for tabulation, taking into account the type of surface of each sector, the rainy and dry seasons and monthly precipitation. The sectors were classified as vegetation area and urban area, in accordance with area characteristics.

- Buildings

The AERMOD model calculates the effect of buildings for punctual sources when the stack height exceeds 2.5 times the height of the surrounding buildings. For such end, the preprocessor BPIPRM was fed area construction obtained from satellite photography.

- Affected population

Annex GDB / mapping / PDF / EIADCRP_IP_002 shows fixed emission sources that will be present in the project as well as the densest population centers in the area of influence.

- Air Quality

To determine the air quality in the study area monitoring was conducted, where the concentration levels of air pollutants Particles less than 10 micrometers (PM10), sulfur oxides (SOx), nitrogen oxides (Nox) and carbon monoxide (CO) were determined. The results allow us to know the current conditions and characteristics of air quality and major sources of emissions that contribute pollutants to the atmosphere.

PM10 monitoring were obtained from high volume equipment for Particulate Matter (Hi-Vol) using the gravimetric analysis method and the NOx and SOx results were obtained from RAC three gases equipment spectrophotometric analysis method.

Based on current regulations and in accordance with the Tracking and Air Quality Monitoring Protocol, five monitoring stations for particulate matter and gases were installed, taking into account the following considerations:

- Installation of industrial camps where the asphalt plant and crushing plant will be located.

- Population centers (listed as potential recipients) that could be affected by development of project activities.

Parameters were evaluated in accordance with the Tracking and Air Quality Monitoring Protocol. Table 7.94 describes the general characteristics of air quality monitoring evaluated parameters.

Table 7.80 General characteristics of evaluated parameters

PARAMETER	DEFINITION	SOURCES	EFFECTS	VARIOUS
Particulates	Any solid or liquid material finely divided other than uncombined water, as measured by federal reference methods (40 CFR 53	Furnaces, crushers, mills, grinders, stoves, calciners, boilers, incinerators, conveyor belts, textile finishing, mixers and hoppers, cupolas, processor, spray booths, digesters, forest fires, among other equipment.	Effects on respiration and respiratory system, aggravation of existing respiratory and cardiovascular disease, lung tissue damage, carcinogenesis and premature mortality.	Examples: dust, smoke, oil droplets, asbestos beryllium
Carbon monoxide	Colorless, odorless, poisonous gas, lighter than air, produced by incomplete combustion of carbon present in the fuel.	Stationary and mobile sources that burn fuels (internal combustion engines, primarily gasoline engines). It is produced in much smaller quantities in domestic sources, volcanic gases emanating swamp gases, coal mines, thunderstorms, photo dissociation of CO2 in the upper atmosphere, fires and aquatic and terrestrial animals, among others.	They can be fatal in a short time in enclosed areas. Reacts with hemoglobin in the blood, preventing the transfer of oxygen.	It is in the atmosphere in concentrations of 0.1 ppm average
Nitrogen oxides	NO, NO2, N2O, N2O3, N2O4, N2O5: six kinds of nitrogen oxides are identified. A level of air pollution referred only to NO and NO2 (colorless	Produced by burning fuel at very high temperatures from nitrogen in the air. They are also produced from coal and nitrogen heavy oils: large electric generators, large industrial boilers, internal combustion	Reduced visibility, irritation of nose and eyes, pulmonary edema, bronchitis and pneumonia; VOCs react under the influence of light to form ozone. Nitrogen oxides are important potential	Excessive concentrations of NO and NO2 in the lower atmosphere causing a brownish color due to light absorption in the blue-green spectrum

PARAMETER	DEFINITION	SOURCES	EFFECTS	VARIOUS
	gases) and are typically reported as Nox.	engines, nitric acid plants.	contributors of harmful phenomena such as acid rain and eutrophication in coastal areas.	band.
Sulfur oxides	Acre, corrosive, toxic gases when sulfur-containing fuel is burned.	Electrical, industrial boilers, smelters, oil refineries, power automobiles, residential and commercial water heaters.	Difficulty breathing when dissolved in nose and upper airway; chronic cough and mucus secretion. It contributes to acid rain and reduced visibility phenomena (according to its concentration).	Sulfur oxides (SOX), generally formed by the combustion of sulfur-containing substances (coal and oil), particularly for steelmaking. It is perceived by smell in concentrations of 3 ppm (0.003%) to 5 ppm (0.005%). When at levels of 1 to 10 ppm induces increased respiratory rate and blood pulse.

Source: Resolution 2154 Tracking and Air Quality Monitoring Protocol.

Air quality for the Pedregal - Catambuco section was monitored by placing five stations in the area of influence of the project for a period of 18 calendar days 24 hours a day.

During this time parameters PM10, nitrogen dioxides and sulfur dioxides were evaluated. The location of the monitoring stations established for the project are shown in the Table 7.95 where the name of the county and the municipality are identified and their respective coordinates are specified; the general location of the points of the stations in the study area are also shown. (See Figure 7.86).

Table 7.815 Location of air quality monitoring stations, Pedregal - Catambuco section

SECTOR	AIR QUALITY POINT	COUNTY	MUNICIPALITY	PLANAR COORDINATES MAGNA SIRGAS ORIGIN WEST	
				EAST	EAST
Pedregal - Catambuco	6	Pedregal	Imués	958,439.945	608,235.425
	7	County seat	Tangua	964,268.717	612,785.492
	8	Chávez	Tangua	966,837.780	614,411.568
	9	El Tambor	Tangua	967,320.276	616,111.612
	10	Catambuco	Pasto	975,477.928	620,217.086

Source: (Gemini Environmental Consultants, 2016)

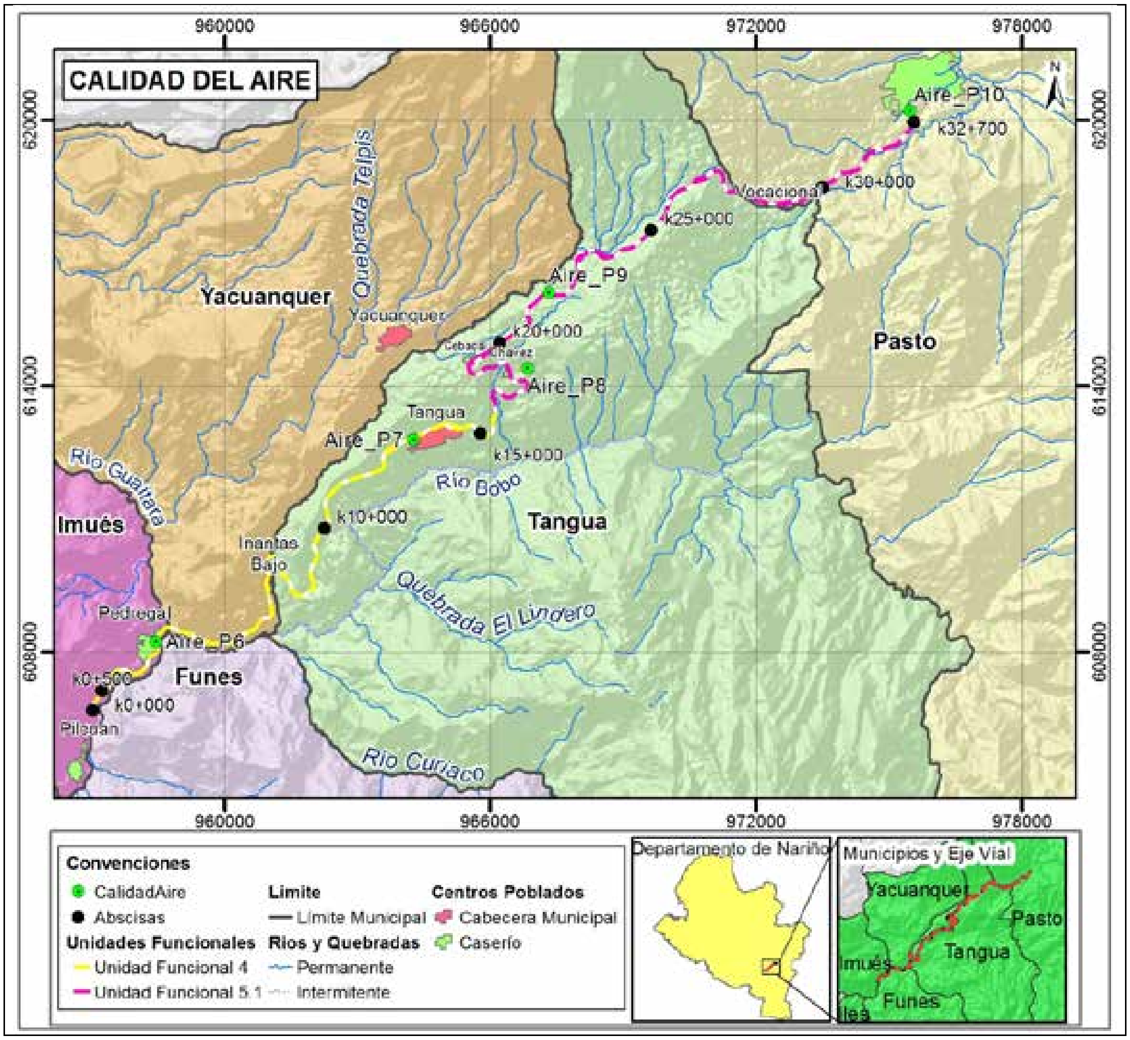


Figure 7.726 Air quality monitoring points, Pedregal - Catambuco Section

Source (Gemini Environmental Consultants, 2016)

Follows the results of air quality concentrations (PM10, SOx and NOx) obtained for each of the evaluated contaminants.

- *Monitoring results*

The daily results of laboratory tests (PM10) for five (5) monitoring stations are shown. As observed, the maximum values obtained are below the ceiling set by Resolution 610 of 2010 of the Ministry of Environment, Housing and Territorial Development

Table 7.82 Lab results Rumichaca - Pasto Road Project, Pedregal - Catambuco section

PARAMETER	DATE	POINT 6	POINT 7	POINT 8	POINT 9	POINT 10
		g / m3	g / m3	g / m3	g / m3	g / m3
PM10	Maximum	27.26	27.13	22,99	18.56	87.54
	Minimum	2.15	4	2.37	0,92	9.93
	Average	10.22	13.17	9.7	7.34	40.73
	Range	25.11	23.13	20.62	17.64	77.61
SOX	Maximum	16.72	20,65	15.68	17,11	30.22
	Minimum	2.96	2,21	2,98	2,98	2,99
	Average	7.83	8.85	7.33	6.53	9.87
	Average	13.76	18.44	12.7	14.13	27.23
NOx	Maximum	2,61	15.91	2,18	4.30	4,29
	Minimum	1.94	1,97	1.94	2.00	1,98
	Average	2,09	2.95	2,03	2,29	2,45
	Maximum	2,61	15.91	2,18	4.30	4,29
CO	Maximum	1,54	1,46	1,67	1,69	1,68
	Minimum	0.6	0,62	0,59	0,59	0,58
	Average	0.95	1	1.3	1.01	1,17
	Rank	0,94	0,84	1.08	1.1	1.1

Source: (ASOAM, 2016)

- Maximum concentrations of particulate matter

Figure 7.87 shows individual data per day obtained in each of the five (5) stations for PM10. According to this information we can see that the stations did not exceed the legal limit daily (100 ug / m3).

