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# 2 GENERAL ASPECTS

## 2.1 BACKGROUND

· **Justification**

As a consequence of National Development PND 2010-2014 “Prosperidad Para Todos” (“Prosperity For All”), and in order to encourage the private sector’s participation in the development of both the productive and social infrastructure that Colombia requires, Law 1508 of 2012 and its subsequent Decrees were issued and established the legal regime of Public Private Associations (PPAs) under a new regulatory framework, which details and deepens the procedures for the selection and recruitment of private investors governing the Program of the Fourth Generation of Roadways Concessions (4G).

With the aforementioned guidelines, the National Council on Economic and Social Policy of Colombia (CONPES in Spanish) created the document CONPES 3760 of 2013: “Roadway Projects under the Form of Public Private Associations: Fourth Generation of Roadways Concessions”.

Under this legal framework and as part of the fourth generation concessions program, the National Infrastructure Agency (ANI in Spanish) via Concession Contract under the PPA Scheme No. 15 of September 11, 2015, granted “Concesionaria Vial Unión del Sur S.A.S.” the concession to perform the studies, design and environmental, property and social management for the Rumichaca – Pasto Divided Highway Project.

In compliance with the recommendations set forth in CONPES Document 3820 to apply the structuring per functional units in Second Wave projects, the Rumichaca – Pasto Divided Highway Project has five Functional Units (FU) based on the designs made previously by the ANI (See **Table 2.1**).

**Table 2.1 The Project’s Functional Units**

| FUNCTIONAL UNIT (FU) | SECTOR | STARTING PK | END PK | LENGTH |
|---|---|---|---|---|
| 1 | 1.1 Rumichaca - Ipiales | PK 0+000 | PK 0+900 | 0.9 Km |
| | 1.2 Ipiales –San Juan | PK 0+900 | PK 17+000 | 16.10 Km |
| | 1.3 San Juan - Contadero | PK 17+000 | PK 25+600 | 8.60 Km |
| 2 | 2.0 Contadero - Iles | PK 25+600 | PK 37+600 | 12.00 Km |
| 3 | 3.0 Iles - Pedregal | PK 37+600 | PK 44+909 | 7.31 Km |
| 4 | 4.0 Pedregal - Tangua | PK 0+000 | PK 15+760 | 15.76 Km |
| 5 | 5.0 Tangua - Catambuco | PK 15+760 | PK 32+700 | 16.94 Km |
| | 5.1 Catambuco - Pasto | PK 32+700 | PK 37+959 | 5.3 Km |

With this, the Project aims to better connect the Southwest of Colombia to help strengthen the region’s development, as it solidifies the international axis uniting Colombia and Ecuador and optimizes road circulation. This reduces accident rates, commute times and vehicle operation costs.

- **Previous Studies and Research**

The development of this EIA took into consideration the previous studies and research conducted by several regional and national entities, all of which are named in detail in **Section 2.3 Methodology** for each component of the different environments: abiotic, biotic and socioeconomic.

- **Delivery of the Request of Subtraction from Forest Reserves of Law 2 of 1959**

The early alerts system – TREMARCTOS Colombia was consulted in order to identify whether or not the Project lies within forest reserve areas declared in Law 2a/59; the results were that the Project is not within the reserves, making the Request of Subtraction unnecessary.

- **Delivery of Request for Restrictions Lift**

The request to lift restrictions was sent via letter before the MADS' Forestry, Biodiversity and Ecosystem Services Office (See **Annex 1. Communications**). In addition, there was a review of the resolutions of the "Corporación autónoma regional de Nariño" (CORPONARIÑO) in order to corroborate the presence of protected species and carry out the restrictions lift procedure; however, the corporation did not find any such species in the area.

- **Formalities Before the Competent Authorities**

The National Infrastructure Agency –ANI, in Spanish-, via document 4120-E1-25763 dated June 20, 2013, requested the opening of the NDA file for the project called "Construction of the Divided Highway between Rumichaca and Pedregal" in the Nariño department. This procedure also saw the opening of file NDA 0905, via letter 4120-E1-25764 of June 20, 2013, formalizing the request to open the NDA file for the project called "Construction of the Divided Highway between Rumichaca and Pedregal" in the Nariño department. File NDA 0906 was also opened as a result of this procedure.

The National Authority for Environmental Licenses – ANLA in Spanish -, via document 4120-E2-25763 dated August 12, 2013, based on Technical Concept 3422 dated August 8, 2013, answered the request made by the ANI via document No. 4120-E1-25763 dated June 20, 2013 on the Project "Construction of the Divided Highway between Rumichaca and Pedregal" in the Nariño department in order to define, for the construction of the divided highway at the Ipiales Diversion, the preparation and presentation of the Environmental Impact Assessment and, for the rest of the route, the presentation of the Environmental Alternatives Diagnostic, except for the segment undergoing improvements and the double lanes that need to be built.

Via document 4120-E1-83 from January 3, 2014, the ANI presented the Environmental Alternatives Diagnostic for the project "Cross through populated areas in the Rumichaca – Pedregal Sector" in the Nariño Department. Then, with file NDA 0905, the ANLA defined an alternative for the project via Writ No 420 from February 4, 2015.

"Concesionaria Vial Unión del Sur SAS", via document No 2016015950-1-000 dated March 31, 2016, informed the ANLA about concession contract - PPA Scheme No. 15 of 2015, signed between the ANI and the aforementioned Company, the object of which is the preparation of the environmental, property and social studies and design, construction, rehabilitation, improvement, operation and maintenance of the Rumichaca – Pasto divided highway in the Nariño Department, which includes the securing of the corresponding environmental licenses among its obligations.

"Concesionaria Vial Unión del Sur SAS", via document No. 2016080942-1-000 dated December 06, 2016, presented the "Environmental Alternatives Diagnostic – DAA for the construction of the Divided Highway between the Towns of San Juan and Pilcuan Viejo, of the Rumichaca – Pasto Divided Highway Project", a road that will pass through the municipalities of Ipiales, Contadero, Imues and Iles, all in the Nariño Department, for its assessment and definition by the ANLA.

The Technical Team of the ANLA prepared Technical Concept 1249 dated March 23, 2017, based on the information supplied by "Concesionaria Vial Unión del Sur SAS" in the Environmental Alternatives Diagnostic – DAA to develop the "Rumichaca - Pasto Divided Highway, San Juan – Pilcuan Segment" project via documents No. 2016080942-1-000 dated December 06, 2016 and 2017014691-1-000 dated February 28, 2017, as well as the corresponding evaluation visit.

Via Writ No. 00948 of March 28, 2017, the ANLA selected Alternative One (1) among all proposals made by "Concesionaria Vial Unión del Sur SAS" as the most suitable from the biotic, abiotic and socioeconomic point of views for the construction of the project named "Divided Highway between the Towns of San Juan and Pilcuan Viejo, del Rumichaca – Pasto Divided Highway Project" in the Nariño Department.

In keeping with the foregoing, the present Environmental Impact Assessment is prepared as it is a requirement to carry out the construction activities for the Rumichaca - Pasto Divided Highway, San Juan – Pilcuan Segment road corresponding to Functional Unit 1, Sector 1.3 and Functional Units 2 and 3, with the description, characterization, analysis and assessment of the physical, biotic and socioeconomic environments of the territory, as well as with the development of the plans and programs for the correct attention to the impacts generated by the environment's different components, always complying with what is set forth in applicable regulations and leading to the granting of the Environmental License.

- **National System of Protected Areas – SINAP; and Protected Areas Sub-System - SIRAP**

The Project required a consult before the National System of Protected Areas – SIRAP and its basic unit, the SINAP, in order to define the ensemble of areas that constitute the declared areas within the National Natural Parks System (PNN in Spanish), the forest reserves areas per Law 2nd/59 and those established by the now extinct INDERENA, the areas established as having special territorial and environmental importance in the municipalities' basic land management plans and schemes.

- **Strategic Ecosystems and Environmentally Sensitive Ecosystems**

Updated certificates (See **Annex 1. Communications**) were requested to determine environmentally sensitive areas and strategic ecosystems. These certificates were issued by the competent bodies and specify whether or not there are, within the road area of influence of the project, areas included in the PNN System, Fauna and Flora Sanctuaries per the UAESPNN, National Forest Reserves (including the forest reserve of Law 2nd/59), Comprehensive Management Districts and/or any other kind of protected area according to the respective regional environmental authorities.

In addition, different official databases were also consulted using for referential purposes the protected areas at the national, regional and local level, and the areas of sensitive biodiversity, including those in the early alert system – TREMARCTOS Colombia, the National Registry of Protected Areas (RUNAP in Spanish), the Geographic Information System for Territorial Planning and Management (SIGOT in Spanish), the Environmental Information System of Colombia (SIAC) and the Portfolio of Priority Areas for Conservation of the Alexander von Humboldt Biological Resources Research Institute. Likewise, the strategic and sensitive ecosystems identified in the Territorial Management Studies (EOT) and Territorial Management Plans (PBOT) of the Municipalities involved in the project and in the Water Resources Management Plans (POHR) of the Guaitara, Boqueron and Sapuyes rivers were also considered.

- **Integrated Management Districts (DMI)**

Strategic ecosystems such as DMIs and/or Regional Integrated Management Districts (DRMIs) were consulted via the early alerts tool Tremarctos-Colombia v. 3.0, with the Ministry of the Environment and Sustainable Development (Forests, Biodiversity and Ecosystem Services Division) and the "Corporación Autónoma Regional de Nariño" (CORPONARIÑO).

- **Regulatory Framework**

Below is the main regulatory framework applicable to the project. (See **Table 2.2)**

**Table 2.2 Regulatory Framework Applicable to the Project**

| REGULATION | NUMBER | MAIN TOPIC |
|---|---|---|
| **Constitutional** | Constitution of 1991 (Articles 1, 7, 8, 79, 80, 84, 95, 209, 332, transitory article 55) | Fundamental principles on constitutional norms, which lays the foundation of the legal regulation applicable to the execution and scope of this document. |
| **Environmental** | Executive Order 2811 of 1974 | Establishes norms on Colombia's forestry economy and on the conservation of renewable natural resources. It also establishes Protected Forest Areas and General Interest Forests. |
| | Law 2 of 1959 | Dictates norms on Colombia's forestry economy and on the conservation of renewable natural resources. It also establishes Protected Forest Areas and General Interest Forests. |
| | Law 99 of 1993 | Creates the Ministry for the Environment, reorganizes the Public Sector charged with managing and safeguarding the environment and renewable natural resources, sets up the National Environment System and dictates other clauses.<br><br>The Ministry must define the policies and regulations to which the recovery, conservation, protection, management and use of renewable natural resources and the environment in Colombia are subject to. |
| | Resolution 541 of 1994 | Establishes the management of the debris generated by the construction process at areas authorized by the competent authorities. |
| | Law 373 of 1997, modified by Law 812 of 2003 | Sets forth the environmental sanctioning procedure as well as other dispositions, issued by the Congress of Colombia. |
| | Law 1333 of 2009 | Sets forth the environmental sanctioning procedure as well as other dispositions, issued by the Congress of Colombia. |
| | Resolution 1280 of 2010 | Established the rates for charging the assessment and follow up services of environmental licenses, permits, concessions, authorizations and other instruments on environmental management and control for construction projects. |

| REGULATION | NUMBER | MAIN TOPIC |
|---|---|---|
| | Resolution 2064 of 2010 | Regulates the measures to be taken after the preventive seizure, restitution or confiscation of wild terrestrial and aquatic flora and fauna specimens, as well as other dispositions. |
| | Resolution 2086 of 2010 | Adopts the methodology to rate penalties. |
| | Resolution 610 of 2010 | Establishes the Norm on Air Quality or Inmission Level for all Colombian territories for referential purposes. |
| | Resolution 650 of 2010<br>And Resolution 2154 of 2010 amending the previous Resolution | Adopts the protocols to monitor and follow up on Air Quality. |
| | Resolution 1527 of 2012 | Sets forth low environmental impact activities that also generate social benefits, meaning they can be implemented in forest reserve areas without the need to subtract the area, as well as other stipulations. |
| | Resolution 0192 of 2014 | Establishes the list of endangered wild species within Colombia's biological diversity found in the national territory, as well as other stipulations. |
| | Decree 1076 of 2015 | Issues the Regulatory Decree on the Environment and Sustainable Development Sector. Also includes the Environmental Guide's Adaptation Program. |
| | Resolution 472 of 2017, which shall enter validity on January 1, 2018 | Regulates the comprehensive management of debris generated by construction and demolition activities (CDD) and other dispositions. |
| | Resolution 751 of March 26, 2015 | Adopts the reference terms to prepare the Environmental Impact Assessment – EIA required to acquire the environmental license for construction projects for roadways and/or tunnels with their respective access, as well as other dispositions. |
| **Ministry of Housing, City Planning and Territory** | Decree 1077 of 2015 | Issues the Regulatory Decree on the Housing, City and Territory Sector. Applicable to solid waste. |
| **Mining** | Law 685 of 2001 | Issues the Code of Mines and other dispositions, among which are references to mining uses for quarries or dragging material. |
| | Decree 1073 of 2015 | Issues the Regulatory Decree of the Mines and Energy Administrative Sector. |
| **Social** | ILO Convention 169<br>(Article 7) | Regulates the fundamental right of indigenous populations and other ethnic minorities to Prior Consultation. |
| | Law 21 of 1991 | Approves Agreement N° 169 on indigenous and tribal peoples in independent countries. |
| | Law 70 of 1993<br>(Decree 1745 of 1995)<br>(Decree 3770 of 2008) | Establishes the mechanism for the protection of the cultural identity and the rights of Colombia's black communities as an ethnic group. |
| | Law 134 of 1994 | Sets forth regulations on citizen participation mechanisms. |
| | Law 388 of 1997 | Modifies Law 9 of 1989 and Law 3 of 1991, and dictates other dispositions on territorial planning. |
| | Law 472 of 1998 | Regulates popular and group-level actions. |
| | Law 1454 of 2011 | Dictates organic norms on territorial planning and modifies other dispositions. |

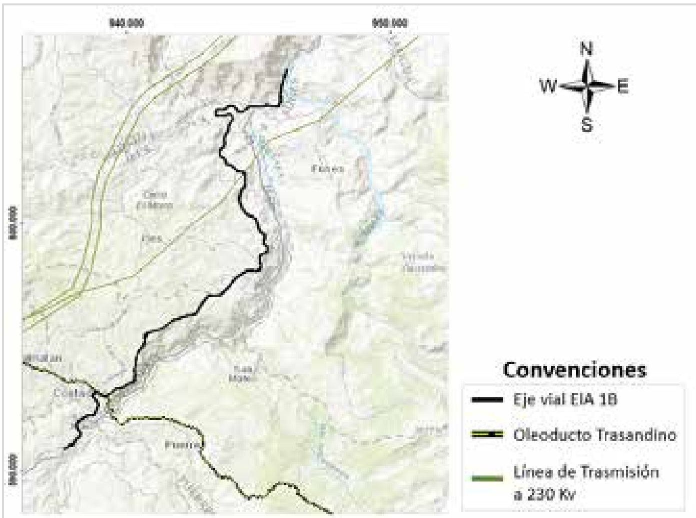
| REGULATION | NUMBER | MAIN TOPIC |
|---|---|---|
| | Statutory Law 1757 of 2015 | Dictates dispositions on the promotion and protection of the right to democratic participation. |
| | Decree by the Ministry for Culture 1080 of 2015 (Which is being incorporated and updated) | Issues the Regulatory Decree on the Cultural Sector corresponding to the Nation's Immaterial Cultural Patrimony. |
| **Administrative** | Law 1437 of 2011 | Administrative Code |
| **Disciplinary** | Law 1801 of 2016 | National Code on Police and Cohabitation |
| **Infrastructure** | Law 1228 of 2008 | Determines the minimum mandatory subtracted land portions or excluded areas for Colombia's national roadway system, creates the comprehensive national system of roadways information and dictates other dispositions. |
| | Resolution 545 of 2008 | Defines the social management instruments applicable to infrastructure projects developed by the National Concessions Institute (INCO), and establishes the criteria to apply the socioeconomic compensation plan. |
| | Resolution 077 of 2012 | Establishes the social management guidelines to prepare and execute plans of involuntary population resettlement to irregular social units occupying terrain required and with concession for infrastructure projects via the ANI. |
| | Law 1682 of 2013 | Adopts measures and dispositions for the transport infrastructure projects and grants extraordinary powers. |
| **Transit** | Law 769 of 2002 | Contemplates the national code on land transit and dictates other provision on the technical-mechanical conditions of the vehicles' transit across the national territory, also signaling construction projects. |

Source: GEOCOL CONSULTORES S.A. 2017

- **Projects' Overlapping**

Once the consult with the ANLA's geographic visor (SIAC (http://sig.anla.gov.co:8083/)) was completed, it was determined that there were two projects of national importance overlapping with the road project, namely: (a) the Orito – Tumaco Trans-Andean Oil Pipeline project (file N° LAM 3518), which intersects with the Project at the Contadero Municipality and is under the operation of Ecopetrol, and (b) the project of the Betania, Altamira, Mocoa and Pasto Double Circuit 230 KV Transmission Line (file N° LAM 3323, Resolution 2268 del 22/11/2006), which intersects with the project at the Iles Municipality and is operated by "Empresa de Energía de Bogotá S.A E.S.P." (See **Figure 2.1**).

**Figure 2.1 Cross of the Rumichaca – Pasto Divided Highway Project, San Juan – Pedregal Segment with Other Projects within the Area of Intervention**




[Translator note: The legend reads: "CONVENTIONS: Axis Road EIS 1B; Trans-Andean Oil Pipeline; 230 Kv Transmission Line].

Source: GEOCOL CONSULTORES S.A. 2017

- **Collection Permit**

The characterization, collection and preservation of the biological samples of the arboreal flora, epiphyte flora and fauna was governed by the Collection Permit granted by Resolution Nº 0343 of March 25, 2015 to "Servicios Geológicos Integrados LTDA. - SGI, LTDA". In the case of the collection of the hydrobiota's specimens, the characterization was done via Resolution 0783 of July 02, 2015 by the company "M&L Consultores Environmentales SAS". (**See. Annex 1 Communications – Collection Permit**).

- **Sources of Materials**

The required rock materials to build the roadway will be obtained from the sources of materials currently operating in the area and which have valid environmental and mining authorizations. Additionally, all digging material that complies with the technical specifications will be used to build embankments. As consequence, the project will not require the direct exploitation of sources of materials. Chapter 3, Project Description, lists the sources of material that may be used.

## 2.2 SCOPE

This document's scope includes the technical and information features of the received designs and technical studies, which implies a project to build roadways established by the Ministry for Transport, the National Roadways Institute (INVIAS) and the ANI.

The study's scope is based on the demands of the Terms of References for the Preparation of the Environmental Impact Assessment – EIA in Projects for the Construction of Roadways and/or Tunnels issued by the Ministry for the Environment and Sustainable Development via Resolution 0751 of March 26, 2015, in addition to the document on General Methodology for the Presentation of Environmental Surveys from 2010, issued by the Ministry for the Environment, Housing and Territorial Development and what is set forth in Resolution 2182 of December 23, 2016, which modifies and consolidates the Geographic Storage Model.

Specifically, this study provides all necessary primary and secondary information to describe and analyze the abiotic, biotic and socioeconomic environments.

- Define the foreseen area of influence of the main impacts the project's execution could cause.
- Characterize the road project's context based on primary and secondary information, taking into consideration the abiotic, biotic and socioeconomic environments within the area of influence of the project, creating the baseline to then define the management measures for the area of influence during the project's development.
- Quantify the demand and use of the renewable natural resources the road project requires, in order to better develop the construction and operation phases.
- Acquire the environmental permits, concessions or authorizations needed for the construction and operation of the project.
- Predict, describe and qualify the impacts currently generated by the development of the community's activities (Scenario without the Project) and those that could be potentially produced during the project's works execution (Scenario with the Project).
- Develop the environmental economic assessment via assigning a market value to environmental impacts in order to economically materialize the project's environmental costs and benefits.
- Establish the main physical, biotic and socioeconomic restrictions, limitations or strengths for the construction of the project and to identify the special management areas that have to be excluded or handled in a restricted manner via environmental zoning.
- Develop an Environmental Management Plan to establish the prevention, mitigation and compensation measures that will be implemented during the construction phase.
- Present a proposal of investment plan of the 1% corresponding to the use of water resources via articulated investment lines with the regional corporation (CORPONARIÑO).
- Present the Compensation Plan due to loss of biodiversity.
- Formulate the risk management plan as a tool of strategic and operative planning to adequately and efficiently manage and control any emergencies or contingencies during the construction phase, and also define the guidelines of the aforementioned plan for the operation phase.
- Design the final restoration and exiting scheme, in order to recover the initial environmental conditions affected by the project's activities.
- Guarantee the participation of ethnic and non-ethnic communities for the preparation of the study via their active participation in the socializing and previous consultation phases of the Project, as well as to integrate and articulate their contributions to the study.

- **Limitations and/or Restrictions and Information Gaps**

In the biotic, abiotic and socioeconomic components there are no limitations, restrictions and/or information gaps.

## 2.3 METHODOLOGY

The Environmental Impact Assessment took place in two phases: the first one was the collection of primary and secondary information for each of the specialties within the area of influence of the project; and the second phase consisted in processing the collected information and executing interdisciplinary workshops to know the scope of the road project, formulate the activities that generate of environmental impacts, discuss environmental impacts with and without the project, prepare environmental management, follow up and monitoring programs and project socializing with the community.

This section presents the different methodologies used by each work area that participated in the preparation of the EIA.

The secondary information revision included baseline cartography, and research on topics such as soils, hydrology, geology, plant formations, road limits, municipal and district limits and existing diagnoses within the area of influence. Similarly, there was a consult of the territorial plans of the municipalities within the area of influence of the project as well as of reports prepared by the IGAC, IDEAM, DANE, INGEOMINAS, SISBEN and the Alexander von Humboldt Biological Resources Research Institute, among others.

### 2.3.1 Methodology to Characterize the Abiotic Component

The field trip for the professionals working on the abiotic component was held on February 17 and March 24, 2017. This trip consisted of the collection of primary information and saw the participation of professionals needed for each described variable and methodology used in the present study.

#### 2.3.1.1 Geology

The development of the geology component, the following methodology was used.

- **Before fieldwork**

Analysis of secondary information including, among others, the following activities:

- **Definition of the regional lithological units that are part of the roadway.**
- **Identification of generalized and specific stratigraphic columns in the area.**
- **Identification of geophysical prospection and drilling developed in the area.**
- **Identification of structural aspects and use of geospheric resources.**
- **Photogeological and geomorphologic analysis based on aerial Pictures and satellite images.**

- **Field**
  - Verification of the geologic cartography and geomorphologic units identified in the phase of Before fieldwork.

A geologic and geomorphologic reconnaissance process in the area via:

- **Outcrops associated with riverbeds and gullies, high cuts, existing diggings, natural rocky outcrops, cuttings and pits, as well as with the information on drillings eventually performed by the geotechnics professionals to identify the lithological units corresponding to the object of study and raising stratigraphic columns.**
- **Location and description of structures such as folds, faults and joints systems, characterization of alluvial deposits at river crossings.**
- **Detailed geologic identification, location and description of critical unstable areas along the roadway, as well as in the areas where preliminary the cartography and the interpretation of Pictures do not allow the necessary level of detail.**
- **Definition of geologic and geomorphologic contacts.**
- **Detailed geologic description of critical unstable areas along the roadway.**

**Picture 2.1 Outcrop seen at the Survey area. Lava Flows with Cooling Flow Structures**

Coordinates (Magna Sirgas West Zone): E 957016, N 606659. Imues Municipality

Source: GEOCOL CONSULTORES S.A., 2017.

· **After fieldwork**

- **Processing of primary information**
- **Preparation of geologic and geomorphologic cartography, at a 1:10000 scale**
- **Preparation of geologic cuttings**
- **Marking of the existing structures; duly identified folds (anticlines and synclines), faults and lineaments, indicating the movement between each bloc.**

#### 2.3.1.2 Geomorphology

This component comprises the identification of the physical changes starting from the forms of relief, the landscape or relief's forming or transforming processes through time and the relationship of the environment's different agents with the different types of rock within the study area; the structural component includes each area's topography, the slope's inclination, the type of drainage and the geodynamic processes that have developed important geoforms in the area of the project along the roadway. The preparation of the geomorphologic component took place in phases comprising the work before, during and after the field.

- **Before fieldwork**

The activities performed during the Before fieldwork started with the consultation of the existing information, bearing the following data in mind:

- The basis for this phase was the available cartography at the Agustín Codazzi Geographic Institute (IGAC) at the 1:25000 scale, as it is the most detailed scale in existence and the most accessible to the consulting group. It is worth noting that cartography at the 1:100000 scale was also consulted, offering less detailed satellite images corresponding to the survey area.
- Analysis of the information of technical reports supplied by the client corresponding to previous studies, including: Definitive Phase III Studies and Design of Functional Areas 1, 2 and 3 of Contract 015 of 2015 signed between the ANI and "Concesionaria Vial Unión del Sur S.A.S", the "Environmental Alternatives Diagnostic for the Rumichaca – Pasto Divided Highway, San Juan - Pilcuan Viejo Segment Project" concession contract under PPA Scheme No. 15 of 2015. "Ucrós y Asociados Abogados".
- Definition of the geomorphologic units at a regional level based on the existing cartography considering the prioritization scheme proposed in the methodology of the 1979 Netherlands International Institute for Aerospacial Studies and Earth Science (ITC), modified by the Geologic Service of Colombia in Carvajal's Proposal from 2012, which sets out areas based on terrain shapes and the processes acting on them, analyzing the following aspects:
  - § Morphostructure: Features associated with the tectonic deformation affecting the landscape's modelling.
  - § Morphogenesis: Origin of the terrain's forms.
  - § Morphometrics: Features of the geoforms based on metric criteria.
  - § Morphodynamics: Denudation processes that have modeled and continue to model the geoforms.

- **Field**

Once the phase of Before fieldwork ended, the field phase began. This phase consists of travelling through the area of influence to adjust the geomorphological contacts defined during the phase of Before fieldwork at the 1:25000 scale, corresponding with the project's working scale.

This phase also included a detailed study of the morphodynamic processes within the area of influence, such as: laminar erosion, concentrated erosion in furrows and ravines, scouring of riverbeds, falling of blocs and debris, among others. These are all geo-referenced using Garmin Oregon 650 GPS.

There was also the collection of primary information, with the following components identified, among others:

- Verification of the identified geologic cartography and geomorphologic units during the phase of Before fieldwork
- Geomorphologic identification, location and description of critical unstable areas along the projected roadway
- Detailed identification and survey of morphodynamic processes, preparation of field formats along the projected roadway and on the area of influence defined by the consultant group
- Definition and description of the geomorphologic sub-units of the area of influence of the project complemented with picture records

**Picture 2.2 Fluvial Origin Formation associated with the Guaitara River**


Coordinates (Magna Sirgas West Zone): E 957054, N 606779. Municipio iles

Source: GEOCOL CONSULTORES S.A., 2017.

- **After fieldwork**

The After fieldwork activities were oriented towards developing and analyzing information on activities both before and during the field, preparation of deliverable products (Cartography, memoirs, databases, thematic maps, among others). This activity used a topographic cartography at the 1:25000 scale of the area of influence, and the activities to be executed are the following:

- Delivery of the formats on the morphodynamic processes identified during the field work (mass removal processes, erosion areas, scouring of riverbeds, among others).
- Definition of the slope categories alongside the roadway represented on a map at the 1:25000 scale per the domains established in the Geodatabase - GDB.

- Identification of areas affected by morphodynamic processes such as laminar erosion, concentrated erosion in furrows and ravines, mass removal processes, falling of blocs and debris, locating them in the maps in accordance with the guidelines set forth by the ANLA.
- Preparation of the geomorphological map at the level of geomorphologic sub-units in accordance with the domains established by the Geodatabase – GDB.
- Preparation of the final document, delivering the description of the resulting geomorphologic units and defining morphostructures, morphometrics and morphodynamics mainly supported by picture records.

#### 2.3.1.3 Landscape

- **Field search**

The zone landscapes are identified as the basic aspects for the component definition.

- **After fieldwork**

o **Overview of the landscape ecology (ecological landscape)**

According to Zonnevel (1979) and Etter (1991), ecological landscape units are defined as a portion of the geographic space, homogeneous in physiognomy and composition, and with a temporal stability pattern derived from complex interaction between and among factors such as climate, rock formations, soils, flora, fauna, and human activities. These units are recognizable across the landscape and may be different from other neighboring units.

For the delimitation of the landscape units, an intersection between geological formations (e.g. physical elements associated with factors such as terrain, slope, inclination, parent material, among others), together with the cover data, since it represents the use of soils and the human footprint in the system. The foregoing results in landscape units that constitute the starting point and analysis unit of the component.

o **Landscape fragility, quality, visibility and integrity analysis**

The landscape visibility analysis corresponds to an exercise composed of a landscape quality and fragility assessment, according to various characteristics and qualities rated based on compiled information and direct observation of the landscape conducted in the field. This analysis helps learn about the landscape quality, fragility and generally define its visibility, in line with methodologies proposed by the US Bureau of Land Management –BLM– developed to evaluate the visual landscape attributes, and define management options to offset the negative effects thereon. The general description of methodologies is shown below.

o **Landscape fragility**

Landscape fragility corresponds to a set of characteristics with a bearing on landscape property change, as well as to absorption of environmental impacts, alterations and modifications caused by human activity, either agricultural, livestock or industrial activities. This assessment integrates biophysical factors (vegetation, fauna, hydrogeological conditions, geographic location) and sociocultural factors (dynamics and anthropic perception), which result in a comprehensive assessment.

**Table 2.3** below shows the factors assessed in the landscape fragility analysis, to subsequently estimate the Visual Absorption Capability as an indicator of the landscape's resilience and response to change and alteration.

**Table 2.3. Criteria and assessment to determine the landscape fragility.**

| FACTOR | CONDITIONS | RATINGS | |
|---|---|---|---|
| | | NOMINAL | NUMERICAL |
| Slope (S) | Slope (Slope >10%) | Low | 1 |
| | Slight slope (7%-10% slope) | Moderate | 2 |
| | Small slope (0-7% slope) | High | 3 |
| Vegetation diversity (D) | Bare soils, beaches, pasture and grass with weeds, industrial zones and artificial territories and swampy areas | Low | 1 |
| | Grass areas with trees and weeds, and floodable thick grassland with no trees | Moderate | 2 |
| | High and low vegetation, floodable high open forest, riparian forest, floodable thick grassland with trees | High | 3 |
| Soil stability and erosionability (E) | High restriction derived from high erosion and instability risks, low potential regeneration | Low | 1 |
| | Moderate restriction due to certain erosion and instability risks and potential regeneration | Moderate | 2 |
| | Low restriction due to low erosion and instability risks and good potential regeneration | High | 3 |
| Soil-vegetation contrast (V) | High visual contrast between the soil and the exposed adjacent vegetation | Low | 1 |
| | Moderate visual contrast between the soil and the exposed adjacent vegetation (all kinds of barren, cultivated and diversified vegetation) | Moderate | 2 |
| | Low visual contrast between the soil and the exposed adjacent vegetation | High | 3 |
| Potential regeneration of vegetation (R) | Low potential regeneration | Low | 1 |
| | Moderate potential regeneration | Moderate | 2 |
| | High potential regeneration | High | 3 |
| Soil and rock color Contrast (C) | High contrast | Low | 1 |
| | Moderate contrast | Moderate | 2 |
| | Low contrast | High | 3 |

Source: Yeomans, 1986.

Once assessed the various attributes having a bearing on landscape fragility, the Visual Absorption Capability is estimated using the following formula: **VAC = P x (D + E + V + R + C)**

These results help categorize the obtained value according to ratings shown in **Table 2.4** below.

**Table 2.4. landscape Categorization ratings according to Fragility.**

| SCALE |
|---|
| Low = ≤ 15 |
| Moderate = 16-30 |
| High = ≥ 31 |

Source: Yeomans, 1986.

o **Landscape visual quality**

This landscape property corresponds to the aesthetic appreciation of the landscape, which is why the observer's perception is key to this analysis in relation to the biophysical and sociocultural context of the assessed area. For the determination of the landscape visual quality, various biophysical attributes and elements (such as topography, vegetation, water, color, adjacent landscape and rarity) and anthropic activities (such as roads, buildings, railroads, agricultural patterns, and public utility lines) are related seeking a comprehensive interpretation of how the landscape characteristics influence the landscape appreciation and aesthetics. The assessed attributes are shown in **Table 2.5** below.

**Table 2.5. Criteria and assessment to rate landscape Visual Quality.**

| COMPONENTS | ASSESSMENT AND RATING CRITERIA | | |
|---|---|---|---|
| Morphology | Very steep (mountainous), marked and prominent terrain, (cliffs, large water areas and rock formations); or terrains with a wide surface variety or very eroded terrains; or dune systems; or presence of a very peculiar and dominant feature. | Interesting erosion shapes or varied terrain in size and shape. Presence of interesting non-dominant or exceptional forms and details. | Flat, low-sloping areas. |
| | 5 | 3 | 1 |
| Vegetation | A wide range of vegetation types, with interesting landforms, textures and distribution. | Certain range of vegetation but one or two types only. | Little or no variety or contrast in vegetation. |
| | 5 | 3 | 1 |
| Water | Dominant factor across the landscape, clean and clear, clear waters (rapids and waterfalls) or sheets of still water. | Moving and still waters, but these do not prevail across the landscape. | Non-existent, imperceptible. |
| | 5 | 3 | 0 |
| Color | Strong and varied color mixes or nice contrast. | Certain variety and intensity in colors and contrasts, but not as a dominant element. | Very low color or contrast variation, very light colors |
| | 5 | 3 | 1 |
| Scenic landscape | The surrounding landscape significantly drives visual quality. | The surrounding landscape moderately increases the overall visual quality. | Adjacent landscape does not influence the overall quality. |
| | 5 | 3 | 0 |
| Rarity | Unique or not very common or very rare in the region; likelihood to find exceptional fauna and vegetation. | Characteristic of or similar to others across the region. | Very common across the region. |
| | 6 | 2 | 1 |
| Human actions | Free from any unwanted aesthetic actions, or with modifications that favorably impact visual quality. | Scenic quality is affected by very low harmonious modifications, but not entirely, or actions do not add visual quality. | Strong and large modifications that reduce or remove the scenic quality. |
| | 2 | 1 | 0 |
| Scenic quality range | A = 19 or + B = 12 to 18 C = 11 or - | | |

Source: BLM, 2011.

o **Landscape visibility**

The visibility analysis was conducted by comparing the results for scope or visual scales and visual sensitivity, for its subsequent integration with the landscape quality, and then the management categories were determined according to the assessed landscape. Thus, following is a description of methodologies for visual scope, sensitivity and visual resources.

§ **Visual scales (scope) and level of interest**

The landscape visual scope is related to the condition of a landscape unit that may or may not be observable from various perspectives. Observation itself is defined by factors such as the ability to distinguish specific limits in the observed unit, types of terrains, characteristics of vegetation, and color contrast among adjacent elements, and it is intervened by atmospheric and light conditions, or presence of other elements that may interfere with observation. Visibility ranges are classified according to the following categories (See **Table 2.6** below).

**Table 2.6. Visibility ranges to determine the landscape Visual Range.**

| VISIBILITY DISTANCE | RANGE (m) | DESCRIPTION |
|---|---|---|
| Short | 0-500 | Visibility of all adjoining details. |
| Medium | 500-2000 | Visibility of overall elements composing the landscape, with visibility of more representative features. |
| High | >2000 | Less details seen in objects; weaker colors, and textures are lost. The observed unit is very hard to see; therefore, its specific details cannot be distinguished. |

Source: BLM, 2011.

On the other hand, the level of interest refers to the degree of importance given by both visitors or local players to a landscape seen from a road, path, viewpoint, or any other infrastructure from which landscape can be enjoyed (MADS, 2012). The analysis of the level of interest of landscape units is conducted through semi-structured field interviews, questioning about the high, medium or low interest generated by each defined unit. They are also related to a visual scale to learn whether distance influences the individuals' perception as to their level of interest, as shown below in **Table 2.7**.

**Table 2.7. Level of Interest Measured via Surveys.**

| VISUAL SCALES | LEVEL OF INTEREST |
|---|---|
| Foreground | High interest |
| | Medium interest |
| | Low interest |
| Background | High interest |
| | Medium interest |
| | Low interest |
| Pan shot | High interest |
| | Medium interest |
| | Low interest |

Source: MADS, 2012.

It is to mention that the methodology used to define visual scales was based on the methodology proposed by the Bureau of Land Management, an agency within the United States Department of the Interior, for the reactivation of turbines and propellers in Ocotillo California, for electrical energy production (BLM, 2011).

§ **Visual sensitivity**

This item is determined by the number of current and potential landscape observers and, therefore, observers of any change or alteration in the landscape. This takes into account aspects such as visual access, frequency and duration of observation, observing audience, type of observation (sporadic, contemplative, scenic enjoyment), type of observers, and particular observable characteristics or elements.

**Table 2.8** below describes the visual sensitivity ranges used to classify this landscape attribute.

**Table 2.8. Ranges to determine landscape Visual Sensitivity.**

| VISUAL SENSITIVITY | DESCRIPTION |
|---|---|
| High | Areas with a high degree of use or visual appreciation, represented by present observers and by the resulting visual scope (short/medium). |
| Medium | Moderate degree of use or visual appreciation, as well as access thereto. Frequent rather than constant observers |
| Low | It corresponds to remote areas, far away from observers; thus use and visual appreciation are deemed to be low. |

Source: BLM, 2011.

§ **Scenic integrity.**

Apart from components explained above, anthropic alterations and interventions in landscape units are assessed based on the scenic integrity analysis, which includes aspects such as clashing elements or chromatic connectivity, assessing the degree and type of visual alteration the assessed landscape is exposed to.

In this regard, scenic integrity refers to how much intervention there is in a landscape visually; it is also the indicator for the assessment of the most sudden changes experienced by the landscape visually. **Table 2.9** below shows the criteria used to determine the scenic integrity, with its corresponding rating ranges.

**Table 2.9. Scenic Integrity Assessment Criteria**

| CRITERIA | DESCRIPTION | RATING | | RATING DESCRIPTION |
|---|---|---|---|---|
| | | NUMERICAL | NOMINAL | |
| Clashing elements | This item refers to the number of clashing elements present in each landscape unit. The greater the number of clashing elements, the greater the impact degree on the scenic integrity of the assessed unit. | 3 | Null | 3 means there are no clashing elements in the landscape unit and 0 means there are more than three clashing elements in the landscape unit. |
| | | 2 | Low | |
| | | 1 | Medium | |
| | | 0 | High | |
| Clash size | This item assesses the impact of clash(es) on a landscape unit as to size. The greater the clash(es), the greater the impact degree on the scenic integrity of the assessed unit. | 3 | Null | 3 means there are no clashing elements in the landscape unit and 0 means clashing elements represent over 30% of the landscape unit |
| | | 2 | Low | |
| | | 1 | Medium | |
| | | 0 | High | |

| CRITERIA | DESCRIPTION | RATING | | RATING DESCRIPTION |
|---|---|---|---|---|
| | | NUMERICAL | NOMINAL | |
| Chromatic connectivity | This item assesses the impact of clash(es) on a landscape unit as to color. The greater the chromatic connectivity of a clashing element with the landscape characteristic, the lesser the impact thereon and, therefore, on its scenic integrity. In contrast, the lesser the chromatic connectivity of a classing element with the landscape characteristic, the greater the impact on scenic integrity. | 3 | High | 3 means high chromatic connectivity in a clashing element with the landscape characteristic, and 0 means there is no chromatic connectivity in a clashing element with the landscape characteristic. |
| | | 2 | Medium | |
| | | 1 | Low | |
| | | 0 | Null | |

Source: MADS, 2012 modified by GEOCOL CONSULTORES S.A., 2016.

When rating landscape units using the five referred criteria, **Table 2.9** above shows the resulting ratings, and assessment is conducted according to the type of scenic integrity shown in **Table 2.10** below.

**Table 2.10. Physical integrity assessment ranges**

| SCENIC INTEGRITY | |
|---|---|
| RANGES | TYPE |
| 0-1 | Very low (VERY ALTERED) |
| 2-3 | Low (MODERATELY ALTERED) |
| 4-5 | Moderate (SLIGHTLY ALTERED) |
| 6-7 | High (APPARENTLY UNALTERED) |
| 8-9 | Very high (UNALTERED) |

Source: MADS, 2012 modified by GEOCOL CONSULTORES S.A., 2017

§ **Sites of landscape interest (scenic attractiveness)**

Sites of landscape interest comprise places of historical, cultural, environmental and ecological significance across the assessed landscape, as determined by both tangible and intangible cultural benchmarks in the territory (because of their economic relevance, ecosystem services, utilization and use of resources, aesthetic value and historical-cultural significance), and functional and structural aspects of the landscape (habitat supply, material flows, energy and information, and maintenance of biodiversity). (See **Picture 2.3** and **Picture 2.4** below)

In this regard, the main information is obtained from semi-structure interviews conducted in local communities, complementing such interviews with a list of potential places of interest. Similarly, after identifying these places and completing the description in the field, their preservation status, related uses, major historical changes, and current threats to and impacts on their elements were determined.

**Picture 2.3 Nuestra Señora de Iles Sanctuary**

**Picture 2.4 Pools and Recreational Centers at Pilcuan, near the Guaitara River**

Source: GEOCOL CONSULTORES S.A., 2017.

- **Fragmentation**

Fragmentation corresponds to a dynamic landscape process, in which covers are losing areas, reduced to a smaller size, and increase the distance in between, which causes isolation and loss of continuity in homogenous items, such as a forest, until finally leading to full loss of connectivity (Renjifo, 1999). This loss of connectivity may respond to factors, events and disturbances subject to natural phenomena, such as flood, landslide, volcanic eruptions, even though it is evident in current remaining landscapes that ecological transformation for the performance of anthropic activities is a process that has accelerated these other processes at the ecological level.

According to Renjifo (1999), in fragmentation –subject to these ecosystem transformation processes– anthropic activities are recognized as highly impacting factors on the state of biodiversity, because it involves the sudden reduction of the habitat areas and available resources for fauna and flora, oftentimes causing extinction processes. Fragmentation may also alter ecological processes, such as migration, floral and fruit processes, the changes of which involve hard effects on the ecological dynamics of complex systems.

Fragmentation processes upon anthropic effects take place when natural covers are modified or replaced with new elements on account of production, industrial and infrastructure activities, which nature determines the impact degree on the natural dynamics of ecosystem. In this regard, both the transformation gradient and the matrix conditions absorbing patches influence fragmentation, because having covers separated by a matrix of fruit crops would not be the same as losing connectivity because of a highway or construction of a city (Donald & Evans, 2006; Henle et *al.*, 2004).

Finally, it is to note that the transformation and fragmentation of ecosystems lead to the modification and subsequent loss of habitats, being them a major driver in losing biodiversity globally, which is a threat to ecological processes, such as genetic exchange and gene flow, seed dispersal, and maintenance of feasible populations, among many others (Fahrig, 2003).

- **Identification of current covers, and change processes associated with the scenario with a project**

Based on the identification of natural land covers in the area of influence of the project, a comparison is made against the potentially affected scenario (or scenario with a project). This aims to make a quantitative comparison of change in representativity by contrasting the occupied area by natural covers by the time the study is conducted (in this case, 2017), and the dynamics it will have after the project will be executed, in terms of fragmentation processes and connectivity.

Apart from comparing the land cover area identified for the assessed period, different change processes are set, which will be developed on account of the project in order to define the percentages of areas that will remain stable, areas that will show changes, and which process they are part of.

The results of this analysis are show in a general figure of change processes for the area of influence of the project, accompanied by a transition matrix that shows the change percentage in the areas of covers within the assessed period of time, being it possible to infer at which space-time scale changes may take place in the landscape.

- **Fragmentation analysis using metrics**

The analysis of the configuration and structure of the landscape elements is developed through a methodology of landscape metrics, also known as fragmentation indicators. This analysis is effective to measure and quantify the composition and structure of landscapes since, as explained by (McGarigal & Marks, 1995), metrics represent the landscape structure and composition within a given period of time, through the characterization of geometry and spatial properties of a patch or mosaic of patches with the help of math algorithms, allowing for a quantitative analysis of change dynamics for all natural covers within a given period of time (Forman & Godron, 1986).

According to the foregoing, landscape metrics are implemented based on the analysis and comparison of covers identified in the area of influence in scenarios with and without a project, and estimated using the Fragstats 4.1 extension developed by McGarigal et *al.* (2012), to compute the relevant estimates.

Methodologies proposed by McGarigal & Marks (1995) –which constitute the conceptual basis of the Fragstats 4.1 software (McGarigal et *al.*, 2012)– proposes a series of algorithms to calculate landscape patterns in terms of three levels or scales of study in respect of which the following metrics are estimated:

i. Class metrics: used to quantify the landscape pattern by contrasting the same kind of patches or patches from the same cover.
ii. Landscape metrics: used to estimate the change pattern of the overall total landscape.

Thus, according to McGarigal & Marks (1995), the patch, class and landscape metric analysis helps find the variety (richness), abundance and spatiality of patches of natural covers present in the landscape, in order to determine patterns, establish the landscape structure, and characterize the spatial processes of transformation and fragmentation experienced by assessed covers within the assessment period.

Patch, class and landscape metrics used for the fragmentation analysis conducted in the areas of influence of the project are described in Table 2.11 below.

