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## INTRODUCTION

TOUCHSTONE GOLDHING SA TOUCHSTONE COLOMBIA SOCIETY (hereinafter TOUCHSTONE) represented with NIT 900.298.295-1 is a foreign capital company with mainly Colombian human resources dedicated to the development of exploration activities geological, extraction and benefit of precious metals (Annex 1.8).

TOUCHSTONE currently aims to advance to the exploitation phase of the "El Pescado" mining project, in the 6055 and 5969 mining concessions located in the Segovia municipality (Antioquia). The area that buys the area of interest measures one hundred hectares, the current use of the land is mining exploitation, livestock and a small area of crops. For the independence of mining and mineral deposits in the concessions, according to the respective Works and Works Programs (hereinafter PTO) approved by the competent mining authority, for each of the licenses it is necessary to independently acquire an Environmental License ( hereinafter LA) before the Regional Autonomous Corporation of Antioquia (hereinafter CORANTIOQUIA) according to production, supported by an Environmental Impact Study (hereinafter EIA) as required by decree No. 2041 of 2014 of LA and the sole regulatory decree of the environment and sustainable development sector No. 1076 of 2015. Before granting the LA, it is necessary to obtain the Definitive Area Subtraction (hereinafter SDA) of the Magdalena River forest reserve (established by law No. 2 of 1959 and the decree No. 111 of 1959) also independent for each mining of the concessions according to the procedure of resolutions No. 1526 of 2012 and No. 1274 of 2014, and decree No. 23 72 of 2010. This document supports the EIA for the concession contract 5969 (Annex 1.6, Annex 1.7 and Annex 1.9).

Both the environmental studies, geological exploration and the PTO design were developed by different companies from 2003 to the year 2013. During the years 2015 and 2016, the engineering company INGEX GRUPO MINERO SA.S. specialized in providing consulting services to the mining sector in the country, initiates the preparation of environmental studies based on the information collected by the companies TOUCHSTONE, CORPORACIÓN MERCEDITAS and SOLUCIONES AMBIENTALES Ltd. offering a group of integral services in all the needs of the mining project, from the initial stage until the start-up and continuous improvement of the mining operation.

The El Pescado mining project in the 5969 concession object of this study, is focused on exploiting and efficiently benefiting the gold reserves in its entirety in a technified way, according to the current regulations (Law No. 685 of 2001 and Decree No. 1073 2015) in harmony with the environment and sustainable development as stipulated by the regulation of natural resources and protection of the environment (decree No. 2811 of 1974 and No. 1076 of 2015).

The EIA for the mining concession 5969 contract was prepared based on the following regulations:

- Reference terms corresponding to the methodology for the presentation of environmental studies.
- The methodology for defining areas of influence of the Ministry of Environment and Sustainable Development (hereinafter MADS) and the National Environmental Licenses Authority (hereinafter ANLA).
- Current mining and environmental regulations.

## 1 GENERALITY

As a first step, the main generalities concerning the development of the Environmental Impact Study (hereinafter EIA) for the mining project "El Pescado"

### 1.1 BACKGROUND

As presented below. The antecedents of abiotic, biotic and social components during the exploration stage.

The municipality of Segovia has been a town of mining tradition since 1852 when the mining company Frontino Gold Mines was established. Until today, mining represents the main line of the economy in the municipality. The auriferous mineralization of the Antioquia northeast is located mainly towards the eastern sector of the Otú-Pericos fault system, embedded in the so-called Batholith de Segovia, recognized by the amount of mineral resources and potential for mining development. Between 2003 and 2005, the owners of concessions 6055 and 5969 made direct geological, geotechnical and hydrogeological exploration; Specifically, in the coordinates presented in Illustration 1-1 and Table 1-1 Magna Geographical Coordinate System with Bogotá datum and "Transverse Mercator".