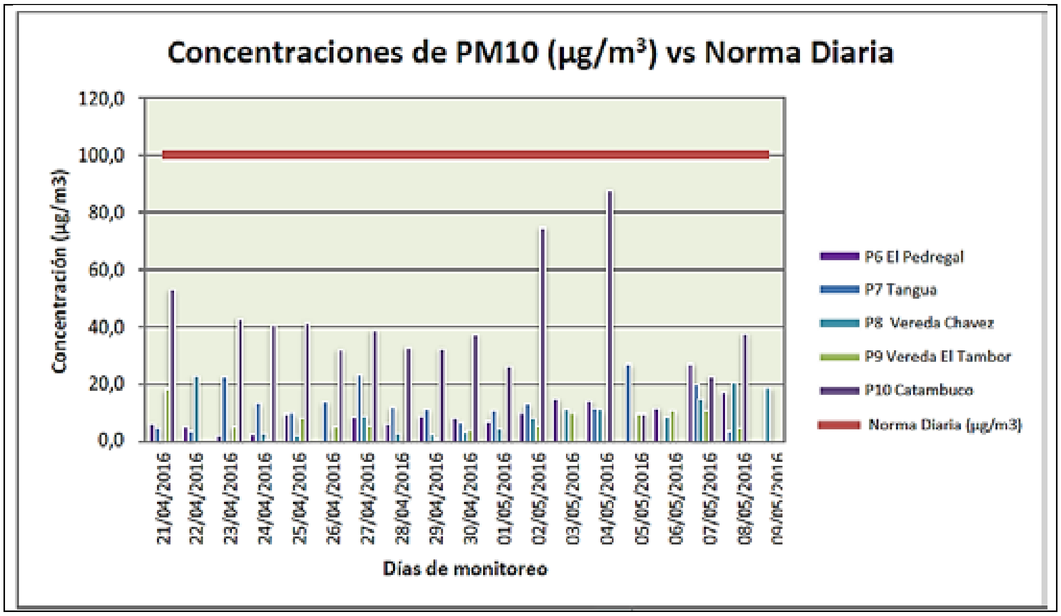


Figure 7.73 Air quality data for PM10 vs Resolution 610 of 2010

Source (ASOAM, 2016)

Figure 7.88 shows maximum concentration values of particles smaller than 10 microns (PM10) obtained for each station and comparison with standard (Resolution 610, 2010); data analysis shows that the highest P10 concentration was in the Catambuco station with a maximum value of 87.54 g / m3, while the lowest concentration was recorded for station P9 El Tambor with a minimum value of 18.56 g / m3.

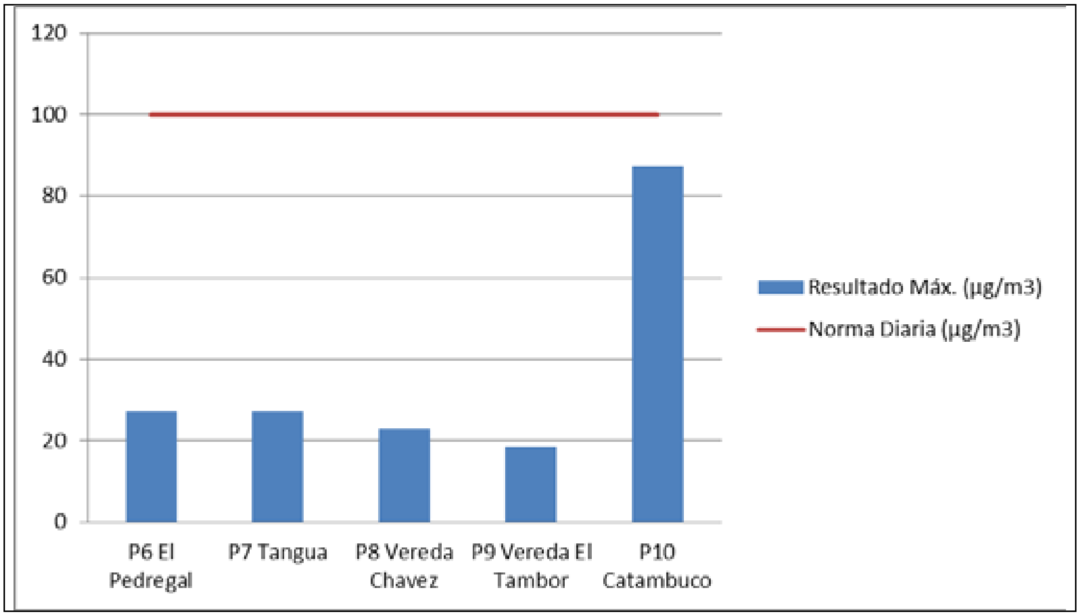


Figure 7.74 Maximum PM10 concentrations (ug / m3) vs Standard Daily (Res. 610, 2010)
Source: (ASOAM, 2016)

Concentrations of particles smaller than 10 microns (PM10) for five (5) monitoring stations located in the Pedragal - Catambuco section are below reference values established in Resolution 610 2010 for daily exposure time (100 g / m3).

Suspended particles cover a broad spectrum of organic or inorganic substances, dispersed in the air that can come from natural and artificial sources (artisanal brickworks, vehicles, crematorium, etc.). Combustion of fossil fuels from traffic (heavy and light vehicles) is a major source of particulate contamination along the corridor and area of influence, it can produce various kinds of particles: large particles, by releasing unburned materials (fly ash), fine particles formed by the condensation of vaporized materials during combustion, and secondary particles, through atmospheric reactions of removed contaminants such as gases. PM10 (“thoracic”) particles below 10 µm could enter the airways affecting health

- Contamination contributions

Atmospheric contamination contributions are presented in the following table including the processing plant to be located in proposed Cebadal and Tangua camps.

Table 7.83 Crushing plants entry records

	CAMPAMENTOS				
DESCRIPCION OPERACIÓN	31+100	PICAPIEDRA	MIKEL	TANGUA	CEBADAL
Equipo de combustión	ver anexo 4	ver anexo 4	ver anexo 4	ver anexo 4	ver anexo 4
Sistema de salida de gases	múltiple de escape seco • conexiones flexibles de acero inoxidable con conexión de boquilla dividida • salida de brida del escape	múltiple de escape seco • conexiones flexibles de acero inoxidable con conexión de boquilla dividida • salida de brida del escape	múltiple de escape seco • conexiones flexibles de acero inoxidable con conexión de boquilla dividida • salida de brida del escape	múltiple de escape seco • conexiones flexibles de acero inoxidable con conexión de boquilla dividida • salida de brida del escape	múltiple de escape seco • conexiones flexibles de acero inoxidable con conexión de boquilla dividida • salida de brida del escape
Combustible empleado	diesel	diesel	diesel	diesel	diesel
Consumo de combustible (kg/hr)y/o (g.p.m)	69120 gal/mes	69120 gal/mes	69120 gal/mes	69120 gal/mes	69120 gal/mes
Flujo másico (kg/hr) gas de combustión	No se reporta	No se reporta	No se reporta	No se reporta	No se reporta
Tiempo de operación	24 horas 7 dias a la semana	25 horas 7 dias a la semana	26 horas 7 dias a la semana	27 horas 7 dias a la semana	28 horas 7 dias a la semana
Producción (kg/hr)/(m3/hr)	73-109 TPH	73-109 TPH	73-109 TPH	73-109 TPH	73-109 TPH
%perdida estimada por finos	7%	7%	7%	7%	7%
Potencia. (BHP) y/o (HP)	15 HP	15 HP	15 HP	15 HP	15 HP
	CAMPAMENTOS				
	31+100	PICAPIEDRA	MIKEL	TANGUA	CEBADAL
Equipo					
Altura de la chimenea (Cono)	0m	0m	0m	0m	0m
Temperatura promedio de salida de gases de chimenea	No aplica	No aplica	No aplica	No aplica	No aplica
Caudal de gases de salida (m3/hr)	8575,9 m3/h	8575,9 m3/h	8575,9 m3/h	8575,9 m3/h	8575,9 m3/h
Velocidad de gases de chimenea	6,19m/s	6,19m/s	6,19m/s	6,19m/s	6,19m/s
Diámetro chimenea	0,7 m	0,7 m	0,7 m	0,7 m	0,7 m
Coordenadas punto de emisión / *Emisiones*	600153,471 / 956663,927	604370,648 / 954904,158	606173,169 / 957180,973	965376,984 / 613320,089	967202,153 / 615913,948
Material particulado	0.972 kg/h	0.972 kg/h	0.972 kg/h	0.972 kg/h	0.972 kg/h
NOx	0.14kg/h	0.14kg/h	0.14kg/h	0.14kg/h	0.14kg/h
SO_2	0.145kg/h	7.145kg/h	0.145kg/h	0.145kg/h	0.145kg/h
PM10*	0.018 kg/h	0.018 kg/h	0.018 kg/h	0.018 kg/h	0.018 kg/h

Table 7.84 Asphalt plants entry records

DESCRIPCION OPERACIÓN	PEAJE 11+200	SAN JUAN	31+100	PICAPIEDRA	MIKEL	TANGUA	CEBADAL
Equipo de combustión	40 Mbtu	40 Mbtu	40 Mbtu	40 Mbtu	40 Mbtu	40 Mbtu	40 Mbtu
Sistema de salida de gases	ventilador	ventilador	ventilador	ventilador	ventilador	ventilador	ventilador
Combustible empleado	Diesel y Fuel Oil.	Diesel y Fuel Oil.	Diesel y Fuel Oil.	Diesel y Fuel Oil.	Diesel y Fuel Oil.	Diesel y Fuel Oil.	Diesel y Fuel Oil.
Consumo de combustible (kg/hr)y/o (g.p.m)	6 gal/h	6 gal/h	6 gal/h	6 gal/h	6 gal/h	6 gal/h	6 gal/h
Flujo másico (kg/hr) gas de combustión	No se reporta	No se reporta	No se reporta	No se reporta	No se reporta	No se reporta	No se reporta
Tiempo de operación	11 horas 7 dias a la semana	11 horas 7 dias a la semana	11 horas 7 dias a la semana	11 horas 7 dias a la semana	11 horas 7 dias a la semana	11 horas 7 dias a la semana	11 horas 7 dias a la semana
Producción de asfalto (kg/hr)/(m3/hr)	146 TPH	147 TPH	148 TPH	149 TPH	150 TPH	151 TPH	152 TPH
Potencia (BHP) y/o (HP)	1800000 BTU/h	1800000 BTU/h	1800000 BTU/h	1800000 BTU/h	1800000 BTU/h	1800000 BTU/h	1800000 BTU/h