**Table 2.11 Metrics Used to analyze the Fragmentation of the Land Natural Covers within the Area of Influence of the project.**

| TYPE | NAME | DESCRIPTION | FORMULA |
|---|---|---|---|
| Class | Class area | Equivalent to the sum of the area in $m^2$ of all patches of the same kind, divided by 10,000 for conversion into hectares.<br><br>Where the CA value is close to 0, it means patch rarity, and as this value increases, it means prevalence. It is expressed in hectares. | $$CA = \sum_{j=1}^{a} a_{ij} \left(\frac{1}{10{,}000}\right)$$ where<br>aij = patch area (m2) ij<br>ij = type of patch |
| Class | Percentage of land | This metric estimates the area percentage in each type of patch in the landscape, getting representativity from each type of patch in respect of the landscape.<br><br>It is expressed as a percentage, reaching zero (0) where the type of patch is less frequent in the landscape (greater fragmentation and lower representativity in the system), and one hundred (100) where the type of patch has larger representativity in the system. | $$PLAND = \frac{\sum_{j=1}^{n} a_{ij}}{A}(100)$$ ;<br>*aij: area of patches of the same kind or cover ($m^2$).*<br><br>*A: total landscape area ($m^2$).* |
| Class | Number of patches | This metric estimates the number of patches of the same kind or cover (abundance), allowing for approximation to the representativity of each patch or cover in the assessed landscape. | NP = ni;<br>*ni: number of patches of the same kind or cover* |
| Class | Largest patch index | This metric estimates the largest patch in a set of patches of the same kind, relating the areas of patches and the total landscape area, and multiplying this value by 100 to get a percentage in a result.<br><br>Where the value is close to zero (0) it means that the largest patch is insignificant in respect of the total landscape area, while the closer to 100%, the larger the area it covers in respect of the total assessed landscape area. | $$LPI = \frac{\max(a_{ij})}{A}(100)$$<br>*aij: area of the patch in square meters*<br><br>*A: total assessed landscape area in square meters* |
| Class | Shape index | The shape index is one of the most commonly used metrics in analyzing fragmentation, because it is an indicator of the patch status in respect of its regular or irregular shape, conditioning the relations between the matrix and other patches.<br><br>The resulting data is expressed as a decimal, greater than or equal to 1. Where the result is close to one (1), the patch has a compact and regular shape (square, round), and where it is greater than one (1), it has a highly irregular shape. | $$SHAPE = \frac{.25\ p_{ij}}{\sqrt{a_{ij}}}$$ ;<br>aij: area of patch of the same kind or cover ($m^2$).<br><br>pij: perimeter of patch of the same kind or cover (m). |

| TYPE | NAME | DESCRIPTION | FORMULA |
|---|---|---|---|
| Class | Proximity index | This metric indicates the number of joints between patches of the same kind through a specific distance (in this case, 500 meters), in relation to the total number of potential sets of patches of the same kind.<br><br>Thus, a connectivity is established between and among patches of the same kind within a 500-meter radius from the assessed patch, in order to check proximity and functionality in the landscape.<br><br>Where the result is close to zero (0), the degree of fragmentation and isolation is high. Where the value is zero (0), the patch has no neighbors of the same kind or cover within the given research range. | $PROX\_MN = \frac{\sum_{g=1}^{n} \frac{a_{ijs}}{h_{ijs}^{2}}}{n_i}$<br>Where:<br><br>hij: distance (m) between patches of the same kind or cover.<br>aij: area (m2) of patches.<br>ni: number of patches of the same kind or cover, within a range or threshold by default. |
| Class | Euclidean distance from the closest | This metric is used to estimate isolation between patches, which is a clear sign of the degree of fragmentation in a landscape. Distance to the closest neighbor is estimated based on Euclidean geometry corresponds to the shortest straight-line distance between the focus patch and its closest neighbor of the same class.<br><br>It is expressed in meters, reaching zero (0) where patches are linked together and connected, and getting away from zero as isolation increases. | $ENN = h_{ij}$<br><br>hij: distance (m) between *patch ij* and the closest neighboring patch of the same kind (class), based on the end to end distance. |
| Landscape | Shannon's diversity index | This index is equal to minus the sum –in all types of connectivity– of the proportional abundance of each type of patch multiplied by the percentage.<br><br>SHDI = 0 where the landscape has only 1 patch (i.e., no diversity). SHDI increases as the number of different types of patches (i.e. patch richness, PR) increases and/or the proportional distribution of the fragment surface between the types becomes fairer. | $SDHI = -\sum_{i=1}^{m} (P_i * \ln P_i)$<br>where,<br><br>Pi: Proportion of occupied landscape by the class type. |

*Source: McGarigal & Marks, 1995*

In addition, the landscape context index was estimated which, according to the General Methodology for the Presentation of Environmental Surveys, results in an isolation or proximity indicator, thus setting the degree of connectivity between patches of the same type or class.

| | | | |
|---|---|---|---|
| Context | Landscape context index | This reflects the connectivity between patches of the same class. It is to mention that this is the only metric that is not implemented using the Fragstats Software, since this index is included in the MAFE 2.0.3 tool, which is used to set the biodiversity offsetting plans. | CP= a / atb;<br>*CP: landscape context*<br>*a: Area of patch of the same class*<br>*atb: total area of patch or buffer* |

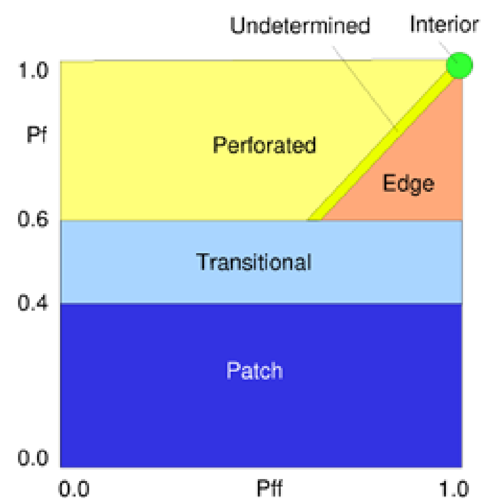
Source: Saenz et *al.*, 2012

- **Fragmentation Category Analysis**

In addition to the analysis of fragmentation indicators, or landscape metrics, the spatialization of fragmentation processes is conducted through GIS SAGA (Riitters et *al.*, 2000), which quantifies the various categories and limits of wooded or natural patches. These results are significant for the identification of the functionality of elements composing the landscape, thus allowing for the understanding of the effects of loss of cover connectivity.

According to the model proposed by Riitters et *al.* (2000), for each assessed cover, the number of core areas, patches, edges, perforations, transitions and interior areas may be estimated (See **Figure 2.2** below), which represent in the aggregate the core characteristics to get a comprehensive reading of fragmentation processes, edge effect and spatial connectivity of the landscape elements. It is to mention that the GIS SAGA model uses raster data; therefore, the presence or absence of pixels associated with wooded covers may be estimated as to complement the index data.

**Figure 2.2 Fragmentation Categories used by the SAGA Model**




Source: Riitters et *al.* (2000)

- **Ecosystem services**

According to the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), ecosystem services include any direct or indirect benefits provided by ecosystems and nature, which generate human well-being conditions, both individually and collectively (Díaz *et* al. 2015). In this context, the analysis of ecosystem services includes understanding ecosystems as service supplying units, and as beneficiaries thereof, with a comprehensive system approach.

- **Identification of ecosystem services for the area of influence of the project**

For the study of ecosystem services, various ratings have been described, albeit the guidelines of the Terms of Reference for the preparation of the Environmental Impact Assessment for road and/or tunnel building projects (MADS, 2015), require information under the classification system for provisioning, regulating, supporting, and cultural services, in line with the Millennium Ecosystem Assessment (MEA, 2003). According to this approach, 4 (four) types of ecosystem services have been identified in relation to the benefit contributed to human beings, either through the direct provision of services, or through the benefit derived from ecological interactions, relations and flows. The ecosystem service classification, according to MEA (2003), is as follows:

- *Provisioning services: comprise services –including goods and products– directly obtained from ecosystems as provisioning for their benefit. Provision services include, among others, use of water, timber, fibers and resins, food from agricultural activities, hunting and fishing products, use of minerals and energy sources (oil, gas, coal), and any other elements obtained by human beings for their daily activities.*
- *Regulating services: correspond to ecosystem process derivatives, i.e. all elements that result from the flow, interrelations and interactions between and among the various components of ecosystems. Regulating services include processes regulating climate, maintenance of air quality, water purification, disease controls and pathogens, soil fertility, erosion control, pollination, among other processes interfering with human well-being conditions.*
- *Supporting services: include all ecological processes consolidating and supporting the functioning and provisioning of the other ecosystem services, directly depending on their existence. In this regard, this category gathers together processes such as biogeochemical cycles (water cycle, nutrient cycling, such as phosphorus, carbon, nitrogen, among others), soil formation processes, primary production (photosynthesis), and habitat, which are essential to keep biodiversity, ecosystems and other associated services.*
- *Cultural services: cover all non-material and intangible benefits received from ecosystems, either through spiritual enrichment, cognitive development, reflection, cultural identity, and aesthetic experiences. This category further includes recreation, tourism, and visual landscape appreciation, as a group of natural items causing satisfaction and enjoyment of the environment.*

According to the foregoing, ecosystem services identified in the area of influence of the project were classified following the aforementioned approach. Thus, semi-structured talks were held with key stakeholders (according to the method proposed by Geilfus, 2002) (**Annex 12. Ecosystem Services**), making a series of core questions that were the basis to inquire into ecosystem services related to the area of influence of the project. This exercise was conducted with the assistance of several key players identified through the conducted field search, with whom recognition and observation tours were completed for the purpose of identifying and describing the ecosystem services.

***a) Significance of or reliance on ecosystem services for/of the local or regional communities***

At this point, stakeholders who benefit from ecosystem services –or also defined as beneficiaries– were identified and described. Martín-López *et* al. (2012) refers to beneficiaries as such stakeholders benefiting directly or indirectly from ecosystem supplied services, as well as other individuals or organizations that may be positively affected by the ecosystem service flow.

To identify these stakeholders or beneficiaries related to ecosystem services, further semi-structure talks (Geilfus, 2002) were developed with key stakeholders identified in the field search, covering the various direct and indirect benefits from ecosystem services. The analyzed variables include the type of used ecosystem service, form and frequency of use, reliance on the related services and status of the service supplying unit as well as any changes found in the service over time.

In addition, reliance of local communities on ecosystem services was determined according to the levels set forth in the Terms of Reference for the preparation of the Environmental Impact Assessment for road and/or tunnel building projects (MADS, 2015), as follows:

- *High reliance: the community's means of subsistence depend directly on the ecosystem service.*
- *Medium reliance: the community benefits from the ecosystem service but its subsistence does not directly depend thereon.*
- *Low reliance: the community benefits from the ecosystem service but its subsistence does not directly depend thereon; and there are other alternatives to the service use.*

### ***b) Level of impact the project would have on ecosystem services***

On the other hand –for the purposes of assessing the potential impact of the project related activities on the ecosystem services–, it is important to learn in detail the constructive and operational phases of the project. Therefore, such activities relating to the use of natural resources are relevant since they enable an approach to the potential impact on units supplying such resource or element that supplies the relevant service. In this phase, it is important to be clearly aware of the resources and amounts required for the implementation of the project, having, for reference, provisioning services such as water, forest resources, and other potential effects on the regulating and cultural services.

One of the appropriate methodologies to conduct the reliance analysis on ecosystem services is described by the International Finance Corporation (IFC), an agency within the World Bank, and Landsberg *et* al. (2011), in its paper "*Ecosystem Services Review for Impact Assessment Introduction and Guide to Scoping"*. This methodology proposal sets out the effect concept (or impact herein), as follows (IFC, 2012):

- *Impact: level of impact of the various constructive, operational and maintenance activities, among others that are part of the project, on the different ecosystem services, throughout the project's life cycle. For the assessment of this indicator, three (3) criteria are described, where satisfaction of at least one in three generates an impact condition on ecosystem services: these criteria include: i) likelihood that the project operations cause an impact on the ecosystem service; ii) The potential impact might cause a negative effect on life, health, safety and/or cultural heritage of Affected Communities; and/or iii) The project exercises direct control over and significant influence on the ecosystem service.*

Similarly, in accordance with the guidelines set forth in the Terms of Reference for the preparation of the Environmental Impact Assessment for road and/or tunnel building projects (MADS, 2015), to determine the project's level of impact on the assessed ecosystem services, the chapter on environmental impact assessment should also be taken into consideration, together with the relevant assessed matrix in the context of the project.

### ***c) Level of reliance of the project on ecosystem services***

As with the degree of reliance of communities on ecosystem services, the methodology approach suggested by Landsberg *et* al. (2011) and the IFC (2012) helps find the project's level of reliance on ecosystem services, according to potential feasible use alternatives, having as high reliance the indispensable services to the project; and for medium and low reliance, services with other supplementary alternatives that may be feasible in cost-effective scenarios (Landsberg et al. 2011).

In this regard, these authors define the concept of reliance on ecosystem services as follows (Landsberg *et* al. 2011 & IFC 2012):

- *Reliance:*
  *Project subordination or demand in respect of the analyzed ecosystem services, in terms of its environmental requirements. Thus, the following reliance criteria are considered: i) The project directly relies on the service for its primary operations; and/or ii) the project directly controls or significantly influences the service.*

To complement the foregoing, the Terms of Reference for the preparation of the Environmental Impact Assessment for road and/or tunnel building projects (MADS, 2015) categorize the project's levels of reliance as follows:

§ High reliance: such activities that are an integral core part of the project directly need the ecosystem service.

§ Medium reliance: certain secondary activities associated with the project directly rely on the ecosystem service but this service might be replaced with an alternative supply.

§ Low reliance: primary and secondary activities do not rely on the ecosystem service.

#### 2.3.1.4 Soils

Following is the description of the methodological guidelines used for the agrological data survey (characterization of soil units, identification of current use, soil potential use and use conflicts) within the area of influence of the project.

This agrological characterization of the area of influence of the project was divided into three phases, to wit:

- **Pre-field**
  - **Phase 1: Secondary data collection, analysis and assessment.**

This phase corresponds to the methodology implemented for the delimitation and characterization of soil units, potential uses, current use, and caused use conflicts; therefore, secondary was collected, treated and analyzed following the current standards provided by the Agustin Codazzi Geographic Institute (IGAC, acronym in Spanish).

**Table 2.12. Secondary data gathered for the soil component**

| CLASS | NAME |
|---|---|
| Cartography | Digital elevation models (DEM) (Adjusted with cartography base at 1.25000.) |
| Report | General survey of soils and land zoning of the Department of Nariño (IGAC, 2004)[1] |
| Part of the same survey | Geology |
| Part of the same survey | Geomorphology |
| Part of the same survey | Vegetation covers |
| Part of the same survey | Climate zones |
| Cartography - Part of the same survey | Slope map |

Source: GEOCOL CONSULTORES S.A. 2017

**Table 2.13. Basic documents to characterize the soil components according to the IGAC**

| IGAC DOCUMENTS |
|---|
| Agustin Codazzi Geographic Institute. A guide to interpreting aerial pictures for soil survey purposes. Code of Document. G410-01/2008. October 2008. Version 1. |
| Agustin Codazzi Geographic Institute. Procedure manual for general, detailed, and semi-detailed soli surveys. Code of Document. P410-01/2008. December 2008. Version 2. |
| Agustin Codazzi Geographic Institute. Soil survey methodology. Code of Document. M40100-01/11. September 2011. Version 1. |
| Agustin Codazzi Geographic Institute. Methodology for land classification by land use capability. Code of Document. M40100-02/10. December 2010. Version 1. |
| Agustin Codazzi Geographic Institute. Procedure manual for the creation of cover and land use maps. Code of Document. P40400-01/11. August 2011. Version 1. |
| Agustin Codazzi Geographic Institute. Procedure manual for the identification, preparation and distribution of analysis samples. Code of Document. P40600-03/June 11, 2011. Version 6. |
| Agustin Codazzi Geographic Institute. In-field work instructions. Code of Document. I410-04/2008. December 2008. Version 1. |
| Agustin Codazzi Geographic Institute. Instructions on final items in thematic cartography. Code of Document. I40500-01/11. December 2011. Version 1. |
| Agustin Codazzi Geographic Institute. A guide to preparing the technical memory of a soil survey. Code of Document. 410-02/2008 December 2008. Version 1. |

Source: GEOCOL CONSULTORES S.A. 2017

**Table 2.14. Other Consulted Documents**

| Documents |
|---|
| Basic Land Use Planning Drawings - Municipality of Ipiales Nariño |
| Land Use Planning Scheme – Municipality of Imues Nariño |
| Land Use Planning Scheme – Municipality of Ilés Nariño |
| Land Use Planning Scheme Contadero – Municipality of Nariño |
| Proposed Geomorphological Cartography Standardization in Colombia |
| Zoning of Conflicts of Land Use in Colombia, Year 2002" |

Source: GEOCOL CONSULTORES S.A. 2017

- **Phase 2: Photo interpretation and creation of Thematic Maps.**

For the determination and adjustment of semi-detailed scale units (1:25.000) basically, the geology, geomorphology, slope maps, digital elevation model (DEM) and the climate zone map were compared.

After defining the preliminary soil units, transects were carefully outlined to cover all potential soil units at the terrain shape level (Scale: 1:25.000).

- **Field.**

Check and characterization observations were developed to characterize each soil unit and thus validate the cartographic units present in the General Survey of Soils and Land Zoning of the Department of Nariño, 2004. Scale: 1:100.000.

Observations (verification) were conducted on the road cuts and trial-pits of 1x1, 20m. Verification points were defined to described the diagnostic characteristics that allowed for the soil taxonomic classification, and trial-pits were sued as pilot zones. Eight (8) characterization trial-pits were created in the survey area, and verification observations were developed in the various road cuts.

The potential use of soil was validated, considering variables such as topography, drainage, erosion, climate, slopes, soil, stoniness, etc., based on the General Survey of Soils and Land Zoning of the Department of Nariño, 2004. Scale: 1:100.000.

According to methodology proposed by the IGAC –the basic data collection mechanism during searches in the field within the survey area– for the validation of soil units the following was developed: verification observations (road cuts) and trial-pits.

**Picture 2.5 Detailed Sampling (soil pits) in the Municipality of Ilés, rural district: Urbano, Coordinates (West Origin Magna Sirgas)** E: 955307 N: 597957

**Picture 2.6 Observation Sampling (road cuttings), Coordinates (West Zone Magna Sirgas) E:** 955958 N: 600752

Source: GEOCOL CONSULTORES S.A. 2017.

- **After fieldwork**

The office phase consisted in preparing the technical memory for soil maps, current use of soils, potential use of soils, and soil use conflicts, as well as interpreting the lab results by cartographic soil unit, and waste dumping analysis.

- **Description of soil units**

Based on secondary data and according to the conducted soil data survey, soil units were described and the soil legends were prepared considering the following: mode profile analysis of soils for each surveyed cartographic unit, and the soil distribution pattern in climate, geology, geomorphology and slope maps. In addition, edaphic limitation data was included to be considered for the definition of agrological classes of soils in the area of influence (erosion processes, working depth, flood, stoniness, among others).

- **Agrological classification and potential use of soils**

The potential use of soils in the survey area was determined according to the Agrological Classification System adopted by the Agustin Codazzi Geographic Institute, "IGAC", composed of eight (8) classes, where the greater the limitations, the greater the numerical value.

**Table 2.15 Diagram of Agrological Classification and Potential Use of Soils.**

| THE INTENSITY OF USE INCREASES → | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CLASSES OF USE CAPABILITY | WILDLIFE | GRAZING OR FOREST | | | CULTIVATION | | | |
| | | Limited | Moderate | Intense | Limited | Moderate | Intense | Very Intense |
| I | | | | | | | | |
| II | | | | | | | | |
| III | | | | | | | | |
| IV | | | | | | | | |
| V | | | | | | | | |
| VI | | | | | | | | |
| VII | | | | | | | | |
| VIII | | | | | | | | |

Limitations and risks increase vertically, and adaptability and freedom for use choice decrease vertically as well.

Source: IGAC 2001.

Apart from classes, also sub-classes are defined according to the soil limitation, either by soil(s), topography (t), drainage (h), erosion (e), climate (c), slopes (p), which are validated in the field to determine such use.

- **Current use of soils.**

For the area of influence, the uses of soils were defined following the methodology of the IGAC according to the Soil Survey Manual of 2010, and uses defined in each Land Use Planning Scheme and Land Use Planning Drawings.

In the survey area, the uses of soils were defined considering the following:

- Agricultural use.
- Livestock use.

- Forestry use.
- Preservation use.
- Infrastructure and/or settlement use.
- Mining/energy use.

o **Soil use conflicts.**

The description of soil use conflicts was developed considering the concepts of a survey conducted by the Agustin Codazzi Geographic Institute: "Zoning of Land Use Conflicts in Colombia, 2002".

Based on information on the defined potential use and current use of soils, the following step is to determine whether there is any disagreement or antagonism between them. The use conflict is determined when making a comparison of the current use recognized in the field (Current Use Map), and the Potential Use of Soil Map, to assess the state of natural resources, and identify areas that may be deteriorated as a result of inappropriate or non-sustainable uses (Barrera, 2002); thus getting areas that show proper use of soils (zones without conflict), and conflicting zones because of misuse (light, moderate, and serious) and overuse of resources (light, moderate, and serious).

o **Infiltration testing.**

The infiltration rate was estimated using the following formula: $\boldsymbol{f} = \boldsymbol{a}\boldsymbol{t}^{\boldsymbol{b}}$ from the KOSTIAKOV method (where: f: infiltration rate, a and b are fitting parameters, and t is time from the infiltration opportunity, in terms of time), for the test site. Where rates tend towards stabilization and attempt to get the greatest number of points, the infiltration rate is determined (cm/h).

o **Waste dumping on soils.**

The physicochemical characterization of soils was developed by taking samples at each diagnostic horizon by mode profile and cartographic soil unit. The parameter analyses were conducted by MCS Consultoría y Monitoreo Ambiental Lab.

The required physicochemical parameters were set for waste dumping modelling, as well as the modelling for the water flow and concentration of substances of environmental interest, for description of the waste dumping on soil activity.

The waste dumping on soil modelling was conducted using HYDRUS 1D (Šimůnek et al., 2012), version 4.15, which numerally solves the Richards equation, for water flow in porous means with variable saturation, as well as advection dispersion equation for transport of solutes.

The risk management plan was prepared and structured following the Terms of References for the "*Risk Management Plan for Waste Dumping Management*", provided by the Ministry of the Environment and Sustainable Development, in compliance with Decree 3930 of 2010, jointly with adjustments referred to in Resolution 1514 of 2012, the Environmental Guides adopted by the Ministry for this kind of projects, and other legal provisions stated by the National System for Disaster Prevention and Service.

#### 2.3.1.5 Hydrology

The development of the hydrologic component aims to identify, characterize and quantify hydrographic zones in respect of the current state of water resources (lentic and lotic systems).

- **Work before fieldwork**
  - **Secondary data collection, analysis and assessment.**

For the purpose of completing the hydrologic characterization of the area of influence, existing secondary data was collected, analyzed and validated, based on the Hydrographic Basin Management Planning (POMCA, acronym in Spanish), as well as existing data at the regional autonomous corporation of Nariño (CORPONARIÑO) on land use planning (POT, acronym in Spanish), and Water Resource Use Planning (POHR, acronym in Spanish), hydrometeorological data collection from the hydrometerology station network of IDEAM located in the area of influence of the project and surrounding areas.

  - **Photo interpretation and creation of thematic maps.**

Analysis based on the following cartographic base: 1:100000 and 1:25000 and World View imagery (January 19, 2015), and Rapideye (January 27, 2016); the existing lentic and lotic systems in the area of influence were identified, which may interfere with the project activities, as well as the drainage system in the zone.

- **Field**

The third step is called field verification, corresponding to the verification of secondary data, with primary data captured at points of control for subsequent contrasting against typified data, specifying the current condition of the zone.

Fieldwork for hydrologic characterization consisted in visiting the lentic and lotic systems (Guaitara, Boqueron, Sapuyes, Humeadora Stream, El Macal Rivers and their main tributaries), conducting the inventory of the major polluting sources, identifying the waste dumping driver and kind. Also, uses and users of water resources were identified, and the community was interviewed in connection with the hydrologic system and the fluvial dynamics of bodies of water (whether permanent or intermittent), to corroborate results reported by IDEAM, and estimates mathematically, in the event that the body of water is not instrumented. It is to clarify that every visited site was georeferenced, and photographic evidence was kept. (See

Picture 2.7)

**Picture 2.7 Guaitara River, rural district: San Juan (Ipiales)**

Source: GEOCOL CONSULTORES S.A., 2017.

o **Recognition and data collection from lentic systems**

These ecosystems –apart from their ecological and environmental significance– are the result of the interrelation of surface water and ground water, which cause large availability of water, mainly during heavy rainfall seasons.

The purpose is to conduct the recognition of lentic systems within the area, according to existing access, to collect the necessary data for their characterization.

For the characterization of such bodies of water, the data is collected from each of them according to the following instructions:

- Accurate date is collected about the general location of each lentic system.
- GPS data is registered using Magna-Sirgas / West Zone coordinates, with the maximum approach to the water mirror, ideally at the center of the water eye.
- Meters above sea level are measured.
- Verify the max. level of overflow of these systems, recording one or more reference points with the GPS (trees, etc.), and the approx. distance from the reference coordinates.
- Determine, where possible, the surface of the body of water relating the area and the perimeters.
- Define the typology of the lentic system, including the name of the aquatic environment locally and regionally.
- Determine the physiognomy of the body of water, which generally refer to vegetation.
- Physically characterize the type of water according to odor and color parameters, if there are any colors in the water, distinguish clean, clear or waste waters.

- Determine the seasonal variation of the body of water: permanent or temporary.
- List the related fauna according to species found: birds, mammals, reptiles, amphibians or others.
- Define the level of preservation of the system: contaminated, clean or protected.
- Determine whether there is any domestic, livestock, agricultural or other uses of water.
- Determine whether the water flow shows any direction.
- Indicate whether the system shows any type of anthropic improvements, such as retaining works, deviations.
- Finally, provide a brief description of that observed in the place.

o **Recognition and data collection from lotic systems**

Lotic water resources are characterized by the formation of currents, i.e. their dynamics are very active and are continuously moving, which help them go through a specific flow according to a given direction, from the source to the mouth into a larger body of water.

The purpose of fieldwork is to validate and complement water system cartography, which is a significant means in decision making concerning the project and availability of this resource.

Therefore, information on lotic system must be provided, according to the following instructions:

- Accurate date is collected about the general location of each lotic system.
- GPS data is registered using Magna-Sirgas / West Zone coordinates, from the point each source is assessed.
- Provide a brief description of that observed in the place
- Determine the type of riverbed flow, permanent or perennial flows keep their water flow throughout the year, while intermittent flows keep their water flow according to rainfall and quick changes in their discharge phase, and are unlikely to have a flow during the dry season.
- Identify the approx. size of riverbed, based on width at the assessment site. The riverbed size is an indicator of its flow, drainage area and gradient. The riverbed width measured from one margin to the other is very useful to size the riverbed.
- Define the bed materials, for classification of the dominant sediment size.
- Identify the bed characteristics across the assessed segment, such as: water inflow (tributaries), characteristics of currents (arms, diverging), bed characteristics, obstacles (rocks, logs, vegetation), among others.
- Indicate any presence of civil works for current management, such as retaining works, rectification works, bridges, or any other structure that changes the natural flow conditions.

Assess stability of mountainsides, according to the following:

§ Very stable mountainsides, even if composed of fine materials, because the river goes through a channel that does not significantly deviate, as to height, from the riverbank.

§ Stable mountainsides, even if they have certain areas where the riverbed-riverbank altitude difference is significant, and there are landslide zones.

§ Highly unstable mountainsides, riverbed limited by vertical walls or highly inclined zones not protected by vegetation.

§ Where mountainsides are very unstable, there is a large amount of collapsed zones.

- Determine the state of the riverside area, indicating whether there is presence of vegetation, type of vegetation, presence of animals, houses, etc.
- Determine the appearance of water according to observations: dirty, clear, muddy, the bed can be seen, barriers to fish passage, floating materials, and others.
- Finally, keep a short record of climate conditions by the time of the field visit, including cloud cover, and percentage of shade over channel because of vegetation
- .

· **After fieldwork**

Using data collected in the field, and secondary data, the area of influence was characterized, as to each variable referred to in the terms of reference and developed as described below:

- Set the hydrographic distribution of the survey area according to guidelines provided for in decree 1640 of 2012, issued by the Ministry of the Environment and Sustainable Development, as well as IDEAM standards.
- Determine the drainage patterns and the characteristics of the water system, using the project's maps and following the methodology to classify currents, and identify the fluvial dynamics of sources that may be affected by the project, and any potential alterations in their natural system (temporal spatial relation of flood).
- Define the morphometric characteristics of each basin in the main currents, which mostly referred to the drainage area (A) in $km^2$, length of the main channel (L) in km, average slope of channel (S) in m/m, coefficient of compactness (Kc), drainage density (Dd), shape factor, basin elevation, and concentration time in minutes. The estimation must be completed considering the formulae provided for each parameter, as well as the hydrographical data of basins.
- Determine the hydrological system and minimum and maximum average multi-year monthly flows of the major currents, for which purpose the records of the hydro-climatological stations present in the survey or surrounding areas were treated, which include current information to determine the characteristic flows of the major currents within the area of influence and currents liable to use in the project related activities.

#### 2.3.1.6 Water Quality

· **Phase 1: Secondary data collection, analysis and assessment**

The physicochemical parameters to assess were defined considering the terms of reference, the related environmental rules, and the technical specifications of the project, as well as the delimited basins, motoring upstream and downstream at the major bodies of water. Also, before the field visit, secondary data was reviewed relating to the previously conducted surveys in the zone, in order to determine the monitoring network present in the survey area, and thus propose, as possible, other monitoring activities in the same places for the multi-temporal analysis of water quality.

- **Phase 2: Field phase.**

Based on the findings of the pre-field activity, 44 sampling stations were established for water quality for the project. The zone characterization was developed between February 26 and March 21, 2017; these months correspond to dry spells in the rainy season by the beginning of the year, and the start of the rainy season of the first half of the year, respectively. The location of sampling points is shown in **Table 2.16** below.

On the other hand, **Table 2.17** below shows the parameters considered for the physicochemical and bacteriological analyses at monitored stations.

**Table 2.16. Sampling Areas - Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment.**

| ID | NAME | DATUM PLANE COORDINATES MAGNA-SIRGAS / WEST ZONE | |
|---|---|---|---|
| | | EAST | NORTH |
| 1 | NN3 stream, upstream | 947096 | 589672 |
| 2 | Guaitara river | 948503 | 590762 |
| 3 | Boqueron river, upstream | 947873 | 591368 |
| 4 | Boqueron river, downstream | 948589 | 590972 |
| 5 | Yamurayán Stream, upstream | 949114 | 592110 |
| 6 | Yamurayán Stream, downstream | 949327 | 591577 |
| 7 | San Francisco Stream, upstream | 949980 | 593156 |
| 8 | San Francisco Stream, downstream | 950086 | 593036 |
| 9 | Cuayarín (Honda) Stream, upstream | 950179 | 593808 |
| 10 | Honda STREAM, UPSTREAM | 950297 | 594011 |
| 11 | Honda Stream, downstream | 950982 | 593341 |
| 12 | Stream tributary of the Culantro Stream, upstream | 950591 | 594688 |
| 13 | Culantro Stream, upstream | 950823 | 594809 |
| 14 | Culantro Stream, downstream | 950603 | 594509 |
| 15 | La Cueva STREAM, UPSTREAM | 951107 | 595359 |
| 16 | La Cueva Stream, downstream | 950979 | 594734 |
| 17 | Stream tributary of the Manzano Stream, upstream | 951604 | 595195 |
| 18 | El Manzano Stream, upstream | 951875 | 595341 |
| 19 | El Manzano Stream, downstream | 952102 | 594886 |
| 20 | Brigada Stream, upstream | 952234 | 595503 |
| 21 | Brigada Stream, downstream | 952271 | 595345 |
| 22 | Tributary of the Humeadora Stream, upstream | 954168 | 596477 |
| 23 | Los Arayanes (Huneadora) Stream, upstream | 954623 | 597220 |
| 24 | El Manzano (Humeadora) Stream, upstream | 954840 | 597388 |
| 25 | Urbano (Humeadora) Stream, upstream | 955161 | 597523 |
| 26 | Humeadora Stream, downstream | 955074 | 597201 |
| 27 | Chorrera Chiquita Watercourse, upstream | 955908 | 598687 |
| 28 | Chorrera Chiquita Watercourse, downstream | 956740 | 599033 |
| 29 | Moledores Stream, upstream | 955872 | 598885 |
| 30 | Moledores Stream, downstream | 956019 | 598991 |
| 31 | El Tablon Stream, downstream | 955333 | 600464 |
| 32 | Tributary of El Tablon Stream, upstream | 955135 | 600723 |

| ID | NAME | DATUM PLANE COORDINATES MAGNA-SIRGAS / WEST ZONE | |
|---|---|---|---|
| | | EAST | NORTH |
| 33 | Tributary of the San Francisco 2 Stream, upstream | 954815 | 601862 |
| 34 | Tributary of the San Francisco 2 Stream, upstream | 954467 | 601562 |
| 35 | San Francisco 2 Stream, upstream | 953962 | 601557 |
| 36 | San Francisco 2 Stream, downstream | 955044 | 602720 |
| 37 | El Macal Stream, upstream | 953397 | 602713 |
| 38 | El Macal Stream, downstream | 954870 | 603721 |
| 39 | Saraconcha Stream, upstream | 953962 | 604651 |
| 40 | Saraconcha Stream, downstream | 953970 | 604830 |
| 41 | Sapuyes River, upstream | 954977 | 605045 |
| 42 | Sapuyes River, downstream | 955466 | 604839 |
| 43 | Guaitara 2 River | 957634 | 607421 |
| 44 | Guaitara 3 River | 956508 | 600552 |

Source: GEOCOL CONSULTORES S.A., 2017.

**Table 2.17 List of the Analytical Methods and Techniques used to Analyze the Physicochemical and Bacteriological Parameters of Monitored Stations**

| PARAMETERS | UNITS | ANALYTICAL TECHNIQUE | METHOD |
|---|---|---|---|
| SAMPLE TEMPERATURE | °C | THERMOMETRIC | SM 2550 B |
| pH | UNITS | ELECTROMETRIC | SM 4500H+ B |
| ELECTRICAL CONDUCTIVITY | µS/cm | ELECTROMETRIC | SM 2510 B |
| DISSOLVED OXYGEN | mg/L O2 | LUMINESCENCE | ISO 17289:2014 |
| RIVERBED | m3/s | AREA – RATE WITH MICRO-FAN OR FLOW METER | WATER MONITORING AND FOLLOW-UP PROTOCOL. CHAPTER 2. IDEAM. 2007 |
| CLOUDINESS | NTU | NEPHELOMETRIC | SM 2130 B |
| ACTUAL COLOR | UPC | SPECTROPHOTOMETRIC – SIMPLE WAVELENGTH | SM 2120 C |
| TOTAL ORGANIC CARBON | mg/L | HIGH COMBUSTION | EPA 5310 B |
| BICARBONATES | mg/L CaCO3 | VOLUMETRIC | SM 2320 B |
| TOTAL ACIDITY | mg/L CaCO3 | VOLUMETRIC | SM 2310 B |
| TOTAL ALKALINITY | mg/L CaCO3 | VOLUMETRIC | SM 2320 B |
| TOTAL HARDNESS | mg/L CaCO3 | VOLUMETRIC - EDTA | SM 2340 C |
| CALCIUM HARDNESS | mg/L CaCO3 | VOLUMETRIC - EDTA | SM 3500-Ca B |
| CHLORIDES | mg/L Cl- | ARGENTOMETRIC | SM 4500-Cl B |
| SULFATES | mg/L S04-2 | TURBIDIMETRIC | SM 4500-SO4 E |
| PHOSPHATES | mg/L P-PO4-3 | ASCORBIC ACID | SM 4500-PO4 E |
| NITRATES | mg/L N-NO3 | COLORIMETRIC | SM 4500-NO3-B |
| NITRITES | mg/L N-NO2 | COLORIMETRIC | SM 4500-NO2 B |
| AMMONIACAL NITROGEN | mg/L | DISTILLATION - VOLUMETRIC | SM 4500-NH3 B - F |
| TOTAL NITROGEN | mg/L N | KJELDAHL - VOLUMETRIC | SM 4500-Norg C, SM 4500-NH3 C |
| TOTAL PHOSPHORUS | mg/L | ASCORBIC ACID | SM 4500 P E |
| INORGANIC PHOSPHORUS | mg/L P | DIGESTION - COLORIMETRIC | SM 4500-P B, SM 4500-P E |
| ORGANIC PHOSPHORUS | mg/L | DIGESTION - COLORIMETRIC | SM 4500-P B, SM 4500-P E |

| PARAMETERS | UNITS | ANALYTICAL TECHNIQUE | METHOD |
|---|---|---|---|
| TOTAL PHENOLS | mg/L | DISTILLATION – DIRECTLY PHOTOMETRIC | SM 5530 B, SM 5530 D |
| TOTAL DISSOLVED SOLIDS | mg/L | ELECTROMETRIC | SM 2510 B |
| SEDIMENTABLE SOLIDS | mL/L-h | VOLUMETRIC (IMHOFF CONE) | SM 2540 F |
| TOTAL SUSPENDED SOLIDS | mg/L | DRYING AT 103-105°C | SM 2540 D |
| TOTAL SOLIDS | mg/L | DRYING AT 103 - 105 °C | SM 2540 B |
| $DBO_5$ | mg/L O2 | 5 DAY INCUBATION - MEMBRANE ELECTRODE | SM 5210 B, SM 4500-O G |
| DQO | mg/L O2 | CLOSED REFLU - VOLUMETRIC | SM 5220 C |
| TOTAL IRON | mg/L | E.A.A. | SM 3030 E, SM 3111 B |
| MAGNESIUM | mg/L | E.A.A. | SM 3030 E, SM 3111 B |
| NICKEL | mg/L | E.A.A. | SM 3030 E, SM 3111 B |
| LEAD | mg/L | E.A.A. | SM 3030 E, SM 3111 B |
| POTASSIUM | mg/L | E.A.A. | SM 3030 E, SM 3111 B |
| SELENIUM | mg/L | E.A.A. HYDRIDE GENERATOR | SM 3114 C |
| BARIUM | mg/L | E.A.A. | SM 3030 E, SM 3111 D |
| CADMIUM | mg/L | E.A.A. | SM 3030 E, SM 3111 B |
| CALCIUM | mg/L | E.A.A. | SM 3030 E, SM 3111 B |
| TOTAL CHROMIUM | mg/L | E.A.A. | SM 3030 E, SM 3111 B |
| SODIUM | mg/L | E.A.A. | SM 3111 B |
| ARSENIC | mg/L | E.A.A. - HYDRIDE GENERATOR | SM 3114 C |
| COPPER | mg/L | E.A.A. | SM 3030 E, SM 3111 B |
| MANGANESE | mg/L | E.A.A. | SM 3030 E, SM 3111 B |
| MERCURY | mg/L | E.A.A./V.F. | SM 3114 C |
| SILVER | mg/L | E.A.A. | SM 3030 E, SM 3111 B |
| ZINC | mg/L | E.A.A. | SM 3030 E, SM 3111 B |
| TENSOACTIVE (SAAM) | mg/L LAS | COLORIMETRIC | SM 5540 C |
| GREASES AND OILS | mg/L | PARTITION - INFRARED | SM 5520 C |
| TOTAL HYDROCARBONS | mg/L | PARTITION - INFRARED | SM 5520 C, SM 5520 F |
| TOTAL COLIFORMS | NMP/100 mL | ENZYME-SUBSTRATUM TRIAL | SM 9223 B |
| THERMO-TOLENTAL COLIFORMS (FECAL) | NMP/100mL | ENZYME-SUBSTRATUM TRIAL | SM 9223 B |

The primary data survey, sample collection in the field, their protection and transportation to the lab were the responsibilities of MCS Consultoria y Monitoreo Ambiental. (A certified lab by IDEAM, Resolution 2892 of December 30, 2016, and Resolution 0049 of January 16, 2017). The collection of water samples at the various sampling stations was conducted according to quality standards set by the lab. “In situ” parameters were collected using a duly calibrated multi-parameter probe with water samples directly collected from the body of surface water. For the determination of other analysis parameters, collected samples were put in vessels, preserved and packed for subsequent transportation to the lab. Additionally, at each monitored site, the custody, coordinate and photographic evidence chain was completed.

- **Valuation of bodies of water (water level, velocity and cross-section)**

For the characterization of the monitoring stations, the accurate valuation of each determined site was conducted.

**Picture** 2.8 below shows the valuation procedure implemented by the lab.

Before getting any new activity started, the best point for the valuation was selected, considering that these are easy-to-access points as well as the identification of any social infrastructure in the area (houses, schools, etc.).

For the selection of sampling sites in the field, the following should be taken into consideration:

- The section must be located over a straight segment of the current, where possible the segment length will have a minimum equivalent to five (5) times the section width.
- The longitudinal slope of the riverbed must be uniform, avoiding segments with strong ruptures in the slope, which slow velocity down, as well as dead waters and countercurrents or whirlpools.
- The bed of the river should be rectangular, with a stable course and without obstacles (logs, trees, large rocks, vegetation, etc.).
- Muddy beds should be avoided.
- Parallel velocities at all points, which form a straight angle with the current cross-section.
- Regular curves for velocity distribution in the section, vertical and horizontal planes.
- Velocities greater than 0,150 m /s.
- Uniform and stable bed.
- Depth deeper than 0.300 m, and high natural margins to prevent overflows at maximum water levels, thus ensuring the calibration of maximum courses.
- Absence of aquatic plants.

**Picture 2.8 Flow Rate Measuring with a Propeller Flow Meter**

Source**:** MCS Consultoría y Monitoreo Ambiental S.A.S., 2017

Following is the information of each site to be submitted:

- Collect accurate information about the general location of each lotic system: name of water current, municipality, rural district, village.
- Record all of the GPS data as Magna-Sirgas / West Zone coordinates, from the point each source is assessed.
- Clearly specify the site ID: Lot 1, Lot 2, etc.

- Type of current: corresponding to the type of flow.
- Determine the height at which the assessment is conducted: upstream, downstream.
- Indicate the maximum width: measured from the left margin to the right margin, and measuring the riverbed in its entirety.
- Indicate the maximum depth: corresponding to the maximum depth after the valuation is conducted.
- Specify the use of soil in the drainage area: select according to the following:
  - Agricultural Use: for irrigation purposes and other related or complementary activities.
  - Residential Use: means the usual domestic use by individuals.
  - Natural Forest: Prevailing vegetation composed of trees.
  - Livestock Use: for consumption by the different types of cattle and other animals, as well as other related or complementary activities.
  - Industrial Use: for activities such as energy generation, mining, hydrocarbons, among others.
- Composition of the riverbed: clay, sand, river stones, or mud.
- Select the used method for the valuation. The method selection will depend on the conditions of the body of water: ford, suspension, boats.
- Measure velocity following the easiest method to implement: floats, micro-fans, fans.
- Measure the cross-section area.
- Prepare a basic chart of the cross-section profile.
- Indicate the total riverbed width.
- Measure the maximum found depth.
- Set the distance data for each margin at the beginning of the sheet of water.

· **Phase 3: After fieldwork.**

The most relevant physicochemical characteristics were defined by basin and its interrelations through a parameter correlation analysis. These correlations were the basis for grouping together the different analyzed parameters at each basin. After this analysis, the Langelier index, Buffer Capacity Index (Tampon), Potential Alteration of Water Quality Index (IACAL), and contamination indexes ICOs and ICA were estimated for the purposes of summarizing the findings obtained from all analysis parameters at each station and basin. It is to note that the comparison limits included herein correspond to such limits set forth in the transitory provisions of Single Decree No. 1076/2015 (articles 2.2.3.3.9.2 to 2.2.3.3.9.10) containing articles 37 to 45 of Decree 1594 of 1984, on certain probable uses, such as the criteria on use of this resources for human and domestic consumption, which provide that for purification only the conventional or disinfection treatment is required, as well as the conditions for agricultural and livestock use, given that the quality criteria for uses of water are not set in Decree 3930 of 2010 (Chapter V, Article 20).

Criteria stated in Resolution 2115 of 2007 on treated water for domestic consumption were taken into consideration in cases in which no limits are provided for in Single Decree 1076 of 2015, so as to have a reference, mostly for water sources for human consumption.

#### 2.3.1.7 Uses of water

· **Before fieldwork**

In determining the uses and users of water resources within the area of influence of the project, secondary data was consulted at Municipal Town Halls (Ipiales, Contadero, Ilés and Imues) and the Regional Autonomous Corporation of Nariño (CORPONARIÑO), for the purpose of setting the basis for current and potential uses of water sources to intervene.

· **Field**

Based on the findings of the pre-field activity, a tour was completed throughout the area of interest where the secondary data was correlated and further data surveys were conducted in the field, by interviewing the community settled upstream and downstream in respect of points intended to be analyzed and prepared for the project works. **Picture 2.9** and **Picture 2.10** below show some uses of water identified in the survey area.

**Picture 2.9 Collection Tank at a Spring at Rural District Tablon Alto. Coordinates (West Zone Magna Sirgas) E: 954060 N: 604342**

Source: GEOCOL CONSULTORES S.A., 2017.

**Picture 2.10 Collection Water Pipe at the Arcoiris Condominium (Pilcuan). Coordinates (West Zone Magna Sirgas) E: 954060 N: 604342**

Source: GEOCOL CONSULTORES S.A., 2017.

· **After fieldwork**

Through information obtained from secondary sources and field search, the uses identified in the area of influence were described, which may be affected by the project activities.

Also, the potential current conflicts regarding availability and uses of water were determined, considering the minimum flow frequency analysis for various return periods, by using the extreme value methods, at each collection section, for which purpose the probability distribution function –with the better adjustment to data– was verified.

### 2.3.1.8 Hydrogeology

· **Before fieldwork and field**

Pre-fieldwork was conducted together with the geology and geomorphology components, identifying any potential sources of reliable information to get useful data.