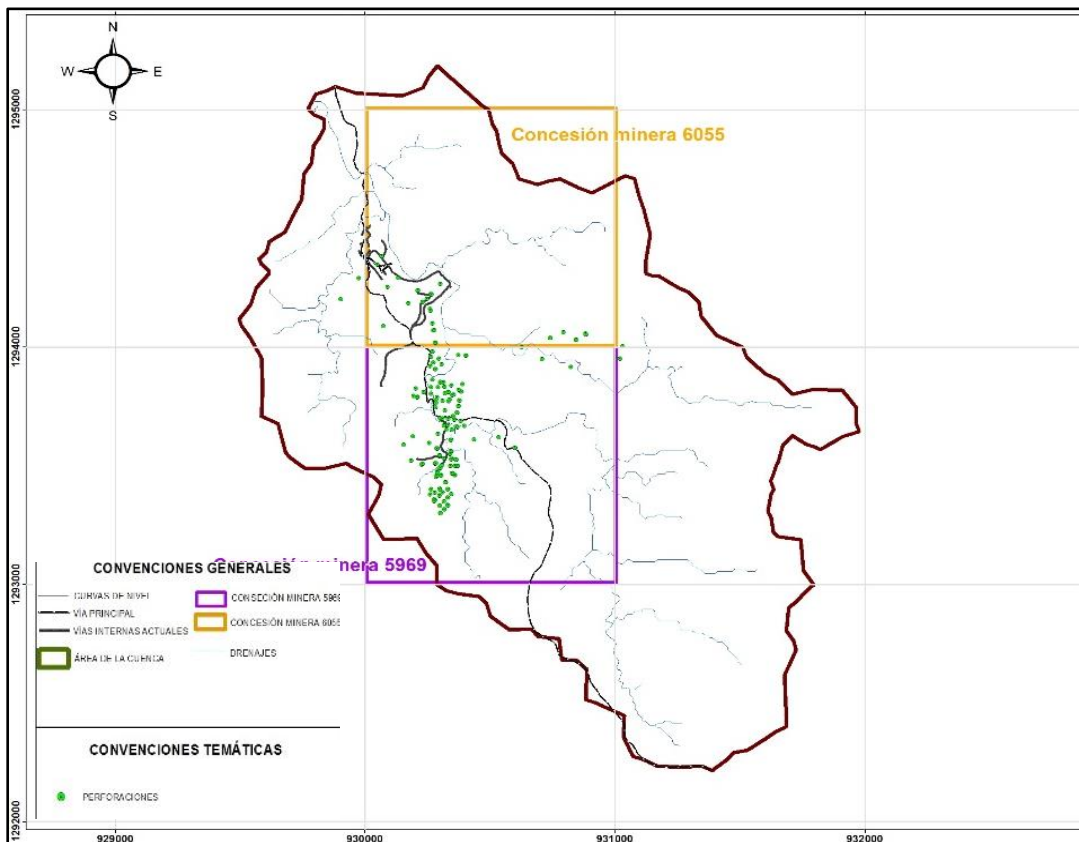


Illustration 1.1 Exploratory mining, geotechnical and hydrogeological drilling  
Source: TOUCHSTONE.