	CAMPAMENTOS						
	PEAJE 11+200	SAN JUAN	31+100	PICAPIEDRA	MIKEL	TANGUA	CEBADAL
Equipo							
Altura de la chimenea	17.5m	17.5m	17.5m	17.5m	17.5m	17.5m	17.5m
Temperatura promedio de salida de gases de chimenea	110ºc	110ºc	110ºc	110ºc	110ºc	110ºc	110ºc
Caudal de gases de salida (m3/hr)	24.5 m3/min	24.5 m3/min	24.5 m3/min	24.5 m3/min	24.5 m3/min	24.5 m3/min	24.5 m3/min
Velocidad de gases de chimenea	6.2 m/s	6.2 m/s	6.2 m/s	6.2 m/s	6.2 m/s	6.2 m/s	6.2 m/s
Diámetro chimenea	0.310/0.40 m (rectangular)	0.310/0.40 m (rectangular)	0.310/0.40 m (rectangular)	0.310/0.40 m (rectangular)	0.310/0.40 m	0.310/0.40 m	0.310/0.40 m
Coordenadas punto de emisión	586267,806; 943819,788	590846,528; 948345,161	600228,612; 956133,8	604504,112; 954920,981	604484,04; 956408,81	965344,59; 613286,37	967254,03; 615945,47
Emisiones							
Material particulado	346.0 ml/m3	346.0 ml/m4	346.0 ml/m5	346.0 ml/m6	346.0 ml/m7	346.0 ml/m8	346.0 ml/m9
NOx	87.9 ml/m3	87.9 ml/m4	87.9 ml/m5	87.9 ml/m6	87.9 ml/m7	87.9 ml/m8	87.9 ml/m9
SO_2	337.2 ml/m3	337.2 ml/m4	337.2 ml/m5	337.2 ml/m6	337.2 ml/m7	337.2 ml/m8	337.2 ml/m9
PM10*	0.320 ml/m3	0.320 ml/m4	0.320 ml/m5	0.320 ml/m6	0.320 ml/m7	0.320 ml/m8	0.320 ml/m9

- *Modeling configuration*

Input data were uploaded to the model in the form of a file in text format with information divided into five sections namely:

CO: Control Parameters
SO: Emission sources
ME: Meteorology
RE: Data of receptors
OU: Control parameters data output

- *Control section*

Table 7.99 shows model input control data.

Table 7.85 Control options fed to the model

Option	Value	Explanation
Title 1	RUMICHACA – PASTO ROAD	Identification
Title 2	PST dispersion model	Identification
Pollutant	PST	Total suspended particles, or appropriate
Elevated terrain	Elev	Flat land
Elevated terrain	Meters	Units of introduced elevations
Run or not	Run	Performs complete run
Averaging	Aual, 24hr	Produces an output table with maximum annual and daily averages
Dispersion	Concentration	Produces concentration data.

Source (ASOAM SAS, 2016)

Contaminant concentrations were calculated for averaging periods defined in Resolution 610 of 2010 MAVDT, which are annual and daily for both PST and PM10.

- Section source

The characteristics of the emission sources are specified here, including the variability of emission over time. In total 416 punctual sources and of area and three roads were fed. The location of these sources are shown in Annex 1.

- Section receptors

Three types of receptors were defined:

- Discrete receptors located in the five monitoring air quality points of the section.

- Cartesian mesh originating in 932.000mE, 578.000mN, 33 grid coordinates in the X axis 32 in the Y axis spaced every 1,000 meters, for a total of 1056 receptors.
- A group of receptors distributed every 500 meters of the road corridor, at distances in meters of 20, 50, 100, 200, 500, 1000, 1500, 2000, 2500, 3000 on either side of the road, for a total of 6920 receptors.

o Output section

The following aspects were defined:

- Name of the output file format data in X, Y, Z: with XYZ extension.
- Write table of maximum in the output file
- Not write table per receptor in the output file.

o Dispersion modeling results

Follows the numbers for the dispersion models for the sampling parameter, having considered the activities and work fronts of asphalt and crushing plants. In addition, mass balances used to generate said models are presented.

CAMP	GENERATOR	FUEL	MP GR / S	NOX GR / S	SOX GR / S	PM 10 GR / S
TANGUA	asphalt plant	Diesel	0.257424	0.0653976	0.2508768	0.00023808
CEBADAL	asphalt plant	Diesel	0.257424	0.0653976	0.2508768	0.00023808
TANGUA	crusher	Diesel	0.26999244	0.0388878	0.04583205	0.00499986
CEBADAL	crusher	Diesel	0.26999244	0.0388878	0.04583205	0.00499986

Annex 7.6.2.6 shows the modelling output files with drawings obtained; and below obtained results are analyzed.

o Isopleth diagram

Figure 7.89 to Figure 7.97 show concentration diagrams for modeled contaminants and Table 7.100 shows maximum permissible levels for contaminants.

Table 7.100 Maximum permissible levels for contaminants

Contaminante	Nivel Máximo Permisible (µg/m³)	Tiempo de Exposición
PST	100	Anual
	300	24 horas
PM10	50	Anual
	100	24 horas
PM2.5	25	Anual
	50	24 horas
SO_2	80	Anual
	250	24 horas
	750	3 horas
NO_2	100	Anual
	150	24 horas
	200	1 hora
O_3	80	8 horas
	120	1 hora
CO	10.000	8 horas
	40.000	1 hora

These images highlight the line from which the ceiling is exceeded according to the standard and in yellow the area of influence of the project.

Outside the area of indirect influence of the project the concentrations are below the standard for all pollutants.

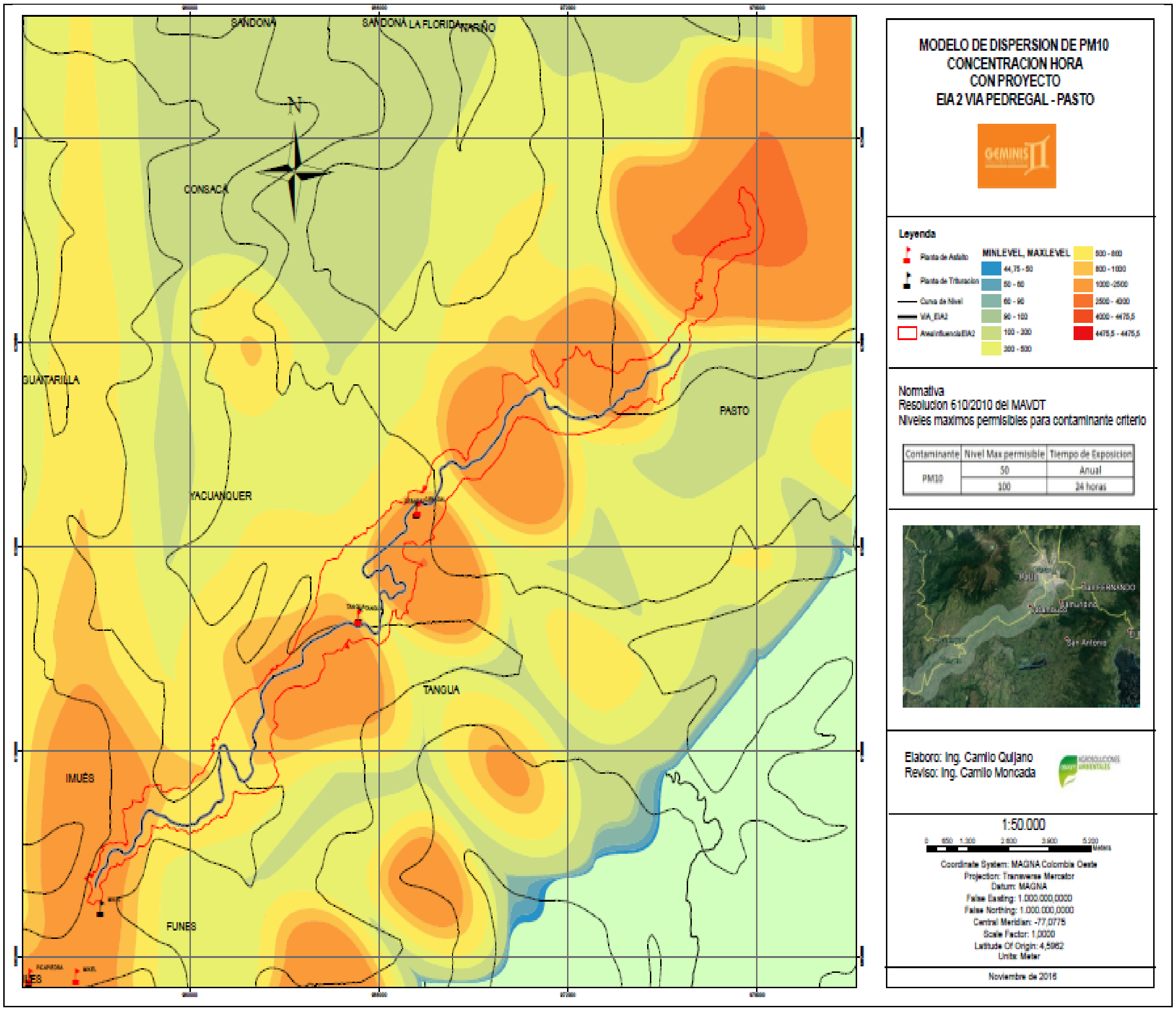


Figure 7.75 PM10 concentrations, annual period

Source (ASOAM SAS, 2016)