· **After fieldwork**

In respect of the hydrogeological conceptual model in the project area throughout the road corridor, the field search was strictly related to the preparation of the stratigraphic and structural model. However, the final product was a hydrogeological mal in Shape format, with the hydrogeological characterization of found materials, following the general structure of ANLA Geodatabase –acronym in Spanish for National Authority for Environmental Licenses.

On the other hand, the following were conducted: hydrogeological conceptual model, ground water occurrence, ground water movement, position recognition of piezometric levels in aquifers, hydrogeological characterization, and preliminary characterization of aquifers, analysis of the water system and ground drainage, which may be starting towards/from the riverbed. Inventory, diagnostics, characterization, determination of current and potential uses of ground water resources (including sources, pits and wells).

o **Ground water site inventory analysis**

The inventory of ground water sites in the survey area was compiled (springs, pits and wells), based on those which inventory had been already completed by the consortium in particular projects. This collected information was processed at the office. As a final result, inventory record cards were prepared (national single form for ground water site inventory provided by INGEOMINAS, Ministry of Environment, Housing and Territorial Development, and IDEAM) and data was analyzed.

**Picture 2.11 Ground Water Outcrops in the form of Springs**

Source: GEOCOL CONSULTORES S.A., 2017. Rural District Tablon Low - Municipality of Iles, Coordinates (Magna Sirgas West Zone) E: 955098, N: 600556

o **Flow systems**

After defining the preferential directions of water flow that regulate ground water circulation in the monitored aquifer systems in the survey area, the recharge and discharge areas of the water systems were established. Using this information, the water contour map of aquifer systems of interest was created (quaternary aquifers), for which purpose georeferencing and altimetry levelling out at the main ground water sites identified during the inventory are required.

- **Geological-geophysical model (aquifer geometry).**

Geoelectrical prospecting consists in determining the soil resistivity at different depths, so as to infer the lithological composition of soils and/or types of fluids therein. Geophysical exploration included the performance of vertical electrical sounding (VESs) to determine contacts in recent deposits with rock units, for the purposes of finding out the geometry of recent formations in sectors where it is fully unknown, or determining how deep certain more permeable lithological formations might be found in the context of low permeability materials.

The indirect soil exploration, isoresistivity maps and analysis of results were completed. For the implementation of vertical electrical sounding (VESs), a Schlumberger device was used. For the collection of data through vertical electrical sounding (VESs), a USA manufactured digital reading device, AGI, SuperSting R1/IP model was used. The vertical electrical sounding (VESs) were conducted, which site selection criteria were as follows: areal distribution, data usefulness, spatial availability and ease of access, performing the aforementioned sounding with AB of 200 m, the location of which will be developed using a GPS Garmin Montana 670.

- **Pumping test and/or slug test**

A hydraulic analysis was conducted in the wells of the survey area, having access to ground water by implementing pumping test in a "single well" (the possibility to form temporary observance wells was evaluated in the field) with a constant flow and recovery. Testing was conducted using the ideal equipment for each particular case. Hydraulic tests are intended to learn about the main hydraulic parameters of the analyzed aquifer, transmissivity, storage coefficient and hydraulic conductivity, as well as well and aquifer loss coefficient. The results and analyses of the pumping test interpretation are essential to develop and make recommendations on the relevant aquifer conditions.

- **Water balance analysis**

This activity includes the assessment of the dynamic water balance distributed for the survey area, considering the climate system of the area using existing data.

- **Analysis of ground water site physicochemical characterization and hydrogeochemical analysis**

Analyses were conducted based on samples collected at the monitored points. For the determination of the hydrogeochemical nature of the survey area, the Aquachem and/or Diagrammes software were used, analyzing the Stiff diagrams. This graphical representation is composed of three axes, each of which plots a cation and an anion. All captions are plotted on the left side of the diagram, while anions are plotted on the right side; as $Na^+$ is compared to $Cl^-$, $Ca^{+2}$ to $HCO_3^-$ and $Mg^{+2}$ to $SO_4^{-2}$. All horizontal axes are extended at the same scale (linear), and concentrations are provided in meq/l. The spatial variation of water mineralization in the aquifer was determined using this analysis; ground water composition and connection with surface bodies of water was also determined.

- **Intrinsic aquifer vulnerability to pollution analysis**

This activity includes the assessment of the intrinsic aquifer vulnerability to pollution, which is used to represent the intrinsic characteristics that determine the aquifer sensitivity to being adversely affected by a pollutant load (Foster, 1987), following the GOD-OPS-CEPIS methodology, 1988, and the DRASTIC methodology in terms of availability of secondary data. Then, the contamination risk caused by the road activity intended to be developed in the area was analyzed.

o **Numerical hydrogeological model – Critical sectors**

The _NUMERICAL HYDROGEOLOGICAL MODEL_ proposes to make a math representation of the hydrogeological conceptual model. For this purpose, the core equations of ground water flow were solved with finite differences so that partial differential equations could be solved, using the VISUAL MODFLOW FLEX PROFESSIONAL software, version 2014.1. (LICENSED SOFTWARE, serial No. VMPST3-460-1775904670-5200, with Dongle serial rlmd1 + 6A01359F), and the VISUAL MODFLOW software, version 2010.1. (Mc Donald and Harbaugh, 1998; Harbaugh et al., 2000), developed by Waterloo Hydrogeologic Inc., recently acquired by Schlumberger Company from its Water Service line. This software processes and postprocesses various other software developed by USGS (United States Geological Survey) such as Modflow, Modpath, Zone Budget and Mt3d. It is a software for modelling quasi three-dimensional ground water flows and transportation of pollutants. It used –for the equation solution system for both flow and transportation– the finite line method.

The main modelling objectives were as follows:

1) Validate the suggested hydrogeological conceptual model,

2) Reproduce the current water system operation,

3) Behavior simulation of ground water resources, where the current position of the piezometric level (stationary status) is determined, as well as how this level may vary upon development of ground water exploitation in different scenarios over time (transitory status). This model should be able to predict hydrogeological behavior alternations in respect of anthropic actions (road building).

4) Assessment of potential pollution, and vulnerability analysis of ground waters of interest,

5) Estimate the approximate value of recharge of aquifers of interest, either from regional aquifers (indirect recharge) or from rainfall (direct recharge), and

6) Identify, prioritize and definition of recharge and infiltration zones to be protected.

Steps taken in implementing the numerical model were as follows:

1. Definition of the modelling area.
2. Generation of the Digital Terrain Model (DTM).
3. Preparation of three-dimensional stratigraphy of the area based on the conceptual model, and incorporation of topographic data.
4. Discretization of net domain or generation of in finite differences, to achieve the numerical stability of the model.
5. Setting of contour or edge conditions.
6. Identification and incorporation of relevant sources and/or drains.
7. Incorporation of the hydrogeological parameters of the system estimated during the first stage of the project.

8. Manual calibration of the current situation using piezometry obtained during fieldworks. Parameters to calibrate will be hydraulic conductivities, river and stream conductance, recharge and entry/exit flows in contour and edge conditions.
9. Analyses of results for flows, estimated piezometry, mass balances, calibrated parameters, and observed level adjustment.
10. Analysis of recharge sensitivity

After analyzing the results from the numerical hydrogeological model, the study was prepared with the main components, results and recommendations.

#### 2.3.1.9 Geotechnics

- **Work before field search**

Pre-field work was conducted together with the geology, geomorphology, edaphology, hydrogeology, hydrology, meteorology and seismic threats, identifying potential sources of reliable information, which may provide useful information.

- **Field**

The objective of the study was to make the diagnosis and geotechnical inspection of the road corridor. This activity was completed meter by meter identifying points and areas with geotechnical issues that might be a threat for the road corridor in general. Activities were developed in detail during various workday sessions, for inspection of the geomorphological, hydrogeological, geological, and geotechnical aspects, the state of existing works and works under construction, intersection of bodies of water, and other determining factors of the current status of the road corridor. During this visit, mass removal processes were identified (landslides, land flows, and mountainside creeping mostly), laminar erosion zones, and focused on furrows and hedges, undermining of side and bed margins; deteriorated and partially collapsed margin protection works at intersections with natural drainage and, in general, deterioration and collapse of the preservation works of the road corridor.

- **After fieldwork**

The geotechnical sectorization of the road corridor was developed considering the type and scope of processes in the corridor.
The information on each special point was provided in the format for critical sites, which includes the location of each point; an overview of the problem experienced in the sector; schemes and photographic evidence to help illustrate the situation; the problem causes (contributing, conditioning, and triggering events, as the case may be); geotechnical recommendations to be considered in mitigating the experienced processes.

#### 2.3.1.10 Atmosphere

- **Climate.**

To characterize the meteorological parameters for temperature, rainfall, relative humidity, wind velocity and direction, sunlight, cloudiness, evaporation, atmospheric pressure, as well as climate classification and zones for the area of influence, the methodology for the climate component was developed, considering the meteorological guidelines and information reported by Colombia Institute of Hydrology, Meteorology and Environmental Studies (IDEAM). The applied methodology includes the following phases:

- **Phase 1: Secondary data collection, analysis and assessment.**

The meteorological records used for the climate analysis are records reported by the nearest stations to the area of influence of the project. Therefore, some nearby climate stations were preliminary identified, as consulted with the IDEAM catalog, taking into consideration the physiographic and hydrographic environment, which were subsequently verified compared to adequacy of information for the 25-year analysis period. active stations used in this component are show in

**Table** 2.18 below.

**Table 2.18 Selected Meteorological Stations.**

| NO. | STATION | CODE | CURRENT | TYPE | HEIGHT MASS | DEPARTMENT | MUNICIPALITY |
|---|---|---|---|---|---|---|---|
| 1 | San Luis | 52055010 | Guaitara | Main synoptic | 2961 | Nariño | Aldana |
| 2 | Funes | 52055200 | Guaitara | Ordinary climatological | 2181 | Nariño | Funes |
| 3 | Común El - Automática | 52045090 | Guaitara | Ordinary climatological | 3141 | Nariño | Pupiales |
| 4 | Gualmatan | 52050100 | Guaitara | Rainfall | 2830 | Nariño | Gualmatan |
| 5 | Puerres | 52050120 | Guaitara | Rainfall | 2764 | Nariño | Puerres |
| 6 | Sindagua | 52055090 | Guaitara | Main climatological | 2800 | Nariño | Tangua |
| 7 | Imues | 52050090 | Guaitara | Rainfall | 2550 | Nariño | Imues |

Source: National Station Catalog. IDEAM, 2017.

§ **Selection of time series.**

For the selection of the analyzed period (1991 to 2016), the records of stations with more integral historical series were considered. These series were subject to data verification processes and missing data generation so that the climate analysis shows results with a low uncertainty level, thus leading to better characterization.

- **After fieldwork**

o **Information analysis.**

The analysis of a meteorological item is based on the results of a process that includes data inventory and selection, purge, selection of period to analyze, and estimate of missing data in the assessed series (*Eslava, Parra and Villalba, 1985*). Methodologies implemented in analyzing climate information are as described below:

- **Estimate of missing data in rainfall data:** Data series reported by IDEAM for the "Daily Rainfall" variable, usually has blank spaces and missing entries because of factors such as lack of someone to write the records, or instrument failures, among others; so the statistical consistency of data must be verified by estimating the missing data. For this purpose, data from index stations that have all of their data is used; these stations are selected considering their proximity and similar height as the surveyed station. Once the full rainfall series is obtained for each station, the average rainfall trends are estimated for the selected analyzed period.

- **Average, maximum and minimum trends by parameter:** after estimating the missing data, average, maximum and minimum trends are estimated for each parameter, preparing different histograms that will help define temporary distributions throughout the year.

- **Spatial analysis of rainfall and temperature:** once completed the temporary rainfall and temperature characterizations based con compiled records, spatial climate distribution figures are developed, known as isohyets and isotherms. Isohyets and isotherms were estimated using a Geostatistics extension: ArcGis 10.1. The IDW method is based on the principle that items are more alike as they are closer, and interpolation is conducted by giving greater weighting to sites closer to the site to forecast than those that are farther; the foregoing with the purpose of spatially learn the values seen on average in the survey area.

Following the methodology proposed by Thornthwaite, the water balance was conducted. This process helped prepared the temporary and spatial analysis of water resource availability in the survey area.

Finally, the climate classification and zoning were developed according to the method proposed by IDEAM in its document named: "Continental, coastal and marine ecosystems in Colombia". According to IDEAM, items deemed to be the most relevant ones for the climate characterization map are temperature and rainfall. This is why other climate elements such as wind direction and velocity, relative humidity, and radiation, among others, were not considered in this analysis.

#### 2.3.1.11 Air Quality and Noise.

The assessment of air quality and noise in the area of influence was conducted through the identification and typification of atmospheric emission generators, and noise associated sources, as well as the potential receiving parties, similarly considering sites where camps contemplated for the project will be located, which are required to provide an emission permit. An air monitoring and environmental noise measurement campaign was developed during daytime and nighttime for business days and holidays, in the various representative points within the area of influence of the project. Also, the behavior of meteorological variables was considered; climate analysis in the context hereof is intended to describe the atmospheric conditions and general dynamics of climate parameters in the area of influence of the project over the sampling period of time, which conditions are ever changing. Thus, data and records were collected from the meteorological station used in the characterization.

- **Phase 1: Pre-field.**

Before the field visit, secondary data on surveys previously conducted in the area were reviewed for monitoring developed in the survey area and then, as possible, propose further monitoring activities in such areas for the multi-temporary analysis of air quality and noise.

- **Phase 2: Field Phase.**

Fieldwork for atmospheric characterization consisted in identifying, through the visit to the area, the existing atmospheric emission sources: fixed, mobile, linear, and area related; as well as noise generating sources, location of human settlements, houses, social infrastructure, and critical pollution areas. Each visited site was georeferenced, with the corresponding photographic evidence.

Based on that inspection, an air and noise monitoring program was set. As for air quality, it was implemented considering 6 representative points in the area of influence, where the following samples were collected: total suspended particles (TSP), particulate matters equal to or lower than 10 microns (PM10), particulate matters equal to or lower than 2.5 microns (PM2.5) nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$), with 24-hour samples over 18 days, and carbon monoxide (CO) was directly measured in continuous sampling; and total hydrocarbons such as methane (HCTM) in sampling for one hour per day over 18 days.

Air quality monitoring activities were performed for eighteen (18) consecutive days by Gestión & Medioambiente, which is certified by IDEAM, under Resolution 2307 of October 13, 2016, as a competent lab to conduct analyses in the air matrix. Equipment, equipment calibration and implemented methodology to find the concentrations of each parameter are presented in **Annex 15. Monitoring_Air Monitoring**. The names and coordinates of stations and the date samples were collected are shown below in

**Table** 2.19.

**Table 2.19. Air Quality Sampling Stations for the Project.**

| STATION | NAME OR LOCATION | MAGNA SIRGAS COORDINATES / WEST ZONE | | SAMPLING DATE |
|---|---|---|---|---|
| | | EAST | NORTH | |
| 1 | San Juan | 948033.6 | 590759.6 | February 19 to March 09, 2017 |
| 2 | Contadero | 947761.9 | 592132.9 | February 22 to March 12, 2017 |
| 3 | 31+100 Camp | 955537.9 | 598054.0 | February 23 to March 13, 2017 |
| 4 | Picapiedra Camp | 956411.5 | 600246.9 | February 19 to March 09, 2017 |
| 5 | Mikel Camp | 955244.4 | 604753.0 | February 23 to March 13, 2017 |
| 6 | Pilcuan | 956709.4 | 605294.5 | February 23 to March 13, 2017 |

Source: field search, GESTIÓN & MEDIOAMBIENTE S.A.S, 2017.

Similarly, for the noise monitoring campaign, for the purposes of meeting the requisites stated in 627 of 2006, six (6) monitoring stations were located in area of influence given their relation to the emission sources and noise receiving parties. At each point, environmental noise measurements were taken during both daytime and nighttime, including measurements on holidays. The names and coordinates of stations where samples were collected are the same as those for air quality shown in

**Table** 2.19 above.

Monitoring activities were performed by Gestión & Medioambiente S.A.S., which is certified by IDEAM, under Resolution 2307 of October 13, 2016, as a competent lab to conduct analyses in the noise matrix.

- **Phase 3: Office phase.**

Once collected data in the field about emission sources, information registered with the GPS, photographic evidence, and collected data were integrated into field formats with their relevant description. Also, the air monitoring and sound pressure measurement campaign results were analyzed and compared according to the environmental regulations in force. For this purpose, the following aspects were considered:

- Monthly variations of the wind rose
- Identification of dry and wet seasons
- Rainfall trends

After the characterization of pollutant and noise emission sources, air quality and noise maps were created, which show critical pollution areas, zones associated with the spatial variation of dispersed pollutants monitored in the field, and day and night isophane maps. For all of the presented cartographic information, tables were filled out for the relevant geodatabase and metadata. The obtained information was included in the dispersion modelling for concentrations of particulate matters and gas that may be generated during the development of the project activities for the purposes of determining the area of influence of these emissions, and assessing the impact of contributions on human settlement areas, and areas of other receiving parties of interest, as part of requisites provided for in Decree 948 of 1995 to apply for an atmospheric emission by fixed source permit.

The simulation of pollutants' behavior projected at the soil level was examined using the atmospheric simulation tool developed by the Regulatory Model Improvement Committee (AERMIC), composed of the American Meteorology Society *(*AMS) and the Environmental Protection Agency (EPA), named AERMOD, (AMS/EPA Regulatory MODel)[2], estimating the pollution contribution due to use machinery present in the industrial camps. Spatial distribution of concentrations was analyzed considering the potential receiving parties and compared against the maximum permitted levels for pollutants, which criteria are stated in the Colombian air quality or immission level regulation in Resolution 610 of 2010[3].

### 2.3.2 Methodology to Characterize the Biotic Component

The field exit of this component was completed once elapsed the waiting periods provided in the national collection permit held with Geocol Consultores S.A. for the performance of these activities. Works were performed between February 22 and March 24, 2017 by a team composed of 6 forest engineers, 3 biologists, and 5 botanists for the epiphyte flora sampling in the zone. Before collecting the primary data in the field for this component, the relevant prior notice of activities was sent to ANLA and corporations having jurisdiction over the area.

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[2] EPA, United States Environmental Protection Agency (2012). User's Guide Addendum for the AMS/EPA regulatory model–AERMOD, Available at http://www.epa.gov/scram001/7thconf/aermod/aermodugb.pdf.
[3] MINISTRY OF ENVIRONMENT, HOUSING AND TERRITORIAL DEVELOPMENT. Resolution 610 of March 24, 2010, modifying Resolution 601 of April 4, 2006. Bogota, 2010. 8 p.

#### 2.3.2.1 Terrestrial Ecosystems

##### 2.3.2.1.1 Flora

Through the compilation of secondary data, the field sample preparation and subsequent treatment and analysis of obtained information, the approach to the current status of vegetation was completed. The analysis of the floral component aims to assess the ecological significance of floral species and diversity. Vegetation covers were characterized within the area of influence of the project for the purposes of learning about the floral objects likely to be intervened or excluded, susceptible of or vulnerable to the effect of environmental impacts. This characterization was developed by establishing forest sampling units (FSU) or parcels. The characterization of land covers was conducted in a quantitative manner in respect of cover units corresponding to: riparian forests, dense forests on the mainland (Dense high Andean forest), high secondary vegetation, low secondary vegetation, and open rocky grassland.

References were used for this study such as the General Methodology for Presentation of Environmental Studies[4], and the Technical Guides to Sustainable Planning and Management of Natural Forests[5], and other science related documents and articles involving floral characterization methods. Based on such references, the following phases were implemented in developing this characterization:

- **PRE FIELD**

  - **Interpretation of satellite images**

For the development of this phase, a WorldView picture taken on January 19, 2015, with a 4 band spectral and 0.50 m spatial resolution, in zones where there was no cover of this picture, we relied on four Rapideye pictures taken on January 27, 2016 (three pictures) and February 21, 2015 (on picture), with a 5 m spatial and 5 band spectral resolution. With such supplies, the identification, delimitation and grouping of cover units were developed at 1: 8000 scale, as well as their preliminary classification according to CORINE Land Cover nomenclature adapted to Colombia by ONF, CIAF and IDEAM[6], with which the preliminary land cover map was created.

- **FIELD SEARCH**

Considering the land cover units in the survey area identified in the previously created map, the verification of such land covers was conducted in the field through points of control, as well as the establishment of forest sampling units in the natural vegetation cover units.

  - **Sampling and sampling unit size**

[4] MINISTRY OF ENVIRONMENT, HOUSING AND TERRITORIAL DEVELOPMENT. 2010. General methodology for the presentation of environmental surveys. Bogota, Colombia 2010. 71 p.

[5] MINISTRY OF THE ENVIRONMENT, 2002. Technical guides to sustainable planning and management of natural forests. Republic of Colombia, Ministry of the Environment, Colombian Reforestation Association (ACOFORE, acronym in Spanish) and the International Tropical Timber Organization (ITTO). Bogota, D.C., p 55.

[6] IGN France Internacional – CIAF. 2006. Details about the CORINE Land Cover nomenclature for land covers. Colombia.

The characterization, collection and preservation of biological samples was covered by Collection Permit granted by Resolution Nº 0343 of March 25 de, 2015, to Servicios Geológicos Integrados LTDA. - SG, LTDA, being it understood that sampling units correspond to the maximum permitted units by such permit, and that the most appropriate unit was defined for the current survey considering the area to sample without exceeding the authorized by the resolution. A simple randomized sampling was collected, because it is the simplest and most commonly used sampling scheme. This type of sampling is commonly used in surveys with little previous information on the vegetation population characteristics to measure. (Mostacedo et al, 2000). For the conduction of this type of sampling, the previous land cover map was used as the basis and reference of the are to survey. Certain potential sampling points were determined in a randomized manner for each potential covers to characterize.

After defining the type of samples, the pre-sampling phase is developed, which consists in having an appropriate number of parcels, and based on collected data on such units, the final number of parcels to have per cover unit and ecosystem is calculated, in order to meet the 95% probability and 15% sampling error, as explained in the Sampling Representativity below. The foregoing in line with the provisions of the terms of reference (MADS 2015) governing this survey.

The size of parcels for each cover unit in the area of influence of the Environmental Impact Assessment for Functional Units 1.2, 2 and 3 (PK 17+000 – PK 25+600, PK 25+600 – PK 37+600 Y PK 37+600 – PK 44+909) of the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment, was defined considering the state of the current natural vegetation in the area, which is known for being highly intervened and reduced to very small areas. A basic sampling unit was thus defined: 0.05 hectares (500 $m^2$), which has been used in natural forests in intervened areas in the tropics and which, according to Becerra (1971), helps get adequate information on secondary forest composition and structure, which is why this surface was used for wooded covers in this survey. In addition, this surface was used as a reference to design and adjust the sampling unit size of vegetation covers, considering certain basic principles mentioned by Mateucci (1982) as well as the consulted specialized literature[7]:

For the sampling unit sizes, "larger sizes are selected for trees; medium sizes are selected for shrub and sawtimber; and small sizes are selected for herbs". This is why larger parcel sizes were selected for covers with trees (riparian forests, high Andean forest, and high secondary vegetation, with parcels of 10*50 m). "If individuals to be counted are small or there are plenty of them, it is better to use small units, as with the low secondary vegetation covers (5*5 m) and open rocky grassland (1*1 m), where individuals are abundant herbs, and certain shrubs regenerate, applying the modified Daubenmire method. Sampling units will be surveyed in

[7] **Coulloudon,** B. 1999. *Sampling Vegetation Attributes, Technical Reference* 1734-4, Bureau of Land Management. Denver, Colorado.
**Daubenmire, R.;** 1959. *A canopy-coverage method of vegetation analysis*. North West Science 31 (1): 4364.
**Gentry, A. H**. 1982. Patterns of Neotropical plant diversity. Evolutionary Biology 15: 1-84.
**Lamprecht, H.** Silvicultura en los Trópicos. [Forestry in the tropics] GTZ. Federal Republic of Germany. 1990.
**Melo Cruz, O & Vargas Ríos, R.** Evaluación ecológica y silvicultural de ecosistemas boscosos [Ecological and forestry assessment of wooded ecosystems]/University of Tolima, CRQ, CARDER, CORPOCALDAS, CORTOLIMA. 2002.
**Matteucci, S. & Colma, A.** 1982. Methodology for vegetation study. General Secretariat of the Organization of American States. Regional program for scientific and technologic development. Washington, D.C.
**Villarreal H., M. Álvarez s. Cordoba, F. Escobar, G. Fagua, F. Gast, H. Mendoza, M. Ospina & A.M Umaña.** Manual de métodos para el desarrollo de inventarios de biodiversidad [Method manual for the development of biodiversity inventories]. Biodiversity Inventory Program. Research Institute Alexander von Humboldt -IAVH. Bogota, 2004.

relation to the cover area to sample, trying to have the species accumulation curves stabilized, indicating that sampling was representative.

In the case of natural regeneration of riparian forests, standardized sizes were implemented, known as Meliacre survey and Linear regeneration sampling, referred to in the "Technical guide to sustainable planning and management of natural forests" (2002) released by the Ministry of the Environment, Acofore and the ITTO. In this case, all species with stems larger than 10 cm DBH and taller than 1.5 m are registered in parcels of 5*5; and individuals with stems shorter than 10 cm DBH and shorter than 1.5 m are included in parcels of 2*2 m.

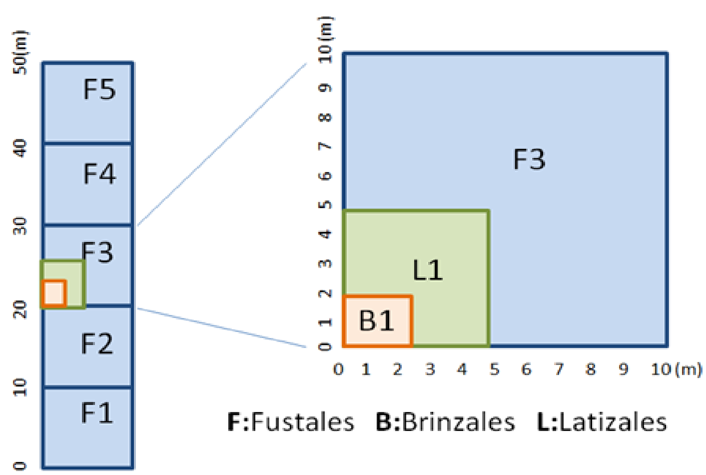
The sampling unit sizes for each assessed vegetation cover are shown below in **Table 2.20.**

**Table 2.20 Design of Land Patches via Coverage**

| LAND COVER UNIT | SAMPLING AREA (m) | | |
|---|---|---|---|
| | Sawtimber | Pole | Sapling |
| Riparian forest, high Andean forest, and high secondary vegetation | 10*50 | 5*5 | 2*2 |
| Low secondary vegetation | 5*5 | 5*5 | 5*5 |
| Open rocky grassland | 1*1 | 1*1 | 1*1 |

Source: GEOCOL CONSULTORES S.A., 2017.

**Figure 2.3 Implemented Patch Scheme**




Source: GEOCOL CONSULTORES S.A., 2017.

**table 2.21** and the **Land cover map** show the location of forest sampling units collected from each vegetation cover.

**Table 2.21. Location of Forest Sampling Units**

| VEGETATION COVER | FOREST SAMPLING UNIT SYMBOL | MAGNA SIRGAS COORDINATES BOGOTA, COLOMBIA | | | |
|---|---|---|---|---|---|
| | | ENTRY | | EXIT | |
| | | East | North | East | North |
| Dense forest on mainland in the high Andean orobioma | BD1 | 951992 | 596318 | 952042 | 596327 |
| | BD2 | 952551 | 596876 | 952557 | 596828 |
| | BD3 | 952543 | 596826 | 952533 | 596873 |
| | BD4 | 952675 | 596988 | 952618 | 597021 |
| | BD5 | 951669 | 596946 | 951712 | 596971 |
| | BD6 | 951754 | 595931 | 951772 | 595887 |
| Riparian forest in the medium Andean orobioma | BR1 | 955120 | 600556 | 955170 | 600565 |
| | BR2 | 954446 | 603176 | 954393 | 603174 |
| | BR3 | 954413 | 602583 | 954457 | 602609 |
| | BR4 | 954353 | 603059 | 954317 | 603020 |
| | BR5 | 956767 | 598731 | 956778 | 598682 |
| | BR6 | 955875 | 599490 | 955917 | 599520 |
| | BR7 | 955236 | 597981 | 955220 | 597956 |
| | BR8 | 954908 | 599309 | 954942 | 599346 |
| High secondary vegetation in the high Andean orobioma | VSA-OaA1 | 951889 | 595282 | 951934 | 595263 |
| | VSA-OaA2 | 951473 | 594964 | 951432 | 594933 |
| | VSA-OaA3 | 951250 | 594916 | 951251 | 594864 |
| | VSA-OaA4 | 952470 | 596301 | 952469 | 956352 |
| | VSA-OaA5 | 952292 | 595975 | 952265 | 596018 |
| | VSA-OaA6 | 952100 | 596241 | 952077 | 596214 |
| High secondary vegetation in the medium Andean orobioma | VSA-OmA1 | 955341 | 600187 | 955316 | 600144 |
| | VSA-OmA2 | 954968 | 600777 | 955013 | 600752 |
| | VSA-OmA3 | 955165 | 603442 | 955205 | 603411 |
| | VSA-OmA4 | 954712 | 603434 | 954750 | 603465 |
| | VSA-OmA5 | 956643 | 598698 | 956635 | 598647 |
| | VSA-OmA1 | 955341 | 600187 | 955316 | 600144 |
| | VSA-OmA2 | 954968 | 600777 | 955013 | 600752 |
| | VSA-OmA3 | 955165 | 603442 | 955205 | 603411 |
| | VSA-OmA4 | 954712 | 603434 | 954750 | 603465 |
| | VSA-OmA5 | 956643 | 598698 | 956635 | 598647 |
| | VSB-omA1 | 955238 | 604906 | | |
| | VSB-omA2 | 955269 | 604910 | | |
| | VSB-omA3 | 954157 | 603469 | | |
| | VSB-omA4 | 954037 | 603571 | | |
| | VSB-omA5 | 956208 | 600420 | | |
| | VSB-omA6 | 956125 | 600400 | | |
| | VSB-omA7 | 955395 | 600205 | | |
| | VSB-omA8 | 955043 | 600527 | | |
| | VSB-omA9 | 947151 | 589662 | | |
| | VSB-omA10 | 954997 | 600804 | | |
| | VSB-omA11 | 955071 | 600929 | | |
| | VSB-omA11 | 955260 | 601608 | | |
| | VSB-omA13 | 956251 | 599845 | | |
| | VSB-omA14 | 956134 | 599897 | | |
| | VSB-omA15 | 947105 | 589645 | | |
| | VSB-omA16 | 956713 | 598582 | | |
| | VSB-omA17 | 956667 | 598931 | | |
| | VSB-omA18 | 955906 | 599729 | | |

| VEGETATION COVER | FOREST SAMPLING UNIT SYMBOL | MAGNA SIRGAS COORDINATES BOGOTA, COLOMBIA | | | |
|---|---|---|---|---|---|
| | | ENTRY | | EXIT | |
| | | East | North | East | North |
| | VSB-omA19 | 954881 | 597148 | | |
| | VSB-omA20 | 955067 | 597178 | | |
| | VSB-omA21 | 955031 | 597189 | | |
| | VSB-omA22 | 954856 | 597287 | | |
| | VSB-omA23 | 948571 | 591035 | | |
| High secondary vegetation in the high Andean orobioma | VSB-oaA1 | 951401 | 594719 | | |
| | VSB-oaA2 | 951366 | 594674 | | |
| | VSB-oaA3 | 951368 | 594638 | | |
| | VSB-oaA4 | 951922 | 597097 | | |
| | VSB-oaA5 | 951904 | 597048 | | |
| | VSB-oaA6 | 952034 | 597061 | | |
| Open rocky grassland in the medium Andean orobioma | Herb1 | 949049 | 591564 | | |
| | Herb2 | 949061 | 591549 | | |
| | Herb3 | 949053 | 591522 | | |
| | Herb4 | 949040 | 591494 | | |
| | Herb5 | 949029 | 591469 | | |
| | Herb6 | 949107 | 591571 | | |
| | Herb7 | 949119 | 591593 | | |
| | Herb8 | 949145 | 591598 | | |
| | Herb9 | 949143 | 591571 | | |
| | Herb10 | 949126 | 591561 | | |
| | Herb11 | 949136 | 591532 | | |
| | Herb12 | 949147 | 591475 | | |
| | Herb13 | 949156 | 591436 | | |
| | Herb14 | 949151 | 591401 | | |
| | Herb15 | 949172 | 591376 | | |
| | Herb16 | 949155 | 591351 | | |
| | Herb17 | 949191 | 591353 | | |
| | Herb18 | 949189 | 591304 | | |
| | Herb19 | 949030 | 591543 | | |

Source: GEOCOL CONSULTORES S.A., 2017.

- **Field information record form**

For each parcel, the field form was filled out, which includes general information on the sampled site (cover, location, plane coordinates, and information on the forest individuals).

The forest inventory for the characterization of natural vegetation covers generally consisted in identifying each individual, completing the consecutive marking (for sawtimber), and collecting the corresponding data: common name, diameter at breast height (DBH), total height, and trade height. According to the characteristics of each cover, certain modifications were implemented in the general inventory methodology. Thus, for the open rocky grassland cover no marking or numbering of individuals in the field was implemented, georeferencing was implementing instead. Data was collected in field forms (analogically), which were subsequently treated at the office.

The identification of floral species was carried out according to the APG III Classification System[8], based on in situ observation of leaves, stems, flowers, and fruits, and the taxonomic key support, and flora manuals of the survey area or alike. As for species that could not be directly defined, vegetation materials –preferably fertile– were collected and sent to a botanist (See **Picture 2.12**).

**Picture 2.12 Sampling of Vegetation Covers within the Project area.**

- **After fieldwork**

[8] **Haston, E., J. E. Richardson, P. E. Stevens, M. W. Chase & D. J. Harris**. 2009. *The Linear Angiosperm Phylogeny Group (LAPG) III: a linear sequence of the families in APG (III)*. Bot. Journ. Linn. Soc. Lond. 161: 128-131.

- **Finding sampling error and descriptive statistical analysis**

  § **Representative samples**

The forest inventory was made with 95% probability and sampling error lower than 15% per cover unit. The purpose of estimating sampling errors is to define an optimal sampling size for each vegetation cover according to heterogeneity found in its biomass, basal area or timber volume, and then based on that provide rough and less biased values for timber volume to remove per hectare in each cover, if required. Thus, it is also a logical premise that in estimating this sampling error measured variables for each individual within the population with known sampling surfaces ($m^2$) should be used.

Total volume was the parameter used to measure sampling accuracy in arboreal covers (gallery forest, high Andean forest, and high secondary vegetation). In the case of arboreal covers, only the volume value of sawtimber was used. *Student's t test* was the statistical method implemented (95% probability and degrees of freedom (n-1) according to the number of sampling units in each cover).

Having the volume (X) and basal area of each cover, the standard deviation (DE), coefficient of variation (CV), sampling error (EM) and number of parcels (n) required to meet an error level of < 15%, were estimated according to the following formulas:

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

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

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

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

The foregoing parameters to estimate correspond to those estimated for riparian forest, high Andean forest and high secondary vegetation covers.

- **Accumulation curves**

In the case of open rocky grassland and low secondary vegetation, considering that a variable for each sampled individual could not be measured as with the other previously explained covers, the representative sample for this item was decided to be measured through a species accumulation curve.

In this case, given that only the presence-absence data was available for each species per sampling unit or parcel, the **Jacknife1 (Ŝjack1)** and **Bootstrap (Ŝboot)** estimators were used, which are based on presence of rare species to project the total number of expected species.

$$\hat{S}_{jack1} = S_{obs} + \left(\frac{m-1}{m}\right)Q_1$$

$$\hat{S}_{boot} = S_{obs} + \sum_{k=1}^{S_{obs}} (1 - p_k)^m$$

Where:

$S_{obs}$ =number of observed species

$m$ = number of sampling parcels or units

$Q_1$ = number of unique species (only found in one single sample)

$p_k$ = proportion of sampling units with the $k$ species.

- **Floral composition and structural analysis of covers with arboreal strata (sawtimber, pole, sapling).**

  - **Horizontal structure**

    - **Abundance of species**

This refers to the number of individuals per hectare and per species in relation to the total number of individuals. For the forest inventory, absolute abundance (number of individuals per species) and relative abundance (proportion of individuals of each species in the total number of individuals in the ecosystem) were estimated.

***Aa =*** *Number of individuals per species*

$$Ar = \frac{\text{Number of individuals per species}}{\text{Number of individuals in the area}} \times 100$$

- **Frequency of the species**

This helps determine the number of parcels a species is found, in relation to the total number of inventoried parcels, or existence or absence of a given species in a parcel.

$$Fa = \frac{\text{Number of sampling units in a species}}{\text{Total number of sampling units}} \times 100$$

$$Fr = \frac{\text{Absolute frequency of a species}}{\text{Total sum of absolute frequency}} \times 100$$

According to absolute frequency, species may be classified as shown below in **Table 2.22**

**Table 2.22. Absolute Frequency Classification**

| CLASS | ABSOLUTE FREQUENCY | DEGREE |
|---|---|---|
| I | 1-20 | Very infrequent |
| II | 20.1-40 | Infrequent |
| III | 40.1-60 | Frequent |
| IV | 60.1-80 | Quite frequent |
| V | 80.1-100 | Very frequent |

Source: GEOCOL CONSULTORES S.A., 2017.

§ **Species dominance**

It is related to the cover degree of species as the representation of the area occupied by the species, and is determined as the sum of horizontal projects of the crown of trees on the ground. Basal areas are used for this purpose, linear correlation by the crown and timber diameter.

**Basal area** $AB = \sum (pi/4 \times D^2)$ Where: D = DBH.

$$Dr = \frac{\text{Total basal area for a species}}{\text{Basal area of all species}} \times 100$$

o **Importance value index (IVI) of species**

The IVI is estimated for each species based on the sum of parameters expressed as a percentage of abundance, frequency and relative dominance. The maximum value for IVI is 300; its results allow for comparison of the ecological weigh of each species within the forest.

***IVI =*** *Relative dominance + Relative abundance + Relative frequency*

o **Importance value index for families(IF)**

Based on previously calculated estimates for species, the importance value index for families may also be estimated. The following values are thus required:

*Relative Abundance of Families RAF*= the sum of abundances of species composing the family /total number of individuals in a cover * 100

*Relative Dominance RDF*= the sum of dominances (basal area) of species composing the family/total dominance of the cover * 100

*Relative richness RRF*= Number of species composing he family /total number of species in the cover * 100

*IVF= RAF + RDF + RRF*

o **Species spatial distribution**

Spatial distribution in forest ecosystems may correspond in general to certain patterns; *random*: individuals are distributed at random within the available space; *regular or uniform*: when individuals somehow tend to keep among them a distance close to similarity; and *clumped*: composed of groups of organisms alternating with open spaces.

For the identification of this type of distribution, the ***distribution index DI*** is implemented:

$$DI = \frac{S^2}{X} * n\text{-}1$$

Where:

$s^2$=*variance of the number of individuals of the species in parcels.*

*X***=***average number of individuals of the species in parcels.*

*n= total number of individuals of the species.*

**Table 2.23. Species Spatial Distribution**

| DISTRIBUTION INDEX | TYPE OF DISTRIBUTION |
|---|---|
| **DI=1** | Random distribution |
| **DI<1** | Uniform distribution |
| **D>1** | Clumped distribution |
| **DI=n** | Maximum aggregation |
| **DI=0** | Maximum uniformity |

Source: Hazen 1966; Malleux 1973; Ludwig 1988[9].

It is to consider that this distribution is merely statistical; therefore, getting to understand is actually more complex. Each species should thus be studied as an independent element, where intrinsic and external biological factors shape their natural distribution.

o **Diametric structure**

For its determination, diameter classes are estimated every 10 cm, starting from class 1 of 10 to 19.9 cm, and so on, according to the forest composition and diameters of found individuals. In each diameter class, the number of assembled individuals is estimated and the total abundance chart for each class is prepare.

o **Volume calculation**

The total volume for pole individuals is calculated based on the basal area, total height and a morphic factor (FM) of 0, according to the cylinder form. Formula is as follows:

$$\boldsymbol{Vt} = 0,\ 7854 \times (DBH)^2 \times TH \times MF$$

Where:

0,7854 (Pi/4) is constant,

DBH: Diameter at breast height in meters.

TH: Total height in meters.

MF: Morphic Factor (0,70). A form factor of 0.7 was agreed upon to be used because it is the standard for tropical and broadleaf species, the latter with a dendrometric type of timber mostly cylindrical (Dávila 2012)[10].

Based on the total value per specie, the diameter class volume is estimated.

For the calculation of the trade height, the same formula is used but trade height (CH) is used instead of total height (TH). In this survey, the trade height of individuals was considered as the maximum height of any kind of timber use, which is generally consistent with the crown of the tree because there are no quality and shape restrictions for use of timber.

9 Hazen, W. 1966. *Analysis of spatial pattern in epiphytes*. Ecology. Vol. 47. N° 4.
Malleux, J. 1973 Análisis de Dispersión de 10 Especies Forestales de un bosque húmedo tropical. V. 5 (1-2): 1-12.
Ludwig, A. 1988. *Statistical Ecology: A Primer in Methods and Computing*.
10 **Dávila, D.E., Alvis, J.F., & Ospina, R.** (2012). Distribución espacial, estructura y volumen de los bosques de roble negro (Colombobalanus excelsa (Lozano, Hern. Cam. & Henao, J.E.) Nixon & Crepet) en el Parque Nacional Natural Cueva de Los Guácharos. Colombia Forestal, 15(2), 207-214.

· **Vertical structure**

According to Mateucci & Colma (1982), vertical structure helps assess the behavior of trees as individuals and species over the soil surface. It is developed based on height, distinguishing each stratum, using both qualitative (profile diagram) and quantitative (Ogawa) methods

o **OGAWA (quantitative) method**

This method consists in determining the presence of stratum in a forest based on the total height chart (axis y) vs. height to the crown base (axis x), according to the OGAWA stratification method.

o **Class of height**

The population structure was estimated setting intervals of class of height according to methodology proposed by Sturges (1926)[11] and distributing the various heights of each small tree individuals in the cover.

o **Arboreal and sub-arboreal stratification**

The veridical stratification of small tree species will be defined based on strata proposed by Rangel and Lozano in 198612 as follows:

Herbaceous stratum: with DBH < 0.8,

Shrubby stratum: woody plants with heights between 1.5 and 4.9 m high,

Sub-arboreal stratum: woody plants with heights between 5 and 11.9 m high

Lower arboreal stratum: woody plants with heights between 12 and 24.9 m high.

Higher arboreal stratum: (As) >25 m

o **Vegetation profiles**

The vegetation profile is the scheme of a forest strip illustrating the number of strata, height and cover. For its preparation, a parcel is selected per inventoried cover unit in the field, and the surveyed data on species, total height, crown height, DBH, and crown – georeferencing distances are used. This information is included in a chart using the SketchUp make software, to thus obtain the vegetation profile of each cover.

· **Diversity indexes**

In order to assess richness or number of populations with different species of individuals composing the forest ecosystem, the specific alpha richness indexes were estimated, i.e. a species richness within a clump or community (Magurran, 2007). Specific richness (S) is the simplest way to measure biodiversity, given that it is only based on the number of species present, without considering their importance value. The ideal way to measure specific richness is having a full inventory that will help us become aware of the total number of species (S) resulting from the community census (Moreno, 2001).

· **Richness indexes.**

[11] **Sturges,** H. 1926. *The choice of class interval. Journal of the American statistical association.* 21: 65-66.

[12] **Rangel –Ch & Velásquez A.** (1997) Vegetation study methods, Colombia Biotic Diversity II. National University of Colombia. Santa fe de Bogota.

- **Combination coefficient**

According to Becerra, (1971), combination coefficient (CM) helps measure intensity in species combinations. It is an approximation to determine the degree of heterogeneity or homogeneity within the forest. It is determined through the existent proportion between the number of species and the total number of individuals. Only the comparison of forests having similar sampling surveys is permitted, due to reliance of the CM of the minimum measurement diameter and the sample size. For its estimation, the number of species found is divided by the total number of surveyed trees, for a figure that will represent the average of individuals in each species, according to the following formula:

$$Cm = \frac{\text{Number of species}}{\text{Total number of individuals}}$$

- **Margalef diversity index.**

This transforms the number of species per sample into a proportion where species are added by sampling expansion; where values lower than 2.0 are deemed to be related to low diversity areas (in general, derived from anthropogenic effects), and values exceeding 5.0 are deemed to be a sign of high biodiversity (Margalef. R, 1995).

$$D_{mg} = \frac{S -}{LnN}$$

Where:

S = number of species

N = total number of individuals

Evenness indexes

Shannon-Wiener Index.

This defines uniformity of importance values through all of the sampling species. In most natural ecosystem, it fluctuates between 1 and 5. Exceptionally there may be ecosystems with greater (tropical forests, coral reefs) or lower values (dessert zones).

$$H' = -\sum p_i \ln p_i$$

- **Simpson's dominance index.**

This index determines whether there are any dominant taxa or species within the sample. The interval ranges from 0 (all species are similarly present) to 1 (one species fully prevails in the community).

$$D = \sum_i \left(\frac{n_i}{n}\right)^2$$

Where $n_i$ is the number of individuals of species i.

· **Natural regeneration.**

The NRI (natural regeneration index) proposed by Finol (1971)[13] is used. This index was estimated based on the phytosociological parameters of regeneration, according to the following:

NRI= (AB% Fr% Ctr%)

Where:

AB%= Relative abundance.

FR%= Relative frequency.

Ctr%= Relative size category.

To obtain Ctr% (Relative size category), the absolute size category (Cta) must be generated in the first place. It is obtained by dividing the number of individuals in the sub-stratum by the total number of individuals of all species. Size categories for Altimetric Classes of Natural Regeneration are show in **Table 2.24** below.