**Table 1.1** Coordinates of exploratory mining, geotechnical and hydrogeological drilling.

Nº	PERFORATION	EAST (X)	NORTH (Y)
1	P1 (Geotechnical & hydrogeological)	929902,1	1294201,4
2	P2 (Geotechnical & hydrogeological)	929974,6	1294290
3	P3 (Geotechnical & hydrogeological)	930073	1294088,1
4	P4 (Geotechnical & hydrogeological)	930088,8	1294253,4
5	P5 (Geotechnical & hydrogeological)	930173,5	1294185,8
6	P6 (Geotechnical & hydrogeological)	930300,3	1294267,4
7	P7 (Geotechnical & hydrogeological)	930203	1293825
8	P8 (Geotechnical & hydrogeological)	930191	1293624
9	P9 (Geotechnical & hydrogeological)	930435,714	1293611,72
10	Deposit explore	930737,213	1294032,38
11	Deposit explore	930735,931	1294031,78
12	Deposit explore	930790,144	1294056,97
13	Deposit explore	930840,162	1294024,89
14	Deposit explore	930841,355	1294025,29
15	Deposit explore	930879,16	1294050,07
16	Deposit explore	930880,947	1294048,08
17	Deposit explore	930878,978	1294047,52
18	Deposit explore	930622,757	1293993,98
19	Deposit explore	930703,751	1293943,97
20	Deposit explore	930819,752	1293910,97
21	Deposit explore	930206,458	1293783,67
22	Deposit explore	930205,044	1293782,26
23	Deposit explore	930284,751	1293781,97
24	Deposit explore	930278,589	1293740,48
25	Deposit explore	930300,751	1293454,97
26	Deposit explore	930264,751	1293856,97
27	Deposit explore	930264,751	1293856,97
28	Deposit explore	930313,127	1293826,08
29	Deposit explore	930313,986	1293825,93
30	Deposit explore	930371,914	1293769,34
31	Deposit explore	930373,914	1293769,34
32	Deposit explore	930380,077	1293807,08
33	Deposit explore	930382,038	1293806,74
34	Deposit explore	930348,03	1293793,36
35	Deposit explore	930349,999	1293793,01
36	Deposit explore	930386,045	1293838,33
37	Deposit explore	930369,751	1293745,97
38	Deposit explore	930371,751	1293745,97
39	Deposit explore	930255,371	1293913,13
40	Deposit explore	930062,41	1294377,12
41	Deposit explore	930062,049	1294376,69
42	Deposit explore	930333,937	1293773,64
43	Deposit explore	930371,064	1293813,73
44	Deposit explore	930340,939	1293832,9
45	Deposit explore	930258,335	1293952,04
46	Deposit explore	930259,316	1293951,87
47	Deposit explore	930347,466	1293702,97
48	Deposit explore	930349,466	1293702,97
49	Deposit explore	930265,728	1293975,03
50	Deposit explore	930268,767	1293929,57
51	Deposit explore	930276,887	1293900,93
52	Deposit explore	930277,754	1293901,07
53	Deposit explore	930277,754	1293901,07
54	Deposit explore	930292,504	1293535,9
55	Deposit explore	930362,616	1293519,49

Nº	PERFORATION	EAST (X)	NORTH (Y)
56	Deposit explore	930360,647	1293519,84
57	Deposit explore	930286,724	1293629,03
58	Deposit explore	930358,563	1293493,17
59	Deposit explore	930358,563	1293493,17
60	Deposit explore	930356,593	1293493,52
61	Deposit explore	930356,211	1293453,65
62	Deposit explore	930354,065	1293454,03
63	Deposit explore	930336,478	1293543,62
64	Deposit explore	930338,199	1293602,45
65	Deposit explore	930341,282	1293602,04
66	Deposit explore	930333,937	1293773,64
67	Deposit explore	930268,767	1293929,57
68	Deposit explore	930365,509	1293717,03
69	Deposit explore	930363,509	1293717,03
70	Deposit explore	930293,724	1293534,37
71	Deposit explore	930295,752	1293535,78
72	Deposit explore	930293,783	1293537,32
73	Deposit explore	930336,751	1293493,97
74	Deposit explore	930336,751	1293493,97
75	Deposit explore	930223,876	1293501,49
76	Deposit explore	930225,156	1293499,78
77	Deposit explore	930223,438	1293498,55
78	Deposit explore	930400,736	1293957,79
79	Deposit explore	930330,388	1293803,86
80	Deposit explore	930329,14	1293804,08
81	Deposit explore	930309,751	1293845,97
82	Deposit explore	930297,335	1293846,04
83	Deposit explore	930297,58	1293846,44
84	Deposit explore	930302,751	1293920,97
85	Deposit explore	930291,751	1293945,97
86	Deposit explore	930365,6	1293655,49
87	Deposit explore	930398,766	1293958,14
88	Deposit explore	930252,381	1293590,2
89	Deposit explore	930342,122	1293555,13
90	Deposit explore	930277,311	1293502,57
91	Deposit explore	930340,152	1293555,47
92	Deposit explore	930276,5	1293503,73
93	Deposit explore	930283,256	1293565,32
94	Deposit explore	930285,061	1293566,79
95	Deposit explore	930282,023	1293566,99
96	Deposit explore	930283,71	1293568,22
97	Deposit explore	930261,58	1294217,27
98	Deposit explore	930259,036	1294216,95
99	Deposit explore	930261,216	1294215,56
100	Deposit explore	930369,751	1293960,97
101	Deposit explore	930346,88	1293462,16
102	Deposit explore	930343,911	1293462,1
103	Deposit explore	930273,575	1293351,54
104	Deposit explore	930274,842	1293350,02
105	Deposit explore	930280,227	1293449,09
106	Deposit explore	930280,227	1293447,09
107	Deposit explore	930344,457	1293522,69
108	Deposit explore	930341,395	1293522,92
109	Deposit explore	930596,739	1293568,87
110	Deposit explore	930595,404	1293568,78