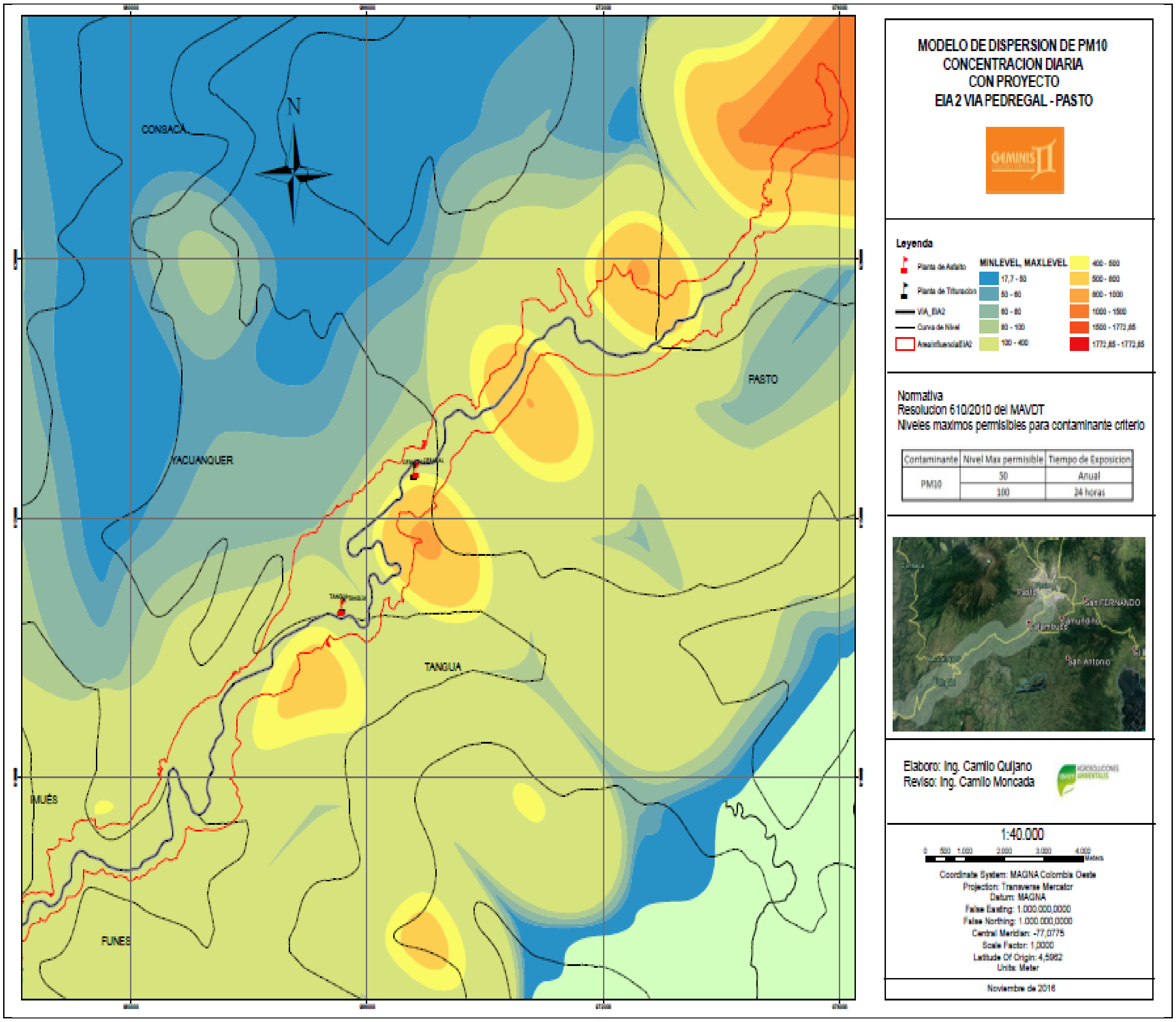
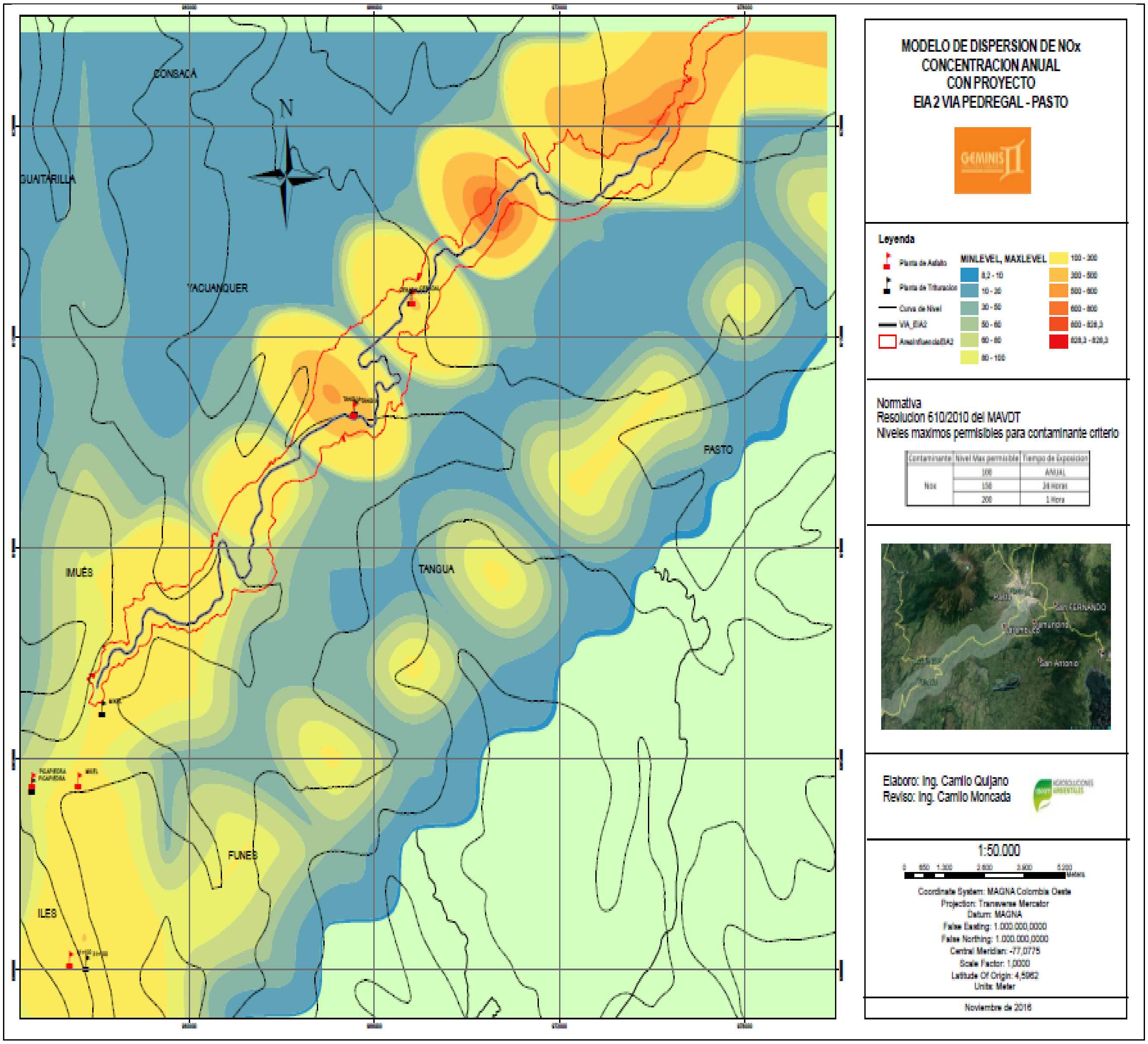


Figure 7.90 PM10 concentraciones, daily periodo
Source (ASOAM S.A.S, 2016)



Photograph 7.91 NO2 concentrations, annual period

Source (ASOAM S.A.S, 2016)

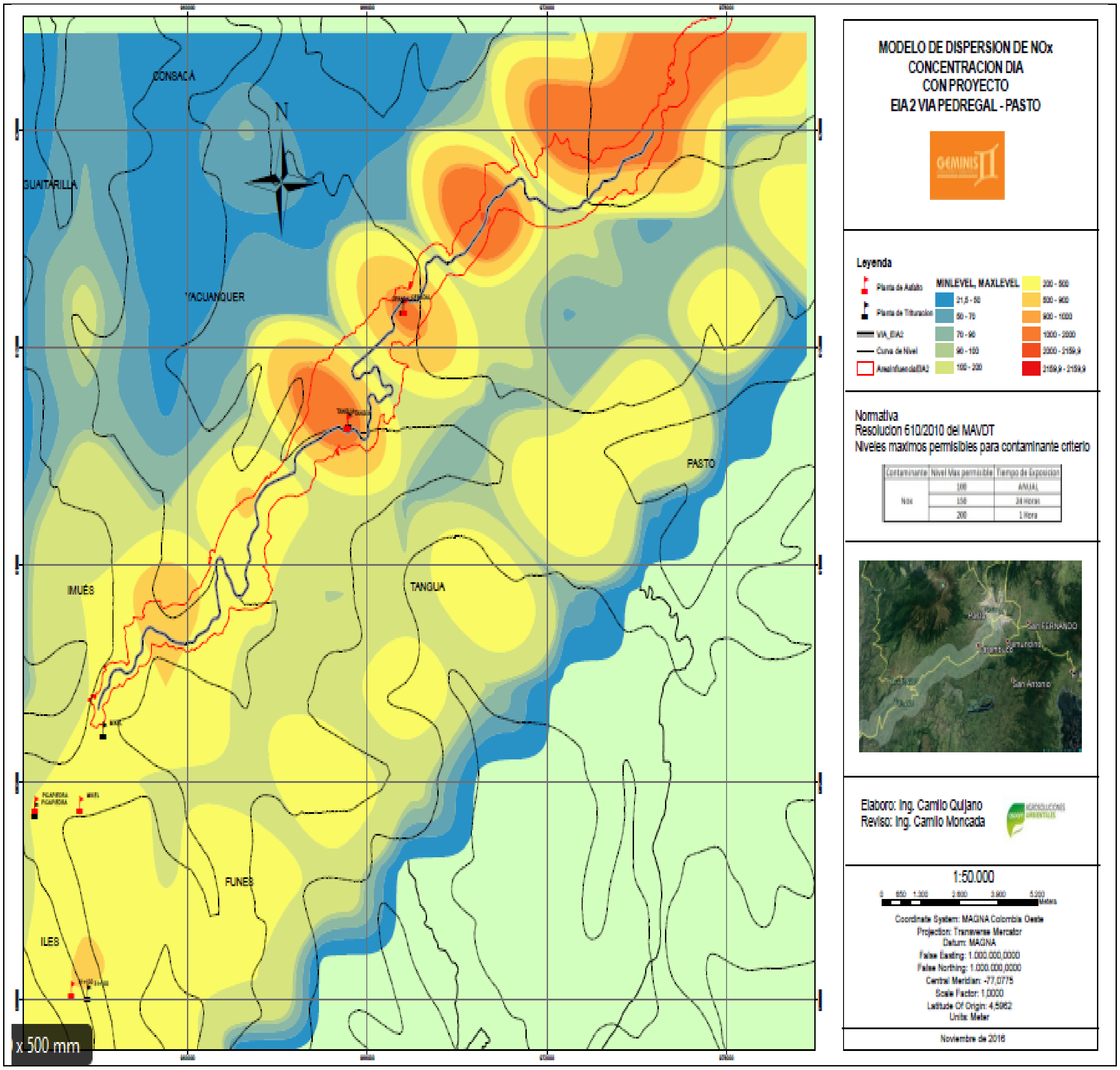


Figure 7.92 NO2 concentrations, daily period

Fuente (ASOAM S.A.S, 2016)