**Table 2.24. Altimetric Classes of Natural Regeneration**

| SIZE CATEGORIES | | INTERVAL (m) |
|---|---|---|
| R1 | Renewal 1 | 0 – 0,10 |
| R2 | Renewal 2 | 0,11 – 0,30 |
| R3 | Renewal 3 | 0,31 – 1,50 |
| L | Poles | ≥1,51 |

Source: GEOCOL CONSULTORES S.A., 2017.

The relative size category (Ctr) of each species, is expressed as a percentage of the total sum of absolute values, according to the following formula:

$$Ctr = \frac{Cta.}{\sum_{i=1}^{0} Cta}$$

Where:

Cta = Absolute size category.

The absolute size category is estimated using the following formula:

$$Cta = CtR1 * nR1 + CtR2 * nR2 + CtR3 * nR3 + CtL * nL$$

Where:

Ct = Phytosociological value of the sub-stratum;

[13] Finol, H. 1971. *New parameters for the structural analysis of tropical virgin forests.* Silva Gandavensis no. 26.

n = number of individuals of the sub-stratum.

· **Family Importance Index (IVF) in regeneration**

For the calculation of the Family Importance Index (IVF) and obtaining the most important families in natural regeneration, Curti's formula (1959)14 was used, with the variance that the basal area was not considered due to the fact that works are conducted with individuals shorter than 10 cm of DBH, with the formula remaining as follows:

IVF = (Nº of species per family/ Nº total species) + (Nº trees per family /Total number of trees) * 100

Floral composition and cover structural analysis with herbaceous stratum.

The following methodology was implemented only for the analysis of the floral composition analysis was completed with the forest composition tool of an **open rocky grassland**.

· **Horizontal structure**

o **Daubenmire method (modified)**

Use of squares or square particles of 1 1*1 m distributed at random. The total XX of samplings were prepare d

(See **Table 2.25** below). The following parameters were assessed for each of them:

o **Species cover**

This defines the degree of percentage occupation of a species for the sampling square area, based on the Daubenmire scale:

**Table 2.25. Daubenmire Scale, Grassland Sampling**

| PERCENTAGE INTERVAL | INTERVAL AVERAGE | CLASS OF COVER |
|---|---|---|
| 0 - 5% | 2,5% | 1 |
| 5 - 25% | 15,0% | 2 |
| 25 - 50% | 37,5% | 3 |
| 50 - 75% | 62,5% | 4 |
| 75 - 95% | 85,0% | 5 |
| 95 - 100% | 97.5% | 6 |

Source: Coulloudon, B. 1999. Daubenmire, R. 1959.

Net cover, absolute cover and relative cover are estimated based on individual rating:

Net cover (CN) =$\sum_j^n q$ij*Xj

Where,

qij= number of ratings by species I in class j

Xj= average of intervals of the relevant class j

14 Curtis, J.T. 1959. *The vegetation of Wisconsin. An ordination of plant communities. Madison:* Univ. of Wisconsin Press.

$$\text{Absolute cover (AC)}= \frac{CNi}{total\ number\ of\ parcels\ or\ squares}$$

$$\text{Relative cover (RC)}= \frac{CAi}{\sum_i^n CN} * 100$$

Frequency of species

$$\text{Absolute frequency (AF)} = \frac{qi}{\boldsymbol{otal\ number\ of\ parcels\ or\ square}}$$

Where,

$q_i$ = number of parcels where species *i* was present.

$$\text{Relative frequency (RF)} = \frac{FAi}{\sum_i^n FA} * 100$$

Species importance value

$$\text{Importance value} = \frac{CRi+FRi}{2}$$

- **Forbidden, endemic, threatened or endangered species with trade, scientific and cultural value**

For the verification of threatened species, the following were consulted: the List of Species in Red Books of Colombia, the IUCN Red List site, the database of the Convention on International Trade in Endangered Species of Wild Fauna and Flora – CITES, and Resolution 192 of 2014 of the Ministry of the Environment and Sustainable Development –MADS, acronym sin Spanish.

Categories are presented by international convention, as a code, where both letters mean a category, as follows: CR – Critically endangered, EN – Endangered, VU – Vulnerable, NT – Near threatened, LC – Least concern, DD – Data deficient, and NE – Not evaluated. Table xx below shows the definition of each category according to IUCN.

### Table 2.26 Classification Categories used by the IUCN

| CATEGORY | EXPLANATION |
|---|---|
| **Extinct (EX)** | A taxon is *extinct* where the individually undoubtedly has vanished. A taxon is presumably extinct when exhaustive researches on their habitats, known and/or excepted, at the right times (days, seasons, annually), and across their area of historical distribution, have not been able to find one single individual. Searches must be conducted over the appropriate periods corresponding to this taxon's life cycle and forms of life. |
| **Extinct in the wild (EW)** | A taxon is *extinct in the wild* when it only survives in captivity or as a population (or populations) completely naturalized outside their original distribution. A taxon is presumably *extinct in the wild* when explorations of their habitats, known and/or excepted, at the right times (days, seasons, annually), and across their area of historical distribution, have not been able to find one single individual. Searches must be conducted over the appropriate periods corresponding to this taxon's life cycle and forms of life. |
| **Critically endangered (CR)** | A taxon is *crucially endangered* when the best evidence available shows that it meets any of the provided criteria. Consequently, it is deemed to face an extremely high risk of extinction in the wild |
| **Endangered (EN)** | A taxon is *endangered* when the best evidence available shows that it meets any of the provided criteria. Consequently, it is deemed to face a very high risk of extinction in the wild. |
| **Vulnerable (VU)** | A taxon is *Vulnerable* when the best evidence available shows that it meets any of the provided criteria. Consequently, it is deemed to face a high risk of extinction in the wild. |
| **Near threatened (NT)** | A taxon is *near threatened* when it has been evaluated according to the relevant criteria and fails to currently meet the criteria for *critically endangered, endangered or vulnerable*, but it almost meets such criteria or may possibly meet them in the near future. |
| **Least concern (LC)** | A taxon is categorized as *least concern* when, having bed evaluated, fails to meet any of the criteria stated for the *critically endangered, endangered, vulnerable or near threatened* categories. The least concern category includes abundant and broad distribution taxa. |
| **Data deficient (DD)** | A taxon is *Data deficient* when there is no sufficient data to conduct an evaluation, directly or indirectly, of its threat with extinction, based on the population distribution and/or status. A taxon within this category may be very well studied and its biology may be very well known, but there are no appropriate data on their abundance and/or distribution. When a taxon is categorized as data deficient, it means that more information is required and the possibility is acknowledged that future researches may prove that a threatened category may be appropriate. It is important to make effective use of any information available. In many cases, it will be necessary to be very careful to choose between data deficient and a threatened condition. If the distribution of a taxon is suspected to be relative restricted if a significant period of time has passed after the latest records of the taxon, then a threatened condition may be reasonable. |
| **Not evaluated (NE)** | A taxon is deemed to be *Not evaluated* when it has not yet been categorized in relation to any of the criteria above. |

Source: International Union for the Conservation of Nature - IUCN

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) has three categories referred to as Appendixes I, II and III, which are lists of species afforded different levels and types of protection for over-exploitation. Appendix I lists such species that are the most endangered or threatened with extinction; Appendix II lists species that even if not threatened with extinction may become so unless trade is closely controlled; and Appendix III lists species included at the request of a party to the convention for the paramount purpose of preventing intensive exploitation.

#### 2.3.2.1.2 Forbidden Species

The characterization work of epiphyte, rupicolous, and terrestrial vascular and non-vascular plants in closed season showed three phases: a before fieldwork phase –which was based on the review of secondary data on the area of influence of the project, and the preparation of field methodology; a field phase – where the proposed sampling was collected; and an after fieldwork phase –in which the work on the herbarium and data treatment were included, together with the preparation of the characterization document of epiphyte, rupicolous, and terrestrial vascular and non-vascular species in closed season, and some other (abundant) species from the Araceae, Bignoniaceae and other families in an epiphyte habitat, found in the sampled covers in the intervention area of the road project.

For the preparation of the document to request the survey on epiphyte, rupicolous, and terrestrial vascular and non-vascular species in closed season found in the intervention area of the road project, the sampling design was prepared in a stratified manner because, given the wide area of the project, being this a linear project, it contemplates two (2) biomes (medium Andean orobioma, and high Andean orobioma). Therefore, the proposal was to work on sampling of epiphyte flora in closed season at the level of ecosystems, i.e. considering the biome and the cover, starting from the fact that, for instance, the Gallery Forest cover of the Medium Orobiome of the Andes will act in a completely different manner compared to the Gallery Forest of the High Orobiome of the Andes, as to composition, structure and diversity of plant communities to characterize for the request of the closed season survey. This is why, the sampling design of the document of the Request of the Closed Season Survey was proposed and developed in respect of ecosystems found in the intervention area of the project.

· **Pre-field**

o **Sampling design and sample size**

The proposed and developed sampling design and sample size were defined at the level of covers in presence of trees and shrub found in the intervention area of the project (**Figure 2.4** and **Table 2.27**). 13 covers with characterized arboreal and/or shrub vegetation were found, considering such covers within the intervention area of the project for the completion of the characterization of epiphyte, rupicolous, and terrestrial vascular and non-vascular plants in closed season, 100 x 10 m parcels were implemented, following the RRED method (Grasdtein et. al, 2003), with a five (5) to eight (8) tree proportion per parcel for epiphyte, rupicolous, and terrestrial non-vascular species from the Bryophyte and Lichen taxonomic groups; and for epiphyte, rupicolous, and terrestrial vascular species from the Bromeliaceae, Orchidaceae, Araceae, Bignoniaceae and other epiphyte families, provided that the cover parcel included such number of trees and/or shrubs (Table 2.27).

Authors such as Zotz & Badel (2011) observed that in a 0.1 h parcel, the sample size was sufficient to get a representative description of the epiphyte vascular community, with about 6 to 8 trees with a DBH preferably larger than 10 cm. In the case of bryophytes –due to the high density of these species– the minimum sampling area was relatively small, where four (4) to five (5) trees may cover most of the local flora species. The number of parcels and phorophyte ratio to define the sample size was used until reaching a ration of eight (8) phorophyte trees characterized per hectare of cover to intervene. Furthermore, the stabilization of the Species Accumulation Curves was considered, which included mathematical estimators proposed by authors such as Villarreal et. al, (2006), which are broadly used, such as the ACE estimator, based on abundance data and used to estimate the sampling effort in relation to vascular epiphytes and Bootstrap, based on presence-absence data (frequency), used for non-vascular epiphytes. It is to clarify that due to high intervention experienced in the surveyed area because of the expansion of the agricultural and livestock border, availability of arboreal cover is very low, which limited the selection of phorophytes for the epiphyte flora sampling.

- **Definition of sampling sites**

Before the field visit, a preliminary definition of cover units with arboreal and/or shrub vegetation in the intervention area of the project was completed, based on available cartography of the zone, establishing a significant number of parcels for the characterization of epiphyte flora, following the parameters of the REDD method (Grasdtein et. al, 2003) and considering that there are four (4) natural covers and nine (9) non-natural covers, which is directly related to availability of arboreal and/or shrub vegetation found in epiphyte flora.

Sampling sites were defined according to the location of vegetation covers found in the intervention area of the road project (See **Annex 10. Epiphytes_4. Cartography**). Parcels to sample were projected over the 13 covers (**Table 2.27**). once in the field, a sample of each selected phorophyte was collected to establish their determination in the herbarium, for subsequent phorophyte preference analysis, because the identity of a phorophyte has shown to influence the settlement and growth of epiphyte species therein, and it should be considered when proposing alternatives to manage these vital species in ecosystems (Laube & Zotz, 2006).

606 100 x 10 m parcels were set in total, distributed according to the intervention area of the project in each of the 13 arboreal or shrub vegetation covers found in the intervention area of the road project (See **Annex 10. Epiphytes_4. Cartography**), looking for the representativity of the eight (8) phorophyte trees characterized per hectare proposed in the RRED methodology (Gradstein et. al, 2003; Zotz & Bader, 2011) and supported by a reliable methodology to estimate the sampling effort: Species Accumulation Curves (**Table 2.27** and **Figure 2.4**), for the sampling of vascular and non-vascular epiphytes, sufficiently robust data to conduct a biodiversity analysis, as stated by Gradstein et. al, (1996), Gradstein et. al, (2003) and Wolf et. al, (2009).

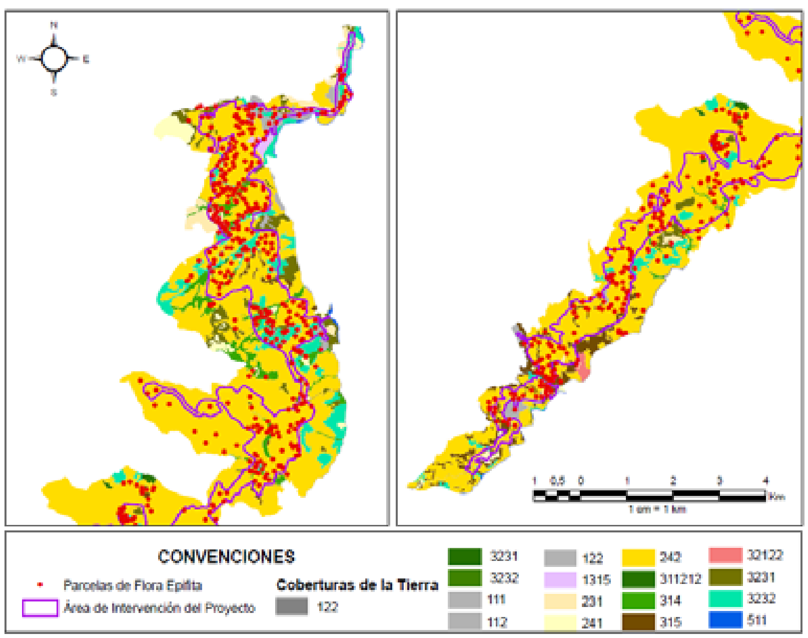
**Table 2.27 Amount of Patches and Phorophytes per Vegetation Cover characterized within the Intervention Areas.**

| LAND COVER | INTERVENTION AREA (ha) | # OF SETTLED PARCELS |
|---|---|---|
| Dense high Andean forest | 3,1 | 5 |
| Riparian forest | 50,7 | 50 |

| LAND COVER | INTERVENTION AREA (ha) | # OF SETTLED PARCELS |
|---|---|---|
| Construction material exploitation | 4,3 | 2 |
| Open rocky grassland | 0,8 | 1 |
| Crop spectrum | 14,0 | 6 |
| Grass and crop spectrum | 1274,7 | 391 |
| Pasture | 16,6 | 12 |
| Forest plantation | 46,0 | 27 |
| Road system and related lands | 5,6 | 1 |
| Continuous urban fabric | 4,9 | 4 |
| Discontinuous urban fabric | 35,5 | 11 |
| High secondary vegetation | 48,3 | 31 |
| Low secondary vegetation | 116,6 | 65 |
| **TOTAL** | **1621,2** | **606** |

Source: GEOCOL CONSULTORES S.A., 2017.

**Figure 2.4 Location of the Characterization Patches of Rock and Land-Growing Epiphyte Flora within the Project Area.**




Source: GEOCOL CONSULTORES S.A., 2017.

o **Secondary data review**

The existing secondary data on the area of influence of the project was reviewed, such as previous floral studies conducted by Rangel (2008) on the richness and diversity of moss and lichens in Colombia. Also, the current legislation on national and regional closed seasons was consulted including, but not limited to, Resolution 0213 of 1977 issued by INDERENA. The resolutions of CORPONARIÑO were also consulted.

- **Field**

o **Selection of phorophytes**

In each of the 606 parcels defined in the 13 arboreal and/or shrub vegetation covers found in the intervention area of the project, visits were conducted between February 23 and March 23, 2017, for the purposes of locating trees and shrubs meeting the phorophyte selection criteria referred to by Wolf (1993), Gradstein et. al, (2003) and Gradstein et. al, 1996. These criteria refer to big trees preferably, with dominant heights in the canopy, diameter at breast height (DBH) exceeding 10 cm (prioritizing those with greater diameters). In the event that only phorophytes with less than 10 cm DBH were registered for the cover and, therefore, the parcel, those available with greater diameters were selected, which bark was fully developed, with cracking and without bark and, where possible, from different species (Zotz & Bader, 2011).

For the sampling, the area of influence of the crown of each selected phorophyte was considered, because shrubs and small trees in the microclimate of phorophytes have epiphyte species adapted to these environmental conditions (Zotz & Bader, 2011). Therefore, epiphytes found in this area of influence of the crown were registered and collected according to the number of phorophytes in the parcel. Also, optional or causal (land) phorophytes were sampled –these can live in the soil or trees (Schimper, 1988; Richards, 1964).

For the cover sampling, the sampling effort was determined by the Species Accumulation Curves, using, for vascular epiphytes, the ACE estimator, which is based on abundance of records, and for non-vascular epiphytes the Bootstrap estimator, which is based on the presence-absence of records in the sampling units (Villarreal et. al, 2006), which corresponded to each phorophyte in the parcels. Each phorophyte was registered in a field form for epiphyte flora (**Figure 2.5**), marking it over the bark and georeferencing its position using a GPS device, thus generating a series of points for each sampled parcel and phorophyte.

**Figure 2.5 Field Format for the Registration of Vascular, Non-vascular, Rock and Land-Growing Epiphytes.**

| | | |
|---|---|---|
| GEOCOL www.geocol.com.co | MUESTREO DE EPIFITAS VASCULARES Y NO VASCULARES | Fecha de Emisión 22/08/2016<br>Revisión: 01<br>Página 1 de1 |

| | | |
|---|---|---|
| Proyecto: | Elaboró: | Cobertura: |
| Departamento: | Municipio: | Tramo/KM: ZODME: |
| Vereda: | Predio: | Coordenadas parcela: |
| Altitud: | Fecha: | |
| Observaciones: | | |

| Voucher | N° Hosp. | N° For. | N° Epi. | T.O. | Morfoespecie | Cobertura (%) No Vasc. | | | | Ubicación de la epifita en el hospedero | | | | | Abun. | N° Foto | Coordenadas Forófito | | Observaciones |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | N | E | S | O | B | T | DB | DM | DE | | | Este | Norte | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |

**Observaciones Generales:**

**Voucher:** Sigla compuesta por la dos iniciales del colector, la sigla de la cobertura, el número de la parcela y el de la morfoespecie. **N° Hosp.:** Número de hospedero forestal.

**TIPO DE ORGANISMO (T.O): Vascular** (V), Musgo (M), Hepática (H), Liquen (L), y Alga (A). **Cobertura (%) No Vasculares: N:** Norte, **E:** Este, **S:** Sur. **O:** Oeste.

**UBICACIÓN: T:** Tronco, **B:** Base, **DB:** Dosel bajo, **DM:** Dosel medio, **DE:** Dosel externo. **Abund.:** Suma de abundancia para epífitas vasculares y de frecuencia para no vasculares.

**EPI**: Epífita, **RUP**: Rupica, **TER**: Terrestre. Lo cual se mencionará en la columna de Observaciones en caso de ser necesario **N° For.**: Número forófito. N° Epi.: Número epífita.

Source: GEOCOL CONSULTORES S.A., 2017.

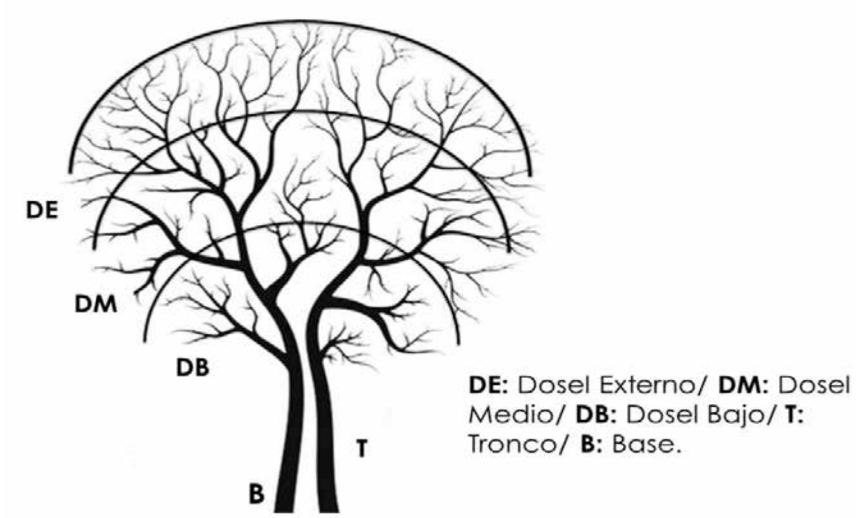
- **Characterization of vascular epiphytes**

The most commonly used measurements for the quantification of abundance of vascular epiphytes include counting the number of individuals found in the phorophyte (Sugden & Robins, 1979; Gentry & Dodson, 1987; Zimmerman & Olmsted, 1992). Where possible, the number of individuals per species was quantified, but for trees with profuse development of epiphytes, counting the number of colonies or patches of each species was deemed to be the best option (Wolf et. al, 2009 y Gradstein et. al, 1996). Vascular epiphytes declared in closed season through Resolution 0213 of 1977 issued by INDERENA, were sampled, i.e. epiphytes from the Orchidaceae and Bromeliaceae families

Abundance categories for the five vertical strata proposed by Johansson (1974) (

**Figure 2.6**) were defined according to frequency and abundance of all of the registered epiphytes, analyzed in the vertical (phorophyte stratum) and in the horizontal plane (between covers). For the sampling registration and collection in medium and high canopy strata, a plantcutter was used, which helped reach higher strata, collecting vascular epiphyte individuals, and cutting small branch fragments; after they reached the ground, the bark fragments were collected for the determination of non-vascular epiphytes.

**Figure 2.6 Phorophyte Stratification for the Sampling of Vascular and Non-vascular Epiphytes.**




Source: Adapted, taken from Johansson (1974); Gradstein et. al, (1996) and Gradstein et. al, (2003).

- **Non-vascular epiphyte sampling**

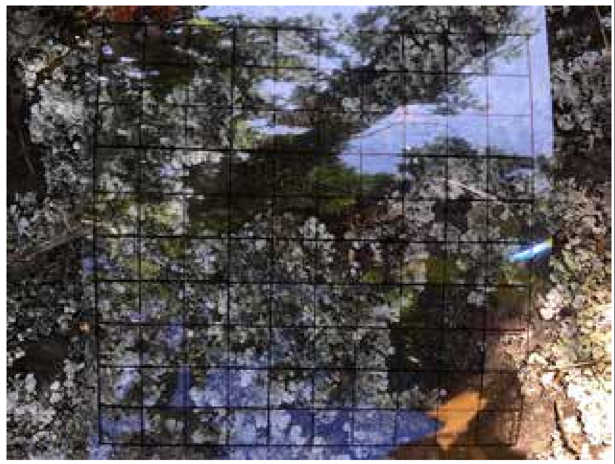
o **Bark bryophytes and lichens.**

Most bryophytes in tropical areas are bark epiphytes, who live in tree barks, lianas, shrubs, small trees, among others. In turn, most bark lichens in Tropical Forests are crustose lichens, which form a thin layer over the bark or even within cells of the peripheral bark. These were collected taking a piece of bark with a sharp object. The collection method used for more conspicuous and better known lichens – which are dense foliage and filamentous– was the manual method, because they were slightly stuck to the substratum. Given the morphophysiological characteristics of non-vascular plants and being them considered as clonal colonies, authors such as Gradstein *et. al*, (1996) and Gradstein *et. al,* (2003) address the representativity of these organisms according to the presence-absence parameters, and state that it is an efficient and robust way to conduct a diversity analysis.

Because of the need to quantify the cover percentage ($cm^2$) of non-vascular epiphytes over phorophytes, because of the epiphyte species density over bryophytes is high, and because plants are small, parcels for such sampling may be small (Gradstein *et. al*, 1996), which is why the clear acetate sheet method was implemented with a 400 $cm^2$ (20 x 20 cm) grid (modified, taken from Iwatsuki, 1960), where each square (4 $cm^2$) represented 1% (**Figure 2.7**). It was directly located over the phorophyte to sample in the "Trunk" stratum, accounting for the number of squares occupied by each non-vascular epiphyte species (Gradstein *et. al*, 2003). Four (4) of these trunk sheets were placed over each phorophyte, at each cardinal direction (North, South, East and West). Using data obtained therefrom, the cover of non-vascular epiphyte species was estimated in square centimeters ($cm^2$) for each vegetation ecosystem within the characterized project area.

**Figure 2.7 Methodology to Estimate the Vegetation Cover of Non-vascular Epiphytes with a clear Acetate sheet (400cm² grid).**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| | | | **Species 1** | | 14% = 56 cm² | | | **Rare** | |
| | | | **Species 2** | | 17% = 68 cm² | | | **Scarce** | |
| | | | **Species 3** | | 69% =275 cm² | | | **Abundant** | |



**400 cm² ACETATE SHEET**

Source: Adapted, taken from Gradstein et. al, (2003).

- **Characterization of rupicolous vascular and non-vascular flora**

In the 606 100 x 10 m parcels, one (1) to three (3) 5 x 5 m sub-parcels were included, according to presence and extension of rupicolous substratum in the parcel, and over the rupicolous substratum registered for these sub-parcels, with areas equal to or larger than 500 cm², minimum one (1) and maximum four (4) 20 x 20 cm sheets (modified, taken from Iwatsuki, 1960) were placed for the calculation of the cover in the case of rupicolous bryophytes and lichens. In turn, for rupicolous vascular species found in such 5 x 5 m sub-parcels, direct collections and counts were taken and conducted for the registration of abundance over these rupicolous substrata (Cetzal-Ix et. al, 2013).

- **Characterization of optional-terrestrial rupicolous vascular and non-vascular flora**

In the 606 parcels proposed in the Definition of sampling sites and selection of phorophytes, zig-zag walks were completed, and where terrestrial vascular species in closed seasons were found, its individuals were registered and counted, according to Cetzal-Ix et al. (2013). As for terrestrial non-vascular species in closed season, where found in the parcels, a 20 x 20 cm (modified, taken from Iwatsuki, 1960) clear acetate sheets were placed for the quantification of the cover in cm² of these terrestrial non-vascular species.

- **Collection and preservation**

For the collection and preservation of epiphyte, rupicolous, and optional terrestrial vascular, non-vascular floral samples, as well as phorophytes, basic sample collection methods were implemented (Herbarium UDBC, 2008), under Collection Permit provided by Resolution Nº 0343 of March 25, 2015, to SERVICIOS GEOLÓGICOS INTEGRADOS LTDA. - SGI, LTDA **(Annex 1. Statements_Collection Permits).**

For the collection and preservation of epiphyte, rupicolous, and terrestrial vascular species samples species, basic sample collection methods were implemented (Herbario UDBC, 2008), conducting the sample collection with a plantcutter, in the case of epiphyte species in the phorophyte stratum corresponding to the canopy, and for direct collection in rupicolous and land substrata, one or two samples of the registered species. Then, using newsprint to dampen the samples with alcohol, which were thus pressed and then packaged in closed bags in the shortest time possible to protect its quality, which is indispensable for subsequent determination at the Herbarium by experts in vascular taxonomy in closed season.

As regards epiphyte, rupicolous, and terrestrial non-vascular species, the sample collection was developed using a magnifying glass, which helped complete the segregation of morphospecies of the registered specimen, with a collection code based on morphospecies, thus avoiding repetitions in sample collection of the same species. To take species samples from the substrate (i.e. bark in the case of epiphyte non-vascular species; rocks for rupicolous species, and directly on the ground for terrestrial species). A sharp object was used to take cilia, in the case of lichens, and Liverwort and rhizoid, in the case of bryophytes, which are very important for subsequent determination at the Herbarium by experts in non-vascular taxonomy in closed season

The preservation of epiphyte, rupicolous, and terrestrial non-vascular species consisted in putting samples in kraft paper bags. The drying process was completed by exposure to air, so paper bags remained open as long as possible. Samples were collected in their fertile conditions; they were in a threatened category or were endemic, among other characteristics. Samples were deposited in herbaria of the Colombian Herbaria Association (ACH, acronym in Spanish), certified by the Alexander von Humboldt Institute, such as the FAUC herbarium of the University of Caldas, under number 28 of the National Single Register of Collections, where the Humboldt Institute includes all of the collections authorized in the country (See **Annex 10. Epiphytes_4. Herbarium Certificate**).

**PICTURE 2.13 Location of Sampling Points**

**Picture 2.14 Phorophyte Marking**

| PICTURE 2.15 IDENTIFICATION OF MORPHOSPECIES | PICTURE 2.16 REGISTRATION OF INFORMATION |
|---|---|
|  |  |

**Picture 2.17 GPS Marking.**

**Picture 2.18 Pressing of Botanic Material.**

Source: GEOCOL CONSULTORES S.A., 2017.

- **After fieldwork Phase**

  - **Taxonomic determinations of botanical samples**

All samples (morphospecies) were collected in the field for their subsequent determination at the herbarium. This activity was carried out by professional experts in determination of epiphyte, rupicolous, and terrestrial vascular and non-vascular species in closed season, so that specimens were determined at the taxonomic level for genus or species (considering the level of complexity in each group, and whether it is taxonomically clear). The drying of bromeliad and orchid botanical samples was developed at the Herbarium of the University of Nariño, and the deposit of samples in the CUVC Herbarium of the University of Valle, in the case of non-vascular species and phorophytes, their drying and determination were developed at the FAUC Herbarium of the University of Caldas, under number 28 of the National Single Register of Collections, where the Humboldt Institute includes all of the collections authorized in the country, where the specimens of the current study were delivered. These Herbaria are members of the Colombian Herbaria Association (ACH, acronym in Spanish), certified by the Alexander von Humboldt Institute, (See **Annex 10. Epiphytes_2. Herbarium Certificates**).

o **Epiphyte, rupicolous and terrestrial flora diversity analysis**

A database was created with data collected in the field and specimens determined at the taxonomic level for genus or species (when possible), which helped organize the various references, and interpret abundance values for vascular epiphytes, and frequency for non-vascular species both vertically, i.e. between the phorophyte strata, and horizontally, i.e. between covers. The floral composition, distribution, abundance and frequency of vascular and non-vascular epiphytes, respectively was determined based on this data, as well as the percentage estimates of covers for non-vascular species.

The composition of epiphyte, rupicolous, and terrestrial vascular and non-vascular species in closed season within the intervention area of the project was determined based on registrations completed in the field, according to taxonomic categories found in the different vegetation units (family, genus and species). Distribution was determined considering two criteria: presence of species in the different characterized covers (horizontal distribution), and presence of species in vertical strata in phorophytes (vertical distribution – base strata, lower canopy, medium canopy, and external canopy). Diversity estimates were calculated using statistical packages (PAST®, Biodiversity®, Estimates®, among others), used to calculate Simpson's dominance index and Shannon diversity index for Alpha (α) diversity. As regards beta (β) diversity, the Bray-Curtis index was used (**Table 2.28**).

**Table 2.28 Alpha and Beta Diversity Indexes used for the Characterization of Vascular and Non-vascular Epiphytes**

| DIVERSITY INDEX15 | | |
|---|---|---|
| Shannon Diversity Index (H´ - Alpha Diversity) | This is a diversity measure for species in a given population (Moreno, 2001). | $H' = -\sum ((Pi/n)Ln(Pi/n))$ Where:<br>Pi= proportional abundance of species i, which involves getting the number of individuals of species i divided by the total number of individuals in the sample. |
| Simpson's index (D – Alpha Diversity) | This index calculates the proportional abundance of species i, i.e. the number of individuals of species divided by the total number of individuals in the sample (Moreno, 2001). | $D = 1 - \sum (P_i)^2$<br>Range of interpretation:<br>0-0,5 very high diversity or very low dominance<br>>0,5-0,7 high diversity or low dominance<br>>0,7-0,8 Medium high diversity or dominance<br>>0,8-0,9 Low diversity – high dominance<br>>0,9-1 Very low diversity – very high dominance. |

15Estimates of alpha (α) diversity will be done using the PAST 4.0®, and the BioDiversity version 2® for beta (β) diversity. EstimateSWin 9.0® will be used for the species accumulation curve.

| DIVERSITY INDEX15 | | |
|---|---|---|
| Bray-Curtis Index (Beta Diversity) | This index compares and analyzes the different species found in sampling units from the different ecosystems for similarity (Mostacedo and Fredericksen, 2000; Villarreal et al., 2006). | $B = \frac{\sum_{i=1}^{S} \lvert X_{ij} - X_{ik} \rvert}{\sum_{i=1}^{S} [X_{ij} + X_{ik}]}$<br>B: Bray-Curtis metrics between samples j and k,)<br>Xij: number of individuals of species i in sample j.<br>Xik: number of individuals of species i in sample k.<br>S: number of species<br>1-B complement<br>Range of interpretation:<br>0-0,5: different<br>0,5-0,8: similar<br>0,8-1: equal |

Source: Moreno (2001); Villarreal et. al, (2006); Mostacedo and Fredericksen (2000).

- **Epiphyte floral sampling effort estimation**

o **Accumulation Curve**

The sampling representativity estimation was developed using EstimateS 9.0®, with a species accumulation curve for each of the 13 arboreal and/or shrub vegetation cover found in the intervention area of the road project, based on logarithmic ration between species registered for each cover vs the number of sampled phorophytes to reach that richness, using richness estimators based on abundance data on vascular epiphytes. Where the accumulation curve was asymptotic or tended towards this, it indicated that, even if the number of sampling units or counted individuals, i.e. increase in the effort, the number of species would not increase. This is why a representative sampling was obtained. Estimators based on abundance and presence-absence were used, seeking to have sampling with species accumulation exceeding 80% (Villarreal et. al, 2006).

Species accumulation curves based on the number of registered epiphyte species against the number of sampled trees, provide information on the minimum sample size (MSS) (Gradstein, 1992; Wolf, 1994; Hietz & Wolf, 1996; Shaw & Bergstrom, 1997; Annaselvam & Parthasarathy, 2001; Flores & García, 2001). Recent studies show that the MSS for vascular epiphytes is relatively small, around 80% of the total estimated number of vascular epiphyte species in one (1) hectare of Bolivian montane forests, were registered through an eight tree sample and the area of influence of its crown (Kromer, 2003).

Approximately half the vascular epiphyte species in a 4,000 km$^2$ region in Mexico was registered in 0.5 hectares of forest (Hietz & Hietz, 1995) a nearly 50% of species in the Sehuencas Valley, Bolivia, were collected in less than 0.1 hectares (Ibisch, 1996). Engwald (1999) inventoried nearly 50% of species within 0.1 hectare of montane forest in La Carbonera. The minimum sample size (TMM) of byrophytes is significantly smaller than that of vascular plants (Gradstein et. al, 1996). A sample of three (3) to five (5) trees contributed 75-80% of the total diversity of bryophytes of a forest mass tropical (Acebey et. al, 2003). The MSS of lichens, however, is larger than that of bryophytes (Sipman, 1996; Komposch & Hafellner, 2000) and may be similar to the MSS of vascular epiphytes.

Based on available data on species-are ratios, Gradstein et. al., (2003) a sample of five (5) to eight (8) trees is suggested for quick and representative sampling of vascular and non-vascular epiphytes within one (1) hectare of tropical forest (RRED analysis - rapid and representative sampling of vascular and non-vascular epiphyte diversity), which method was followed to study epiphyte flora of vegetation formation in the area of the requested survey in closed season.

#### 2.3.2.1.3 Fauna

- **Before fieldwork**

The characterization of wild fauna associated to ecosystems in the area of influence of the project was developed based on the guidelines provided for in the General Methodology for the Presentation of Environmental Surveys (MAVDT, 2010) and the Method Manual for the Development of Biodiversity Inventories (Villarreal et al., 2010), using a combination of direct and indirect registration techniques, as authorized by biological diversity science research permit No. 0343 issued on March 25, 2015 by the Authority for Environmental Licenses –ANLA.

Data was collected using the previously provided field forms, each of which containing relevant information to determination and ecological analysis. **Annex 11. Fauna_Forms Field** show the registration forms for each fauna group, according to the methodology implemented in the field phase, which were used to collect primary information during the field activities carried out between February 22 and March 16, 2017. These forms are as follows:

- FT 29 FAUNA SURVEY
- FT 138 FAUNA CAPTURE – BIRDS
- FT 153 HERPETOFAUNA CAPTURE
- FT 156 FLYING MAMMAL RECORD
- FT 157 FAUNA TRANSECTS
- FT 160 FAUNA SAMPLING SITES
- FT 161 MAMMAL RECORDS THROUGH CAMERA TRAPS
- FT 162 SHERMAN TRAP RECORDS

Before the field visit for the characterization of wild fauna in the area of influence of Rumichaca – Pasto Divided Highway Project, San Juan – Pedregal Segment, specialized literature and databases of science collections were also reviewed to compile information on species potentially present across the region. Reviewed databases were provided by the Institute of Natural Sciences of the National University of (ICN), Alexander Von Humboldt Institute, University of Nariño, and the Colombian Biodiversity Information System (SIB). The municipalities part of the area of influence of the project were included as the parameters of the search filter, as well as an altitudinal range 2800 -1700 MASL.

Finally, using Google Earth satellite images, certain preliminary points were located for the project's fauna sampling. These sites were selected based on habitat supply (arboreal or shrubby land covers) within the area of influence of the project.

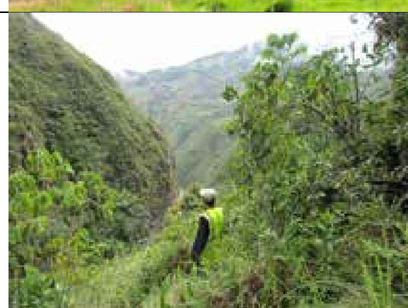
- **Sampling sites.**

The development of fauna samplings in the area of influence of the project covers 17 major sampling areas, in which specific sites were selected to install equipment and apply registration techniques to each assessed group. Due to the high degree of transformation in the area caused by anthropic intervention related to sociocultural and economic dynamics in the region, the definition of sampling sites was restricted, which were defined following criteria such as presence of water sources, natural vegetation patches, distance from towns, industrial zones and roads.

Also, the characterization of the various land covers part of the area of influence, and their distribution were taken into consideration in selecting the sampling areas (See Chapter 5. CHARACTERIZATION OF THE AREA OF INFLUENCE COMPONENT FLORA, TABLE 5.5), aiming to conduct a comprehensive assessment of the area to intervene and the potential impacts caused by the development of the different activities of the project. **Table 2.29** below shows the sampling sites and their coordinates.

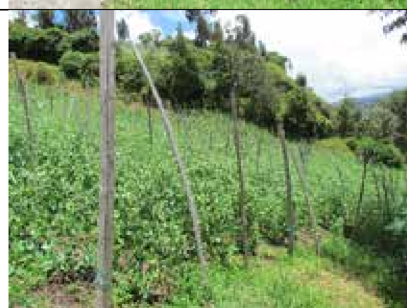
**Table 2.29 Location of Wild Fauna Sampling Sites within the area of Influence of the project.**

| SAMPLING SITES | DESCRIPTION | PICTURE | COORDINATES (MAGNA SIRGAS WEST ZONE) | |
|---|---|---|---|---|
| | | | EAST | NORTH |
| SITE | Municipality of Imues, rural district: Pilcuan, pasture cover and mosaic of pasture and crops. |  | 956546 | 604796 |
| SITE_2 | Municipality of Iles, rural district: El Porvenir, mosaic of crops and high secondary vegetation cover. |  | 953697 | 604824 |

| SAMPLING SITES | DESCRIPTION | PICTURE | COORDINATES (MAGNA SIRGAS WEST ZONE) | |
|---|---|---|---|---|
| | | | EAST | NORTH |
| SITE_3 | Municipality of Iles, rural district: Tablon Alto, gallery forest and riparian forest cover, mosaic of pasture and crops, open rocky grassland |  | 954492 | 602689 |
| SITE_4 | Municipality of Iles, rural district: Loma Alta, gallery forest and riparian forest, mosaic of pasture and crops, low secondary vegetation. |  | 953501 | 600747 |
| SITE_5 | Municipality of Iles, rural district: Urbano, high secondary vegetation cover. |  | 956845 | 598496 |
| SITE_6 | Municipality of Iles, rural district: Urbano, gallery and riparian forest cover. |  | 955232 | 598222 |

| SAMPLING SITES | DESCRIPTION | PICTURE | COORDINATES (MAGNA SIRGAS WEST ZONE) | |
|---|---|---|---|---|
| | | | EAST | NORTH |
| SITE_7 | Municipality of Contadero, rural district: San José de mosaic of grass and crop cover. |  | 954154 | 596913 |
| SITE_8 | Municipality of Contadero, rural district: Las Cuevas, low secondary vegetation, Dense high Andean forest, mosaic of grass and crop covers. |  | 951170 | 594495 |
| SITE_9 | Municipality of Contadero, rural district: Las Delicias, mosaic of grass and crop, forest plantation, low secondary vegetation covers. |  | 950290 | 593079 |
| SITE_10 | Municipality of Contadero, rural district: El Rosal de San Francisco, forest plantation covers. |  | 948951 | 592762 |

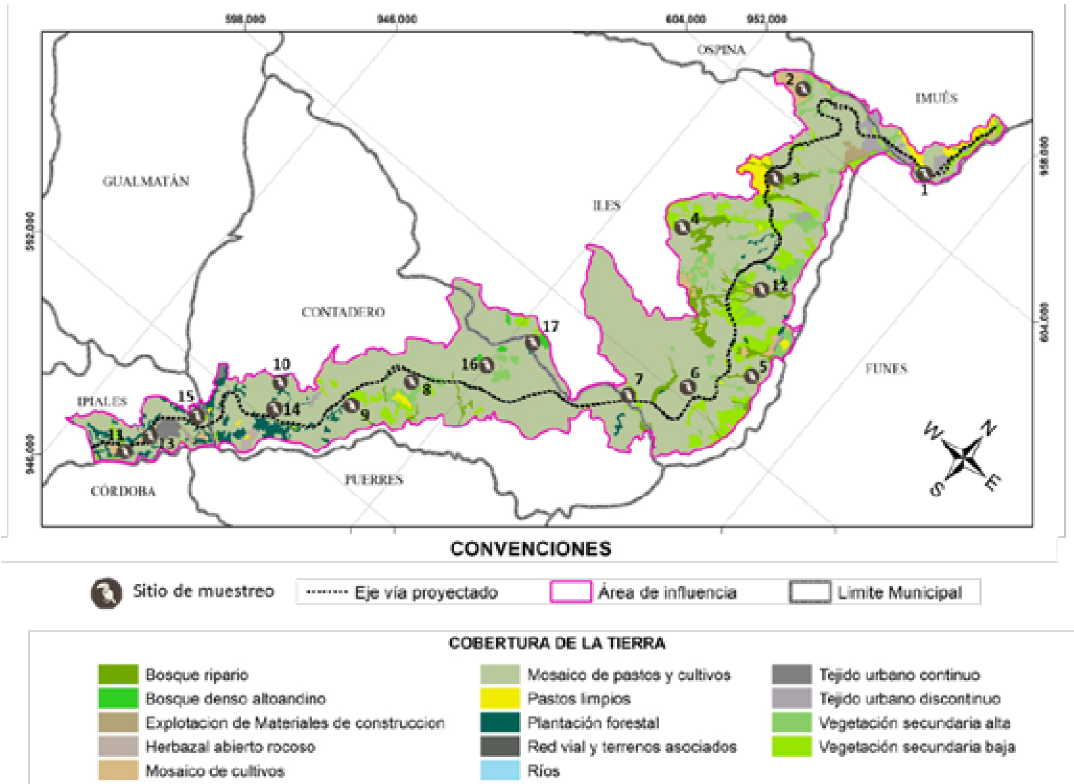
| SAMPLING SITES | DESCRIPTION | PICTURE | COORDINATES (MAGNA SIRGAS WEST ZONE) | |
|---|---|---|---|---|
| | | | EAST | NORTH |
| SITE_11 | Municipality of Ipiales, rural district: El Rosal, mosaic of grass and crop, forest plantation, pasture covers. |  | 947007 | 589125 |
| SITE_12 | Municipality of Iles, rural district: Tablon Low, mosaic of grass and crop, gallery riparian forest, high secondary vegetation covers. |  | 955592 | 600780 |
| SITE_13 | Municipality of Ipiales, rural district: San Juan, low secondary vegetation, forest plantation covers. |  | 947450 | 590091 |
| SITE_14 | Municipality of Contadero, rural district: San Francisco, mosaic of grass and crop cover. |  | 949096 | 592295 |

| SAMPLING SITES | DESCRIPTION | PICTURE | COORDINATES (MAGNA SIRGAS WEST ZONE) | |
|---|---|---|---|---|
| | | | EAST | NORTH |
| SITE_15 | Municipality of Ipiales, rural district: Boqueron, low secondary vegetation, forest plantation cover. |  | 947983 | 591191 |
| SITE_16 | Municipality of Contadero, rural district: San Andres, mosaic of grass and crop, Dense high Andean forest covers |  | 951922 | 595994 |
| SITE_17 | Municipality of Iles, rural district: Yarqui, Dense high Andean forest cover. |  | 952553 | 596912 |

Source: GEOCOL CONSULTORES S.A, 2017.

Figure 2.8 shows the location of these 17 sampling sites for the characterization of wild fauna within the area of influence of the project, distinguished according to the registration techniques and vegetation covers or habitats assessed in each case.

**Figure 2.8 Location of Wild Fauna Sampling Sites within the area of Influence of the project.**




Source: GEOCOL CONSULTORES S.A, 2017.

- **Secondary data**

A comprehensive literature review relating to species potentially present in the zone was completed, including books, science articles and databases. For each fauna group (amphibians, reptiles, birds and mammals), data on reported species for the survey area was gathered, particularly those present in the Department of Nariño and the municipalities of Contadero, Iles, Imues and Ipiales. For this purpose, records covering the altitudinal range of the survey area were taken into consideration. The consulted sources of information include the collections of the Institute of Natural Science of the National University of Colombia (ICN), University of Nariño, Alexander von Humboldt Institute and the Colombian Biodiversity Information System (SIB). Also, previously conducted surveys in the area were reviewed, such as the EIA for the Rumichaca – Pasto Divided Highway Project (Géminis Consultores, unpublished).