Nº	PERFORATION	EAST (X)	NORTH (Y)
111	Deposit explore	930594,928	1293568,61
112	Deposit explore	930529,739	1293613,95
113	Deposit explore	930264,751	1294093,97
114	Deposit explore	930255,751	1294153,97
115	Deposit explore	930269,751	1294063,97
116	Deposit explore	930277,751	1294011,97
117	Deposit explore	930242,751	1294197,97
118	Deposit explore	930206,751	1294232,97
119	Deposit explore	930207,11	1294233,32
120	Deposit explore	930229,764	1293803,97
121	Deposit explore	930229,764	1293803,97
122	Deposit explore	930280	1293758
123	Deposit explore	930180	1293516
124	Deposit explore	930180	1293516
125	Deposit explore	930128	1294286
126	Deposit explore	930044	1294341
127	Deposit explore	930309,284	1293387,79
128	Deposit explore	930331,181	1293367,02
129	Deposit explore	930296,794	1293375,11
130	Deposit explore	930315,434	1293349,28
131	Deposit explore	930332,333	1293366,95
132	Deposit explore	930278,551	1293386,35
133	Deposit explore	930288,631	1293457,99
134	Deposit explore	930296,718	1293373,82
135	Deposit explore	930259,985	1293379,76
136	Deposit explore	930290,62	1293478,36
137	Deposit explore	930299,206	1293332
138	Deposit explore	930279,956	1293355,78
139	Deposit explore	930284,79	1293510,02
140	Deposit explore	930230,19	1293509,13
141	Deposit explore	930330,549	1293334,21
142	Deposit explore	930264,431	1293401,37
143	Deposit explore	930230,733	1294191,6
144	Deposit explore	930299,515	1293544,45
145	Deposit explore	930260,839	1294154,41
146	Deposit explore	930316,814	1293317,6
147	Deposit explore	930276,489	1294071,76
148	Deposit explore	930331,2	1293333,03
149	Deposit explore	930280,993	1294018,9
150	Deposit explore	930316,909	1293316,46
151	Deposit explore	930276,908	1293352,15
152	Deposit explore	930301,351	1293301,4
153	Deposit explore	930302,197	1293298,86
154	Deposit explore	930298,819	1293331,18
155	Deposit explore	930340,709	1293499,89
156	Deposit explore	930307,931	1293503,84