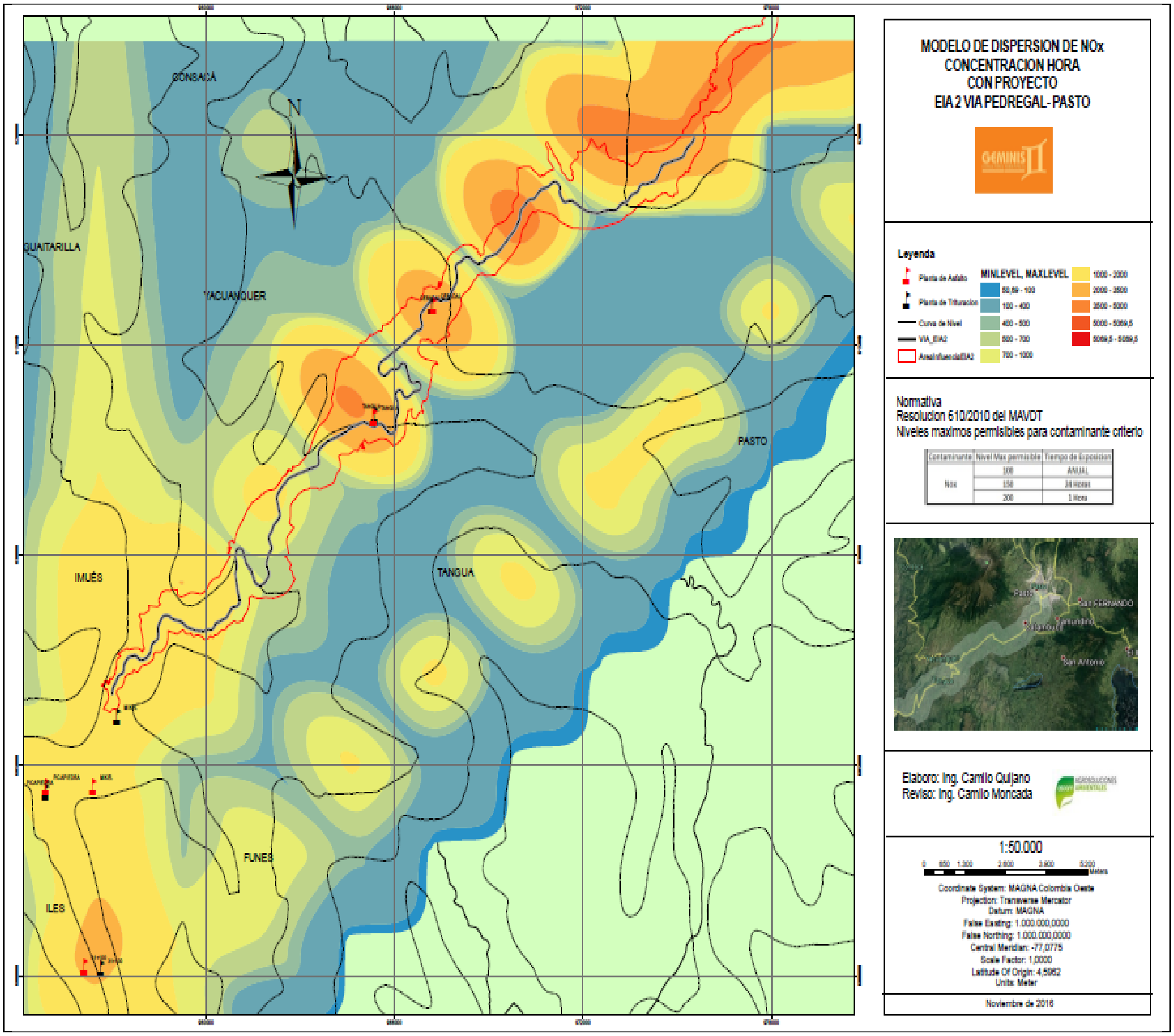


Figure 7.76 NO2 concentrations, hour period
Source (ASOAM S.A.S, 2016)

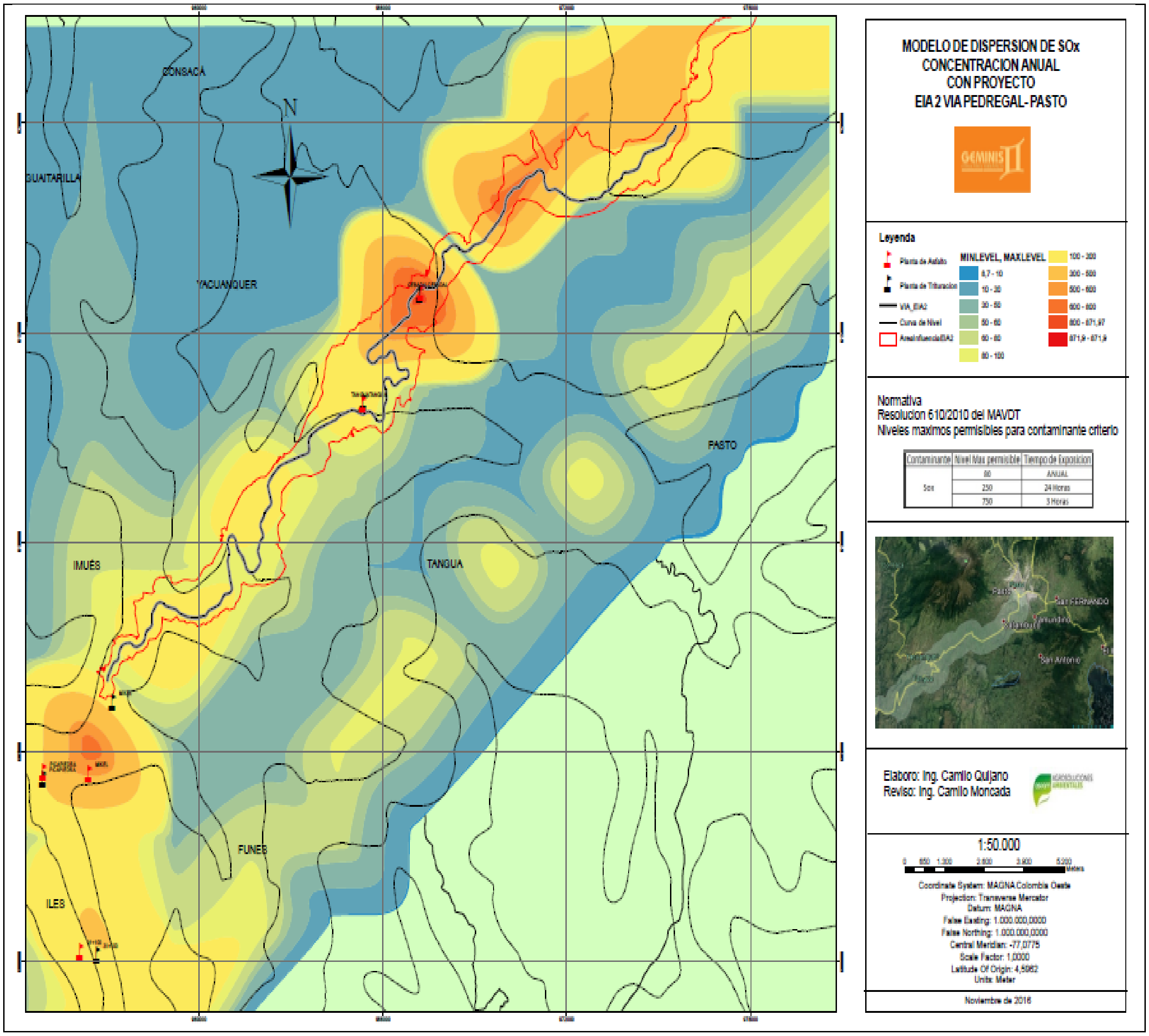


Figure 7.774 SO2 concentrations, annual period

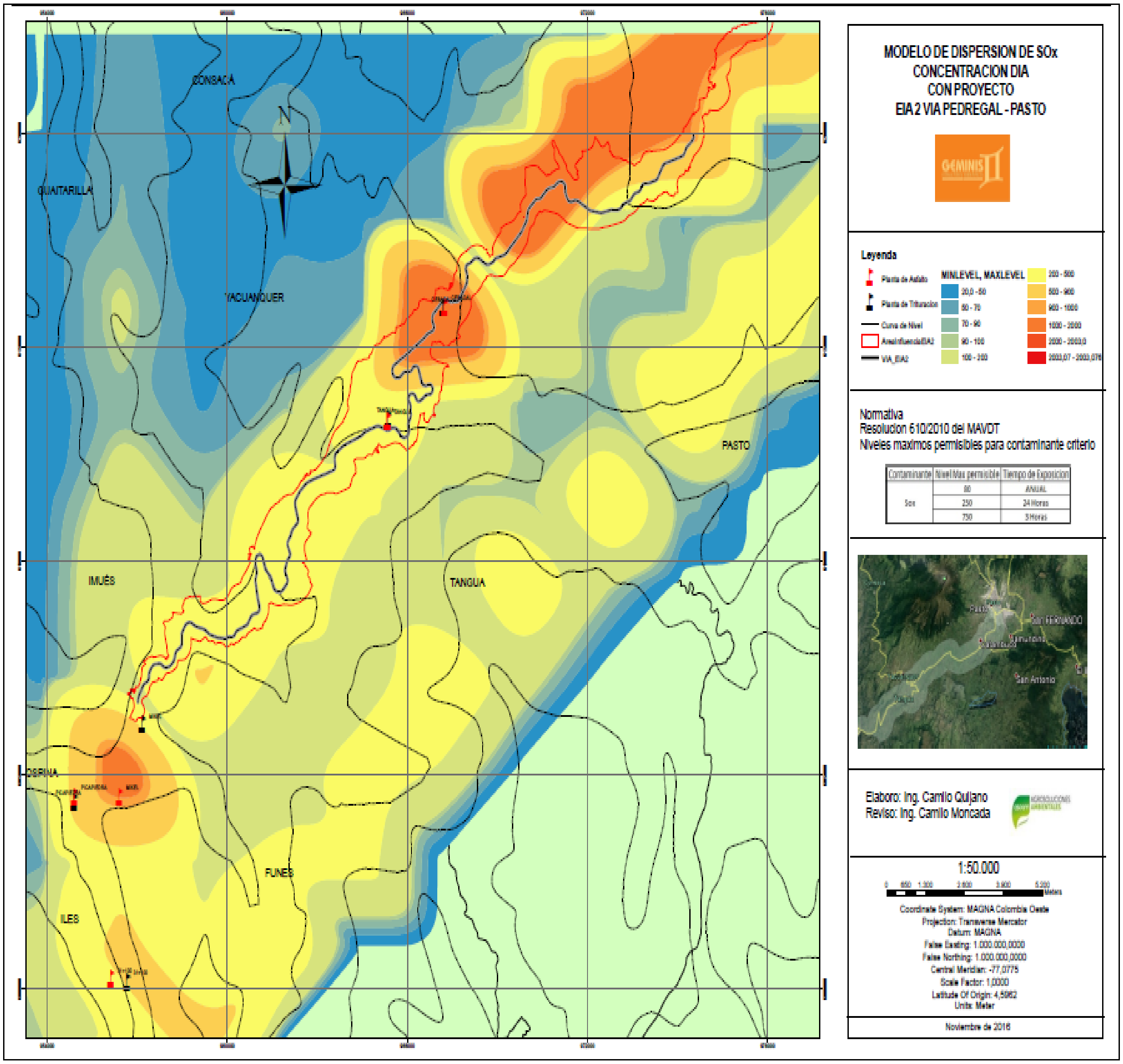


Figure 7.785 SO2 concentrations, daily period

Source (ASOAM S.A.S, 2016)