Information on the categories for the various faun groups in connection with illegal trade was obtained from the appendixes of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), in force from January 2, 2017. As for threatened species in the national territory, lists published by the Ministry of Environment, Housing and Territorial Development (MAVDT) through Resolution 0192 of February 10, 2014, were also reviewed. Also, species and categories included in the red books of Colombia, published by the Alexander von Humboldt Institute on mammals (Rodríguez – Mahecha et al., 2006), reptiles (Castaño – Mora, 2002 and Morales – Betancourt et al., 2015), amphibians (Castaño – Mora, 2006) and birds (Rengifo et al., 2002 and Rengifo et al., 2014). Likewise, the global classification according to the International Union for Conservation of Nature and Natural Resources (IUCN), version 2016-3, was reviewed.

- **Field**

For the field phase, first, the provisions of the Terms of Reference for the preparation of the Environmental Impact Assessment – EIA for road and/or tunnel building projects issued in 2015 by the Ministry of the Environment and Sustainable Development (MADS) and the National Authority for Environmental Licenses (ANLA) as well as the research permit granted by Resolution 0343 of March 25, 2015, were considered.

o **Record methods.**

Once identified and selected the sampling sites, the different methodologies were applied at each site in different hours during the day according to the assessed fauna group. Another wild fauna detection mechanism was defined by completing semi-structured surveys to inhabitants of the areas in order to learn about the presence of the different species, migration routes, shelter, among others. Identification of species by inhabitants was carried out with illustrated guides. In the case of certain hepertofauna and mammalian species, the survey was conducted during daytime; while for other species (amphibians and bats) it was conducted during nighttime.

§ **Herpetofauna (Amphibians Reptiles).**

Data on composition, richness and relative abundance of amphibians and reptiles in various types of habitats, represented by the vegetation cover units described in the floral characterization were considered for this study. The transect technique for visual encounter surveys with variable length and no determined time was implemented (Crump and Scott, 1994), so as to cover a representative area according to the type of surveyed habitat which, in this case, corresponds to transects of about 800-2,500 m long, day and night, using 1 man-hour as the sampling time unit.

- **Casual sampling (Crump and Scott, 1994).**

Transects for Visual Encounter Surveys (VES) are a very effective standard method for the inventory and monitoring of amphibians in an area to get the largest number of species within the shortest period of time by expert sample collectors, and compile a list of species (composition of the species of a group), and estimate the richness and relative abundance of species (**Picture 2.19**).

This method consists in walking randomly (sampling through visual encounter surveys) by a stream, around a swamp, or following a portion of a forest, observing and carefully looking for any amphibians or reptiles that may be found outside the water, along the banks, up to 20 meters from each margin of streams, and 2.0 high. Only sampling with transacts were used in this study, with diurnal and nocturnal walks between 8:00 and 12:00 hours for diurnal species, and between 18:00 and 22: hours for nocturnal species at different sites, actively looking for individuals everywhere possible: vegetation, fallen leaves, under trunks and stones.

In some cases, individuals which noise were heard were recorded and subsequently reviewed and compared to the databases of Amphibian Web Ecuador (http://zoologia.puce.edu.ec/Vertebrados/Anfibios/AnfibiosEcuador/Default.aspx); the call database of Amphibian Web (http://www.amphibiaweb.org); and the Fonozoo database available online at (http://www.fonozoo.com). The sampling effort for the transect technique took 186 man-hours. **Table 2.30** below show the coordinates for transects conducted during the field phase.

**Picture 2.19 Sampling Method by Casual Encounter to Characterize Herpetofauna.**

Search for amphibians and reptiles over vegetation during nighttime. Municipality of Iles, rural district: Loma Alta. Coordinates (Magna Sirgas West Zone) (E953501 N600747).

Search for amphibians and reptiles in daytime in mosaic of grass and crop cover. Municipality of Ipiales, rural district: San Juan. Coordinates (Magna Sirgas West Zone) (E947152 N589741).

Source: GEOCOL CONSULTORES S.A, 2017.

**Table 2.30 Location Coordinates of the Transects for Observing and Capturing Herpetofauna (Amphibians and Reptiles).**

| SAMPLING SITE | | COORDINATES (MAGNA SIRGAS WEST ZONE) | | | |
|---|---|---|---|---|---|
| | | START | | END | |
| SAMPLING_ ID | ASSESSED VEGETATION COVER OR HABITAT | EAST | NORTH | EAST | NORTH |
| TRHER_1 | Pasture | 956546 | 604796 | 956391 | 604705 |
| TRHER_2 | Mosaic of grass and crop, gallery and riparian forests | 953729 | 604822 | 953679 | 605071 |
| TRHER_3 | Pasture, gallery and riparian forests | 953697 | 604824 | 953583 | 604667 |
| TRHER_4 | Mosaic of pasture and crops, Pasture | 953729 | 604822 | 953736 | 604491 |
| TRHER_5 | Pasture | 953646 | 604809 | 953538 | 604697 |
| TRHER_6 | Open rocky grassland | 954492 | 602689 | 954302 | 602323 |
| TRHER_7 | Open rocky grassland, Low secondary vegetation | 954507 | 602729 | 954248 | 602477 |
| TRHER_8 | Grass with weeds, gallery and riparian forests | 953507 | 600682 | 954002 | 601551 |
| TRHER_9 | Grass with weeds, Pasture | 953501 | 600747 | 953637 | 601134 |
| TRHER_10 | Low secondary vegetation, Mosaic of pasture and crops | 955075 | 597206 | 954749 | 597050 |
| TRHER_11 | Mosaic of pasture and crops | 954154 | 596913 | 954440 | 597041 |
| TRHER_12 | Mosaic of pasture and crops, Low secondary vegetation | 950614 | 594566 | 951181 | 594575 |
| TRHER_13 | Low secondary vegetation, Mosaic of pasture and crops | 951170 | 594495 | 950857 | 594450 |
| TRHER_14 | Road system, railroad, and related lands, Pasture | 950940 | 593349 | 950629 | 593292 |

| SAMPLING SITE | | COORDINATES (MAGNA SIRGAS WEST ZONE) | | | |
|---|---|---|---|---|---|
| | | START | | END | |
| SAMPLING_ ID | ASSESSED VEGETATION COVER OR HABITAT | EAST | NORTH | EAST | NORTH |
| TRHER_15 | Mosaic of pasture and crops | 949813 | 593225 | 950290 | 593079 |
| TRHER_16 | Mosaic of pasture and crops, Road system, railroad, and related lands | 947114 | 589622 | 947299 | 589684 |
| TRHER_17 | Mosaic of pasture and crops | 946901 | 589447 | 947007 | 589125 |
| TRHER_18 | Open rocky grassland, Low secondary vegetation | 954511 | 602664 | 954320 | 602424 |
| TRHER_19 | Low secondary vegetation | 954371 | 602553 | 954338 | 602402 |
| TRHER_20 | Open rocky grassland, Low secondary vegetation | 954377 | 602677 | 954264 | 602377 |
| TRHER_21 | Low secondary vegetation | 954512 | 602623 | 954887 | 602911 |
| TRHER_22 | Low secondary vegetation, Open rocky grassland | 954524 | 602629 | 954710 | 602762 |
| TRHER_23 | Mosaic of pasture and crops, Pasture | 953715 | 604825 | 953726 | 604816 |
| TRHER_24 | High secondary vegetation | 956845 | 598496 | 956861 | 598502 |
| TRHER_25 | Mosaic of pasture and crops | 955372 | 598283 | 954925 | 598635 |
| TRHER_26 | Gallery and riparian forests | 955208 | 598241 | 955223 | 598238 |
| TRHER_27 | Gallery and riparian forests, Mosaic of pasture and crops | 955232 | 598222 | 955334 | 598325 |
| TRHER_28 | Forest plantation | 948951 | 592762 | 948943 | 592761 |
| TRHER_29 | Mosaic of pasture and crops | 949936 | 593916 | 950140 | 594145 |
| TRHER_30 | Mosaic of pasture and crops | 950925 | 594459 | 950853 | 594445 |
| TRHER_31 | Low secondary vegetation, Mosaic of pasture and crops | 947125 | 589618 | 947104 | 589605 |

Source: GEOCOL CONSULTORES S.A, 2017.

- **Specimen capture and identification.**

Capture of individuals was carried out manually (**Picture 2.20**) for amphibians and saurian. As for snakes, snake tongs and hooks were implemented, capturing all observed specimens within 2 m height. Each captured specimen was kept in plastic and fabric bags for subsequent measuring, description, and photographic evidence, providing the following information: date and time of capture, height the specimen was found at (vertical position vs ground), substrata it was found on (leaves L, fallen leaves FL, rocks RC, trunk, TR, branch B, moss M).

Collections were conducted because data on species in this zone of the country is deficient. Specimen collections followed the protocols provided in the research permit as follows: amphibians were put to sleep by administering human anesthetic such as benzocaine, lidocaine or xylocaine (oral); then they were placed in wet chambers containing liquid preservatives; and finally put in a vessel containing ethyl alcohol 70 percent to prevent deterioration. As for reptiles, they were put to sleep administering Nembutal 10 percent in the heart, and then formol 10 percent in the body to prevent decomposition; and then finally put in wet chamber for final set.

Individuals were not collected; they were identified and after completion of the relevant morphometric measurements and photographic evidence, they were released in the same place they were found.

**Picture 2.20 Capture and Identification of Specimens to Characterize Herpetofauna.**

Sound detection of amphibians in reproduction phase. Municipality of Iles, rural district: Tablon Alto. Coordinates (Magna Sirgas West Zone) (E954262 N602351).

Registration of the major morphological features of each individual. Municipality of Iles, rural district: Urbano. Coordinates (Magna Sirgas West Zone) (E955232 N598222).

Source: GEOCOL CONSULTORES S.A, 2017.

§ **Birds.**

For the characterization of avifauna in the area of influence of the project, capture with mist nets and visual and sound detection techniques were implemented, according to procedures stated in the Method Manual for the Development of Biodiversity Inventories (Villarreal et al., 2006). Captures with mist nets help find small birds that are very hard to observe or distinguished; observation transects help inventory most of medium-size and large birds, as well as those found in higher vegetation strata (Stiles y Rosselli, 1998).

- **Observation method.**

Seven transects and four visual and sound detections points were used, covering the vegetation cover units found the various sectors of the area of influence of the project and the road rout. During these transects – 0.733 to 2.1 km long– walks at a constant speed (about 1 km/h) were taken to register observed or heard individuals at a maximum distance of 25 m through the transect (

**Picture** 2.21). In turn, for the detection of silent or hard-to-observe species, the intensive search technique was implemented. Information on activity, related cover, forage strata, consumed food, sex (where possible), and community organization.

**Picture 2.21 Method for Visual and Sound Detection to Register Birds.**

Photographic evidence of birds. Municipality of Iles, rural district: Loma Alta, Coordinates (Magna Sirgas West Zone) (E953639 N600987).

Observation of birds. Municipality of Iles, rural district: Urbano. Coordinates (Magna Sirgas West Zone (E955831 N596641).

Source: GEOCOL CONSULTORES S.A, 2017.

Transects were developed in hours during which birds are active the most: during the morning, between 6:00 and 11:00 hours, and during the afternoon between 16:00 and 18:00 hours. A total of 14 transects were completed, with a sampling effort for this technique of 33.34 km*hour, and three observation points were also implemented (**Table 2.31**).

Sometimes recordings were made of heard individuals, and comments, which were subsequently reviewed and compared to existing sound guides, such as the "Sound guide of birds in the Colombian Andes" (Álvarez et al., 2000), and the Xeno-canto database, available online (www.xeno-canto.org).

**Table 2.31 Location Coordinates of the Transects for the Visual and Sound Detection of Birds within the Area of influence of the project.**

| SAMPLING SITE | | COORDINATES (MAGNA SIRGAS WEST ZONE) | | | |
|---|---|---|---|---|---|
| | | START | | END | |
| SAMPLE_ID | ASSESSED VEGETATION COVER OR HABITAT | EAST | NORTH | EAST | NORTH |
| TRAAV_1 | Gallery forest, mosaic of pasture and crops, low secondary vegetation | 953404 | 600478 | 954018 | 601389 |
| TRAAV_2 | Gallery forest, mosaic of pasture and crops | 954646 | 603406 | 954370 | 603077 |
| TRAAV_3 | Mosaic of pasture and crops, high secondary vegetation | 953534 | 604849 | 953602 | 604701 |
| TRAAV_4 | Mosaic of pasture and crops, low secondary vegetation | 955090 | 597199 | 955166 | 597405 |
| TRAAV_5 | Gallery forest, mosaic of pasture and crops | 955032 | 598642 | 954948 | 599413 |
| TRAAV_6 | Gallery forest, mosaic of pasture and crops | 951936 | 595062 | 951580 | 594706 |

| SAMPLING SITE | | COORDINATES (MAGNA SIRGAS WEST ZONE) | | | |
|---|---|---|---|---|---|
| | | START | | END | |
| SAMPLE_ID | ASSESSED VEGETATION COVER OR HABITAT | EAST | NORTH | EAST | NORTH |
| TRAAV_7 | Gallery forest, mosaic of pasture and crops | 950941 | 593358 | 950628 | 593279 |
| TRAAV_8 | Mosaic of pasture and crops, high secondary vegetation | 956098 | 605003 | 956553 | 604821 |
| TRAAV_9 | Gallery forest, Mosaic of pasture and crops | 951770 | 595967 | 951959 | 595659 |
| TRAAV_10 | Gallery forest, Mosaic of pasture and crops | 954318 | 602407 | 954365 | 602628 |
| TRAAV_11 | Mosaic of pasture and crops, low secondary vegetation, Gallery forest. | 954553 | 602624 | 954416 | 602862 |
| TRAAV_12 | Low secondary vegetation | 956861 | 598504 | 956838 | 598440 |
| TRAAV_13 | Gallery forest | 955196 | 598279 | 954924 | 598448 |
| TRAAV_14 | Mosaic of pasture and crops, forest plantation | 948944 | 592785 | 948945 | 592753 |
| TRAAV_15 | Mosaic of pasture and crops | 949940 | 593920 | 950113 | 594230 |
| TRAAV_16 | Mosaic of pasture and crops cover, low secondary vegetation, forest plantation | 947120 | 589626 | 947296 | 589682 |
| POBAV_1 | Mosaic of pasture and crops | 951922 | 595994 | | |
| POBAV_2 | Dense low forest | 952551 | 596876 | | |
| POBAV_3 | Mosaic of pasture and crops, forest plantation | 947983 | 591191 | | |

Source: GEOCOL CONSULTORES S.A, 2017.

- **Technique of capture.**

8 to 12 12x2.5 m mist nets were run, and a 32 mm mesh eye net was run in certain vegetation covers in the survey area (**Picture 2.22**). The net period was between 6:00 hours and 18:00 hours. This sampling effort made with this technique tool 572 hours – net. **Table 2.32** below show the coordinates of places where these nets were used.

**Picture 2.22 Method for Capture in Mist Nets for Registering Birds.**

Mist net activity. Municipality of Iles, rural district: Loma Alta- Coordinates (Magna Sirgas West Zone) (E953567 N600816).

Running of mist nets. Municipality of Contadero, rural district: Las Cuevas. Coordinates (Magna Sirgas West Zone) (E951170 N594495).

Capture for morphometric data records. Municipality of Contadero, rural district: Las Cuevas. Coordinates (Magna Sirgas West Zone) (E951170 N594495).
Source: GEOCOL CONSULTORES S.A, 2017.

Captured individuals were taken out the nets and put in fabric bags to be taken to the data site, where tarsus, wing, tail, corners, exposed and total culmen were measured; age, sex, reproduction phase, fat and deterioration of plumage were determined. All captured individuals were released to their natural habitat, without putting any of them to sleep or collecting specimens. For the taxonomic determination of captured birds, the "Colombian Bird Guide" (Hilty y Brown, 2001), "Birds of Northern South America" (Restall et al., 2009) and "The Field Guide to the Birds of Colombia" (McMullan et al., 2010) were followed.

**Table 2.32 Location Coordinates of the Mist Nets for Capturing Birds.**

| SAMPLING SITE | | COORDINATES (MAGNA SIRGAS WEST ZONE) | | | |
|---|---|---|---|---|---|
| | | START | | END | |
| ASSESSED VEGETATION COVER OR HABITAT | SAMPLE_ID | EAST | NORTH | EAST | NORTH |
| Gallery forest and mosaic of pasture and crops | REDAV_1A | 953620 | 600846 | 953585 | 600765 |
| Gallery forest | REDAV_1B | 953565 | 600811 | 953592 | 600927 |
| High secondary vegetation | REDAV_2 | 953601 | 604656 | 953545 | 604692 |
| High secondary vegetation | REDAV_3 | 951161 | 594488 | 951194 | 594556 |
| Gallery forest | REDAV_4A | 954333 | 602465 | 954376 | 602548 |
| Low secondary vegetation, mosaic of pasture and crops | REDAV_4B | 954602 | 602584 | 954545 | 602622 |
| Gallery forest and mosaic of pasture and crops | REDAV_5 | 955194 | 598277 | 955164 | 598237 |
| Secondary vegetation and forest plantation | REDAV_6 | 947125 | 589670 | 947064 | 589736 |

Source: GEOCOL CONSULTORES S.A, 2017.

§ **Mammals.**

Direct and indirect registration techniques were implemented, including observation walks and use of camera traps for medium-large mammals, using Sherman and Tomahawk traps for small non-flying mammals such as marsupials and rodents. Mist nets were also run for (bats).

§ **Non-flying mammals**

- **Trapping.**

ü **Sherman and Tomahawk traps**

To capture small and medium non-flying mammals, a total of 157 8x9x23 cm Sherman traps were set at the selected sampling sites. These traps were distributed by stations in the different covers. Traps were set on the ground (**Picture 2.23**), in about 15 stations, four traps each, with oatmeal, peanuts, and vanilla essence or banana as bait. Traps were active during the night and the following days after their installation, and were checked the following morning and recharged where required. This sampling effort, using this technique, took 12264 hours-trap.

**Picture 2.23 Method for Capture Using Sherman Traps.**

Location of Sherman traps. Municipality of Contadero, rural district: Aldea de Maria vegetacion Mosaic of pasture and crops. Coordinates (Magna Sirgas West Zone) (E950057 N593056).

Location of Sherman traps. Municipality of Contadero, rural district: San Jose de Quisnamuez. Gallery and riparian forest. Coordinates (Magna Sirgas West Zone) (E955018 N597167).

Source: GEOCOL CONSULTORES S.A, 2017.

**Table** 2.33 below shows the Location Coordinates of Sherman and Tomahawk traps at the sampling sites.

**Table 2.33 Location Coordinates of the Sherman Traps to capture Small, Non-flying Mammals.**

| SAMPLING SITE | | COORDINATES (MAGNA SIRGAS WEST ZONE) | |
|---|---|---|---|
| ASSESSED VEGETATION COVER OR HABITAT | SAMPLE_ID | EAST | NORTH |
| Gallery and riparian forests, Mosaic of pasture and crops | TShE_1-4 | 954376 | 602497 |
| | TShE_1-4 | 954378 | 602499 |
| | TShE_1-4 | 954372 | 602496 |
| | TShE_1-4 | 954386 | 602498 |
| | TShE_1-4 | 954382 | 602497 |
| | TShE_1-3 | 954373 | 602567 |
| | TShE_1-3 | 954375 | 602555 |
| | TShE_1-3 | 954369 | 602561 |
| | TShE_1-3 | 954379 | 602563 |
| | TShE_1-2 | 954443 | 602579 |
| | TShE_1-2 | 954456 | 602580 |
| | TShE_1-2 | 954450 | 602582 |
| | TShE_1-2 | 954448 | 602578 |
| | TShE_1-1 | 954503 | 602604 |
| | TShE_1-1 | 954506 | 602600 |
| | TShE_1-1 | 954506 | 602606 |
| | TShE_1-1 | 954512 | 602602 |
| | TShE_1-5 | 954447 | 602756 |
| | TShE_1-5 | 954455 | 602722 |
| | TShE_1-5 | 954486 | 602705 |
| | TShE_1-5 | 954500 | 602675 |
| | TShE_1-6 | 954622 | 602722 |
| | TShE_1-6 | 954643 | 602721 |
| | TShE_1-6 | 954623 | 602775 |
| | TShE_1-6 | 954625 | 602798 |
| | TShE_1-6 | 954616 | 602781 |
| Gallery and riparian forests, Mosaic of pasture and crops | TShE_2-1 | 953700 | 600949 |
| | TShE_2-1 | 953725 | 600974 |
| | TShE_2-1 | 953698 | 600995 |
| | TShE_2-1 | 953621 | 600958 |
| | TShE_2-1 | 953661 | 600954 |
| | TShE_2-2 | 953539 | 600878 |
| | TShE_2-2 | 953535 | 600852 |
| | TShE_2-2 | 953504 | 600835 |
| | TShE_2-2 | 953533 | 600867 |
| | TShE_2-2 | 953554 | 600889 |
| | TShE_2-2 | 953522 | 600860 |
| | TShE_2-3 | 953649 | 600986 |
| | TShE_2-3 | 953654 | 600993 |
| | TShE_2-3 | 953660 | 601001 |
| | TShE_2-3 | 953657 | 601015 |
| | TShE_2-4 | 953615 | 601035 |
| | TShE_2-4 | 953604 | 601027 |
| | TShE_2-4 | 953604 | 601012 |

| SAMPLING SITE | | COORDINATES (MAGNA SIRGAS WEST ZONE) | |
|---|---|---|---|
| ASSESSED VEGETATION COVER OR HABITAT | SAMPLE_ID | EAST | NORTH |
| | TShE_2-4 | 953600 | 600992 |
| | TShE_2-4 | 953588 | 600988 |
| | TShE_2-5 | 953450 | 601016 |
| | TShE_2-5 | 953442 | 601023 |
| | TShE_2-5 | 953460 | 600985 |
| | TShE_2-5 | 953447 | 601005 |
| | TShE_2-5 | 953449 | 600993 |
| Gallery and riparian forests, Mosaic of pasture and crops | TShE_3-1 | 955242 | 598112 |
| | TShE_3-1 | 955245 | 598121 |
| | TShE_3-1 | 955221 | 598116 |
| | TShE_3-1 | 955224 | 598096 |
| | TShE_3-1 | 955234 | 598104 |
| | TShE_3-2 | 955186 | 598050 |
| | TShE_3-2 | 955206 | 598048 |
| | TShE_3-2 | 955174 | 598061 |
| | TShE_3-2 | 955170 | 598039 |
| | TShE_3-3 | 955235 | 598012 |
| | TShE_3-3 | 955242 | 598015 |
| | TShE_3-3 | 955247 | 598019 |
| | TShE_3-3 | 955253 | 598027 |
| | TShE_3-4 | 955169 | 597997 |
| | TShE_3-4 | 955181 | 597996 |
| | TShE_3-4 | 955159 | 598004 |
| | TShE_3-4 | 955178 | 598006 |
| | TShE_3-5 | 955152 | 598297 |
| | TShE_3-5 | 955159 | 598304 |
| | TShE_3-5 | 955162 | 598307 |
| | TShE_3-5 | 955169 | 598312 |
| | TShE_3-5 | 955167 | 598296 |
| | TShE_3-6 | 955114 | 598308 |
| | TShE_3-6 | 955104 | 598316 |
| | TShE_3-6 | 955109 | 598322 |
| | TShE_3-6 | 955117 | 598328 |
| Gallery and riparian forests, low secondary vegetation | TShE_4-1 | 955011 | 597189 |
| | TShE_4-1 | 955006 | 597191 |
| | TShE_4-1 | 955011 | 597194 |
| | TShE_4-1 | 955016 | 597191 |
| | TShE_4-1 | 955013 | 597185 |
| | TShE_4-2 | 955041 | 597162 |
| | TShE_4-2 | 955040 | 597164 |
| | TShE_4-2 | 955046 | 597162 |
| | TShE_4-2 | 955045 | 597166 |
| | TShE_4-2 | 955045 | 597159 |
| | TShE_4-2 | 955051 | 597159 |
| | TShE_4-3 | 955052 | 597217 |

| SAMPLING SITE | | COORDINATES (MAGNA SIRGAS WEST ZONE) | |
|---|---|---|---|
| ASSESSED VEGETATION COVER OR HABITAT | SAMPLE_ID | EAST | NORTH |
| | TShE_4-3 | 955056 | 597219 |
| | TShE_4-3 | 955055 | 597223 |
| | TShE_4-3 | 955058 | 597225 |
| | TShE_4-3 | 955049 | 597223 |
| | TShE_4-4 | 955019 | 597172 |
| | TShE_4-4 | 955021 | 597176 |
| | TShE_4-4 | 955025 | 597174 |
| | TShE_4-4 | 955026 | 597169 |
| | TShE_4-4 | 955032 | 597167 |
| | TShE_4-5 | 955028 | 597248 |
| | TShE_4-5 | 955024 | 597252 |
| | TShE_4-5 | 955020 | 597258 |
| | TShE_4-5 | 955018 | 597261 |
| | TShE_4-5 | 955018 | 597253 |
| Mosaic of pasture and crops, forest plantation | TShE_5-1 | 950161 | 592966 |
| | TShE_5-1 | 950146 | 592953 |
| | TShE_5-1 | 950134 | 592946 |
| | TShE_5-1 | 950171 | 592963 |
| | TShE_5-1 | 950188 | 592954 |
| | TShE_5-2 | 950150 | 593019 |
| | TShE_5-2 | 950142 | 593028 |
| | TShE_5-2 | 950137 | 593017 |
| | TShE_5-2 | 950146 | 593056 |
| | TShE_5-2 | 950156 | 593056 |
| | TShE_5-3 | 950107 | 592964 |
| | TShE_5-3 | 950084 | 592975 |
| | TShE_5-3 | 950069 | 592997 |
| | TShE_5-3 | 950062 | 593009 |
| | TShE_5-3 | 950086 | 592957 |
| | TShE_5-4 | 950064 | 593042 |
| | TShE_5-4 | 950073 | 593029 |
| | TShE_5-4 | 950091 | 593039 |
| | TShE_5-4 | 950085 | 593015 |
| | TShE_5-4 | 950058 | 593054 |
| | TShE_5-5 | 950003 | 593109 |
| | TShE_5-5 | 950013 | 593097 |
| | TShE_5-5 | 950023 | 593086 |
| | TShE_5-5 | 950034 | 593081 |
| Mosaic of pasture and crops, forest plantation | TShE_6-1 | 946898 | 589401 |
| | TShE_6-1 | 946906 | 589405 |
| | TShE_6-1 | 946904 | 589409 |
| | TShE_6-1 | 946914 | 589401 |
| | TShE_6-2 | 946941 | 589389 |
| | TShE_6-2 | 946931 | 589395 |
| | TShE_6-2 | 946937 | 589401 |

| SAMPLING SITE | | COORDINATES (MAGNA SIRGAS WEST ZONE) | |
|---|---|---|---|
| ASSESSED VEGETATION COVER OR HABITAT | SAMPLE_ID | EAST | NORTH |
| | TShE_6-2 | 946933 | 589389 |
| | TShE_6-3 | 946960 | 589354 |
| | TShE_6-3 | 946967 | 589349 |
| | TShE_6-3 | 946975 | 589344 |
| | TShE_6-3 | 946978 | 589337 |
| | TShE_6-4 | 947027 | 589318 |
| | TShE_6-4 | 947018 | 589316 |
| | TShE_6-4 | 947035 | 589346 |
| | TShE_6-4 | 947039 | 589318 |
| | TShE_6-5 | 947040 | 589291 |
| | TShE_6-5 | 947048 | 589298 |
| | TShE_6-5 | 947066 | 589298 |
| | TShE_6-5 | 947065 | 589311 |
| | TShE_6-6 | 947051 | 589259 |
| | TShE_6-6 | 947058 | 589262 |
| | TShE_6-6 | 947061 | 589270 |
| | TShE_6-6 | 947065 | 589265 |
| | TShE_6-7 | 947048 | 589237 |
| | TShE_6-7 | 947040 | 589243 |
| | TShE_6-7 | 947040 | 589237 |
| | TShE_6-7 | 947035 | 589240 |
| | TShE_7-7 | 947006 | 589125 |
| | TShE_7-7 | 946998 | 589131 |
| | TShE_7-7 | 947002 | 589134 |
| | TShE_7-7 | 946997 | 589127 |

Source: GEOCOL CONSULTORES S.A, 2017.

For the sample collection, Tomahawk traps (30X20x50 cm) were used, which were placed in some Sherman trap stations for greater efficiency of traps, with canned sardines and oatmeal as bait. **Table 2.34** below shows the Location Coordinates of these devices. **Picture 2.24** below shows a specimen captured using this method.

**Table 2.34 Location of Tomahawk Traps**

| LOCATION | COVER | EAST | NORTH |
|---|---|---|---|
| Municipality of Iles, rural district: Tablon Alto | Gallery and riparian forests | 954453 | 602576 |
| Municipality of Iles, rural district: Tablon Alto | Gallery and riparian forests | 954378 | 602493 |
| Municipio Iles, rural district: Loma Alta | Gallery and riparian forests | 953550 | 600877 |
| Municipality of Iles, rural district: Urbano | Gallery and riparian forests | 955234 | 598115 |

Source: GEOCOL CONSULTORES S.A, 2017.

**Picture 2.24 Possum (Didelphis marsupialis) Specimen captured in a Tomahawk Trap.**

Iles, Tablon Alto, Gallery and riparian forests, Coordinates (Magna Sirgas West Zone) e 954453 N602576

Source: GEOCOL CONSULTORES S.A, 2017.

- **Camera traps**

10 camera traps –Bushnell (Trophycam), 8 megapixels– were set in the area of influence. These camera traps were placed at the base of trees in place where trails, tracks were left by mammals (

**Picture** 2.25). Sardines were used as bait to increase the number of resulting photographic evidence. Sardine cans were placed within reach of the cameras and then holes were made in cans for continuous smell coming from them. Traps operated throughout the period they remained at the sampling sites from their set, and visited every two days for more bait, if required. At the end of the sampling phase, cameras were removed and pictures were analyzed. The sampling effort with this technique took 3028 hours/camera.

**Picture 2.25 Method to Register Mammals using Camera Traps.**

Location of camera trap. Municipality of Iles Rural District Tablon Alto. Gallery and/or riparian forest cover. Coordinates (Magna Sirgas West Zone) (E953726 N600917)

Location of camera trap. Municipality of Ipiales, Village of San Juan. Forest Plantation cover. Coordinates (Magna Sirgas West Zone) (E 947449 N 590092)

Source: GEOCOL CONSULTORES S.A, 2017.

**Table 2.35** below shows the Location Coordinates for the 10 camera traps set in the area of influence of the project.

**Table 2.35 Location Coordinates of Camera Traps for Registering Non-flying Mammals.**

| SAMPLING SITE | | COORDINATES (MAGNA SIRGAS WEST ZONE) | |
|---|---|---|---|
| SAMPLE_ID | ASSESSED VEGETATION COVER OR HABITAT | EAST | NORTH |
| CT_1 | Gallery and riparian forests | 953404 | 601116 |
| CT_ 2 | Gallery and riparian forests | 953727 | 600919 |
| CT_ 3 | Gallery and riparian forests | 953835 | 600647 |
| CT_4 | Gallery and riparian forests | 955023 | 597200 |
| CT_5 | Low secondary vegetation | 955001 | 597244 |
| CT_6 | Forest plantation | 954870 | 596915 |
| CT_7 | Mosaic of pasture and crops | 954632 | 602786 |
| CT_8 | Forest plantation | 949096 | 592295 |
| CT_9 | Forest plantation | 947450 | 590091 |
| CT_10 | Forest plantation | 947317 | 589994 |

Source: GEOCOL CONSULTORES S.A, 2017.

- **Transect Observation.**

23 observation transects were completed –with a variable length of 2.0 to 4.0 km. Transect walks were taken at a constant speed (about 1 km/h) to register observed or heard individuals at a maximum distance of 25 m from each transect for detection of terrestrial and arboreal mammals. These walks were taken intending to find direct evidence of presence of mammals from understory to the canopy in the different vegetation covers found at the sampling site. Also, burrows, tracks, excrement, feeding areas, skulls and other traces that might help indirectly determine the presence of mammals in the zone. Where individuals were found, data on such species were collected, such as consumed food, behavior, and vegetation stratum where it was found. As for

tracks, morphometric measurements were taken, which helped determined their species. This sampling effort took 46 hours/man. The location of each transect is shown in **Table 2.36** below.

**Table 2.36 Location Coordinates of Transect Observation for Registering Mammals.**

| SAMPLE_ID | ASSESSED VEGETATION COVER OR HABITAT | START | | END | |
|---|---|---|---|---|---|
| | | East | North | East | North |
| Transect-1 | Low secondary vegetation | 956841 | 598492 | 956843 | 598441 |
| Transect-2 | Mosaic of pasture and crops | 953747 | 604827 | 953683 | 605068 |
| Transect-3 | Mosaic of pasture and crops | 954499 | 602678 | 954462 | 602767 |
| Transect-4 | Mosaic of pasture and crops | 953699 | 604829 | 953553 | 604861 |
| Transect-5 | Mosaic of pasture and crops | 953797 | 604769 | 953552 | 604892 |
| Transect-6 | Low secondary vegetation, Mosaic of pasture and crops | 956325 | 604912 | 956438 | 604724 |
| Transect-7 | Gallery and riparian forests, Mosaic of pasture and crops | 954683 | 602730 | 954530 | 602791 |
| Transect-8 | Gallery and riparian forests, Mosaic of pasture and crops, low secondary vegetation | 954336 | 602713 | 954543 | 602621 |
| Transect-9 | Gallery and riparian forests, Mosaic of pasture and crops | 953496 | 600850 | 953436 | 601145 |
| Transect-10 | Gallery and riparian forests | 953536 | 600758 | 953687 | 601074 |
| Transect-11 | Gallery and riparian forests, Mosaic of pasture and crops | 953725 | 601027 | 953939 | 600747 |
| Transect-12 | Mosaic of pasture and crops, forest plantation | 954997 | 596667 | 954804 | 596910 |
| Transect-13 | Mosaic of pasture and crops, low secondary vegetation | 953323 | 601116 | 953911 | 601664 |
| Transect-14 | Mosaic of grass and crop cover, high secondary vegetation | 953900 | 600495 | 953937 | 600564 |
| Transect-15 | Gallery and riparian forests, Mosaic of pasture and crops, mosaic of crops | 955592 | 600780 | 955256 | 600569 |
| Transect-16 | Gallery and riparian forests, Mosaic of pasture and crops | 955310 | 598316 | 955188 | 598161 |
| Transect-17 | Gallery and riparian forests, low secondary vegetation | 955076 | 597171 | 954954 | 597294 |
| Transect-18 | Gallery and riparian forests, Mosaic of pasture and crops | 950935 | 593355 | 950633 | 593294 |
| Transect-19 | Mosaic of pasture and crops, forest plantation | 949776 | 593114 | 950287 | 593091 |
| Transect-20 | Mosaic of pasture and crops, forest plantation | 949105 | 592243 | 948955 | 592410 |
| Transect-21 | Dense low forest, Mosaic of grass and crop cover | 952423 | 596536 | 952553 | 596912 |
| Transect-22 | Mosaic of pasture and crops, forest plantation | 947575 | 590059 | 947379 | 590173 |
| Transect-23 | Mosaic of pasture and crops, forest plantation | 948544 | 592049 | 948257 | 592198 |

Source: GEOCOL CONSULTORES S.A, 2017.

- **Search for trails**

During the walks, a search for trails left by mammals was conducted, such as tracks, vegetation alterations, excrement, burrows, nest, sleeping places, rooting places, or any other signs of their presence. This helps detect species that, due to their cryptic, nocturnal or twilight habits, are hard to observe directly and sometimes this is the only useful method to infer the presence of a mammal in a given area. Once found such trail, it was photographed (

**Picture** 2.26); it was identified using literature materials as support (Navarro and Muñoz, 2000; Emmons, 1999; Chame, 2002) as well as the experts' local knowledge.

**Picture 2.26 Tracing and Some Traces used for the Indirect Registration of Mammals.**

Armadillo burrow (*D. novemcinctus*). Municipality of Iles Rural District Tablon Alto finca la Ranchería, Gallery and/or riparian forest. Coordinates (Magna Sirgas West Zone) (E 953598 N 601004).

Fox tracks (*D. pernigra*). Municipality of Iles, rural district: el porvenir, mosaic of grass and crop cover. Coordinates (Magna Sirgas West Zone) (E 953751 N604830)

Source: GEOCOL CONSULTORES S.A, 2017.

§ **Flying mammals (bats)**

- **Captures with mist nets**

8-10 mist nets (2,5 x 12 m) were set to capture bats within 96 to 120 linear meters per sampling point (

**Picture** 2.27), which were placed in strategic places such as flat areas, mountain edges, native forests or close to crops. Nets were run at 17:30, when bats start their foraging activities, and were removed at 22:00. After running nets, checks were carried out every hour to take captured individuals out. Specimens were put in fabric bags and taken to the closest site for data processing, which included morphometric measurements, and age, sex and reproduction phase data, as well as the relevant photographic evidence (Picture 2.11). Keys given by Muñoz (2001) and Aguirre et al (2009) were followed in identifying specimens; these keys are based on external features, skull and body size, and mainly the forearm size. In addition, Emmons (1999), Voss and Emmons (2000), Dos Reis, (2007), and Solari (2013) were reviewed for further ecological and distribution information.

**Picture 2.27 Method to Capture and Register Bats using Mist Nets.**

Mist nets to capture bats. Municipality of iles. Rural district: el porvenir. High secondary vegetation. Coordinates (Magna Sirgas West Zone) (E 953578 N 604680).

Registration of morphological data for identification. Municipality of iles. Rural district: Tablon alto. Coordinates (Magna Sirgas West Zone) (E 954674 N 602737).

Source: GEOCOL CONSULTORES S.A, 2017.

For the capture of bats with mist nets, 7 sampling stations were set; eventually, nocturnal monitoring was simultaneously conducted at 2 different sampling points over various periods during sampling, for a total of 16 sampling days. The sampling effort with this technique took 13,440 hours/net. **Table 2.37** below show the location coordinates of mist nets set for bats. It is to mention that some points are the same as for the capture of birds.

**Table 2.37 Location of Net Points for the Capture of Flying Mammals (Bats).**

| ASSESSED VEGETATION COVER OR HABITAT | SAMPLE_ID | COORDINATES (MAGNA SIRGAS WEST ZONE) | |
|---|---|---|---|
| | | East | North |
| Mosaic of crops | Red_Arom_1 | 956394 | 604770 |
| | Red_arom_2 | 956386 | 604770 |
| | red_arom_3 | 956377 | 604769 |
| | red_Arom_4 | 956368 | 604770 |
| | red_arom_5 | 956358 | 604770 |
| | red_arom_6 | 956338 | 604773 |
| | Red_arom_7 | 956325 | 604779 |
| | Red_arom_8 | 956312 | 604786 |
| | Red_arom_9 | 956310 | 604773 |
| | red_arom_10 | 956308 | 604757 |

| ASSESSED VEGETATION COVER OR HABITAT | SAMPLE_ID | COORDINATES (MAGNA SIRGAS WEST ZONE) | |
|---|---|---|---|
| | | East | North |
| High secondary vegetation and mosaic of pasture and crops | red_arcoir_1 | 953564 | 604680 |
| | red_arcoir_2 | 953579 | 604681 |
| | red_arcoir_3 | 953588 | 604683 |
| | red_arcoir_4 | 953597 | 604678 |
| | red_arcoir_5 | 953600 | 604670 |
| | red_arcoir_6 | 953602 | 604664 |
| | red_arcoir_7 | 953598 | 604688 |
| | red_arcoir_8 | 953606 | 604697 |
| | red_arcoir_9 | 953678 | 604790 |
| | red_arcoir_10 | 953681 | 604801 |
| | red_arcoir_11 | 953689 | 604813 |
| | red_arcoir_12 | 953701 | 604813 |
| | red_arcoir_13 | 953717 | 604812 |
| Gallery and riparian forests, Mosaic of pasture and crops | Red_lomalt_1 | 953578 | 600751 |
| | Red_lomalt_2 | 953587 | 600763 |
| | Red_lomalt_3 | 953593 | 600775 |
| | Red_lomalt_4 | 953598 | 600788 |
| | Red_lomalt_5 | 953604 | 600802 |
| | Red_lomalt_6 | 953612 | 600815 |
| | Red_lomalt_7 | 953623 | 600828 |
| | Red_lomalt_8 | 953624 | 600840 |
| | Red_lomalt_9 | 953623 | 600853 |
| Gallery and riparian forests, Mosaic of pasture and crops, Low secondary vegetation | Red_bruj_1 | 954540 | 602630 |
| | Red_bruj_2 | 954553 | 602621 |
| | Red_bruj_3 | 954566 | 602614 |
| | Red_bruj_4 | 954576 | 602607 |
| | Red_bruj_5 | 954589 | 602597 |
| | Red_bruj_6 | 954598 | 602587 |
| | Red_bruj_7 | 954675 | 602739 |
| | Red_bruj_8 | 954669 | 602746 |
| | Red_bruj_9 | 954660 | 602755 |
| | Red_bruj_10 | 954649 | 602777 |
| High secondary vegetation | red_cuv_cap_1 | 951208 | 594586 |
| | red_cuv_cap_2 | 951207 | 594575 |

| ASSESSED VEGETATION COVER OR HABITAT | SAMPLE_ID | COORDINATES (MAGNA SIRGAS WEST ZONE) | |
|---|---|---|---|
| | | East | North |
| | red_cuv_cap_3 | 951198 | 594562 |
| | red_cuv_cap_4 | 951189 | 594548 |
| | red_cuv_cap_5 | 951189 | 594532 |
| | red_cuv_cap_6 | 951188 | 594514 |
| | red_cuv_cap_7 | 951177 | 594499 |
| | red_cuv_cap_8 | 951165 | 594481 |
| | red_cuv_cap_9 | 951145 | 594482 |
| Gallery and riparian forests, Mosaic of pasture and crops | red_cen_1 | 955141 | 598277 |
| | red_cen_2 | 955145 | 598258 |
| | red_cen_3 | 955153 | 598245 |
| | red_cen_4 | 955162 | 598229 |
| | red_cen_5 | 955157 | 598212 |
| | red_cen_6 | 955177 | 598209 |
| | red_cen_7 | 955192 | 598202 |
| | red_cen_8 | 955205 | 598214 |
| | red_cen_9 | 955220 | 598231 |
| Forest plantation | Red_ARD1 | 946923 | 589248 |
| | Red_ARD2 | 946931 | 589257 |
| | Red_ARD3 | 946941 | 589264 |
| | Red_ARD4 | 946951 | 589270 |
| | Red_ARD5 | 946956 | 589280 |
| | Red_ARD6 | 946928 | 589248 |
| | Red_ARD7 | 946939 | 589251 |
| | Red_ARD8 | 946950 | 589256 |

Source: GEOCOL CONSULTORES S.A, 2017.

§ **Surveys**

To complement the sampling techniques described above, 11 surveys were conducted with locals (

**Picture** 2.28), whose houses were close to sampling sites, to inquire into hard-to-observe species and/or very low population densities in the area. For this purpose, illustrated guides for the various taxonomic groups were used, considering representative data such as common name given to a species, observation frequency, and type of habitat where a species has been seen. **Table 2.38** below shows the location of sites where these surveys were done.

**Picture 2.28 Semi-Structured Fauna Surveys conducted with locals**

Survey with inhabitants of La Aldea de Maria, Municipality of Contadero. Coordinates (Magna Sirgas West Zone) (E949649 N593036).

Source: GEOCOL CONSULTORES S.A, 2017.

**Table 2.38 Location Coordinates of the Non-Structured Fauna Surveys.**

| REGISTRATION METHOD | SURVEYED FAUNA GROUP | PLACE | COORDINATES (MAGNA SIRGAS WEST ZONE) | |
|---|---|---|---|---|
| | | | EAST | NORTH |
| One-on-one interviews with structured guide | Amphibians, reptiles and mammals | Contadero/Aldea de María/Casco urbano | 949649 | 593036 |
| | | Imues/ pilcuan/ las Juntas | 956315 | 604916 |
| | | Contadero/ San Andres/ Not registered | 951756 | 595984 |
| | | Contadero/ Mazano/ Ospina Pérez | 952360 | 506717 |
| | | Iles/ Loma Alta/ la ranchería | 953502 | 600747 |
| | | Ipiales/ la soledad | 944792 | 586853 |
| | | Contadero / Capulí | 949075 | 594.387 |
| | | Contadero / Culantro | 950577 | 594600 |
| | | Iles / porvenir / el girasol | 953699 | 604810 |
| | | Iles / Tablon Alto | 954694 | 602749 |
| | | Contadero / San Francisco/ el rosal | 948171 | 592138 |

Source: GEOCOL CONSULTORES S.A, 2017.

- **After fieldwork**

o **Data analysis.**

Based on data collected in the field for each fauna group, a database was created, grouping the registered species according to their taxonomic classification, and information on abundance and studied ecological data were included as well. Taxonomic names used in this survey are according to those given by SACC - South American Classification Committee (Remsen et al., 2014, updated on February 8, 2017) for birds; Wilson & Reeder (2005, 2007; updated in January 2017) and Solari et al., (2013) for mammals; Uetz & Hošek (2016) for reptiles; Frost (2016) and Acosta & Cuentas (2017) for amphibians. Based on the resulting primary data, the following analyses were conducted:

§ **Representative sampling**

- **Species accumulation curve and maximum expected richness**

Species accumulation curves were prepared to determine the representation of registered species within the community. These curves were compared to the maximum expected richness according to functions shown in **Table 2.39** below.