Nº	PERFORATION	EAST (X)	NORTH (Y)
157	Deposit explore	930345,923	1293527,26
158	Deposit explore	930315,305	1293531,2
159	Deposit explore	930290,921	1293830,66
160	Deposit explore	930263,062	1293830,68
161	Deposit explore	930348,362	1293798,3
162	Deposit explore	930318,838	1293805,8
163	Deposit explore	930332,404	1293672,18
164	Deposit explore	930269,038	1293981,09
165	Deposit explore	930269,038	1293981,09
166	Deposit explore	930193,279	1293794,34
167	Deposit explore	930154,403	1293588,54
168	Deposit explore	930332,477	1293697,52
169	Deposit explore	930347,161	1293650,65
170	Deposit explore	930263,385	1293802,92
171	Deposit explore	930309,414	1293774,25
172	Deposit explore	930309,704	1293699,94
173	Deposit explore	930299,285	1293543,45
174	Deposit explore	930304,159	1293459,72
175	Deposit explore	930314,751	1293670,35
176	Deposit explore	930289,455	1293472,57
177	Deposit explore	930333,696	1293771,47
178	Deposit explore	930284,469	1293777,54
179	Deposit explore	930356,385	1293693,43
180	Deposit explore	930363,811	1293663,79
181	Deposit explore	930382,638	1293688,96
182	Deposit explore	930298,926	1293701,23
183	Deposit explore	930397,06	1293668,99
184	Deposit explore	930347,161	1293650,65
185	Deposit explore	930318,373	1293733,03
186	Deposit explore	930324,964	1293650,67
187	Deposit explore	930322,111	1293430,29
188	Deposit explore	930301,038	1293491,09
189	Deposit explore	930321,37	1293431,14
190	Deposit explore	930300,364	1293492,53
191	Deposit explore	930371,252	1293499,65
192	Deposit explore	930298,054	1293403,02
193	Deposit explore	930298,054	1293403,02
194	Deposit explore	930371,252	1293499,65
195	Deposit explore	930331,396	1293402,26
196	Deposit explore	930297,388	1293401,18
197	Deposit explore	930330,116	1293401,24
198	Deposit explore	930344,399	1293381,9
199	Deposit explore	930309,469	1293389,22
200	Deposit explore	931019,6	1293951,47
201	Deposit explore	931019,6	1293951,47
202	Deposit explore	931030,721	1294003,16

Source: TOUCHSTONE, 2016.

With the data obtained from exploration works, the following information was obtained:

1. Geotechnical parameters.
2. Calculation of mineral resources (gold ore from the deposit or deposit).
3. Geometrical design of mineral resources.
4. Quantification of the cutting tenor.
5. Calculation of mining reserves.

The mining history and the geological-mining potential of the region was one of the main determinants for TOUCHSTONE to acquire the concessions.

In 2008, after conducting a preliminary analysis, TOUCHSTONE entered the village of El Pescado of the municipality of Segovia to develop the following exploration activities (Prospecting or tours without perforations or interventions) confirmatory and complementary type "Brownfield" (Exploration project where previously exploitations and / or explorations have been presented) in the mining concession 5969:

1. Search of bibliographic information.

Search and analysis of bibliographic information available with the objective of learning about old studies in the region.

2. Prospecting or indirect exploration of the subsoil
  - Review of secondary information, photointerpretation and base cartography.
  - Cartographic survey of local and structural geology, for analysis.
  - Topographical survey of old mining works, characterization of structures mineralized and sampling in mineralization, for laboratory analysis.
  - Sampling of active sediments, analysis and geochemical interpretation to identify anomalous zones with mineralization.
  - Indirect exploration with geophysics to know the lithology at depth and anomalous zones with mineralization.

The results obtained by TOUCHSTONE in this phase increased the interest in direct exploration mining (drilling) to size the mineralization at greater depths; for this he requested to the MADS through file No. 4120-E1-35370 the temporary subtraction of area in the forest reserve of the Magdalena River. Through resolution No. 0173 of 2013 and temporary theft is acquired together with a series of obligations.

Subsequently TOUCHSTONE, in communication under file No. 4120-E1-25721 of August 2, 2013 reiterated in communication No. 4120-E1-26148 of August 6, 2013, requests that the terms, obligations and conditions of resolution No. 0173 of 2013 are suspended due to the presence guerrilla in the area subject to the abduction. Attaching copy of certification of July 29, 2013, issued by the secretary general and government of the municipality of Segovia in which he states that "according to the Security Council held on July 15 of this year, it was possible to verify by the police and national army authorities, public order in the following villages: "El Pescado: There is a presence of the narco-terrorist organization Captain Mauricio del ELN (...) Cuturú low, medium and high: there is interference from the 4th front of the Farc..."