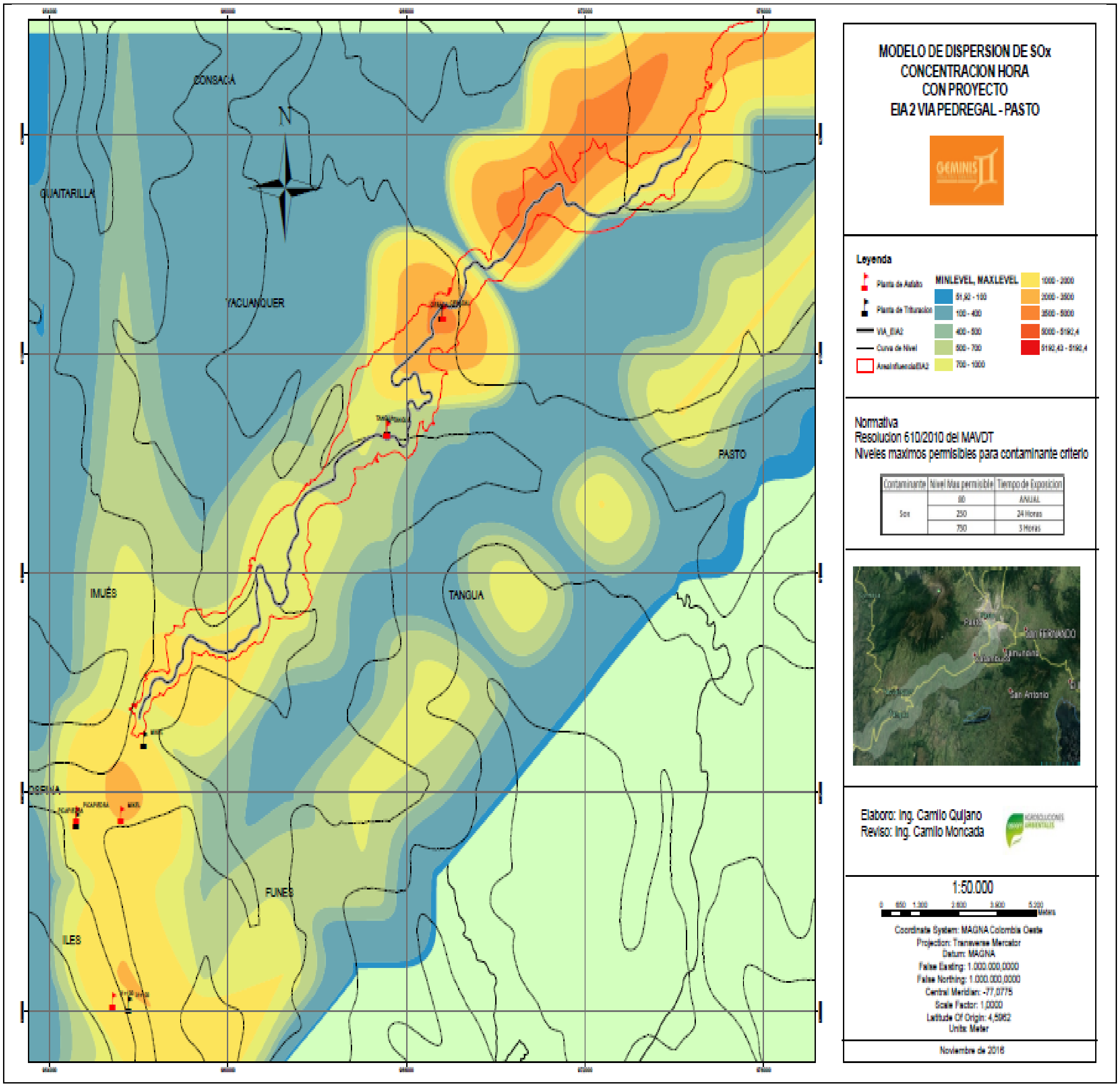


Figure 7.979 SO2 concentrations, 3 hour period

Source (ASOAM S.A.S, 2016)

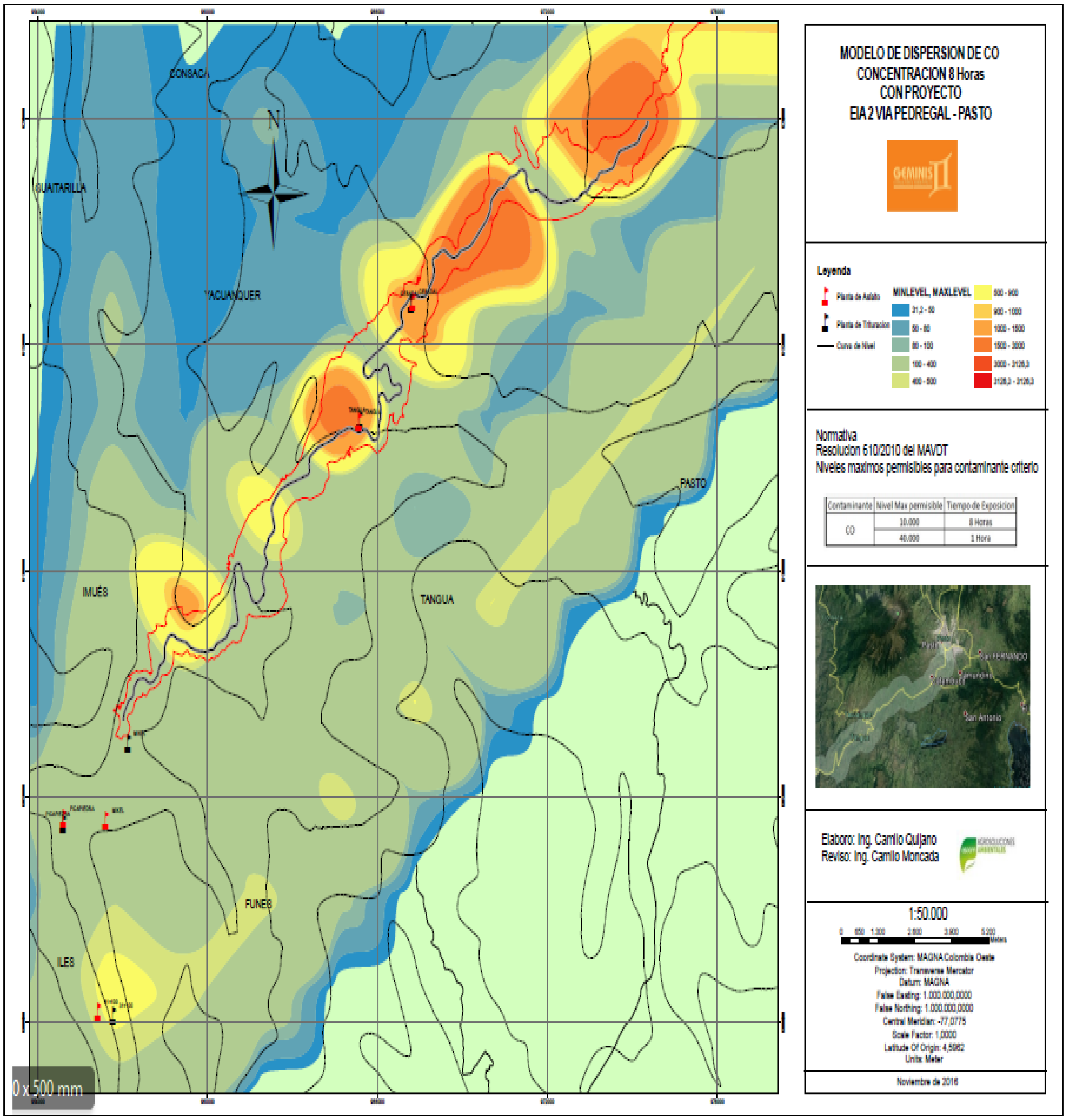


Figure 7.807 CO concentrations, 8 hour period
Source (ASOAM S.A.S, 2016)

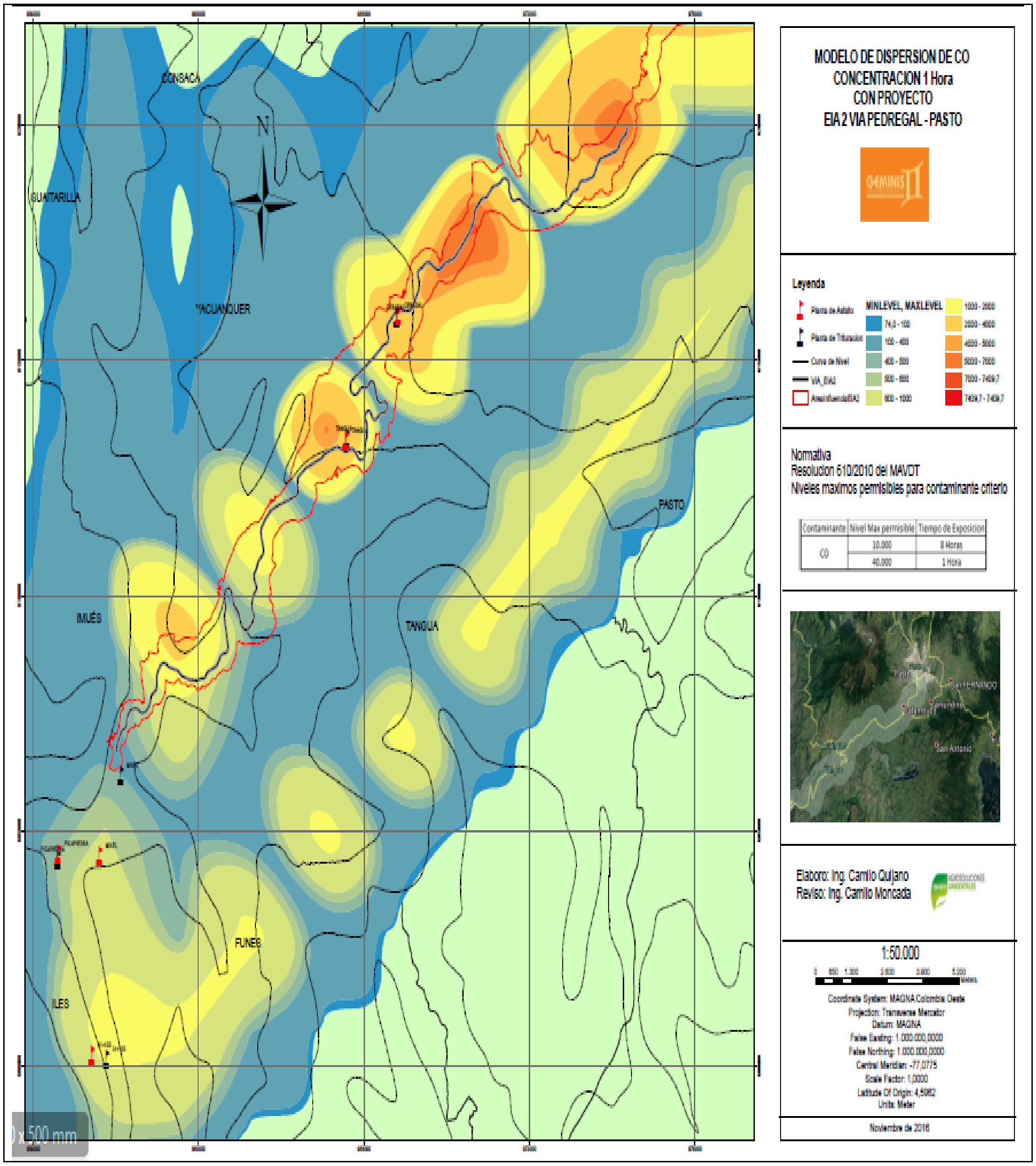


Figure 7.81 CO concentrations, 1 hour period

Source (ASOAM S.A.S, 2016)

Follows the volumetric flow in the following table; information used to run the models:

	ATMOSPHERIC EMISSION SOURCE INFORMATION		Volumetric flow emissions			
	CAMP	Flow m3 / s	mp g / m3	NOx mg / m3	SOx g / m3	PM10 ug / m3
Asphalt plants	Tangua	0.744	346000	87900	337200	320
	CEBADAL	0.744	346000	87900	337200	320
Crushing plants	Tangua	2.3769	113,587.288	16360.309	19281.7927	2103.468296
	CEBADAL	2.3769	113,587.288	16360.309	19281.7927	2103.468296

Based on the above, control measures leading to reducing emission values generated by plants (asphalt and crushers) must be implemented; information to be corroborated in detail during implementation and selection of the final equipment; based on which the efficiencies and type of control systems to implement will be calculated in order to ensure compliance with the permissible maximums of Resolution 610 of 2010.