**Table 2.39 Estimators Used for the Representativity of the Fauna Sampling.**

| TAXONOMIC GROUP | ESTIMATORS | | |
|---|---|---|---|
| Amphibians | Chao 2 | Jack 1 | Bootstrap |
| Reptiles | Chao 2 | Jack 2 | Bootstrap |
| Birds | Chao 1 | ACE | Michaelis-Menten |
| Mammals | Chao 1 | Chao 2 | Michaelis-Menten |

Source: GEOCOL CONSULTORES S.A, 2017.

For the preparation of curves, maximum samples were defined for each group as per date, location, and method of capture, in order to minimize the size difference between samples, and thus make them more appropriate for the analysis, according to Villarreal et al. (2006). In the case of herpetofauna, curves were created based on the number of transects at the different sampling points.

Species accumulation curves and maximum expected richness functions were developed using the EstimateS software (Colwell, 2010), by which the expected value of species in different sizes in the sample was estimated:

$$E(S) = \sum 1 - \frac{(N - N_i)/n}{N/n}$$

Where:

E(S) = Number of species found in size n of the sample.

N = Total number of individuals in the sample.

n = Standardized sample size.

Ni = Number of individuals in la i-nth species.

The Chao 2 curve is a non-parametric estimation statistically because it does not take the type of distribution of the dataset and does not adjust data to a given model. This is deemed to be the least biased estimation for small samples (Moreno, 2001):

$$Chao_2 = S + \frac{L^2}{2M}$$

Where:

L= number of species found in one sample only (“unique” species)

M= number of species found in exactly two samples

S= total number of species

Jack 1 estimation is based on the number of species found in one sample only (L). It is a tool used to reduce bias in estimated values and, in this case, to reduce the underestimation of the actual number of species in the community based on the number of species in a community based on the represented number in a sample (Moreno, 2001).

$$Jack\ 1 = S + L\frac{m-1}{m}$$

Where:

m= number of samples

L= number of species found in one sample

S= total number of species

Bootstrap estimation is based on pj, the proportion of sampling units containing each species j. Apparently, it is less accurate than the others. This is the richness estimator (Mora, 2001).

$$Bootstrap = S + \sum (1 - pj)^n$$

Where:

S= total number of species

pj= proportion of sampling units containing each species

The Chao 1 curve, in turn, is estimated based on the number of singletons (species with one registration) and doubletons (species with two registrations) (Colwell, 2010):

$$S_{chao} = S_{obs} + \frac{F^2}{2D}$$

Where:

S obs = observed richness.

F = Singletons.

D = Doubletons.

The ACE (Abundance-base Coverage Estimator) estimator is a modification of the Chao-1 index, which does not only consider species with one individual only (singletons) but also species deemed as rare (10 or less individuals), and abundant species (more than 10 individuals), with the following formula (Colwel, 2010):

$$S_{ace} = S_{abund} + \frac{S_{rare}}{C_{ace}} + \frac{F_1}{C_{ace}}\gamma^2_{ace}$$

Sabund = Number of abundant species (more than 10 individuals)

Srare = Number of rare species (10 or less individuals)

F1 = Number of species with one individual only (singletons)

□┬╢╳粫efficient of variation of species with one individual only

Cace = Sample abundance coverage estimator, which formula is as follows:

$$C_{ace} = 1 - \frac{F_1}{\sum_{i=1}^{10} iFi}$$

On the other hand, the Michaelis-Menten curve is based on the proportion of observed richness in respect of the total number of individuals in the sample (Colwell and Coddington, 1994):

$$S(n) = S_{max} - \frac{S_{max}n}{B + n}$$

Where:

S(n) = sample richness

S max = Maximum estimated richness

n= individuals in the sample

B= Michaelis-Menten estimated constant.

Additionally, behavior was analyzed in samples of species with one individual only in the sample, which stabilization is reached when most species in the community have already been registered.

- **Sampling effort and successful capture**

The sampling effort for the visual and sound detection technique (birds) and direct and indirect walk observation (non-flying mammals) was understood as the sum of the product of walked distance in each transect and the observation time. The sampling success was obtained by dividing the number of observations or registrations by the sampling effort.

For captures with mist nets (birds and bats), the sampling effort was estimated in terms of hour-net, where 1 hour-net means a 12 m net run for an hour (Rhalf et al., 1996). Thus, the sampling effort with this technique corresponds to the sum of the product of the number of nets and hours nets are run; and the capture success is the quotient between the number of captures and the sampling effort.

In the case of the Sherman and Tomahawk traps, the sampling effort was estimated in terms of traps-night, by multiplying the number of traps set by the number of effective nights such traps were active. As for camera traps, the sampling effort was estimated in terms of cameras-night, by multiplying the number of cameras by the number of nights in operation. In both cases, the sampling success resulted from dividing the number of registrations by the sampling effort.

- **Community and diversity analysis**

The community analysis (amphibians, reptiles, birds and mammals) was conducted based on attributes such as composition, richness, abundance, and diversity, which were assessed for the various land covers identified in the forest inventory.

Alpha diversity was analyzed based on richness, dominance and evenness. For specific richness, absolute richness was estimated, i.e. the number of registered species per vegetation cover. In addition, the Fisher's alpha (α) index, which is based on the logarithmic series model of species abundance distribution, and is independent of the sample size, which allows for comparisons even if the sampling effort is not the same among different sites (Moreno, 2001). This index is calculated using the following formula:

$$S = \alpha ln \frac{1 + N}{\alpha}$$

Where:

S = number of species in the sample

N = total number of individuals in the sample

α = parameters estimated by iterations seeking to match both sides of the equation.

As for dominance, the Simpson's index was calculated. This index indicates the probability that two individuals selected randomly from a sample are from the same species (Moreno, 2001):

$$D = \sum \frac{n_i(n_i - 1)}{N(N-1)}$$

Where:

ni= number of individuals of the i-nth species

N = total number of individuals in the sample.

This index's disadvantage is it is strongly influenced by the importance of the most abundant species (Magurran, 2004).

As for evenness, the Shannon's index was applied, which indicates the degree of uniformity in the species distribution in the sample. It assumes that individuals are selected randomly and that all species are represented in the sample. It reaches values of zero when there is one species only, and logarithm S when all species are represented by the same number of individuals (Moreno, 2001). Its calculation is based on the following formula:

$$H' = -\sum p_i \times \ln p_i$$

Where pi means the proportional abundance of species i.

Just as the previous one, the Shannon index is strongly influenced by the most abundant species (Villarreal et al., 2006).

Beta diversity was assessed in terms of similarity observed among the assessed habitats in terms of species shared by them. Conglomerates were analyzed using the Bray-Curtis index or quantitative Sorensen index, which is very robust and considers the lowest abundance of shared species:

$$I_{Scuant} = \frac{2pN}{aN + bN}$$

Where,

aN=Number of individuals at site A

bN= Number of individuals at site B

pN=Sum of the lowest abundance of each species shared by both sites.

- **Ecological relations**

Certain ecological attributes were analyzed in the registered species, including habitat, social organization, trophic structure, activity rates, stratum, spatial distribution patterns, and seasonal concentration sites.

ü **Herpetofauna**

Habitat preferences were determined according to the species' association with each cover and level of exclusivity or otherwise in each of them. Likewise, the terrestrial, arboreal and semiaquatic habits were assessed, as well as diets, including insectivores, other invertebrates, carnivores and omnivores.

ü **Birds**

Habitat preferences were evaluated based on the vegetation cover units where species were registered. The survey also took into consideration the fact that the avifauna distribution is strongly regulated by the vegetation structure and floral composition (Mills et al., 1991). Likewise, the avifauna distribution was analyzed, and the vertical space occupied by each species was defined, distinguishing five strata: (H-Su) Herbaceous-Soil (inside arboreal and shrub vegetation, and in the lands); (Sob) Understory (less than 3 m inside arboreal and shrub vegetation, but not in the ground); (Med) Medium strata (between 3 and 10 m, in the secondary vegetation, forest or shrubs); (Dos) Canopy of fragmented forest or secondary vegetation; (Ae) Aerial; (Aq) Aquatic).

On the other hand, the trophic structure was analyzed according to food habits and foraging strategies, following the statements provided by Stiles and Rosselli (1998), with some modifications, thus establishing 17 guilds: (FAH) Frugivore-arboreal-hawker; (FGUG) Frugivore-ground to undergrowth, (SG) seed-eater, (IF) insectivore-frugivore, (NI) nectivore-insectivore, (IBE) insectivore-bark excavator, (IPG) insectivore-perch gleaner, (IV) insectivore-air hawker, (IGUG) insectivore-ground and undergrowth gleaner, (IFH) Insectivore-foliage hawker, (IFG) insectivore-foliage gleaner, (IAQ) Insectivore-aquatic, (IVP) insect and vertebrate predator, (HER) herbivore, (S) scavengers, and (OM) omnivore.

For the analysis of the avifauna behavior, species were classified according to the social organization into four categories: (S) single, (C) couples, (MG) monospecific groups, (MF) mixed-species flock.

ü **Mammals**

Habitat was analyzed, considering their association with the types of cover to establish exclusivity on certain type of habitat or each species' capability to use different types of habitat. Also, spatial distribution was analyzed for each group through the area, and potential sites where they may concentrate over different climate seasons.

As for the trophic structure, non-flying mammals were classified according to the type of used resources by each species, further analyzing the nocturnal or diurnal and terrestrial or arboreal habits of each species, which represents a difference in how they use resources.

As regards bats, the trophic structure was analyzed according to the method proposed by Soriano (2000), which provides trophic categories not only based on the type of used resource but also on strategy implemented to get the resource. Considering that the same species oftentimes belongs to more than one trophic category, but does not show one or another diet to the same extent, where zero mean the least importance, and one the highest importance. This importance for a species' diet corresponds to the trophic value, the sum of which per species always equals one (1); and its sum within a trophic category represents the Trophic Equivalent (TE), which symbolizes diet importance within a community or another group.

o **Species of interest**

Loss of biodiversity is a phenomenon of increasing interest over the past years, given its relation to the ecosystem functioning. This is why fauna species with the highest extinction vulnerability are of special interest, because of their life features, significant hunting, limited distribution or loss of habitat.

§ **Threatened species**

For each fauna group within the area of influence of the project, the threatened category was identified for the registered species, according to Resolution 0192 of February 10, 2014 of the Ministry of Environment and Social Development (MADS), the red books of Colombia (mammals, Rodríguez – Mahecha et al., 2006; reptiles, Castaño-Mora, 2002 and Morales-Betancourt et al., 2015; amphibians, Rueda-Almonacid et al., 2004; birds, Rengifo et al., 2002 and Rengifo et al., 2014) and the red list issued by the International Union for Conservation of Nature (IUCN, 2016. Version 2016-3).

IUCN, together with experts in each group, assesses the population state of different species, which are classified into eight categories according to their level of extinction vulnerability:

- **Extinct (EX):** When undoubtedly the last living individual in the taxon has died.
- **Extinct in the wild (EW):** A taxon which specimen only survive in captivity; and exhaustive researches in their natural environment have not found other individuals.
- **Critically endangered (CR):** This taxon shows extremely high probabilities of extinction in the wild.
- **Endangered (EN):** When a taxon faces a very high risk of extinction in the wild.
- **Vulnerable (VU):** A taxon is deemed to face a high risk of extinction in the wild.

- **Near threatened (NT):** When a taxon fails to meet the criteria to be classified as threatened (CR, EN, VU) but may meet such criteria in the near future.
- **Least concern (LC):** These taxa are very abundant and widely distributed, so their extinction probability is very low.
- **Data deficient (DD):** Taxa the distribution and abundance of which have not been surveyed very well. Even if not classified into the threatened category, recommendations have been given on giving them the same conservation priority until sufficient data is obtained for proper assessment.

However, the same species may be evaluated differently locally or regionally, for which each country may conduct a different assessment, even based on the same criteria and categories. In Colombia this evaluation is published in the red book series of Colombia, as well as through Resolution 0192 of February 10, 2014 of MAVDT.

§ **CITES species category**

On the other hand, the Convention on International Trade in Endangered Species of Wild Fauna and Flora – CITES– also hast a list of highly vulnerable species based on their actual or potential trade value, included in three appendixes as per risk of extinction and level of trade:

- **Appendix I:** Species with the highest risk of extinction; trade is prohibited.
- **Appendix II:** Species that are not threatened now but their indiscriminate trade may lead to a reduction in their population viability.
- **Appendix III:** Species show a low level or are not threatened. However, their trade requires regulations that guarantee their sustainable use.

§ **Endemic species**

Another type of particularly fragile species: endemic and near-endemic species which, given their low distribution capability, very specific habitat requirements or geographic isolation, are only present in a small location and limited to one country because their population is very limited and their reproduction success is very low (Begon et al, 2006). This situation tends towards extensively feeding back within an inadequate habitat for the species. Also, presence of endemic and near-endemic species was determined, according to reports released online, such as www.xeno-canto.org, www.reptile-database.org, www.research.amnh.org/vz/herpetology/amphibia y www.iucnredlist.org

§ **Migratory species**

Migratory species were defined according to the Migratory Species Plan (MAVDT and WWF, 2009) and the Plan for Conservation of Migratory Birds in Colombia (Fundación ProAves, 2009).

Also, the sustained population decrease is a phenomenon frequently seen in migratory birds (Fundación ProAves, 2009), because loss of habitat globally directly affects migratory corridors and provisions areas. The migration phenomenon further changes population dynamics for both migratory and resident birds, since population inflows reduce the supply of resources locally (Hilty and Brown, 2001); so special attention is to be given to migratory species in the ecological characterization of zones.

§ **Tremarctos - Colombia**

Additionally and according to the guidelines provided for in the Method Manual for the Preparation of Environmental Surveys, focus species (threatened, migratory and endemic species) were analyzed as well as natural and transformed ecosystems using the early warning system known as TREMARCTOS-COLOMBIA. The information was compared to results found in the baseline of this survey.

Biological collection with review and delivery of the collected material, corresponding to: Biological Collections of University Antonio Nariño and the Alexander von Humboldt Institute (IAvH).

### 2.3.2.2 Aquatic Ecosystems

- **Phase 1: Secondary data collection, analysis and assessment**

Hydrobiological communities to characterize were determined considering the terms of reference for the road project. As for aquatic ecosystems, basins in the survey area were considered, with upstream and downstream monitoring for their main bodies of water (as access was possible). Similarly, before the field visit, secondary data from previous surveys done in the area was reviewed to determine the monitoring networks present in the survey area and propose, as possible, monitoring for the same points for the conduction of multi-temporary analysis of water quality. The monitoring activities of hydrobiota were developed under Survey Permit for the collection of wild specimens from biological diversity under **Resolution 0783 of July 2, 2015 issued by the MADS.**

The following section is twofold (2): first, the description of sampling stations deployed in the survey area. Second, the methodological process for the monitoring development conducted by MCS Consultoría y Monitoreo Ambiental S.A.S.

- **Sampling Stations**

44 water quality Sampling Stations were set for the project. The characterization was developed between February 26 and March 21, 2017. These stations were located at the sites listed below in **Table 2.40.**

**Table 2.40. Sampling Areas - Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment.**

| SAMPLING POINT | PICTURE | DATE | COORDINATES (MAGNA SIRGAS WEST ZONE) | |
|---|---|---|---|---|
| | | | EAST | NORTH |
| **EL MANZANO HUMEADORA STREAM, UPSTREAM**<br>Lotic body of water, with a low level of water, straight stream, stable riverbed, moderate deposition, composed of sand and rocks; slightly cloudy water. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; emergent macrophytes; no characteristic odors or presence of oil in the body of water. |  | 06-03-2017 | 954840 | 597388 |

| SAMPLING POINT | PICTURE | DATE | COORDINATES (MAGNA SIRGAS WEST ZONE) | |
|---|---|---|---|---|
| | | | EAST | NORTH |
| **HUMEADORA STREAM, DOWNSTREAM**<br>Lotic body of water, with a medium level of water, straight stream, stable riverbed, moderate deposition, composed of clay and sand; moderately cloudy water. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. |  | 06-03-2017 | 955074 | 597201 |
| **URBANO HUMEADORA STREAM**<br>Lotic body of water, with a low level of water, straight stream, stable riverbed, low deposition, composed of sand and rocks; cloudy water. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; emergent macrophytes; no characteristic odors or presence of oil in the body of water. |  | 06-03-2017 | 955161 | 597523 |
| **SAN FRANCISCO STREAM, UPSTREAM**<br>Lotic body of water, with a low-medium level of water, meandering stream, stable riverbed, low deposition, composed of sand and rocks; slightly cloudy water. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; emergent macrophytes; no characteristic odors or presence of oil in the body of water. |  | 27-02-2017 | 949980 | 593056 |
| **SAN FRANCISCO STREAM, DOWNSTREAM**<br>Lotic body of water, with a low-medium level of water, meandering stream, stable riverbed, low deposition, composed of sand and rocks; slightly cloudy water. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; emergent macrophytes; no characteristic odors or presence of oil in the body of water. |  | 27-02-2017 | 950086 | 593036 |

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|---|---|---|---|---|
| **YAMURAYAN STREAM, UPSTREAM**<br>Lotic body of water, with a low-medium level of water, straight stream, stable riverbed, moderate deposition, composed of clay and sand; cloudy water. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; emergent macrophytes; no characteristic odors or presence of oil in the body of water. |  | 27-02-2017 | 949114 | 592110 |
| **TRIBUTARY OF CULANTRO STREAM, UPSTREAM**<br>Lotic body of water, with a low level of water, meandering stream with slopes, stable riverbed, high deposition, composed of clay and sand; cloudy water. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; emergent macrophytes; no characteristic odors or presence of oil in the body of water. |  | 02-03-2017 | 950591 | 594688 |
| **CULANTRO STREAM, DOWNSTREAM**<br>Lotic body of water, with a low level of water, meandering with slopes, stable riverbed, high deposition, composed of clay, sand and rocks; cloudy water. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. |  | 02-03-2017 | 950603 | 594509 |
| **LA CUEVA STREAM, DOWNSTREAM**<br>Lotic body of water, with a low level of water, straight stream, stable riverbed, low deposition, composed of sand, fallen leaves and rocks; clear water Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. |  | 02-03-2017 | 950979 | 594739 |

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| **EL MANZANO STREAM, UPSTREAM**<br>Lotic body of water, with a low level of water, meandering with slopes, stable riverbed, low deposition, composed of rocks; clear water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | 05-03-2017 | 951604 | 5958195 |
| **MANZANO STREAM, DOWNSTREAM**<br>Lotic body of water, with a low level of water, meandering with slopes, stable riverbed, low deposition, composed of rocks; clear water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | 05-03-2017 | 952102 | 594886 |
| **TRIBUTARY OF HUMEADORA, UPSTREAM**<br>Lotic body of water, with a low level of water, straight stream, stable riverbed, low deposition, composed of rocks and sand; clear water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | 05-03-2017 | 954168 | 596477 |
| **BRIGADA STREAM, UPSTREAM**<br>Lotic body of water, with a low level of water, straight stream, stable riverbed, low deposition, composed of mud and clay; slightly cloudy water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | 04-03-2017 | 952234 | 595503 |

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| **BRIGADA STREAM, DOWNSTREAM**<br>Lotic body of water, with a low level of water, straight channel covered by vegetation, stable riverbed, low deposition, composed of mud and clay; slightly cloudy water. Very low vegetation alteration, local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | 04-03-2017 | 952271 | 595345 |
| **MANZANO STREAM, DOWNSTREAM**<br>Lotic body of water, with a low level of water, inclined, like a waterfall, stable riverbed, low deposition, composed of rocks; clear water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | 04-03-2017 | 951875 | 595341 |
| **CUAYARIN STREAM, UPSTREAM**<br>Lotic body of water, with a low level of water, straight stream, stable riverbed, low deposition, composed of mud and clay; clear water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. |  | 28-02-2017 | 950179 | 593808 |
| **YAMURAYAN STREAM, DOWNSTREAM**<br>Lotic body of water, with a low level of water, straight channel covered by vegetation, stable riverbed, low deposition, composed of mud, clay and fallen leave; clear water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. |  | 28-02-2017 | 949327 | 591577 |

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| **LA HONDA STREAM, UPSTREAM**<br>Lotic body of water, with a low level of water, straight extended channel covered by vegetation and fallen leaves, stable riverbed, low deposition, composed of mud, clay and fallen leaves, slightly cloudy water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | 28-02-2017 | 950297 | 594011 |
| **MOLEDORES STREAM, UPSTREAM**<br>Lotic body of water, with a low-medium level of water, straight stream, stable riverbed, low deposition, composed of mud and clay, slightly cloudy water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. |  | 08-03-2017 | 955872 | 598885 |
| **MOLEDORES STREAM, DOWNSTREAM**<br>Lotic body of water, with a medium-high level of water, meandering stream, stable riverbed, low deposition, composed of sand and rocks, slightly cloudy water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. |  | 08-03-2017 | 956019 | 598991 |
| **LA CUEVA STREAM, UPSTREAM**<br>Lotic body of water, with a low level of water, straight stream, stable riverbed, moderate deposition, composed of mud and clay, slightly cloudy water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. |  | 03-03-2017 | 951107 | 595359 |

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| **CULANTRO STREAM, UPSTREAM**<br>Lotic body of water, with a low level of water, stagnant water, stable riverbed, moderate deposition, composed of mud, clay and fallen leaves, slightly cloudy water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. |  | 03-03-2017 | 950823 | 594809 |
| **HONDA STREAM, DOWNSTREAM**<br>Lotic body of water, with a low-medium level of water, stable riverbed, moderate deposition, composed of sand and rocks; clear water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | 09-03-2017 | 950982 | 593341 |
| **CHORRERA STREAM, DOWNSTREAM**<br>Lotic body of water, with a medium level of water stable riverbed, moderate deposition, composed of sand and rocks, slightly cloudy water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | 09-03-2017 | 956740 | 599033 |

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| **ARRAYANES STREAM, UPSTREAM**<br>Lotic body of water, with a low-medium level of water, stable riverbed, moderate deposition, composed of sand, mud and clay, slightly cloudy water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | 07-03-2017 | 954623 | 597220 |
| **CHORRERA CHIQUITO STREAM, UPSTREAM**<br>Lotic body of water, with a low level of water, stable riverbed, moderate deposition, vegetation cover, composed of sand, mud and clay, slightly cloudy water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | 07-03-2017 | 955908 | 598687 |
| **BOQUERON RIVER, UPSTREAM**<br>Lotic body of water, meandering stream with a medium-high level of water stable riverbed, moderate deposition, composed of sand and rocks, moderately cloudy water and high velocity. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. |  | 26-02-2017 | 947873 | 591368 |
| **BOQUERON RIVER, DOWNSTREAM**<br>Lotic body of water, meandering stream with a medium-high level of water stable riverbed, moderate deposition, composed of sand and rocks, moderately cloudy water and high velocity. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. |  | 26-02-2017 | 948589 | 590972 |

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| **GUAITARA RIVER**<br>Lotic body of water, with canal recto with a medium-high level of water stable riverbed, moderate deposition, composed of sand, mud and rocks, cloudy water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. |  | 26-02-2017 | 948503 | 590762 |
| **NN3 STREAM**<br>Lotic body of water, straight channel, with a very low level of water, stable riverbed, low deposition, composed of sand, mud and rocks; clear water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | 26-02-2017 | 947096 | 589672 |
| **AF SAN FRANCISCO 2A STREAM, UPSTREAM**<br>Lotic body of water, straight channel, with a low level of water, stable riverbed, low deposition, composed of sand, mud and rocks, cloudy water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | 12-03-2017 | 954815 | 601862 |
| **AF SAN FRANCISCO 2B STREAM, UPSTREAM**<br>Lotic body of water, with a waterfall, with a low-medium level of water, stable riverbed, low deposition, composed of sand, mud and rocks, cloudy water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | 12-03-2017 | 954467 | 601562 |

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| **AF EL TABLON STREAM, DOWNSTREAM** | | | | |
| Lotic body of water, meandering stream, with a low-medium level of water, stable riverbed, low deposition, composed of sand, mud and rocks, cloudy water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | 12-03-2017 | 955135 | 600723 |
| **EL TABLON STREAM, DOWNSTREAM** | | | | |
| Lotic body of water, with small sizes, with a low level of water, stable riverbed, low deposition, composed of sand and mud, cloudy water. Low vegetation alteration; local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | 12-03-2017 | 955333 | 600464 |
| **SARACONCHA STREAM, UPSTREAM** | | | | |
| Lotic body of water, with a low-medium level of water, stable riverbed, low deposition, composed of sand and rocks, cloudy water. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; Presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | 14-03-2017 | 953962 | 604651 |
| **SARACONCHA STREAM, DOWNSTREAM** | | 14-03-2017 | 953970 | 604830 |

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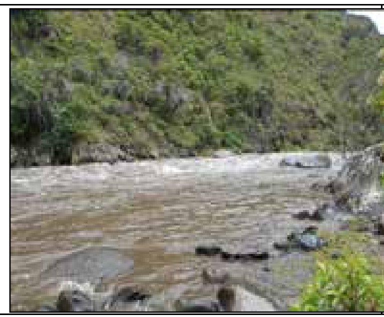
| Lotic body of water, with a low-medium level of water, stable riverbed, low deposition, composed of sand and rocks, cloudy water. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; Presence of macrophytes; no characteristic odors or presence of oil in the body of water. |  | | | |
| **EL MACAL STREAM, UPSTREAM** |  | 14-03-2017 | 953397 | 602713 |
| Lotic body of water, with a low-medium level of water, stable riverbed, low deposition, composed of sand and rocks, cloudy water. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; Presence of macrophytes; no characteristic odors or presence of oil in the body of water. | | | | |
| **SAN FRANCISCO 2 STREAM, UPSTREAM** |  | 13-03-2017 | 953962 | 601557 |
| Lotic body of water, with a low-medium level of water, stable riverbed, low deposition, composed of sand and rocks, cloudy water. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. | | | | |
| **SAN FRANCISCO 2 STREAM, DOWNSTREAM** |  | 13-03-2017 | 955044 | 602720 |
| Lotic body of water, with a medium level of water stable riverbed, low deposition, composed of sand and rocks, cloudy water. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. | | | | |
| **EL MACAL STREAM, DOWNSTREAM** | | 13-03-2017 | 954870 | 603721 |

| | | | | |
|---|---|---|---|---|
| Lotic body of water, with a medium-high level of water, stable riverbed, low deposition, composed of sand and rocks, cloudy water and high velocity. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. |  | | | |
| **GUAITARA 2 RIVER** |  | 16-03-2017 | 957634 | 607421 |
| Lotic body of water, with a medium-high level of water, stable riverbed, low deposition, composed of sand and rocks, wide dimensions, cloudy water and high velocity. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. | | | | |
| **SAPUYES RIVER, UPSTREAM** |  | 15-03-2017 | 954977 | 605045 |
| Lotic body of water, with a medium-high level of water, stable riverbed, low deposition, composed of sand and rocks, wide dimensions, cloudy water and high velocity. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. | | | | |
| **SAPUYES RIVER, DOWNSTREAM** |  | 15-03-2017 | 955466 | 604839 |
| Lotic body of water, with a medium-high level of water, stable riverbed, low deposition, composed of sand and rocks, wide dimensions, cloudy water and high velocity. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. | | | | |
| **GUAITARA 3 RIVER** | | 27-03-2017 | 956508 | 600552 |

| | | | | |
|---|---|---|---|---|
| Lotic body of water, with a medium-high level of water, stable riverbed, low deposition, composed of sand and rocks, wide dimensions, cloudy water and high velocity. Moderate vegetation alteration. Local use of soils corresponds to that of a native forest. Riparian vegetation composed of shrub and herb covers; no characteristic odors or presence of oil in the body of water. |  | | | |

Source: GEOCOL CONSULTORES S.A., 2017.

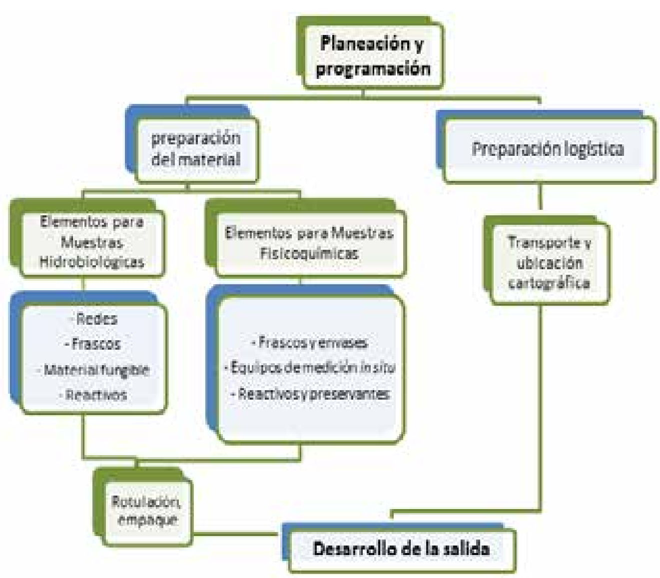
- **Methodological process**

Processes used for the physicochemical, microbiological and hydrobiological characterization of the survey area are based on the texts of APHA-AWWA-WPCF (American Public Health Association), AWWA (American Water Works Association), and WPCF (Water Pollution Control Federation), Standard Methods, Edition 22 (2012).

o **Preparation Phase**

This phase is fundamental to the appropriate development of the other processes, because this phase is charged with the planning and scheduling required so that the field phase is developed without difficulties. **Figure 2.9** shows the steps taken during this phase to determine the monitoring stations and tests to be conducted at each point.

**Figure 2.9 Preparation Phase Activities.**

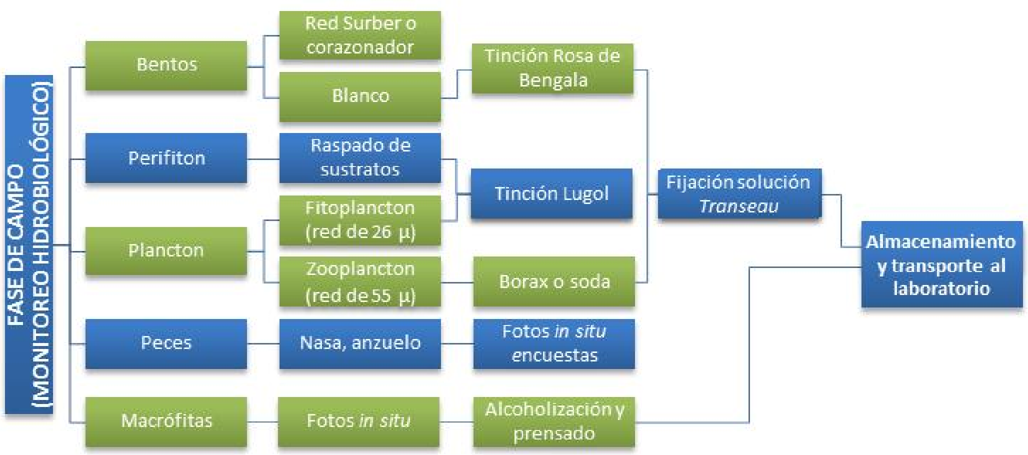


Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

- **Field phase – hydrobiological communities**

All of the field visit related activities are carried out during this phase. After identifying the monitoring stations, samples were collected according to the specific community intended to consider. Once collected, samples were labeled and accurately registered filling out the field forms including sampling date and time, sample collector, origin and state, type of community, type of fixation, and other relevant observations. Samples were sent to and analyzed by MCS Consultoría y Monitoreo Ambiental S.A.S. (ISO 9001:2008 certified and registered with IDEAM (**Figure 2.10**).

**Figure 2.10 Field Phase Activities for Hydrobiological Sampling.**




Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

- **Planktonic community**

Samples were collected of planktonic communities (phytoplankton and zooplankton), using a 10 L bucket and a 26 µm net to collect phytoplankton, and a 55 µm net to collect zooplankton. These tools were previously purged (washed with water from the monitoring station) to remove contamination from other bodies of water that were previously monitored using the same tools. For the collection of these samples, a low velocity current zone was selected, where a maximum of 150 L are collected per sampling station.

**Picture** 2.29.

The, the sample preservation phase is completed, which may vary according to the corresponding community. The phytoplankton sample is put in 250 mL amber plastic bottles and then fixed with Transeau solution (distilled water, alcohol 90% and formol 40% 6:3:1) proportion 1:1 per sample volume; Lugol drops are added for easier observation and identification of microorganisms. Finally, samples are labeled and stored in the change of custody and field forms. On the other hand, the zooplankton samples are deposited into duly labeled amber bottles, with a narcotic agent (soda and/or borax). Once microorganisms are asleep (this process takes about 30 minutes after adding the narcotic agent), a fixing solution is added (Ethanol 70%). Samples are sent to the lab for subsequent analysis. This community was evaluated only for monitored lentic bodies of water (

**Table** 2.41**;**

**Picture** 2.29).

**Table 2.41 Plankton Sampling Effort**

| CODE | NAME OF STATION | TYPE | PLANKTON |
|---|---|---|---|
| | | | FILTERED VOLUME (L) |
| SUP 1 | AF EL TABLON STREAM, DOWNSTREAM | Lotic | 100 |
| SUP 2 | AF SAN FRANCISCO 2A STREAM, UPSTREAM | | |
| SUP 3 | AF SAN FRANCISCO 2B STREAM, UPSTREAM | | |
| SUP 4 | TRIBUTARY OF HUMEADORA UPSTREAM | | |
| SUP 5 | TRIBUTARY OF CULANTRO STREAM, UPSTREAM | | |
| SUP 6 | LA CUEVA UPSTREAM | | |
| SUP 7 | EL MACAL STREAM, DOWNSTREAM | | |
| SUP 8 | EL TABLON STREAM, DOWNSTREAM | | |
| SUP 9 | ARRAYANES STREAM, UPSTREAM | | |
| SUP 10 | BRIGADA STREAM, DOWNSTREAM | | |
| SUP 11 | BRIGADA STREAM, UPSTREAM | | |
| SUP 12 | CUAYARIN STREAM, UPSTREAM | | |
| SUP 13 | CULANTRO STREAM, DOWNSTREAM | | |
| SUP 14 | CULANTRO STREAM, UPSTREAM | | |
| SUP 15 | EL MACAL STREAM, UPSTREAM | | |
| SUP 16 | EL MANZANO STREAM, UPSTREAM | | |
| SUP 17 | EL MANZANO HUMEADORA STREAM, UPSTREAM | | |
| SUP 18 | HONDA STREAM, DOWNSTREAM | | |
| SUP 19 | HUMEADORA STREAM, DOWNSTREAM | | |
| SUP 20 | LA CUEVA STREAM, DOWNSTREAM | | |
| SUP 21 | LA HONDA STREAM, UPSTREAM | | |
| SUP 22 | MANZANO STREAM, DOWNSTREAM | | |
| SUP 23 | MANZANO STREAM, UPSTREAM | | |
| SUP 24 | MOLEDORES STREAM, DOWNSTREAM | | |
| SUP 25 | MOLEDORES STREAM, UPSTREAM | | |
| SUP 26 | NN3 STREAM | | |
| SUP 27 | SAN FRANCISCO 2 STREAM, DOWNSTREAM | | |
| SUP 28 | SAN FRANCISCO 2 STREAM, UPSTREAM | | |
| SUP 29 | SAN FRANCISCO STREAM, DOWNSTREAM | | |
| SUP 30 | SAN FRANCISCO STREAM, UPSTREAM | | |
| SUP 31 | SARACONCHA STREAM, DOWNSTREAM | | |
| SUP 32 | SARACONCHA STREAM, UPSTREAM | | |
| SUP 33 | URBANO STREAM, HUMEADORA | | |
| SUP 34 | YAMURAYAN STREAM, DOWNSTREAM | | |
| SUP 35 | YAMURAYAN STREAM, UPSTREAM | | |
| SUP 36 | BOQUERON RIVER, DOWNSTREAM | | |
| SUP 37 | BOQUERON RIVER, UPSTREAM | | |

| CODE | NAME OF STATION | TYPE | PLANKTON |
|---|---|---|---|
| | | | FILTERED VOLUME (L) |
| SUP 38 | GUAITARA RIVER | | |
| SUP 39 | GUAITARA 2 RIVER | | |
| SUP 40 | GUAITARA 3 RIVER | | |
| SUP 41 | SAPUYES RIVER, DOWNSTREAM | | |
| SUP 42 | SAPUYES RIVER, UPSTREAM | | |
| SUP 43 | ZANJA CHORRERA DOWNSTREAM | | |
| SUP 44 | ZANJA CHORRERA CHIQUITO UPSTREAM | | |

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017

**Picture 2.29 Plankton Community Sampling**

La Honda Stream, upstream (Municipality of Contadero: Coordinates (Magna Sirgas West Zone) E950297 N 594011)

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

- **Periphyton**

Samples of the peripheral community were collected by scraping substrata completely submerged in the body of water, such as rocks, trunks, leaves, or any other type of natural or artificial substrata showing signs of being submerged for several days, considering, in addition, that the area where monitoring was conducted directly received sunlight.

A brush was used as a collection tool for the removal of the peripheral material, considering a 36 $cm^2$ area, for various substrata to get a representative area of substrata present in the body of water (≥ 72 cm2), in a 100 m transect per monitored station (**Table 2.42**).

The removed material from the various structured was washed and re-suspended in an amber plastic bottle, moving the brush inside the bottle, and then Lugol drops were added, and Transeau solution 1:1 was used, for easier identification of microorganisms in the Lab. Finally, samples were labeled, registered in field forms, and stored in a polystyrene box for transportation to the lab (

**Picture** 2.30).

**Table 2.42 Periphyton Sampling Effort**

| CODE | NAME OF STATION | TYPE | PERIPHYTON SAMPLED AREA ($CM^2$) |
|---|---|---|---|
| SUP 1 | AF EL TABLON STREAM, DOWNSTREAM | Lotic | 72 |
| SUP 2 | AF SAN FRANCISCO 2A STREAM, UPSTREAM | | |
| SUP 3 | AF SAN FRANCISCO 2B STREAM, UPSTREAM | | |
| SUP 4 | TRIBUTARY OF HUMEADORA UPSTREAM | | |
| SUP 5 | TRIBUTARY OF CULANTRO STREAM, UPSTREAM | | |
| SUP 6 | LA CUEVA UPSTREAM | | |
| SUP 7 | EL MACAL STREAM, DOWNSTREAM | | |
| SUP 8 | EL TABLON STREAM, DOWNSTREAM | | |
| SUP 9 | ARRAYANES STREAM, UPSTREAM | | |
| SUP 10 | BRIGADA STREAM, DOWNSTREAM | | |
| SUP 11 | BRIGADA STREAM, UPSTREAM | | |
| SUP 12 | CUAYARIN STREAM, UPSTREAM | | |
| SUP 13 | CULANTRO STREAM, DOWNSTREAM | | |
| SUP 14 | CULANTRO STREAM, UPSTREAM | | |
| SUP 15 | EL MACAL STREAM, UPSTREAM | | |
| SUP 16 | EL MANZANO STREAM, UPSTREAM | | |
| SUP 17 | EL MANZANO HUMEADORA STREAM, UPSTREAM | | |
| SUP 18 | HONDA STREAM, DOWNSTREAM | | |
| SUP 19 | HUMEADORA STREAM, DOWNSTREAM | | |
| SUP 20 | LA CUEVA STREAM, DOWNSTREAM | | |
| SUP 21 | LA HONDA STREAM, UPSTREAM | | |
| SUP 22 | MANZANO STREAM, DOWNSTREAM | | |
| SUP 23 | MANZANO STREAM, UPSTREAM | | |
| SUP 24 | MOLEDORES STREAM, DOWNSTREAM | | |
| SUP 25 | MOLEDORES STREAM, UPSTREAM | | |
| SUP 26 | NN3 STREAM | | |
| SUP 27 | SAN FRANCISCO 2 STREAM, DOWNSTREAM | | |
| SUP 28 | SAN FRANCISCO 2 STREAM, UPSTREAM | | |
| SUP 29 | SAN FRANCISCO STREAM, DOWNSTREAM | | |
| SUP 30 | SAN FRANCISCO STREAM, UPSTREAM | | |
| SUP 31 | SARACONCHA STREAM, DOWNSTREAM | | |
| SUP 32 | SARACONCHA STREAM, UPSTREAM | | |
| SUP 33 | URBANO STREAM, HUMEADORA | | |
| SUP 34 | YAMURAYAN STREAM, DOWNSTREAM | | |
| SUP 35 | YAMURAYAN STREAM, UPSTREAM | | |
| SUP 36 | BOQUERON RIVER, DOWNSTREAM | | |
| SUP 37 | BOQUERON RIVER, UPSTREAM | | |
| SUP 38 | GUAITARA RIVER | | |
| SUP 39 | GUAITARA 2 RIVER | | |
| SUP 40 | GUAITARA 3 RIVER | | |
| SUP 41 | SAPUYES RIVER, DOWNSTREAM | | |
| SUP 42 | SAPUYES RIVER, UPSTREAM | | |
| SUP 43 | ZANJA CHORRERA DOWNSTREAM | | |
| SUP 44 | ZANJA CHORRERA CHIQUITO UPSTREAM | | |

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017

**Picture 2.30 Periphyte Community Sampling**

Yamurayan Stream, downstream (Municipality of Contadero. Coordinates (Magna Sirgas West Zone) E949327 N591577)

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

- **Aquatic Macroinvertebrate Community**

The macroinvertebrate samples were composed of various sub-samples per monitoring station. Multiple zones with various characteristics were chosen considering: water current impact, type of substratum, water velocity, among others. This helped characterized different macroinvertebrate groups, thus getting a comprehensive representative sample of the assessed ecosystem.

Samples were collected using a Surber sampler (363 µm) in six different zones in a 100m transect (**Table 2.43**). After selecting the area, the sampling net was placed over the riverbed against the current, removing the substratum from the corresponding sampling area, so that the removed material was swept by the current into the net cone (**Picture 2.31**). Areas with greater probabilities of microorganism presence were swept. In zones where the current was very low or there was no current at all, a current was generated with the hands or feet so that microorganisms could be removed from the substratum into the net cone.

**Table 2.43 Aquatic Macroinvertebrates Sampling Effort**

| CODE | NAME OF STATION | TYPE | BENTHOS<br>SAMPLED AREA SURBER SAMPLING NET: ($M^2$) |
|---|---|---|---|
| SUP 1 | AF EL TABLON STREAM, DOWNSTREAM | Lotic | 0,54 |
| SUP 2 | AF SAN FRANCISCO 2A STREAM, UPSTREAM | | |
| SUP 3 | AF SAN FRANCISCO 2B STREAM, UPSTREAM | | |
| SUP 4 | TRIBUTARY OF HUMEADORA UPSTREAM | | |
| SUP 5 | TRIBUTARY OF CULANTRO STREAM, UPSTREAM | | |
| SUP 6 | LA CUEVA UPSTREAM | | |
| SUP 7 | EL MACAL STREAM, DOWNSTREAM | | |
| SUP 8 | EL TABLON STREAM, DOWNSTREAM | | |
| SUP 9 | ARRAYANES STREAM, UPSTREAM | | |

| CODE | NAME OF STATION | TYPE | BENTHOS |
|---|---|---|---|
| | | | SAMPLED AREA SURBER SAMPLING NET: ($M^2$) |
| SUP 10 | BRIGADA STREAM, DOWNSTREAM | | |
| SUP 11 | BRIGADA STREAM, UPSTREAM | | |
| SUP 12 | CUAYARIN STREAM, UPSTREAM | | |
| SUP 13 | CULANTRO STREAM, DOWNSTREAM | | |
| SUP 14 | CULANTRO STREAM, UPSTREAM | | |
| SUP 15 | EL MACAL STREAM, UPSTREAM | | |
| SUP 16 | EL MANZANO STREAM, UPSTREAM | | |
| SUP 17 | EL MANZANO HUMEADORA STREAM, UPSTREAM | | |
| SUP 18 | HONDA STREAM, DOWNSTREAM | | |
| SUP 19 | HUMEADORA STREAM, DOWNSTREAM | | |
| SUP 20 | LA CUEVA STREAM, DOWNSTREAM | | |
| SUP 21 | LA HONDA STREAM, UPSTREAM | | |
| SUP 22 | MANZANO STREAM, DOWNSTREAM | | |
| SUP 23 | MANZANO STREAM, UPSTREAM | | |
| SUP 24 | MOLEDORES STREAM, DOWNSTREAM | | |
| SUP 25 | MOLEDORES STREAM, UPSTREAM | | |
| SUP 26 | NN3 STREAM | | |
| SUP 27 | SAN FRANCISCO 2 STREAM, DOWNSTREAM | | |
| SUP 28 | SAN FRANCISCO 2 STREAM, UPSTREAM | | |
| SUP 29 | SAN FRANCISCO STREAM, DOWNSTREAM | | |
| SUP 30 | SAN FRANCISCO STREAM, UPSTREAM | | |
| SUP 31 | SARACONCHA STREAM, DOWNSTREAM | | |
| SUP 32 | SARACONCHA STREAM, UPSTREAM | | |
| SUP 33 | URBANO STREAM, HUMEADORA | | |
| SUP 34 | YAMURAYAN STREAM, DOWNSTREAM | | |
| SUP 35 | YAMURAYAN STREAM, UPSTREAM | | |
| SUP 36 | BOQUERON RIVER, DOWNSTREAM | | |
| SUP 37 | BOQUERON RIVER, UPSTREAM | | |
| SUP 38 | GUAITARA RIVER | | |
| SUP 39 | GUAITARA 2 RIVER | | |
| SUP 40 | GUAITARA 3 RIVER | | |
| SUP 41 | SAPUYES RIVER, DOWNSTREAM | | |
| SUP 42 | SAPUYES RIVER, UPSTREAM | | |
| SUP 43 | ZANJA CHORRERA DOWNSTREAM | | |
| SUP 44 | ZANJA CHORRERA CHIQUITO UPSTREAM | | |

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017

**Picture 2.31 Benthic Community Sampling**

Cauyarín Stream. upstream (Municipality of Contadero. Coordinates (Magna Sirgas West Zone) E950179 N593808)

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

The collected samples were put in Ziploc hermetic bags separately, fixed with Transeau solutions, and dyed using rose Bengal (for easier separation in the lab). The bags were hermetically sealed, labeled and packaged for subsequent identification in the lab.

- **Ichthyofauna**

Samples were collected using the following fishing tools:

Cast net: Active fishing that helps capture organisms of different sizes, in all different strata of the water column. A cast net (maximum 1.8 m high and 1 cm for the holes) was used for maximum periods of 2 hours, and cast max. 25 times. Trawl net:  maximum 6 m long and 2 m high; and maximum 15 trawls per 10 m transect (

**Table** 2.44**; Picture 2.32**).

Collected fish are anesthetized with clove essence. Fish which size is no longer than 10 cm are fixed with formol 10%, putting them in this reagent in wide mouth bottles hermetically sealed. Specimens longer than 15 cm are additionally injected formol 10% at various points of their bodies (pectoral and dorsal fins, anus, mouth and muscle) to ensure the fixing of their tissues. These specimens are transported in Ziploc bags with holes put in 20 L cans with formol 10%. Samples are put in a plastic container or polystyrene box on completion of information in the chain of custody and field forms according to the sampling method and effort.

**Table 2.44 Ichthyofauna Sampling Effort**

| CODE | NAME OF STATION | TYPE | ICHTHYOFAUNA | |
|---|---|---|---|---|
| | | | CAT NEST (NUMBER OF CAST) | CAST NET (NUMBER OF CAST) |
| SUP 1 | AF EL TABLON STREAM, DOWNSTREAM | | | |
| SUP 2 | AF SAN FRANCISCO 2A STREAM, UPSTREAM | | | |
| SUP 3 | AF SAN FRANCISCO 2B STREAM, UPSTREAM | | | |
| SUP 4 | TRIBUTARY OF HUMEADORA UPSTREAM | | | |
| SUP 5 | TRIBUTARY OF CULANTRO STREAM, UPSTREAM | | | |
| SUP 6 | LA CUEVA UPSTREAM | | | |
| SUP 7 | EL MACAL STREAM, DOWNSTREAM | | | |
| SUP 8 | EL TABLON STREAM, DOWNSTREAM | | | |
| SUP 9 | ARRAYANES STREAM, UPSTREAM | | | |
| SUP 10 | BRIGADA STREAM, DOWNSTREAM | | | |
| SUP 11 | BRIGADA STREAM, UPSTREAM | | | |
| SUP 12 | CUAYARIN STREAM, UPSTREAM | | | |
| SUP 13 | CULANTRO STREAM, DOWNSTREAM | | | |
| SUP 14 | CULANTRO STREAM, UPSTREAM | | | |
| SUP 15 | EL MACAL STREAM, UPSTREAM | | | |
| SUP 16 | EL MANZANO STREAM, UPSTREAM | | | |
| SUP 17 | EL MANZANO HUMEADORA STREAM, UPSTREAM | | | |
| SUP 18 | HONDA STREAM, DOWNSTREAM | | | Not completed* |
| SUP 19 | HUMEADORA STREAM, DOWNSTREAM | | | |
| SUP 20 | LA CUEVA STREAM, DOWNSTREAM | | | |
| SUP 21 | LA HONDA STREAM, UPSTREAM | | | |
| SUP 22 | MANZANO STREAM, DOWNSTREAM | Lotic | 5 | |
| SUP 23 | MANZANO STREAM, UPSTREAM | | | |
| SUP 24 | MOLEDORES STREAM, DOWNSTREAM | | | |
| SUP 25 | MOLEDORES STREAM, UPSTREAM | | | |
| SUP 26 | NN3 STREAM | | | |
| SUP 27 | SAN FRANCISCO 2 STREAM, DOWNSTREAM | | | |
| SUP 28 | SAN FRANCISCO 2 STREAM, UPSTREAM | | | |
| SUP 29 | SAN FRANCISCO STREAM, DOWNSTREAM | | | |
| SUP 30 | SAN FRANCISCO STREAM, UPSTREAM | | | |
| SUP 31 | SARACONCHA STREAM, DOWNSTREAM | | | |
| SUP 32 | SARACONCHA STREAM, UPSTREAM | | | |
| SUP 33 | URBANO STREAM, HUMEADORA | | | |
| SUP 34 | YAMURAYAN STREAM, DOWNSTREAM | | | |
| SUP 35 | YAMURAYAN STREAM, UPSTREAM | | | |
| SUP 36 | BOQUERON RIVER, DOWNSTREAM | | | |
| SUP 37 | BOQUERON RIVER, UPSTREAM | | | |
| SUP 38 | GUAITARA RIVER | | | |
| SUP 39 | GUAITARA 2 RIVER | | | 5 |
| SUP 40 | GUAITARA 3 RIVER | | | |
| SUP 41 | SAPUYES RIVER, DOWNSTREAM | | | |
| SUP 42 | SAPUYES RIVER, UPSTREAM | | | |
| SUP 43 | ZANJA CHORRERA DOWNSTREAM | | | Not completed* |
| SUP 44 | ZANJA CHORRERA CHIQUITO UPSTREAM | | | |

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017

*Fishing gear that was not used due to the morphological characteristics of the bodies of water.

**Picture 2.32 Ichthyofauna Sampling**

Guaitara River (Municipality of Ipiales, Coordinates (Magna Sirgas West Zone): E948503 N590762)

Guaitara 2 River (Municipality of Ipiales: Coordinates (Magna Sirgas West Zone) E957634 N607421)

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

Additionally, the inhabitants of the zone were interviewed for further data on seasonal and migratory fauna species, which are not seen all year long and possibly not observed by the time the field phase was conducted. Also, information on richness of vertebrate groups was obtained as well as signs of population conditions, local common names, and significance of these species for trade and/or culturally.

- **Aquatic macrophytes**

Manual collection in each quadrant in a parallel transect.

A maximum of 5 1m$^2$ (1 x 1 m) quadrants per monitoring stations is implemented through a 50m long transect. This is parallel to the aquatic system margin, exactly in the area in between the land and the aquatic areas (littoral zone). The cover (percentage) of the various macrophyte morphospecies will estimated at each quadrant. Once obtained such cover percentages, the detailed photographic evidences are developed for the various vegetation structures of morphospecies present at each quadrant, including, stem, leaves (front and back), petiole, flower, fruit, root, bloom, details on reproduction structures, general view, among others. Should any of the specimens not be taxonomically identified, it is collected definitely for preservation and transportation to the lab.

The collected materials are previously washed with a lot of water to remove excess organic matter or sediments from roots and leaves, and then pressed using newsprint. Each specimen is preserved with alcohol 70%. Samples are sent in plastic or polystyrene vessel on completion of information in the chain of custody and field forms (

**Picture 2.33**). **Table 2.45** below summarizes the sampling efforts at each station.

**Picture 2.33 Macrophyte Monitoring**

Guaitara River (Municipality of Ipiales: COORDINATES (MAGNA SIRGAS WEST ZONE) E948503 N590762)

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

**Table 2.45 Aquatic Macrophytes Sampling Effort**

| CODE | NAME OF STATION | TYPE | MACROPHYTES SAMPLED AREA ($M^2$) |
|---|---|---|---|
| SUP 1 | AF EL TABLON STREAM, DOWNSTREAM | Lotic | 5 |
| SUP 2 | AF SAN FRANCISCO 2A STREAM, UPSTREAM | | |
| SUP 3 | AF SAN FRANCISCO 2B STREAM, UPSTREAM | | |
| SUP 4 | TRIBUTARY OF HUMEADORA UPSTREAM | | |
| SUP 5 | TRIBUTARY OF CULANTRO STREAM, UPSTREAM | | |
| SUP 6 | LA CUEVA UPSTREAM | | |
| SUP 7 | EL MACAL STREAM, DOWNSTREAM | | |
| SUP 8 | EL TABLON STREAM, DOWNSTREAM | | |
| SUP 9 | ARRAYANES STREAM, UPSTREAM | | |
| SUP 10 | BRIGADA STREAM, DOWNSTREAM | | |
| SUP 11 | BRIGADA STREAM, UPSTREAM | | |
| SUP 12 | CUAYARIN STREAM, UPSTREAM | | |
| SUP 13 | CULANTRO STREAM, DOWNSTREAM | | |
| SUP 14 | CULANTRO STREAM, UPSTREAM | | |
| SUP 15 | EL MACAL STREAM, UPSTREAM | | |
| SUP 16 | EL MANZANO STREAM, UPSTREAM | | |
| SUP 17 | EL MANZANO HUMEADORA STREAM, UPSTREAM | | |
| SUP 18 | HONDA STREAM, DOWNSTREAM | | |
| SUP 19 | HUMEADORA STREAM, DOWNSTREAM | | |
| SUP 20 | LA CUEVA STREAM, DOWNSTREAM | | |
| SUP 21 | LA HONDA STREAM, UPSTREAM | | |
| SUP 22 | MANZANO STREAM, DOWNSTREAM | | |
| SUP 23 | MANZANO STREAM, UPSTREAM | | |

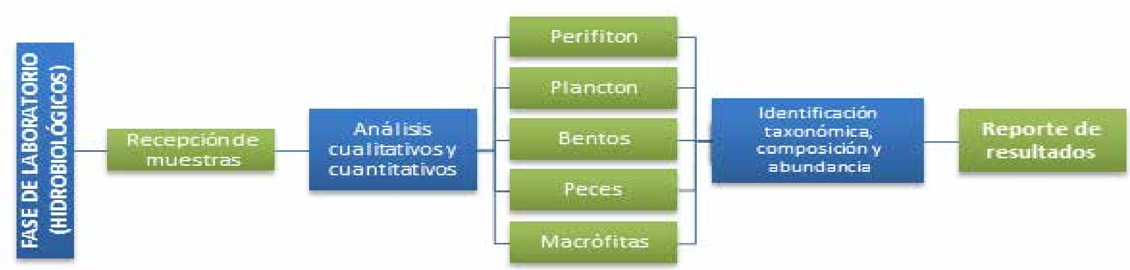
| CODE | NAME OF STATION | TYPE | MACROPHYTES SAMPLED AREA ($M^2$) |
|---|---|---|---|
| SUP 24 | MOLEDORES STREAM, DOWNSTREAM | | |
| SUP 25 | MOLEDORES STREAM, UPSTREAM | | |
| SUP 26 | NN3 STREAM | | |
| SUP 27 | SAN FRANCISCO 2 STREAM, DOWNSTREAM | | |
| SUP 28 | SAN FRANCISCO 2 STREAM, UPSTREAM | | |
| SUP 29 | SAN FRANCISCO STREAM, DOWNSTREAM | | |
| SUP 30 | SAN FRANCISCO STREAM, UPSTREAM | | |
| SUP 31 | SARACONCHA STREAM, DOWNSTREAM | | |
| SUP 32 | SARACONCHA STREAM, UPSTREAM | | |
| SUP 33 | URBANO STREAM, HUMEADORA | | |
| SUP 34 | YAMURAYAN STREAM, DOWNSTREAM | | |
| SUP 35 | YAMURAYAN STREAM, UPSTREAM | | |
| SUP 36 | BOQUERON RIVER, DOWNSTREAM | | |
| SUP 37 | BOQUERON RIVER, UPSTREAM | | |
| SUP 38 | GUAITARA RIVER | | |
| SUP 39 | GUAITARA 2 RIVER | | |
| SUP 40 | GUAITARA 3 RIVER | | |
| SUP 41 | SAPUYES RIVER, DOWNSTREAM | | |
| SUP 42 | SAPUYES RIVER, UPSTREAM | | |
| SUP 43 | ZANJA CHORRERA DOWNSTREAM | | |
| SUP 44 | ZANJA CHORRERA CHIQUITO UPSTREAM | | |

Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017

- **Lab phase – hydrobiological samples**

Samples collected in the field were analyzed during this phase, by determining the composition and abundance of hydrobological communities at the surveyed monitoring stations. This is one of the most important phases because results for the monitored communities are obtained during this phase (**Annex 15. Monitoring_Monitoring Surface Water Quality**). **Figure 2.11** below shows the activities carried out during this phase.

**Figure 2.11 Lab phase activities - Hydrobiological Communities**




Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

- **Periphyton**

The count and identification of organisms were done using a Sedgwick-Rafter counting slide. Organisms found in various stripes were counted, through zig-zag sweepings, using a compound light microscope at a 40X magnification, considering the methodology laid down in APHA-AWWA-WPCF; APHA (American Public Health Association), AWWA (American Water Works Association) and WPCF (Water Pollution Control Federation), and the Standard Methods Edition 22 (2012).

The taxonomic identification and location were determined based on taxonomic keys, drawings and descriptions such as those provided by Edmondson (1959), Needham and Needham (1962), Bicudo and Bicudo (1970), Prescott (1970), Bourrelly (1972 y 1981), Pennak (1978), Parra et al. (1982), Anagnostidis and Komarek (1986, 1989), Lopretto and Tell (1995). The ITIS database was used for the taxonomic definition of these communities.

- **Benthic community**

The collected aquatic macroinvertebrate samples will be separated passed through a sieve of different microns (500 µm and 1,18 mm), and analyzed in white enamel trays, object-holders, using a light microscope or a stereoscope (10x and 40x), as required. For the identification of the benthic community and its taxonomic location, specialized literature was reviewed such as: Linares and Vera (2012), Epler (2010, 2006), Morales-Castaño and Molano-Rendón (2008), RoughLaw and Solis (2008), Domínguez et al. (2006), Heckman (2006), Manzo (2005), Oliveira et al. (2005), Zúñiga et al. (2004), Posada-García and Roldán (2003), Roldán (2003, 1996 and 1989), Fernández and Domínguez (2001), Rodríguez et al. (1992), Mc Cafferty (1981), among others.

For benthos, a total count of counted individuals for each given taxon and the sampling area (Surber sampling net), thus registering a total number of individuals per area; in this case per square meter (Ind/m2).

- **Planktonic community**

The count and identification of organisms were done using a Sedgwick-Rafter counting slide. Organisms found in various stripes were counted through zig-zag sweepings, using a compound light microscope at a 40X magnification for phytoplankton, and at 10X and 40X magnifications for zooplankton, considering the methodology laid down in APHA-AWWA-WPCF; APHA (American Public Health Association), AWWA (American Water Works Association) and WPCF (Water Pollution Control Federation), the Standard Methods Edition 22 (2012). Counts were done per each observed morphospecies.

The taxonomic identification and location were determined based on taxonomic keys, drawings and descriptions such as those provided by Edmondson (1959), Needham and Needham (1962), Bicudo and Bicudo (1970), Prescott (1970), Bourrelly (1972 y 1981), Pennak (1978), Parra et al. (1982), Anagnostidis and Komarek (1986, 1989), Lopretto and Tell (1995). The ITIS database was used for the taxonomic definition of these communities.

- **Ichthyofauna**

Each collected specimen is analyzed using a stereoscope; various characteristics are observed according to the taxonomic group of each organism. Some of the most common characteristics found are the number of scales, teeth, number of radius and bones in the fins, among others.

The taxonomic determination is based on specialized keys, descriptions and lists of species. Given specimens are separated by morphospecies and sampling stations in glass bottles with alcohol 75%, which are labeled indicating the basic collection data (sample collector, place, date, etc.).

- **Aquatic macrophytes**

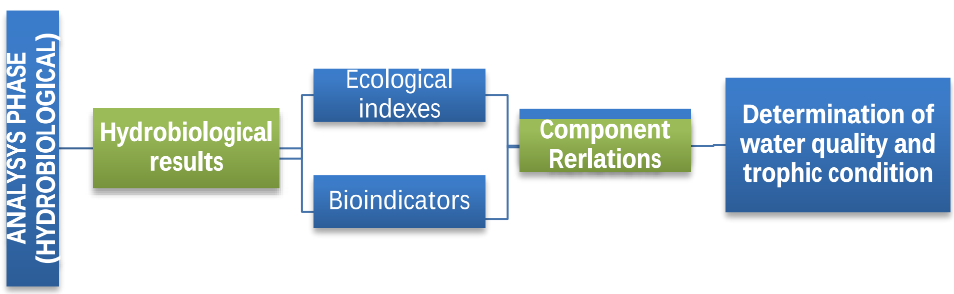
As for aquatic macrophytes, the vegetation structures of the collected materials were observed, and pictures were reviewed for observation of and details on non-lasting characteristics such as color, for identification of families using the taxonomic key (Gentry, 1993) and the implementation of the floral formula for identification of genera and species (Velásquez, 1994: APGIV, 2016).

In certain determinations, macrophytes were dissected using a stereoscope (at 6x, 60x magnifications) tongs and small needles, considering the methodology laid down in APHA-AWWA-WPCF; APHA (American Public Health Association), AWWA (American Water Works Association) and WPCF (Water Pollution Control Federation), the Standard Methods Edition 22 (2012). Hierarchies were defined using the APGIV taxonomic system (2016) of the Virtual Herbarium of Tropics.

· **Analysis Phase – hydrobiological parameters**

This phase consists in tabulating and evaluating obtained results and subsequently determining the trophic conditions of the sampling stations. Figure 2.12 below shows the activities carried out to fulfill the objectives set for each phase.

**Figure 2.12 Analysis Phase Activities.**




Source: MCS Consultoría y Monitoreo Ambiental S.A.S., 2017.

· **Structure and composition**

Based on results obtained in the lab for each surveyed hydrobological community, the composition of each community is described to the taxonomic level of morphospecies, i.e. the consolidation of registered species for a community, and abundance or number of individuals per sampling site. With this in mind, obtained results were collected in primary tables considering the following as density units: individuals/cm$^2$ for periphyton, individuals/ m$^2$ for macroinvertebrates; or individuals/ml, for planktonic communities. Additionally, charts were developed for richness and abundance by division or phylum for benthos, periphyton, phytoplankton and zooplankton.

· **Ecological attributes**

The richness and diversity factors were estimated for the surveyed hydrobiological communities based on abundance matrixes of each morphospecies at the surveyed sampling stations. Diversity indexes have been typically to somehow characterize abundance relations in species. Diversity is defined by two components:

(1) the total number of species and (2) evenness or how abundances are distributed among species in a given sample. The combination of both components is expressed through diversity indexes. These ecological attributes were estimated with PAST 3.0®, free software (Hammer et al., 2001). Following is a brief description of the theoretical grounds of the conducted analyses:

- **Shannon-Wiener Index**

$$H' = -\sum pi \ln pi$$

This shows the uniformity of importance values for all species in the sample. It measures the average uncertainty degree to predict what species an individual selected at random from a collection will belong to (Magurran, 1988; Peet, 1974). It assumes that individuals are selected at random and that all species are represented in the sample. It has values between zero –when there is only one species– and logarithm S –when all species are represented by the same number of individuals (Magurran, 1988). It generally takes values between 1 and 4.5, and values higher than 3 are typically interpreted as "diverse".

- **Dominance Index**

$$\lambda = \sum pi^2$$

Where: **pi =** proportional abundance of species i, i.e. the number of individuals of species i divided by the total number of individuals in the sample.

This index shows the probability that two individuals selected at random from a sample are from the same species. The higher this probability, the lower the diversity in the community. This is strongly influenced by the significance of the most dominant species (Magurran, 1988; Peet, 1974). Given that its value is inverse to evenness, diversity may be estimated as 1 – λ (Lande, 1996).

- **Pielou's measure of evenness**

$$J' = \frac{H'}{H'max} \text{ Where } H'max = \ln(S).$$

The evenness or uniformity index measures the proportion of observed diversity in relation to the maximum expected diversity. Its values ranges from 0 to 1, where 1 corresponds to such situations in which all species are evenly abundant (Magurran, 1988). If all species in a sample show to have the same level of abundance, the index used to measure evenness should be a maximum and, therefore, should decrease towards zero as relative abundance becomes less even.

- **Physicochemical, microbiological and hydrobiological parameter correlation**

Based on obtained results, various statistical analyses were conducted, mostly multivariate analyses, which are statistical methods which purpose is to analyze data where there are more than two measured variables per case. Following is a description of implemented tools for this study.

- **Spearman's correlation coefficient**

These coefficients will be estimated to establish correlations between environmental and biological variables in the event that multivariate analyses provide no significant results. Spearman's correlation coefficient is a nonparametric association measure based on ranges, which may be used for discrete or continuous variables (Balzarini et al., 2008). The null statistical hypothesis defined in this analysis is the lack of association in variables, which is why the purpose hereof was to assess the possibility to reject this hypothesis. InfoStat ®, the free version (Di Rienzo et al., 2008) was the statistical software used in this study.

#### 2.3.2.2.1 Multi-temporary Analysis of Aquatic Ecosystems in the Survey Area

The multi-temporary analysis contemplated results between 2016 (August and December) and 2017 of the hydrobiological communities. Data was processed in two phases:

During the *first* phase the existing biological data is gathered and analyzed for all monitored stations within the survey area, corresponding to 26 bodies of water, and 44 monitoring stations (See Table 2.46)

**Table 2.46 Sampling Stations – Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment.**

| NUMBER | NAME | PLANE COORDINATES DATUM MAGNA SIRGAS WEST ZONE | |
|---|---|---|---|
| | | EAST | NORTH |
| 1 | NN3 stream, upstream | 947096 | 589672 |
| 2 | Guaitara river | 948503 | 590762 |
| 3 | Boqueron river, upstream | 947873 | 591368 |
| 4 | Boqueron river, downstream | 948589 | 590972 |
| 5 | Yamurayán stream, upstream | 949114 | 592110 |
| 6 | Yamurayán stream, downstream | 949327 | 591577 |
| 7 | San Francisco stream, upstream | 949980 | 593156 |
| 8 | San Francisco stream, downstream | 950086 | 593036 |
| 9 | Cuayarín (Honda) stream, upstream | 950179 | 593808 |
| 10 | Honda stream, upstream | 950297 | 594011 |
| 11 | Honda stream, downstream | 950982 | 593341 |
| 12 | Stream tributary of Culantro stream, upstream | 950591 | 594688 |
| 13 | Culantro stream, upstream | 950823 | 594809 |
| 14 | Culantro stream, downstream | 950603 | 594509 |
| 15 | La Cueva stream, upstream | 951107 | 595359 |
| 16 | La Cueva stream, downstream | 950979 | 594734 |
| 17 | Stream tributary of Manzano stream, upstream | 951604 | 595195 |
| 18 | El Manzano stream, upstream | 951875 | 595341 |
| 19 | El Manzano stream, downstream | 952102 | 594886 |
| 20 | Brigada stream, upstream | 952234 | 595503 |
| 21 | Brigada stream, downstream | 952271 | 595345 |
| 22 | Tributary of Humeadora stream, upstream | 954168 | 596477 |
| 23 | Los Arayanes (Huneadora) stream, upstream | 954623 | 597220 |
| 24 | El Manzano (Humeadora) stream, upstream | 954840 | 597388 |
| 25 | Urbano (Humeadora) stream, upstream | 955161 | 597523 |
| 26 | Humeadora stream, downstream | 955074 | 597201 |
| 27 | Zanja Chorrera Chiquita upstream | 955908 | 598687 |
| 28 | Zanja Chorrera Chiquita downstream | 956740 | 599033 |
| 29 | Moledores stream, upstream | 955872 | 598885 |
| 30 | Moledores stream, downstream | 956019 | 598991 |
| 31 | El Tablon stream, downstream | 955333 | 600464 |
| 32 | Stream tributary of El Tablon stream, downstream | 955135 | 600723 |

| NUMBER | NAME | PLANE COORDINATES DATUM MAGNA SIRGAS WEST ZONE | |
|---|---|---|---|
| | | EAST | NORTH |
| 33 | Tributary of San Francisco 2 stream, upstream | 954815 | 601862 |
| 34 | Tributary of San Francisco 2 stream, upstream | 954467 | 601562 |
| 35 | San Francisco 2 stream, upstream | 953962 | 601557 |
| 36 | San Francisco 2 stream, downstream | 955044 | 602720 |
| 37 | El Macal stream, upstream | 953397 | 602713 |
| 38 | El Macal stream, downstream | 954870 | 603721 |
| 39 | Saraconcha stream, upstream | 953962 | 604651 |
| 40 | Saraconcha stream, downstream | 953970 | 604830 |
| 41 | Sapuyes river, upstream | 954977 | 605045 |
| 42 | Sapuyes river, downstream | 955466 | 604839 |
| 43 | Guaitara 2 river | 957634 | 607421 |
| 44 | Guaitara 3 river | 956508 | 600552 |

Source: GEOCOL CONSULTORES S.A., 2017.

During the *second* phase, bodies of water with monitoring continually over time and space, and full biological data on communities were selected. The relevant analysis is conduced considering that previous water quality surveys has been conducted for the main currents in the area of influence of the Rumichaca – Pasto Divided Highway Project, San Juan – Pedregal Segment. For the performance of the multi-temporary analysis, information was used from monitoring activities developed by Consorcio SH, in the survey area, by hiring Agrosoluciones Environmentales ASOAM S.A.S. (a lab certified by IDEAM by Resolution 1556 of August 14, 2015, modified by Resolution 2191 of October 7, 2015 for the performance of water quality monitoring activities), and INCO ENVIRONMENTAL S.A.S. (a lab certified by IDEAM by Resolution 2189 of October 7, 2015, for the performance of water quality monitoring activities). These studies found 9 bodies of water in the San Juan – Pedregal segment.

**Table 3. 110** and **Table 3. 111** below show the name of the stations with their coordinates and the date on which the monitoring activities were carried out, and the results thereof, respectively.

**Table 2.47 Aquatic Ecosystems selected for the Multi-temporary Analysis of the Survey Area.**

| ID | NAME OF STATION IN THE CONDUCTED SURVEY | COORDINATES DATUM MAGNA SIRGAS BOGOTA ZONE | | SOURCE | SAMPLING DATE |
|---|---|---|---|---|---|
| | | EAST | NORTH | | |
| M1 | Guaitara River | 948495 | 590756 | ASOAM S.A.S | Aug - 2016 |
| M2 | Guaitara River | 948495 | 590756 | INCOAMBIENTAL | Dec - 2016 |
| M3 | Guaitara River | 948503 | 590762 | This survey | Feb - 2017 |
| M4 | Boqueron River upstream | 947870 | 591392 | ASOAM S.A.S | Apr - 2016 |
| M5 | Boqueron River upstream | 947893 | 591358 | INCOAMBIENTAL | Dec - 2016 |
| M6 | Boqueron River upstream | 947873 | 591368 | This survey | Feb - 2017 |
| M7 | Boqueron River downstream | 948597 | 590968 | ASOAM S.A.S | Apr - 2016 |
| M8 | Boqueron River downstream | 948523 | 590981 | INCOAMBIENTAL | Dec - 2016 |

| ID | NAME OF STATION IN THE CONDUCTED SURVEY | COORDINATES DATUM MAGNA SIRGAS BOGOTA ZONE | | SOURCE | SAMPLING DATE |
|---|---|---|---|---|---|
| | | EAST | NORTH | | |
| M9 | Boqueron River downstream | 948589 | 590972 | This survey | Feb - 2017 |
| M10 | Humeadora Stream upstream | 954839 | 597388 | ASOAM S.A.S | Apr - 2016 |
| M11 | Humeadora Stream upstream | 954841 | 597387 | INCOAMBIENTAL | Dec - 2016 |
| M12 | El Manzano (Humeadora) Stream upstream | 954840 | 597388 | This survey | Feb - 2017 |
| M13 | Humeadora Stream downstream | 955078 | 597206 | ASOAM S.A.S | Apr - 2016 |
| M14 | Humeadora Stream downstream | 955101 | 597178 | INCOAMBIENTAL | Dec - 2016 |
| M15 | Humeadora Stream downstream | 955074 | 597201 | This survey | Feb - 2017 |
| M16 | El Macal Stream upstream | 953397 | 602713 | ASOAM S.A.S | Apr - 2016 |
| M17 | El Macal Stream upstream | 953395 | 602717 | INCOAMBIENTAL | Dec - 2016 |
| M18 | El Macal Stream upstream | 953397 | 602713 | This survey | Feb - 2017 |
| M19 | El Macal Stream downstream | 955018 | 603796 | ASOAM S.A.S | Apr - 2016 |
| M20 | El Macal Stream downstream | 955031 | 603800 | INCOAMBIENTAL | Dec - 2016 |
| M21 | El Macal Stream downstream | 953970 | 604830 | This survey | Feb - 2017 |
| M22 | Sapuyes River upstream | 954927 | 605082 | ASOAM S.A.S | Apr - 2016 |
| M23 | Sapuyes River upstream | 954925 | 605066 | INCOAMBIENTAL | Dec - 2016 |
| M24 | Sapuyes River upstream | 954977 | 605045 | This survey | Feb - 2017 |
| M25 | Sapuyes River downstream | 955660 | 604838 | ASOAM S.A.S | Apr - 2016 |
| M26 | Sapuyes River downstream | 955649 | 604826 | INCOAMBIENTAL | Dec - 2016 |
| M27 | Sapuyes River downstream | 955466 | 604839 | This survey | Feb - 2017 |

Source: GEOCOL CONSULTORES S.A., 2017.

- **Community and diversity analysis**

Additionally, a comparative analysis was conducted between the different sampling periods for each analyzed body of water. The composition and structure of communities were analyzed as well as their diversity and bioindication.

Richness and abundance of the main taxonomic groups composing each community were assessed. The richness and structure indexes were applied to determined diversity. In the first case, specific richness (S) was analyzed, and the Fisher Index (Alfa) was estimated, which is independent of the sample size and helps make comparisons although no similar sampling efforts vs other sites are available. It is estimated with the following formula:

$$S = \alpha ln \frac{1 + N}{\alpha}$$

Where:
S = number of species in the sample
N = total number of individuals in the sample
α = parameter estimated by iterations seeking to match both sides of the equation.

As for the structure analysis, dominance and evenness indexes were applied. In the first case, the Simpson's index was estimated, which shows the probability that two individuals selected at random from a sample are from the same species (Moreno, 2001):

$$D = \sum \frac{n_i(n_i - 1)}{N(N - 1)}$$

Where:

$n_i$= number of individuals of the i-nth species
N = total number of individuals in the sample.

The Shannon index was applied for the estimation of evenness. It shows the uniformity degree of distribution of species the sample:

$$H' = -\sum p_i \times \ln p_i$$

Where $p_i$ is the proportional abundance of species *i.*

The Pielou's measure of evenness (J') was also analyzed, which relates Shannon's diversity to the maximum expected evenness according to richness found in the sample:

$$J' = \frac{H'}{H'max}$$

Where *H'max* = ln(S) y *H'* is the value of the Shannon index.

Finally, for the analysis of abundance of some species in communities, the Hill numbers were estimated. This is a series of numbers that allow for the estimation of the effective number of species in a sample, i.e. a measure of the number of species when each species is weighted according to its relative abundance (Moreno, 2001). In the Hill numbers, the most important numbers are as follows:

N0 = total number of species (S)

N1 = number of abundant species = $e^{H'}$, being H' the Shannon index.

N2 = number of very abundant species = 1/λ, being λ the Simpson's index.

They are found in units of numbers of species, even if the value of N1 and N2 may be hard to interpret. The higher the number of species, the lower the importance given to rare species, and the lower the values of N1 and N2.

- **Bioindicators**

The bioindicator nature or process of registered taxa was analyzed according to Pinilla (2000) and Ramírez (2000), considering certain limitations due to the degree of taxonomic resolution to genus and higher levels, given that different species in the same genus or family may have different levels of tolerance to habitat conditions.

The pollution biotic indexes described below were estimated to determine the quality of the bodies of water based on hydrobiological communities.

§ **Periphyton**

The Palmer and Pampean Diatom (IDP) indexes were estimated.

The Palmer index –designed to estimate organic population– derives from the sapreobic index designed by Pantle and Buck, which groups species together according to their pollution levels. It is estimated based on the following formula (Lucursi and Gómez, 2003):

$$S = \frac{\sum_{i=1}^{n} s_i h_i v_i}{\sum_{i=1}^{n} s_i h_i}$$

Where,

$s_i$ = saprobic valence of the species (the level of tolerance of a species to organic pollution (it fluctuates between 0 and 4).

$v_i$ = value indicator of the species (it fluctuates between 0 and 5).

$h_i$ = abundance of the species.

The resulting values are interpreted in the table below (**Table 2.48)**

**Table 2.48 Water Quality Classification using Palmer Index.**

| INDEX VALUE | POLLUTION LEVEL |
|---|---|
| 1,0 – 1,5 | Absence of pollution |
| 1,5 – 2,5 | Weak organic pollution |
| 2,5 – 3,5 | Moderate organic pollution |
| 3,5 – 4,0 | Strong organic pollution |

Source: Pinilla, 2000.

The Pampean Diatom (IDP) index was designed to assess eutrophication and organic pollution in rivers and streams, according to diatom communities (Bacillariophyta). It is estimated with the following formula (Gómez and Lucursi, 2001):

$$IDP = \frac{\sum_{j=1}^{n} I_{idpj} \times A_j}{\sum_{j=1}^{n} A_j}$$

Where,

$I_{idp}$ = IDP value for the species (it fluctuates between 0 and 4)

$A_j$ = Relative abundance of the species.

This index varies between zero and four, with values below 0.5 being a very good quality indicator, and values greater than 3 indicate very bad quality (**Table 2.49**).

**Table 2.49 Pampean Diatom and Water Quality Ratio and Degree of Athropogenic Disturbances.**

| INDEX VALUE | WATER QUALITY | WATER CHARACTERISTICS | DISTURBANCE DEGREE | COLOR |
|---|---|---|---|---|
| 0 – 0,5 | Very good | No pollution, natural state, few nutrients, and little organic enrichment | Minimum: low human influence | |
| >0,5 – 1,5 | Good | Slight pollution and eutrophication, low levels of nutrients and organic matter. | Minor: extensive livestock and agriculture. | |
| >1,5 – 2 | Acceptable | Moderate pollution and eutrophication: high concentrations of nutrients and organic matter. | Moderate: industrial activity and/or intensive livestock. | |
| >2 – 3 | Bad | Strong pollution and eutrophication, presence of partially deteriorated organic matter, nitrites, ammonium and amino acids | Strong: intensive agriculture and livestock, industrial activity and population density. | |
| >3 – 4 | Very bad | Very strong pollution and eutrophication, high concentrations of organic matter, predominance of reduction processes and presence of industrial products. | Very strong: intensive industrial activity and significant population density. | |

Source: Gómez and Lucursi, 2001.

§ **Aquatic macroinvertebrates.**

Three quality indexes were analyzed for this community: BMWP adapted to Colombia, ASPT and IB.

The Biological Monitoring Working Party (BMWP) index was conceived as a simple and quick method to assess water quality with macrovertebrates as bioindicators, and for its application it is only necessary to reach the family level and data are qualitative, i.e. with data on presence or absence of organisms. This index helps estimate the quality of an aquatic ecosystem based on the assessment of species living therein, according to the assignment of a given value to each species according to their level of tolerance to pollution, from 1 to 10; so the most tolerant families get the lowest number compared to those requiring better water quality in their habitats (Álvarez-Arango, 2005). This index was adapted to Colombia by Roldán (2003) by the name of BMWP/Col, as an approach for the assessment of aquatic ecosystems in mountains.

For estimation, it is necessary to add the number assigned to each family as per their level of tolerance to pollution, and the product is the index value. The higher the sum, the lower the pollution in the analyzed area (**Table 2.50**).

**Table 2.50 Water Classification and Ecological Meaning per the BMWP Index.**

| CLASS | QUALITY | VALUE OF BMWP | MEANING | COLOR |
|---|---|---|---|---|
| I | Good | >150 | Very clean waters | |
| | | 101 – 120 | Unpolluted waters | |
| II | Acceptable | 61 – 100 | Slighted polluted waters: pollution effects are seen | |
| III | Doubtful | 36 – 60 | Moderately polluted waters | |
| IV | Critical | 16 – 35 | Very polluted waters | |
| V | Very critical | <15 | Significantly polluted waters; critical situation | |

Source: Álvarez-Arango, 2005.

The average score per taxon (ASPT) is also a very useful index for water quality assessment. It is estimated by dividing the total score of BMWP by the number of classified taxa, which expresses the suggestion average of water quality for macroinvertebrate families at a given site (Álvarez-Arango, 2005). The ASPT values are between 0 and 10. A low ASPT value associated with a low score of BMWP will indicate serious pollution conditions (**Table 2.51**).

**Table 2.51 Water Classification and Ecological Meaning per the ASPT Index.**

| CLASS | QUALITY | VALUE OF BMWP | MEANING | COLOR |
|---|---|---|---|---|
| I | Good | >9 – 10 | Very clean waters | |
| | | >8 – 9 | Unpolluted waters | |
| II | Acceptable | >6,5 – 8 | Slighted polluted waters: pollution effects are seen | |
| III | Doubtful | >4,5 – 6,5 | Moderately polluted waters | |
| IV | Critical | >3 – 4,5 | Very polluted waters | |
| V | Very critical | 1 – 3 | Significantly polluted waters; critical situation | |

Source: Álvarez-Arango, 2005.

Finally, the family biotic index, developed by Hilsenhoff (1988) is equivalent to indexes above, but its value derives from the fact that it considers the proportional abundance of the registered families. The following formula is applied:

$$IBF = \frac{\sum n_i T_i}{N}$$

Where,

$n_i$ = number of individuals per taxon.

$T_i$ = weighting value assigned to each taxon.

N = total number of individuals in the sample.

The weighting value is the same as values for the and ASPT indexes. The index values show an inversely proportional relation to good water quality, and directly proportional to the degree of organic pollution. **Table 2.52** below shows the assessment scale for water quality according to this index.

**Table 2.52 Classification and Pollution Degree of Water Quality using Hilsenhoff Family Biotic Index (FBI).**

| BIOTIC INDEX | WATER QUALITY | POLLUTION DEGREE | COLOR |
|---|---|---|---|
| 7,26 – 10,0 | Excellent | Apparently no organic pollution | |
| 6,51 – 7,25 | Very good | Slight organic pollution | |
| 5,76 – 6,50 | Good | Moderate organic pollution | |
| 5,01 – 5,75 | Average | Average organic pollution | |
| 4,26 – 5,00 | Average – poor | Significant organic pollution | |
| 3,76 – 4,25 | Poor | Very significant organic pollution | |
| 0,00 – 3,75 | Very poor | Serious organic pollution | |

Source: GEOCOL CONSULTORES S.A., 2017.

Also, pollution indexes were compared to hydrobiological indexes for assessment of the conditions of each source of water in connection with the various types of pollution.

### 2.3.3 Methodology to Characterize the Socioeconomic Component

The socioeconomic component characterization responds to the need to implement a participative process, where the community's knowledge of the territory, cosmovision, culture, economy, social relations, and other aspects were incorporated into the survey elements and analysis by the professional experts.

Therefore, meetings were scheduled for the first awareness period with the 4 town halls, and 28 rural districts or minor territorial units that are initially part of the area of influence of the project. These awareness meetings were developed between February 21 and March 3, 2017.

Awareness meeting calls were notified by letter to the presidents of the boards of minor territorial units and to the municipal authorities of major territorial units. There were also telephone and personal contacts, and fliers and posters were delivered in such places where information was provided on the time and date for previously scheduled meetings with the presidents of the community boards.

After this initial activity, a field search activity was carried out for collection of primary data on each territorial unit –both minor and major units–; the rural district record was completed; the existing social infrastructure points were surveyed, such as churches, education and healthcare centers, and community rooms. This field search was conducted during 10 days: between February 24 and March 5, 2017.

Meetings were scheduled for the second awareness period, during which a workshop was provided on the impact on the 28 rural districts or minor territorial units of the area of influence, for 7 days. These meetings were held between March 23 and March 29, 2017.

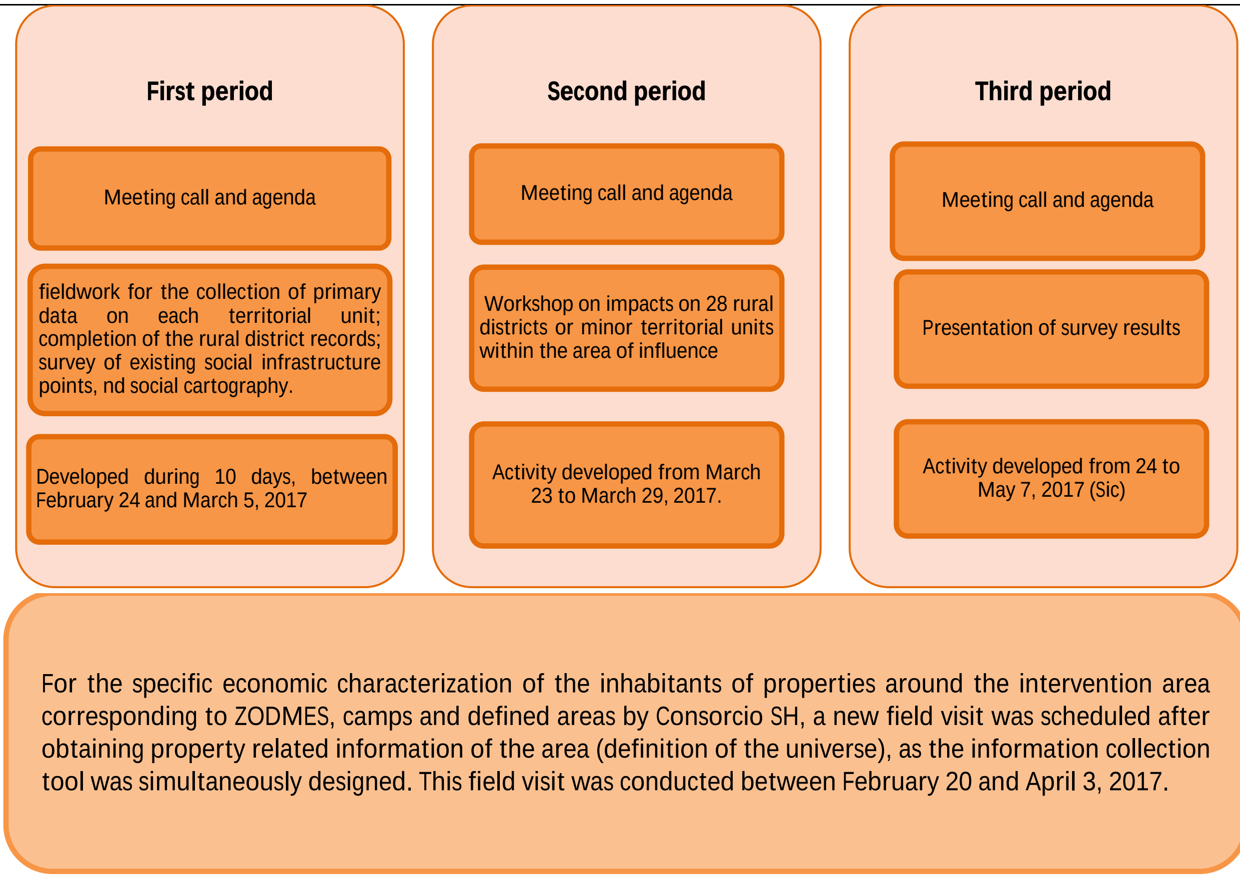
As regards the economic characterization of the population in the area of influence of the project, a new field visit was scheduled after obtaining property related information of the area to define the universe, as the information collection tool was simultaneously designed. This visit was conducted between February 20 and April 3, 2017.

The third and last awareness period –in which the survey results were presented– took 14 days: between 24 - May 7, 2017 (Sic). In order to provide communities with this information, a sort of master class was developed, during which attendees were able to give their opinions and talk about their concerns, which were settled by professionals from Geocol Consultores S. A and Consorcio SH. See **Picture 2.34**

**Picture 2.34 Third Period - Results in the Minor Territorial Units**

Source : GEOCOL CONSULTORES S.A, 2017

**Figure 2.13 Data Collection Scheme**




Source: GEOCOL CONSULTORES S.A 2017

The socioeconomic characterization of nonethic communities was developed according to the terms of reference for the preparation of the Environmental Impact Assessment –EIA– in road and/or tunnel building projects, issued by the Ministry of Environment and Sustainable Development. Following is the implemented methodology.

#### 2.3.3.1 Work before field search.

This activity helped create a vision, in general and institutional terms, of the economic, social, and cultural conditions of the population around the survey area –both minor and major territorial units.

**Table** 2.53 below shows the corresponding components and sources consulted with the different institutions. The specificity of data provided by them helped diversify the information, and improve the quality of statistical and community analysis data relating to the project.

**Table 2.53 Sources of Information on the Socioeconomic Base.**

| COMPONENT | SECONDARY SOURCE | OTHER SOURCES |
|---|---|---|
| Demographic dimension<br>Spatial dimension<br>Economic dimension | National Administrative Department of Statistics - DANE,<br>Territorial entities and other sources of secondary data. | Land Use Planning of the Municipality of Ipiales: 1998-2000<br>Land Use Planning Scheme of:<br>Municipality of El Contadero: October 2001.<br>Municipality of Iles: November 2003<br>Municipality of Imues: June 2004<br><br>Municipal Development Plans 2016 -2019.<br>Ipiales: "Ipiales Capital del Sur" [Ipiales, Capital of the South]<br>Contadero: "Trabajemos juntos por el Rescate y el Progreso de El contadero"<br>[Let's work together on the rescue and progress of El Contadero]<br>Iles: "Con Equidad y Compromiso Social Vivir Dignamente es Posible"<br>[Upon equality and social commitment, living with dignity is possible]<br>Imues: "Imues con un mejor Futuro" [Imues with a better future] |
| Cultural dimension | Primary data,<br>Colombian Institute of Anthropology and History – ICANH,<br>INCODER, Ministry of Culture and Ministry of the Interior | Existing studies on the project area, research centers (university, others), NGOs and<br>Indigenous and Afro-Colombia Associations. |
| Archeological aspects | Primary data, Ministry of Culture, and Colombian Institute of<br>Anthropology and History<br>– ICANH. | Existing studies on the project area, research centers (university, others) |
| Administrative political dimension | Territorial entities, DANE,<br>IGAC and primary data. | Land Use Planning of the Municipality of Ipiales: 1998-2000 |

| COMPONENT | SECONDARY SOURCE | OTHER SOURCES |
|---|---|---|
| Development trends | | Land Use Planning Scheme of:<br>Municipality of El Contadero: October 2001.<br>Municipality of Iles: November 2003<br>Municipality of Imues: June 2004<br><br>Municipal Development Plans 2016 -2019.<br>Ipiales: "Ipiales Capital del Sur" [Ipiales, Capital of the South]<br>Contadero: "Trabajemos juntos por el Rescate y el Progreso de El contadero"<br>[Let's work together on the rescue and progress of El Contadero]<br>Iles: "Con Equidad y Compromiso Social Vivir Dignamente es Posible"<br>[Upon equality and social commitment, living with dignity is possible]<br>Imues: "Imues con un mejor Futuro" [Imues with a better future] |

Source: GEOCOL CONSULTORES S.A., 2017.