To estimate the models with project with control, the basis are emissions from asphalt and crushing plants located at the works fronts, taking into account the mass balance calculated values; dispersion and / concentration levels not in compliance with established environmental regulations. Therefore, the implementation of control systems with a minimum emission efficiency of 85% was considered desirable, so as to not exceed the maximum allowable established in Resolution 0610 of 2010.

Based on modeling with project and once evidenced exceedances of concentrations established by Resolution 610 of 2010, implementing control actions and / or mitigation at the source measures were considered, which should be reviewed during the detailed engineering phase, project phase where replacing emission generating equipment or implementing emission control systems will be considered, for a minimum removal of 85% to comply with the standard and as analyzed in the dispersion models of numeral 8.3 of Annex 7.6.2, which evidences compliance with the standard.

In addition to the aforesaid, to clarify that a detailed analysis of generation sources and therefore emissions due to their future operation is being prepared. Given the aforementioned, less uncertainty in modeling with project is expected resulting in greater control engineering detail validation required in order to comply with the national air quality standard, Resolution 610 of 2010.

o 7.6.2.5 Calibration

The model was calibrated using the results of air quality monitoring conducted for the baseline.

Road emission was iteratively adjusted for calibration, and successive model runs were made until n the monitoring points had concentrations close to those obtained by measurement, which is determined by a percentage error indicator given by:

$$E = 100\frac{\sum_i^n |Cmodelada, i - Cmedida|}{\sum_i^n Cmedida}$$

For calibration purposes, the baseline scenario was used as a basis by reference only five (5) sampling points: the following tables show the results obtained which show an error between 2% to 9%, i.e., a confidence level of the baseline modeling exercises on the order of 91% on average.

The following tables show obtained results:

Table 7.101 PM_{10} calibration results

Site	Point	Modeled Concentration, mg / m3	Emission g / s	Modeled Concentration, mg / m3	Emission g / s	Modeled Concentration, mg / m3	Emission g / s	Modeled Concentration, mg / m3	Emission g / s	Modeled Concentration, mg / m3
El Pedregal	6	27.26	1.00E-05	3.88	7.03E-05	21.82	8.78E-05	21.91	1.09E-04	27.32
Tangua	7	27.13	1.00E-05	7.30	3.71E-05	71.74	1.40E-05	40.03	1.90E-06	27.14
Chavez	8	22.99	1.00E-05	1.86	1.24E-04	4.21	6.76E-04	2.76	5.63E-03	23.05
El Tambor	9	18.59	1.00E-05	7.65	2.43E-04	30.72	1.73E-05	18.72	1.73E-05	8,55
Catambuco	10	87.54	1.00E-05	1.74	5.04E-04	4.65	9.49E-03	151.39	5.49E-03	86,32
Error indicator				85%		87%		53%		9 %

Source (ASOAM SAS, 2016)

Table 7.86 NO_2 calibration results

Site	Point	Modeled Concentration, mg / m3	Emission g / s	Modeled Concentration, mg / m3	Emission g / s	Modeled Concentration, mg / m3	Emission g / s	Modeled Concentration, mg / m3
El Pedregal	6	2,61	9,00E-06	2,53	9,28E-06	2.6	9,03E-06	2.6
Tangua	7	15.91	3,00E-05	14.4	3,31E-05	15.89	3,00E-05	15.89
Chávez county	8	2,18	2.00E-05	2,06	2,12E-05	2,18	2.00E-05	2,18
El Tambor county	9	4.3	8,00E-06	4.3	8,00E-06	4.3	8,00E-06	4.3
Catambuco	10	4,29	5,00E-05	4,18	5,13E-05	4.28	5,01E-05	4.28
Error indicator				13%		7%		7%

Source (ASOAM SAS, 2016)

Table 7.87 SO_2 calibration results

Site	**Point**	**Modeled Concentration, mg / m3**	**Emission g / s**	**Modeled Concentration, mg / m3**
El Pedregal	6	16.72	5,95E-05	16.7
Tangua	7	20,65	4,30E-05	20.64
Chávez county	8	15.68	1,52E-04	15,65
El Tambor county	9	17,11	3,18E-05	17.1
Catambuco	10	30.22	3,61E-04	30,15
Error indicator				2%

Source (ASOAM SAS, 2016)

Table 7.88 CO calibration results

Site	Point	Modeled Concentration, mg / m3	Emission g / s	Modeled Concentration, mg / m3
El Pedregal	6	0.95	3,38E-06	0.948
Tangua	7	1	2,08E-06	0,998
Chávez county	8	1.3	1,26E-05	1,32
El Tambor county	9	1.01	1,88E-06	1.01
Catambuco	10	1,17	1,40E-05	1,17
Error indicator				6%

Source (ASOAM SAS, 2016)

- *Conclusions and recommendations*

The areas with higher PM10, SOx, NOx, CO concentrations are at the end of the section, in the municipality of Pasto, which makes perfect sense considering population density of the area, in addition to the presence of industrial processes developed in the city of Pasto, so probably by dispersion city activities contribute to the dispersion modeling conducted for this study. Other areas of lesser magnitude are located in the municipalities of Yacuanquer and Tangua, in this case their contribution is smaller since their activities generate, to a lesser extent, the pollutants of interest.

Outside the area of project influence, concentrations are lower than the norm for all pollutants except for a limited area in the urban area of the municipality of San Juan de Pasto, in the north end of the area of influence; this is consistent with what was discussed in the previous paragraph.

Overall, apart from identified sources, other environmental factors that most affect the results of the dispersion are human settlements and all human activities related to the socioeconomic development of the area.

There is a relationship between relief and Isopleths configuration seen in the movement of contaminants towards the foothills, especially in the Galeras volcano.

The maximum contribution to the concentration was obtained for November.

It is recommended to evaluate the possibility of installing a permanent weather station to support future dispersion models mid-span. A station can help sustain the impact on modeled population.

For future monitoring, monitoring stations should be located according to the modeling results, taking into account the maximum and low concentration areas, according to the Tracking and Monitoring Air Quality Protocol (MAVDT, 2010).

The results obtained from the modeling in this scenario, having considered the commissioning of asphalt and crushing plants, show a minimal increase in concentrations relative to those presented for modeling without the project taking into account the allowable maximum levels for contaminants criteria set out in Resolution 0610 of 2010.

Based on the aforesaid, it is necessary to implement control measures leading to reducing emission values generated by plants (asphalt and crushers), information that should be corroborated in detail during implementation and selection of the final equipment; based on which the efficiencies and type of control systems should be calculated in order to ensure compliance with the maximum permissible of Resolution 610 of 2010; management measures the environmental license amendment of the PMA should consider.

7.7 Construction materials

Required raw material for construction and execution of road works are extracted from river stone aggregates as drag material or rock mass as selected aggregates usually processed.

The required amounts are usually quite important and this Pedregal - Catambuco project is no exception. The estimated amount of stone materials is shown in the following Table 7.105.

Table 7.89 Estimated rock materials

stone material	Estimated amount (m3)
TERRAPLAIN ROCKS	320807
CUT ROCK	18,058
SUB BASE	204005

BASE	137547
ROCKY MATERIAL FOR ASPHALT	124836
SELECTED MATERIAL	67563
CRUSHED	166354
SAND	69075
Approximate Total:	**1108245**

7.7.1 Exploiting materials (quarry and drag)

This involves making a new resource exploitation in the area, but considering the needs of the project and existing quarries it was determined that these cater the needs of materials required for execution of project works, reason why it is not necessary to apply for quarry material or exploitation of drag stream materials permit.

7.7.2 Procurement of materials in existing sources

The need to obtain material to develop the project refers to construction of the road and other concrete works like plates, pilots, sewers, box culvert, bridges and ditches among others.

This material will be obtained from sources legally established and recognized under environmental license by the Regional Autonomous Corporation CORPONARIÑO and the National Mining Agency (ANM). Table 7.106 and Figure 7.98 show extraction sites and marketing of building materials legally established near the area of project development where the project can purchase from. To note that before project commencement, the validity certificates and authorization of the sources of material must be requested from the Regional Autonomous Corporation.

Table 7.90 Sources of materials in the Pedregal-Catambuco section project area

Planar Coordinates		NAME	ANM CODE	CORPONARIÑO FILE No.	APPROVING - LICENSE RESOLUTION
EAST	NORTH				
975244	621115	EL HUECO	GLC - 111 of January 4, 2007	2442	Res. No. 934 of December 4, 2008
974261	628415	LA VICTORIA	GTRC - 0105-9 of July 3, 2009	163	Res. No. 226 of July 2, 1996

Planar Coordinates		NAME	ANM CODE	CORPONARIÑO	APPROVING -
972886	629680	SAN JAVIER QUARRY	IFK - 08251 of July 6, 2009	LSC-004-12	Res. No. 584 of September 18, 2012
943149	624620	LA CONCEPCIÓN	JB7-14351 October 16, 2009	LSC-009-10	Res. No. 662 of August 9, 2010
976172	621466	LAS TERRAZAS	GTRC - 0081-08 of April 11, 2008,		Res. No.180 July 1, 2003
973085	632598	LA VEGA	HJN - 11331X; July 10, 2008	735	No. 075 Res. - March 17, 1998
974715	6298881	LA ROCA	HHA - 15551: January - 04 2007	LSC-005-09	No. 551 Res. - July 31, 2009
977846.7	623101.5	CHAPALITO QUARRY	ICR - 08291 - June 5, 2009	LSC-001-10	No. 341 Res. - November 23, 2009
977840	623090	ARMENIA	Res. 003 354 December 4, 2015	170	Res No. 154 -. April 29, 1997
974039	629322	OCCIDENTE	GTRC - 0079-08 April 11, 2008	2329	No. 353 Res. - September 30, 2002
973600	620925	BRISEÑO BAJO	Res. 002616 July 3, 2014	224	Res No. 181 -. May 22, 1997
973922	629280	BRISEÑO ALTO	Res. 002992 November 11, 2015	956	Res No. 200 -. June 10, 1998
974337	622150	LOS PALMOS	GBN-101 - June 1, 2006	2410	Res No. 0021. - January 8, 2008
981970	624059	CALIDAD	IFM-16061 November 2, 2007	2429	No. 649 Res. - September 19, 2008

Planar Coordinates		NAME	ANM CODE	CORPONARIÑO	APPROVING -
977293	623791	LA LORIANA	WGLR-0194-08 November 7, 2008	821	Res No. 179 -. June 1, 1998

Source: Adapted from CORPONARIÑO, 2016.