§ **Cartographic and other reviews**

Other available resources such as maps, satellite images, Google Earth images and aerial images were reviewed to identify the communities that are part of the area of influence.

### 2.3.3.2 Field search

- **Planning**

For the identification of municipalities, municipal authorities, social stakeholders present in the area of influence of the project, and creation of the preliminary social maps of the survey area, a tour was taken in the first place throughout the municipalities or major territorial units covering the project area to verify the potential territorial expansion of population areas with urban infrastructure of the municipalities and villages contemplated within the area of influence of the project.

Then, the social stakeholders were identified. Field activities were scheduled and the awareness meetings were prepared. For this purpose, information to be provided to the local municipal authorities and communities for awareness was prepared (presentation, posters and fliers).

This information was notified through letters of invitation intended to call the authorities and communities for an awareness meeting relating to the preparation of the Environmental Impact Assessment, posters and invitation fliers, which were posted at strategic sites with large flow of individuals. It is to highlight that during the field search public mass call mechanisms were designed so that the company could attend these awareness processes, such as broadcasting.

Likewise, other mechanisms used during this awareness process included information transmission by means of fliers delivered to community leaders notifying of the topics to explain, as well as the "word of mouth" campaigns implemented by the community to discuss community related matters.

Thus, according to the terms of reference, three periods were implemented for the development of the engagement guidelines concerning this awareness process:

- Project Awareness.
- Impact workshops and management steps.
- Workshops for the presentation of results.

- **Awareness**

The first awareness sessions in the field were held with the local authorities of the major territorial units and communities from minor territorial units to disseminate information on the scopes of the project and the Environmental Impact Assessment, as well as the contents of this EIA according to the terms of reference and activities relating to the collection of primary and secondary data, focused on the effort of the consulting team in the field.

On the other hand, these authorities and communities engaged in the information collection activities from the socioeconomic and population related perspectives in connection with the social behavior of the inhabitants and specificities. This information was based on the municipal development as well as on information previously provided by these entities, and data contained on the rural district records completed with the communities.

Then, the environmental impacts were identified and the communities were asked about their prevention, mitigation, correction and compensation measures that may apply to the project. These results were collected and incorporated into the survey. Such results correspond to proposal submitted by the community during the second period of awareness. Finally, the third meeting was held, during which the survey results were presented.

- **Data collection**

As regards secondary data, the local administration entities of each municipality (major territorial units) were approached, specifically planning units, the health secretary's office, education and SISBEN, with the following documents being obtained: Municipal Development Plans, Land Use Planning Plans and Schemes, General Demographic Stats by SISBEN, and epidemiological profiles, among other documents. Also, other sources of information were consulted, such as DANE general census 2015, and DANE's website on ethnic groups; department and municipal development plans of the 3 municipalities contemplated in the survey area; lists of indigenous communities and Afro-descendant associations prepared by the Ministry of the Interior and Justice; the National Planning Department's website, among others.

For the collection of primary data, outreach activities were developed with community leaders in the minor territorial units so that they could be notified of the work to be developed within the area, and ask them for the data necessary for the socioeconomic characterization by developing various activities to such end.

**Picture 2.35 Data Collection. Rural District: San José de Quisnamuez. Coordinates Magna Sirgas West Zone: E 953981 N 596583**

**Picture 2.36 Social Cartography Drawing at Rural District of San José de Quisnamuez. Coordinates Magna Sirgas West Zone: E 955093. – N 601279**

Source: GEOCOL CONSULTORES S.A., 2017.

**Picture 2.37 Social data collection in the rural area**

| Data survey. Rural District: Iscuazan<br>Coordinates Magna Sirgas West Zone: E 949759 N 596130 | Social Cartography Drawing. Rural District: Pilcuan Viejo<br>Coordinates Magna Sirgas West Zone: E 955391 N 604935 |
|---|---|
|  |  |

Source: GEOCOL CONSULTORES S.A., 2017.

The Rural District record is completed to get information on demographic, spatial, economic, cultural, administrative political information, as well as development trends and archaeological trends.

This record includes in the first part, the general data of the Community Action Board such as president and contact details; this is followed by the population process, and historical backgrounds of the Rural District. Then, it includes information on public utilities and social services, followed by financial information, including livelihood related activities. Then, information on holidays and traditions. Finally, it includes the administrative political organization and development trends relating to the activities and projects developed in the communities. (See **Annex 13. Social**)

In addition, the socioeconomic record was specifically implemented for properties bear the intervention zone, corresponding to ZODMES, camps and defined areas by Consorcio SH for the development of the project. It was completed in order to get accurate socioeconomic data related to the social units of the area.

Social maps (being this a conceptual and methodological proposal that contributes to the development of comprehensive knowledge of the territory) enabled communication processes among participants by drawing, which shows the inhabitants' knowledge of their territory, as seen in the photographic evidence taken during the field search. As referred to in Source : GEOCOL CONSULTORES S.A, 2017 above, this activities was carried for 10 days, between February 24 and March 5, 2017.

On the other hand, for the social cartography activity, participants, using a piece of paper, drew a sketch of their territory, identifying bodies of water, crops, infrastructure, existing pollution points therein, with color markers for reference.

#### 2.3.3.3 After fieldwork

This project phase begins with the tabulation and organization of the collected materials in the field (rural district records, socioeconomic data, photographic evidence, georeferenced data, social cartography, impact matrixes).

After the data has been tabulated, charts and tables are created for easier data analysis, and the photographic evidence and secondary data necessary for the development of the document are listed.

Internally, for the preparation of the assessment, zoning, Environmental Management Plan and other chapters, meetings are held for review, analysis thereof and agreement thereupon.

### 2.3.4 Methodology for the Demand, Use and/or Affectation of the Natural Resources

Considering the project characteristics, the following permits were applied for: surface water, waste dump, channel occupation, forest use, atmospheric emissions and construction materials.

As a result of the above, in defining the demand for natural resources, the project activities and the need to use natural resources were analyzed, for which purpose the methodological process below was prepared and followed.

- **Identification of work or activity requiring the relevant natural resource.**
- **Need of that recourse.**
- **Determination of whether obtaining a permit or concession is mandatory.**
- **Determination of permit or concession (amount).**
- **Identification of authorized suppliers (as for the construction materials).**

- **Surface water harvesting**

For the surface water harvesting request, the water sources that might have a significant water flow for harvesting were identified. Variables considering to determine the harvesting areas in surface currents were as follows:

- Hydrological context
- Availability of this resource during the year seasons
- Required water level for the project
- Access to the water current
- Current and potential water use conflicts

After the characterization of the above by conducting a hydrological and water quality survey, the net supply level of these bodies was determined for the requested season, and the supplying capacity was verified. Once identified these aspects, the infrastructure of the water harvesting, transportation and storage system was described.

- **Waste dumping**

  - **Waste dumping in bodies of water**

Dumping strips were validated through bathymetries, tracer testing, and flow capacity. Similarly, physicochemical, bacteriological and hydrobiological monitoring activities were carried out at the strips or dumping sites. Then, with results being in the lab, the assimilation capacity of the surface source was determined, according to the provisions laid down in Decree 1076 of 2015, to hold, before the environmental authority, the dumping feasibility, using a mathematical model (software Qual2K), which will simulate the behavior of the physicochemical parameters of the receiving body of water in three scenarios (without treatment, with generated and treated dumping, and maximum treated waste to dump).

Finally, the treatment system, water flow, dumping characteristics (continuously or intermittently), class, dumping quality, and type of structure for dumping were described.

  - **Waste dumping on the ground**

A physicochemical characterization was carried out for the disposal of waste water in Solis, by collecting samples at each diagnostic horizon per model profile and cartographic unit of Solis. The parameter analysis were conducted by MCS Consultoría y Monitoreo Ambiental, and the infiltration tests were developed by Geocol Consultores S.A.

The analysis of physicochemical parameters was required by the dumping modeling and water flow and concentration of substances of environmental interest in both residential and industrial waste water. The dumping modelling in Solis was created with HYDRUS 1D (Šimůnek et al., 2012), version 4.15, which numerically solves Richards equation for water flow in porous means with variable saturation, as well as advection dispersion equations for transport of solutes.

- **Channel occupation**

Channel occupation requests were based on the specific requirements of the project's road design as considered for the environmental license formality.

- **Forest use**

For the purposes of determining the for the volume of forest use in forests to intervene for the appropriate development of the project, samples of natural covers liable to forest use were collected (dense forest, riparian forest, high secondary vegetation), satisfying 95% with a sampling error below 15% for each cover. Additionally and for the purposes of estimating the volume of isolated trees, an inventory of the entire vegetation was developed (census) within the areas contemplated for the Zodmes construction, which are distributed throughout the intervention area. This activity consisted in identifying each sawtimber (DBH > 10 cm), marking and data collection: common name, DBH, total height and trade height, and location coordinates, Magna Colombia West Zone, (**Annex 9. Flora**). Data was collected using field forms (**Annex 9. Flora**), and subsequently digitized and treated at the office.

Floral species were identified according to the APG III16 classification system and the aforementioned methodology implemented for the characterization of natural vegetation covers.

**Picture 2.38 Vegetation inventory within the intervention area of the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment.**

Source: GEOCOL CONSULTORES S.A., 2017.

The level of threat was verified for species included in the inventory, and then compared to lists of threatened floral species in Colombia issued by the Ministry of Environment, Housing and Territorial Development by Resolution No. 383 of 2010, Resolution 192 of 2014, the red books of the Humboldt Institute. Found individuals of species reported by these sources were classified into three size categories (sawtimber, pole and sapling), georeferenced, marked and photographed for evidence.

After obtaining data on these individuals, the volume of timber to remove for the referred works was estimated, as well as the basal area of each individual per floral unit. Then, volumes were estimated using the following equations.

The total volume of timber was estimated according to the following equation:

V= Basal area x total height x shape factor (0,7)

The volume of trade timber was estimated according to the following equation:

V= Basal area x trade sawtimber height x shape factor (0,7)

- **Atmospheric emissions**

[16] **Haston, E., J. E. Richardson, P. E. Stevens, M. W. Chase & D. J. Harris**. 2009. *The Linear Angiosperm Phylogeny Group (LAPG) III: a linear sequence of the families in APG (III)*. Bot. Journ. Linn. Soc. Lond. 161: 128-131.

The sites where camps will be deployed were validated, which corresponds to the emission sources for the project. Likewise, potential receiving parties were identified and an air quality monitoring plan was prepared based thereupon. Afterwards, having the lab results, pollution dispersion was determined considering the provisions of Decree 948 of 1945, and Resolution 619 of 1997, to hold, before the environmental authority, the dumping feasibility, using a mathematical model (software AERMOD), which will simulate the behavior of dispersion of pollutants in the area of influence.

### 2.3.5 Methodology for Environmental Assessment

For the purposes of learning about the environmental conditions of the zone, an environmental impact assessment was conducted in respect of activities without project, i.e. activities carried out by the community of the area of influence, and activities to be carried out for the road project (scenario with the project). The implemented methodology consisted in assigning values to a series of attributes that describe the significance of the environmental impact, developed by Vicente Conessa Fernández, 2010. Following is the description of steps taken to assess the environmental impacts for both scenarios.

- **Identification and classification of environmental impacts**

In the initial phase, the survey activities were analyzed, and resources required by each activity were defined. The, based on the foregoing, impacts and effects were identified, which might be caused by the project and, for the scenario without project, activities developed in the survey area were defined as well as their effects on the environment for an approach to potential impacts. The double entry matrix was the implemented tool in both cases.

In addition, the implemented methodology for the environmental impact assessment includes in its assessment criteria those deemed as cumulative, as described in Decree 2041 of October 15, 2014 of the Ministry of the Environment and Sustainable Development (MADS).

The identification and classification process was developed following these general steps:

**Identification of the project activities**: a brief description of every activity carried out by the community (scenario without the project) and activities carried out for the project.

**Characterization of the area of influence of the project:** based on the abiotic, biotic and socioeconomic baseline information, a diagnostic of the current state of the survey area and its current socio-environmental issues is made.

**Definition of the required natural resources**: the needs to use the natural resources required by activities performed or expected in relation to the survey are identified.

**Inventory of generated waste by the activity**: a list of the type of generated waste by activities relating to the different processes in connection with the scenario without/with the project (domestic, industrial, special waste), which may have negative impacts on the environment.

**Definition of the significance of environmental impacts and effects:** to establish the significance of environmental impacts a matrix form is filled out listing the activities, environmental aspects, identified impacts caused by them, and then this data is compared against the assessment criteria (See **Table 2.54**).

After identifying and assessing these impacts, they are compared to the Environmental Management Plan so as to set their corresponding management actions, whether for prevention, mitigation, correction and/or offset.

- **Environmental Impact Significance Assessment (EIS)**

The environmental importance is assessed according to the Nature, Intensity, Duration, Frequency, Recoverability, Reversibility, Time, Effect, Resilience, Synergy and Accumulation criteria, which are assessed according to **Table 2.54** below.

The values of the **ENVIRONMENTAL IMPACT SIGNIFICANCE** are estimated based on the weighting of values for the criteria referred to in the preceding paragraph.

**Table 2.54 Criteria for the Environmental Impact Significance Assessment (EIS)**

| ATTRIBUTE | DEFINITION | SCALE | RANGE |
|---|---|---|---|
| **Nature or Character (C)** | It is the benefit (+) or damaging (-) nature of the different actions acting on the various related factors. | Beneficial<br>Damaging | (+)<br>(-) |
| **Intensity (INT)** | It is understood as the level of effect of an action on the specific environmental item.<br>**Low**: its effect is only a minimal modification in the assessed socio-environmental element.<br>**Medium:** Even if there are changes or modifications, these changes or modifications do not involve a serious effect on the assessed socio-environmental element.<br>**High:** Its effect causes a serious impact on the socio-environmental element.<br>**Very high:** it means a nearly total effect on the assessed socio-environmental element.<br>**Total:** Full damage or alteration of the socio-environmental element. | Low<br>Medium<br>High<br>Very high<br>Total | 1<br>2<br>4<br>8<br>12 |
| **Extension (EXT)** | This refers to the location of effects considering the area of influence of the project, according to the assessed socio-environmental element.<br>**Exact:** where the impacting action causes a very localized effect, i.e. only one intervention site. From the social perspective, it refers to the property level.<br>**Partial:** effects go beyond all | Exact<br>Partial<br>Extensive<br>Total | 1<br>2<br>4<br>8 |

| ATTRIBUTE | DEFINITION | SCALE | RANGE |
|---|---|---|---|
| | of the intervention sites within the area of influence of the project. As to the social environment, it refers to the rural district level.<br>**Broad:** effects extend to the closest sites to the area of influence of the project. From the social perspective, it refers to the municipal level.<br>**Total:** The impact fully covers both the direct and indirect area of influence. For the social item, it covers all of the populations of area of influence. | | |
| **Duration (DUR)** | It means the apparent period of time over which the impact remains after occurrence.<br>**Brief:** where the effect lasts less than one month.<br>**Temporal:** where the effect lasts between 1 and 3 months.<br>**Persistent:** between 4 and 10 months.<br>**Permanent:** where duration is longer. | Brief<br>Temporal<br>Persistent<br>Permanent | 1<br>2<br>4<br>7 |
| **Frequency (F)** | Periodicity means the frequency of the impact sign in the development of the environmental aspect.<br>**Irregular**: the assessed environmental aspect caused the impact unexpectedly or only once over time aspect environmental.<br>**Periodic:** the assessed environmental aspect caused the impact cyclically or recurrently.<br>**Continuo:** the assessed environmental aspect caused the impact constantly over time. | Infrequent<br>Periodic<br>Continuous | 1<br>3<br>7 |
| **Recoverability (RC)** | This refers to the possibility and time to introduce corrective actions or measures to solve caused impacts.<br>**Recoverable:** (immediately or in medium term) an impact which may be removed upon implementation of corrective measures assuming an | Recoverable<br>Mitigable<br>Irrecoverable | 1<br>4<br>7 |

| ATTRIBUTE | DEFINITION | SCALE | RANGE |
|---|---|---|---|
| | alteration that may be replaceable (e.g., where vegetation is removed from an area, fauna disappears; when the area is reforested, fauna will come back).<br>**Mitigable:** an impact which effect may be alleviated upon implementation of mitigation measures (e.g., noise barriers).<br>**Irrecoverable:** an impact which alteration or loss of environment may be repaired (e.g., any cement or concrete work). | | |
| **Reversibility (RV)** | This means the possibility of restoration to initial conditions before the relevant action by natural means, after the action stops affecting the environment.<br>**Reversible:** The affected socio-environmental element returns itself to natural conditions in less than 12 months.<br>**Medium reversibility:** The environmental element takes 1 to 5 years to return to natural conditions.<br>**Irreversible:** The environmental element takes 5 years, or failure to return by natural means to previous conditions will be assumed. | Reversible<br>Medium reversibility<br>Irreversible | 1<br>4<br>7 |
| **Time (T)** | The impact sign is defined based on the period of time between the action and its effect on the assessed socio-environmental element.<br>**Immediate**: If time passed is null.<br>**Medium term**: where the relevant period takes between 1 and 3 months.<br>**Long term:** the impact lasts more than 3 months. | Long term<br>Medium term<br>Immediate | 1<br>2<br>4 |
| **Effect (EF)** | Cause-effect relationship | Indirect<br>Direct | 1<br>4 |
| **Resilience (RS)** | Ability to absorb disturbances, without significantly altering its structure and functional characteristics. | For (-) impacts:<br>High<br>Medium<br>None | <br><br>1<br>2 |

| ATTRIBUTE | DEFINITION | SCALE | RANGE |
|---|---|---|---|
| | **High:** return to original conditions takes less than two (2) years<br>**Medium**: two to fifteen years (2 -15).<br>**Low or null:** over 15 years or never returns to its natural state without management actions.<br><br>**Note:** the Resilience Classification should be consistent with reversibility (RV) for negative impacts | For (+) positive:<br><br>Baja<br>Media<br>Alta | 4<br><br>1<br>2<br>4 |
| **Synergy (SY)** | This means the combination of several impacts that cause bigger effects than generated if occurring independently. | Non-synergistic<br>Synergistic | 1<br>4 |
| **Accumulation (A)** | Impact increases progressively after the activity is performed, when the actions causing it persists continuously or repeatedly. | Noncumulative<br>Cumulative | 1<br>4 |

Source: Vicente Conesa Fernández-Vítora. Methodological guide to assessing the environmental impact. Adapted GEOCOL CONSULTORES S.A. 2017.

- **Environmental significance assessment and determination (EIS).**

Impact assessment is a process that helps define the significance of an impact in an organized manner and, based on this, provide the socio-environmental management actions to take.

The significance of an impact is determined from a correlation of attributes, considering the equation included in **Table 2.55** below, which give a value to the most impactful actions (high negative values), not very impactful (low negative impact) and beneficial (high and low positive values)

According to the foregoing, serious and critical impacts require special management actions; irrelevant or insignificant and moderate impacts require general management actions. Activities that cause critical or unacceptable environmental impacts should be reassessed not because of the impact but from the social and/or environmental project/activity feasibility perspective. **Table 2.55** below shows the different assessment levels derived from the conduction of an environmental impact assessment according to the aforementioned methodological parameters.

**Table 2.55 Hierarchical Ranges of the Impact according to the Environmental Importance (EIS).**

| | | | |
|---|---|---|---|
| **Environmental Significance (ES)** | Environmental impact significance is understood as an action on a given socio-environmental.<br>It is estimated as follows:<br>**ES = +/- ((3 x I) + (2 x EX) + DU + PR + MC + RV + MO + EF + RS +SI + A)** | **Slight or irrelevant impact** | < 33 |
| | | **Moderate Impact** | Between 33 - 51 |
| | | **Serious Impact** | Between 52 - 74 |
| | | **Critical Impact** | > a 74 |

Source: GEOCOL CONSULTORES S.A., 2017.

- **LEVEL OF NEGATIVE GLOBAL INTERVENTION (LNGI)**

The Level of Global Intervention is a value set in percentage terms, which help verify the comprehensive effect level of a project or several activities, considering the minimum and maximum ratings of the assessed environmental criteria.

It is thus a complement to the analysis conducted following an environmental impact assessment methodology which, in this case, is the Methodology of Vicente Conesa Fernández, applied to both scenarios without/with project, as well as to the project.

The Level of Global Intervention is estimated according to this formula below:

$$LGIn = 100\% - \frac{(Max.Int. - Int) * 100\%}{(Max.Int. - Min.Int.)}$$

Where:

- **LGIn** means the level of negative global intervention of the project. (For scenario without the project, this refers t the series of activities carried out to date).
- **Int** means the total level of intervention of the project or activities, derived from adding the negative impacts of all actions (absolute data).
- **Max. Int.** means the maximum negative assessment that may be given to the project or activities (absolute data). (This value corresponds to interactions that would cause negative impacts by the maximum value possible per environmental impact, which corresponds to -100).
- **Min. Int.** means the negative assessment that it may have (absolute data) (this value corresponds to the number of interactions that would have negative impacts by the potential number per environmental impact, which corresponds to -14).

The level of global intervention value should be compared to values listed in **Table 2.56** below to thus mathematically determine which was the most impactful activity socio-environmentally.

**Table 2.56 Impact Assessment and Classification.**

| LEVEL OF NEGATIVE GLOBAL INTERVENTION (LGNI) | CATEGORY |
|---|---|
| 0 – 25 % | Low level of intervention |
| 25.1 – 50 % | Medium level of intervention |
| 50.1 – 75 % | High level of intervention |
| 75.1 – 100 % | Very high level of intervention |

Source: Inter-American Development Bank. Environmental Project Analysis. 2006.

### 2.3.6 Zoning methodology

The zoning methodology for this survey was based on the implementation of concepts, criteria and classifications in respect of physical or abiotic, biotic and socioeconomic and cultural environment variables.

The environmental zoning is operatively developed through a Geographic Information System, into which data resulting from the qualitative and quantitative analysis of prioritized variables in the physical or abiotic, biotic and socioeconomic and cultural zoning were entered for the analysis and determination of environmental sensitivity of the area of influence of the project.

The result of the environmental zoning is the base to establish –together with the environmental assessment of the project– the Environmental Management Zones for activities to develop in order to establish exclusion areas, areas liable to intervention with restrictions, and areas liable to intervention.

### 2.3.7 Economic Assessment Methodology

The economic assessment of environmental impacts was conducted following the General Methodology for the Presentation of Environmental Surveys, number 2.3.2, thus determining the economic assessment process in the Environmental Impact Assessment, and according to the Technical Manual for the Economic Assessment of Environmental Impacts in Projects Subject to Environmental. (CEDE – UNIANDES - MAVDT 2010).

For the project's environmental impact assessment –benefits and costs–, the baseline information, area of influence, environmental impact identification and assessment, and the environmental management plans designed to prevent, mitigate or offset environmental impacts were taken into consideration.

The document contains the identification and classification of positive and negative impacts that may be caused by the project activities on the abiotic, biotic and socioeconomic items.

In this context, the economic assessment starts with the series of impact that, given the value of their environmental significance, have been assessed as serious negative or costly environmental impacts, as well as positive impacts that constitute environmental benefits.

### 2.3.8 Environmental Management Plan Methodology

The ***Environmental Management Plan (PMA)*** was prepared considering the environmental assessment of this project; and based on the identification of the project activities, the likelihood that impacts may be caused on the abiotic, biotic and socioeconomic environments.

The scope of every Environmental Management Plan aims at providing the necessary tools for the good management of elements composing the abiotic, biotic and socioeconomic environments during the development of the project activities. Similarly, such plan complies with the applicable Colombian legal regulations to this type of projects, considering the guidelines set forth in the Terms of Reference for the Preparation of Environmental Impact Surveys in road and/or tunnel building projects, issued by the Ministry of the Environment and Sustainable Development in 2015.

The environmental management plan is introduced together with a series of plans necessary to prevent, mitigate, counteract and offset impacts caused by the project during the different phases. Every identified impact includes their relevant management actions. Therefore, the different plans are presented as index cards containing the following information: objectives, goals, phase, socio-environmental impacts to manage, type of action, measures to develop, indicators, place of implementation, execution manager, required personnel, monitoring and follow-up, beneficiaries, population to benefit, engagement mechanisms and strategies, execution schedule, quantification and costs.

### 2.3.9 1% Investment Plan Methodology

The 1% investment plan was prepared in three phases:

**Phase 1**: Identification of river basins subject to harvesting, eligible activities, and tentative areas.

Harvesting points proposed in chapter 7 hereof, the categorization of the relevant basins, and secondary data thereon were considered for the purposes of identifying the lines of intervention applicable to the 1% investment included in the land use planning and water resource management plans (article 5 of Decree 1900 of 2006, article 2.2.9.3.1.4 of Decree 2099 of 2016 and article 2.2.9.3.1.9 of Decree 2099 of 2016), which leads to the determination of tentative areas where the investment is suggested to be made.

**Phase 2**: Proposed works and activities to perform.

Considering the technical concepts and those suggested in the land use planning and water resource management plans, specific activities were planned in which it was proposed to invest on the resources.

**Phase 3:** Tentative budgets and schedules.

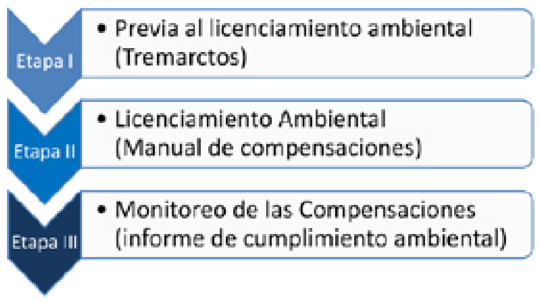
The total amount to invest was estimated according to article 3 of decree number 1900 of 2006. A particular item was assigned to the execution of each action, distinguishing manpower, supplies, and other costs, as well as the corresponding investment schedules.

### 2.3.10 Biodiversity Offsetting Plan Methodology

The biodiversity loss offsetting plan for the Rumichaca – Pasto Divided Highway Project, San Juan - Pedregal Segment, was prepared according to criteria laid down in the Biodiversity Offsetting Manual, adapted by Resolution 1517 of 2012 of the Ministry of the Environment and Sustainable Development (MADS), and the terms of reference for the preparation of the Environmental Impact Assessment for road and/or tunnel building projects, adopted by the MADS by Resolution 0751 of March 26, 2015.

Biodiversity offsetting contemplates three phases in its plan. First, the early phase, using the TREMARCTOS-COLOMBIA; second, the environmental license process, and offset actions are suggested; third, development of monitoring and follow-up activities. This document suggests the first two phases for the implementation of the manual (**Figure 2.14**).

**Figure 2.14 Sector Planning Phases for Biodiversity Offsetting**




Source: MADS, 2012.

In the first phase, early warnings were analyzed with TREMARCTOS COLOMBIA 3.0 to determine whether the intervention area of the project overlaps with the sensitive species distribution zone, with the national, regional or local protected areas, or conservation priority zones. Also, the distribution of offset factors defined for the survey area was analyzed.

In the second phase, the offset factors applicable to the project, search for equivalent ecosystems for offsetting, and the preparation of proposed offsetting actions were defined.

The offset factors were estimated for natural ecosystems and secondary vegetation, taking into consideration that the Biodiversity Offsetting Manual only contemplates the offsetting of these two ecosystems. This assessment was based on the National List of Offsetting Factors, which considers aspects such as representativity, rarity, remanence, and transformation rates for each terrestrial natural ecosystem.

Based on the aforementioned variables and the classification of ecosystems overlapping with the intervention area of the road project, the total offset factors for natural ecosystems and secondary vegetation were set according to the number of individual offset factors; the areas to offset were determined as follows:

- **15+ year natural forests, grasslands and secondary vegetation**

$$Ac = Ai \times \Sigma Fc$$

Where,

Ac = Area to offset in natural ecosystems
Ai= Area to impact by the project development
Σ Fc= Number of offset factors

- **Secondary vegetation under 15 (low secondary vegetation)**

$$Acvs = Ai \times (\Sigma Fc/2)$$

Where,

Acvs= Area to offset in secondary vegetation
Ai= Area to impact by the project development
Σ Fc= Number of offset factors

To define which areas to offset, areas ecologically equivalent to the affected areas were searched for, which, as possible, are part of the area of influence of the project, and liable to effective conservation. For the identification of these areas, the determining criteria below proposed in the biodiversity offsetting manual were met:

a) The same natural ecosystem as the affected ecosystem.
b) Equivalent in size or area to offset to the impacted ecosystem segment.
c) Equivalent or better landscape conditions and context vs the impacted ecosystem segment.
d) Equal or greater species richness vs the impacted ecosystem segment.
e) Within the area of influence of the project.
f) Where not possible, attempts will be made so that the area to offset will be within the same water sub-zone of the project, as close as possible to the impacted area.
g) If the ecologically equivalent area is not found in the same water sub-zone of the project, the surrounding water sub-zones will be considered, as close as possible to the impacted area.
h) Where possible, ecologically equivalent areas will be favored in the municipality where the project is located.
i) If no enough ecologically equivalent areas are found, ecological restoration activities will be carried out. These activities may include landscape management tools (silvopastoral, agroforestry, silviculture activities, etc.) until compliance with the area to offset. The prioritization of these areas will be according to the National Restoration Plan.
j) The currently protected areas by the National System of Protected Areas –SINAP, acronym in Spanish– may be a target offset area if a), b), c) and d) above are met, and if any property and expansion remediation activities are required, provided that ecological restoration or deforestation or deterioration prevention measures are included.

In assessing these criteria, the Ma.F.E v2.0 tool was implemented to map the areas with ecosystems equivalent to those within the intervention area of the road project. On the other hand, the virtual platform of the Colombian Environmental Information System was consulted to identify areas covered by any sort of national, regional or local protection, as well as the conservation priority areas overlapping with or located within the water zone or sub-zone of the area of influence of the project.

Based on the obtained results, the patches and total available area were identified to offset the impacted ecosystems. This information helped determined which offset actions might be the most appropriate, and then the relevant proposal was prepared, which includes various phases, a schedule and general expense, as well as the potential risk assessment in preparing the offset plan.

### 2.3.11 Cartographic methodology

When identifying the secondary data, the Agustin Codazzi Geographic Institute (IGAC) was found to be the main source of information –which is the official entity responsible for the country's cartography. When reviewing this information, the area of influence was found to be covered by 448IC, 448IA, 448IB, 429IIIC and 429IIID at 1:25.000 scale, digital format, in the process to update Colombia baseline cartography at 1:25.000 scale; the harvesting areas was directly obtained using satellite images, as show below in **Figure 2.15.**

**Figure 2.15. Coverage of IGAC Charts at 1:25.000 Scale.**


Source: GEOCOL CONSULTORES S.A., 2017.

There was also information available from other sources of geographic data such as the cartographic data attached to the PBOT documents of the municipalities of the area of influence.

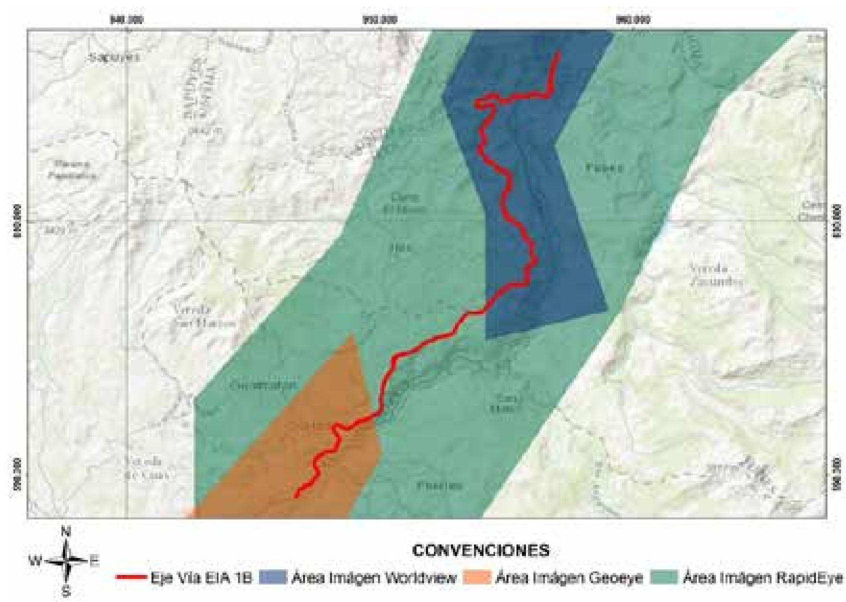
As regards thematic information, this was collected from institutions such as Ingeominas, Ideam, Ministry of the Environment, Regional Autonomous Corporations, Governor's Offices, Dane, Icanh, among others. This information became the preliminary supply for the specialization of the required themes to map in the survey.

Then, the georeferencing and cartographic data capture activities were carried out, thus determine the space of basic and thematic layers according to sources of secondary data.

- **Primary data treatment**

Data deemed as primary were pre-treated in this phase in order to have information to update the basic maps and create the thematic layers. As for remote sensors, World view Multiband –4 bands– images were available, Resolution: 50 cm dated January 19, 2015, and Rapideye multibands –5 bands– spatial resolution 5 m, dated January 27, 2015; thus entirely covering the area of influence for the area of interest of the project (See **Figure 2.16**).

**Figure 2.16. Satellite Images and Coverage.**




Source: GEOCOL CONSULTORES S.A., 2017

The specifications of imagery used to update the baselines cartography are as follows (See **Table 2.57**):

**Table 2.57. Images Used to Update the Baseline Cartography.**

| IMAGE | YEAR | RADIOMETRIC RESOLUTION | SPATIAL RESOLUTION |
|---|---|---|---|
| WorldView | 2015 | 16 bits | 50 cm |
| Geoeye | 2015 | 16 bits | 50 cm |
| Rapideye | 2015 | 16 Bits | 5 m |

Source: GEOCOL CONSULTORES S.A., 2017.

- **Georeference**

The georeferencing process was carried out during this phase in connection with secondary data from different sources. The cartographic data capture of geographic entities of interest –both for baseline cartography and themes– was developed. Topology rules for vector data, attribute addition, element continuity and classification, among others, were taken into account during this process; scale: 1:25.000.

- **Graphic and alphanumeric reports**

The final primary (or base) theme layers were created from captured secondary data and data provided by professional experts. The space and attribute edition was developed in this process for each theme.

Graphic and alphanumeric reports were prepared in a cross-cutting manner in the cartography related process, both for the Before fieldwork phase and the After fieldwork phase. This phase included the preparation of support materials for the document, for presentations, and for the analysis of the environmental and socioeconomic conditions, as well as the production of alphanumeric reports specific to the area of influence of the project.

- **Cartography update based on remote sensing data**

The baseline cartography was updated during this phase following digitizing processes, data capture and readjustment regarding such data captured in the previous phases. Following is a brief description of the main updated geographic entities:

- Simple drainages and bodies of water: the drainage routes and paths were updated based on data from the IGAC sheets at 1:25.000 scale, and other supporting satellite imagery.
- Roads: the road typology of information contained in maps base: 1:25.000 was compared to surveyed data collected by the professional expert from the civil area in the field.
- Administrative limitations: To get the data layer, the different sources of secondary and geographic data available were compared: IGAC 1:25.000 and 1:100.000 maps and PBOT maps of the municipalities of the area of influence.

The creation of the thematic cartography was based on previously treated primary geographic data as well as on the analysis of areas verified in the field according to the criteria of the expert responsible for the field visit.

- **Baseline cartography geodatabase structure**

The baseline cartography geographic database structure was based on the data model proposed by the IGAC, incorporating the updated geographic elements which attributes were completed; sub-types and domain layers were assigned; continuity was verified; symbols were determined; and items included in the cartography deliverables in the Geodatabase were classified.

- **Geoprocessing and spatial analysis of thematic layers – abiotic, biotic and socioeconomic environments**

The synthesis layers of the abiotic, biotic and socioeconomic environments were generated in this phase, which summarize the characterization of the survey area in accordance with the environmental baseline. For this purpose, the variables generated in the previous phases were consolidated through cross-disciplinary spatial analysis and geoprocessing processes developed jointly with experts in each theme.

As regards the abiotic environment, the climate variables were modeled and geoprocessed for the climate zones; the hydrological modelling was developed for basins; physical variables were geoprocessed for geotechnical stability; and spatial analysis tools were implemented for slope determination, among others.

As regards the biotic environment, remote sensing data was interpreted digitally and/or visually; and for the socioeconomic environment, social and physical variables were geoprocessed for archaeological potential, also considering the results of the archaeological survey.

- **Thematic GDB structure – ANLA model**

Based on Resolution 2182 of December 23, 2016, modifying and consolidating the Geographic Storage Model, the Geodatabase was structured by datasets or feature dataset on abiotic, biotic, socioeconomic environments, landscape, project, risks and threats, soil protection and zoning, which data resulted from the previous phases; and their attributive structure was also developed, i.e. after uploading the geometric data, the set of attributes for each layer was completed based on information provided by the professional experts in each theme.

- **Preparation of Thematic Map Deliverables**

Final map deliverables were created according to the parameters set in the General Methodology for the Presentation of Environmental Survey, adopted by Resolution 1503 of August 4, 2010. For this purpose, a map format was designed as well as the symbol representation of each item or cartographic variables included in the Baseline Cartography Database and the Thematic Geodatabase.

To ensure homogeneity and quality in cartographic representations, the ICAG Data Model for Cartography Geodatabases was taken into consideration.

Maps were created using a licensed desktop version of ArcGis 10.0, and include a legend describing each theme prepared by the professional expert in accordance with the characterization of the survey area and the environmental zoning and management chapters.

A folder named MXD containing the map project files (.mdx), and a folder named PDF containing the thematic maps (PDF) for quick view and consultation are the resulting deliverables of this phase.

**Table 2.58 Thematic Maps**

| NUMBER | MAP NAME |
|---|---|
| 1 | General localization |
| 2 | Project infrastructure |
| 3 | Area of physical-biotic influence |
| 4 | Area of socioeconomic influence |
| 5 | Geology |
| 6 | Slopes |
| 7 | Morph dynamic processes |
| 8 | Geomorphological units |
| 9 | Local landscape units |
| 10 | Soils (agrological types) |
| 11 | Current use |
| 12 | Potential use |
| 13 | Conflict of use |
| 14 | Hydrology |
| 15 | Climate zones |
| 16 | Isohyetals |
| 17 | Isotherms |
| 18 | Hydrogeology |
| 19 | Geotechnics |
| 20 | Air quality |
| 21 | Noise |
| 22 | Ecosystem |

| NUMBER | MAP NAME |
|---|---|
| 23 | Land covers |
| 24 | Fauna (vegetation covers-sampling points) |
| 25 | Strategic, sensitive ecosystems, and/or protected areas |
| 26 | Socioeconomic |
| 27 | Zones of archaeological interest and potential |
| 28 | Biotic environment zones |
| 29 | Abiotic environment zones |
| 30 | Socioeconomic environment zones |
| 31 | Total environmental zones |
| 32 | Management zones |
| 33 | Uses |
| 34 | Risk analysis |
| 35 | 1% investment |
| 36 | Monitoring sites |

Source: GEOCOL CONSULTORES S.A., 2017.

- **Metadata**

The cartographic process documentation was prepared by entering metadata in Excel worksheet forms provided by ANLA and regulated by 4611. Geographic metadata was included for each theme and general metadata was entered for each cartographic baseline.

- **Cartographic annex.**

Finally, information regarding the **Cartography Annex** was compiled in a folder containing the following:

- GDB folder: Baseline Cartography Geodatabase and Thematic.
- MXD folder: map files in .mxd format.
- PDF folder: maps in .pdf format.
- SUPPLIES folder: all of the geographic raster data collected for this survey.
- METADATA folder: generated metadata in .xml format.

### 2.3.12 Professionals who participated in the Preparation of the EIS.

A cross-disciplinary professional team was required for the conduction of this Environmental Impact Assessment.

**Table** 2.59 below shows the details of the team members.

**Table 2.59. List of Professionals who participated in the EIS.**

| NAME | PROFESSION | ACTIVITY |
|---|---|---|
| Néstor Vásquez Pérez | Civil Engineer, Master in Natural Resources Management | Project Manager |
| Adriana Lucia Montealegre Arévalo | Environmental Engineer. Specialization in Engineering Project Management | Physical Coordinator |
| Angelica Iboniee Prada | Biologist | Biotic Coordinator |
| Elsa Ximena Hernández | Social Worker, Specialization in Socio-Environmental Management | Social Coordinator |
| Alcides Aguirre | Geologist, Specialization in Geothermal Energy, Master in Ground Water Hydrology | Physical Leader |
| Nestor Nonzoque | Biologist, Specialization in Environmental Engineering | Fauna Component Leader |
| Daniela Alejandro Camargo | Forest Engineer, Specialization in Environmental Law | Flora Component Leader |
| Luz Adriana Molina García | Forest Engineer | Epiphyte Flora Component Leader |
| Claudia rozo Torres | Anthropologist & Archaeologist. Specialization in Environmental Impact Assessment | Social Leader |
| Jair Felipe Miranda Gómez | Environmental Engineer, Specialization in Water Resources | Project Professional – Environmental Component |
| Andres Felipe Saavedra Orjuela | Environmental Engineer & Civil Engineer | Project Professional – Environmental Component |
| Iván David Páez Montero | Environmental Engineer | Project Professional – Environmental Component |
| Sergio Castaño Ramírez | Environmental Engineer | Project Professional – Environmental Component |
| Kaboj Peralta | Civil Engineer | Project Professional – Project Description |
| Ana Marcela Ricardo Arrieta | Agricultural Engineer, Specialization in Environmental Engineering | Project Professional – Soil Component |
| Wilson Danilo Patiño | Engineering Geologist, MSc. in Water Systems | Project Professional – Physical Component |
| Eldibrando Patiño | Engineering Geologist, Magister in Geotechnics | Project Professional – Physical Component |
| Ana María González | Ecologist, MSc. Biodiversity Conservation and Sustainable Use | Project Professional – Component landscape |
| Natalia Salazar | Forest Engineer, Specialization in Geographic Information Systems | Project Professional – Forest Component |
| Mario Jiménez | Forest Engineer. Specialization in Environmental Project Assessment | Project Professional – Forest Component |
| Erika Ceballos | Agroforestry Engineer | Project Professional – Forest Component |
| Emilsen Ruales | Agroforestry Engineer | Project Professional – Forest Component |
| Leonardo Malagon | Forest Engineer, Master in Agricultural Sciences Entomology | Project Professional – Forest Component |
| Karina Mejia | Forest Engineer, Specialization in Environmental Engineering | Project Professional – Forest Component |
| Guillermo Alberto Reina Rodríguez | Biologist-Botanist - PhD. | Project Professional – Epiphyte Flora Component |

| NAME | PROFESSION | ACTIVITY |
|---|---|---|
| Briyith Díaz Sierra | Biologist | Project Professional – Epiphyte Flora Component |
| Jenny Alexandra Bolaños Guaranguay | Biologist | Project Professional – Epiphyte Flora Component |
| Diego David Mora | Biologist | Project Professional – Epiphyte Flora Component |
| German Téllez | Forest Engineer | Project Professional – Epiphyte Flora Component |
| Mario Andres Suarez | Biologist | Project Professional – Epiphyte Flora Component |
| Astrid Lucero Erazo | Biologist | Project Professional – Epiphyte Flora Component |
| Javier Guarín | Biologist | Project Professional – Component Fauna (mammals) |
| Duberney Garcia | Biologist, Est. MSc. Biodiversity Conservation and Sustainable Use | Project Professional – Component Fauna (birds) |
| Alexandra Estevan | Social Worker | Project Professional – Social Component |
| Pilar Triana | Social Psychologist, Specialization in Environmental Project Assessment | Project Professional – Social Component |
| Yuly Joya | Social Worker | Project Professional – Social Component |
| Claudia Bello | Social Worker, Specialization in Environmental Project Assessment | Project Professional – Social Component |
| Joy Moreno | Social Psychologist | Project Professional – Social Component |
| Lina Arias | Social Communicators | Project Professional – Social Component |
| Magüi Stephania Botero | Political Science, Specialization in Soil Markets and Policies | Project Professional – Social Component |
| Mary Stephanie Torres | Psychologist, Master in Gerontology | Project Professional – Social Component |
| María Alejandra Ibarra | Social Worker, Specialization in Project Management | Project Professional – Social Component |
| Lady Nathalia Vallejo | Psychologist, Specialization in Social Management | Project Professional – Social Component |
| Sandra León | Social Worker | Project Professional – Social Component |
| Laura Mesa | Social Worker, Specialization in Socio-Environmental Management | Project Professional – Social Component |
| Adriana González | Economist | Project Professional – Social Component |
| Oscar Stiven Reyes Muñoz | Topographer | SIG professional |
| Jenny Lorena Soler Orjuela | Teaching Technologist | Document edition |
| MCS consultoría y Monitoreo Ambiental | Laboratory | Water Quality Monitoring |
| Gestión y Medio Ambiente | Laboratory | Quality of Air and Noise Monitoring |

Source: GEOCOL CONSULTORES S.A., 2017.