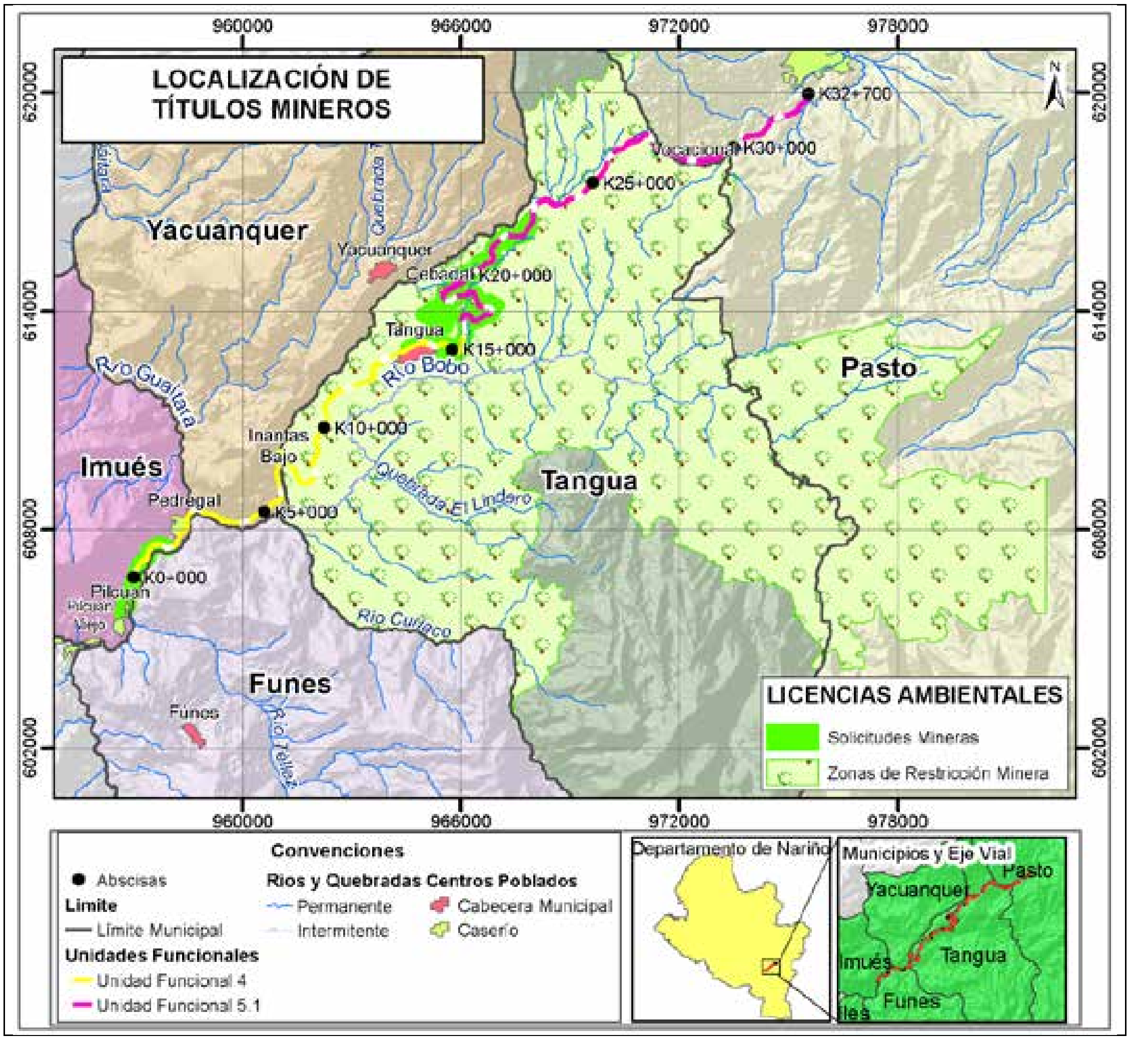


Figure 7.82 Location mining titles

Source (Gemini SAS Consultants, 2016)

- Mining permits and environmental authorizations

Each related source has the proper operation permits such as the mining title issued by ANM and the environmental permit whose information is annexed to this study. See Annex 7.7.2

The Concesionaria Vial Unión del Sur S.A.S may work with other mining and marketing companies of different materials to those discussed above, provided that they submit the relevant environmental and operational documentation required by the environmental authority. This information shall be attached to the environmental compliance reports - ICA

- Volumes of required material for the work

Volumes of material that the main region quarries could supply are listed in Table 7.107, amounts that together add up to almost 6 times the initially estimated need for the road project.

Table 7.91 Volume material sources

MATERIAL SOURCE	ESTIMATED VOLUME m3
La Vega	750000
La Victoria	2942730
El Hueco	37000
San Javier	2000000
Briceño Bajo	1230000

The materials will be used for the different construction requirements among which the causeways, ripraps, sub-bases, bases, special paving, selected fillers, filters, prepare hydraulic concrete and asphaltic concrete.

- *Type of material in some sources in the region*

San Javier:
The quarry has andesitic lavas outcropping of the Lavas (TQvl) unit, are light gray in color, have plagioclase up to 1 mm (Photo 8.7). Lavas are jointed, the thickness of the outcropping is 15m and the corresponding to stripping of 1m to 2m topsoil and

pyroclastic flow. These rocks are being exploited and crushed for different uses: base, subbase, asphalt and concrete

La Vega:
The outcropping lithology in the La Vega mine is columnar lavas from the Lavas (TQvl) unit; these lavas are dark and show sporadic plagioclase phenocrysts. They are generally very hard rocks and are being exploited and crushed for base, subbase, paving, concrete, asphalt, filter and rockfill. The outcropping is 20m high and 40m long.

Briceño Bajo:
The outcropping lithology in the Briceño Bajo mine is andesite lavas from the Lavas (TQvl) unit; lavas are light gray and present plagioclase phenocrysts of up to 1 mm. They are generally very hard rocks and are being exploited and crushed for base, subbase, paving, concrete, asphalt, filter and rockfill. The outcropping is 15m high and 35m long.

La Victoria
In the mine the Lavas (TQvl) unit outcrops, composed of light gray andesite and present plagioclase phenocrysts up to 1 mm in diameter, they are hard rocks and are covered by 1m organic soil. Currently the mine exploits these for base, subbase, asphalt, filter and rockfill. The outcrop 15m high and 30m long.

El Hueco
It has ash deposits which will be used for specific concretes.

- Access roads

Heavy vehicles will be used to obtain and transport the material; they will access through existing unpaved roads to each material source. See Figure 7.99.

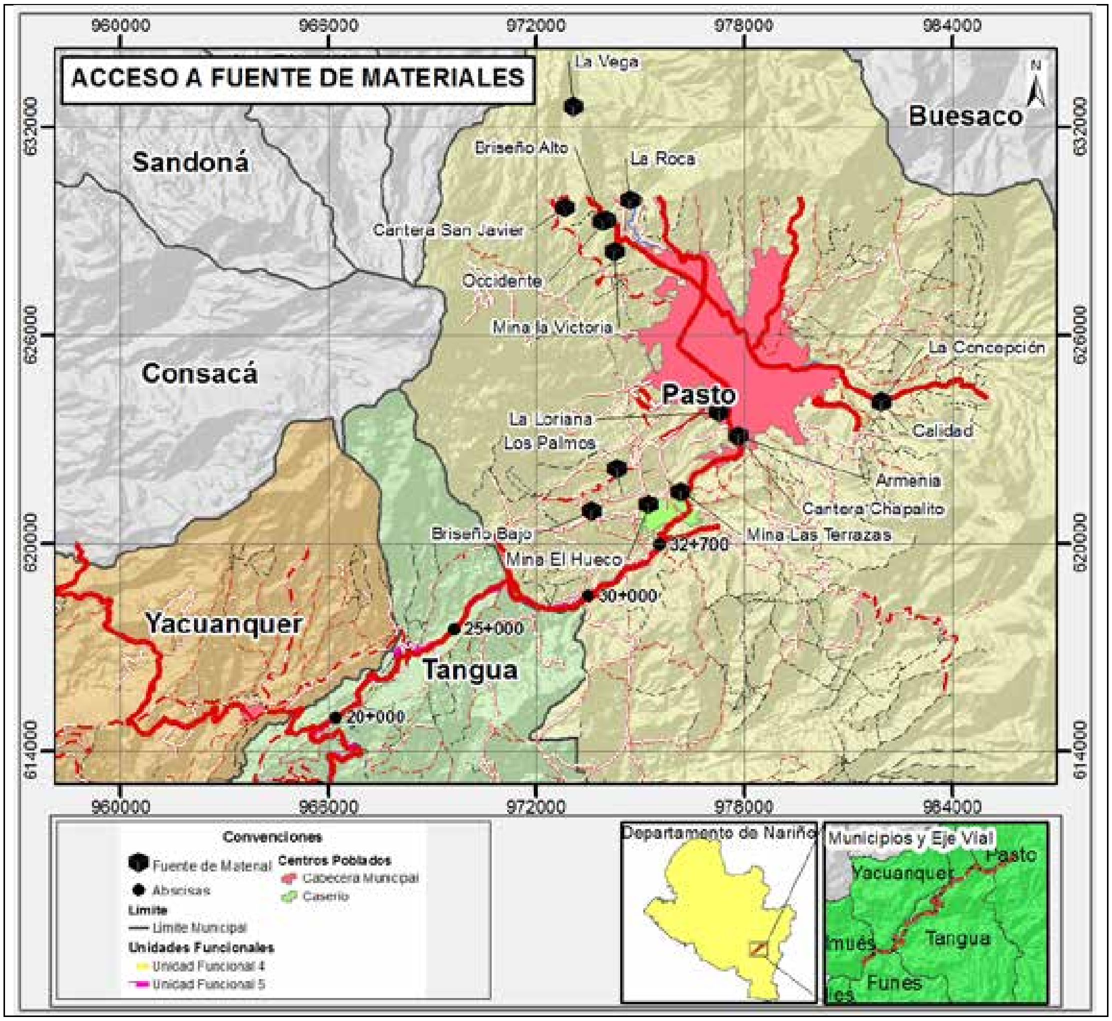


Figure 7.100: Access to sources of materials
Source (Gemini SAS Consultants, 2016)

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