In said communication, it is further informed that due to the situation of public order, the company has not been able to carry out the works, authorized activities or comply with the terms, obligations and conditions that were imposed by resolution No. 0173 of 2013. For the above, MADS through Resolution No. 1109 of 2013, temporarily suspends the terms, obligations and Conditions of Resolution No. 0173 of 2013.

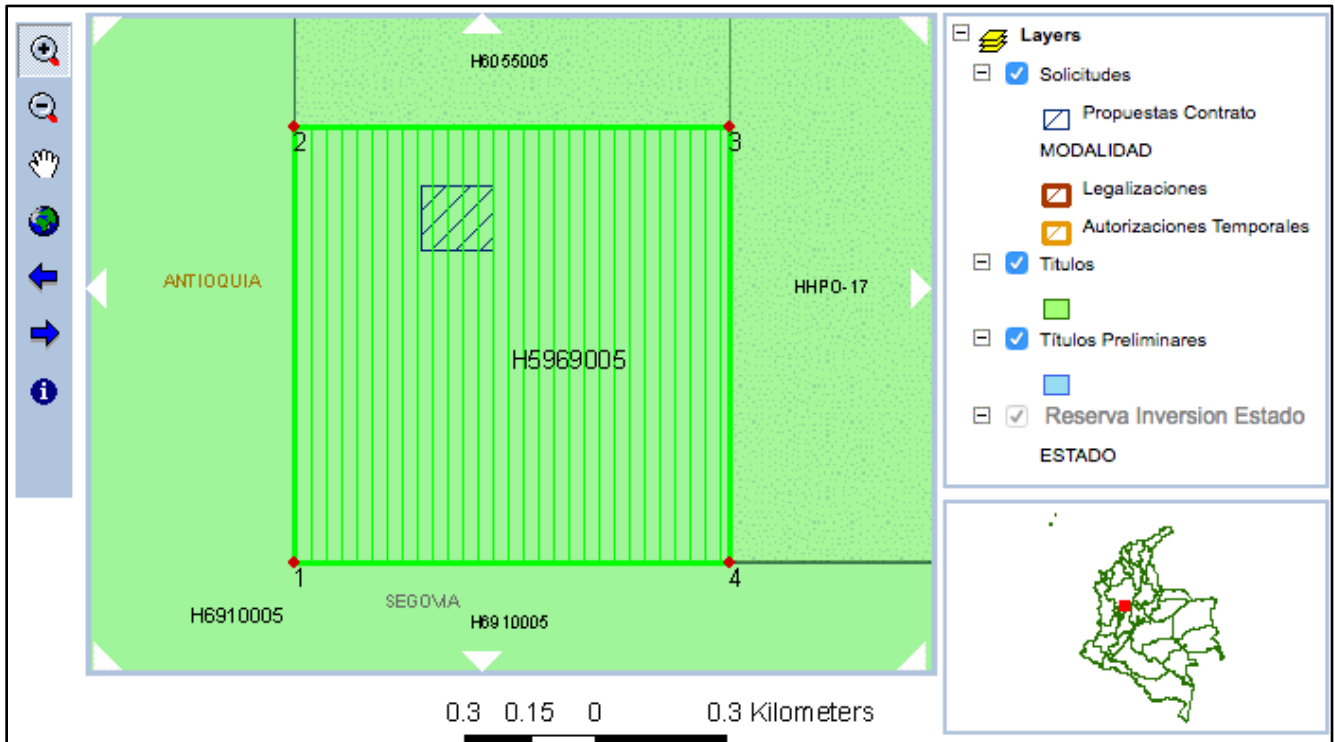
In the years 2012 and 2013 the consulting company CORPORACIÓN MERCEDITAS raised a baseline environmental and social for an Environmental Impact Study and a Subtraction of Temporary Areas; and in the 2015 and 2016 the consulting company INGEX GRUPO MINERO S.A.S redesigned the PTO and complemented At the same time, the environmental studies necessary for the definitive subtraction of area in the reserve forestry and environmental impact studies, which requires the development of the gold mining project El Pescado in the 5969 concession.

In 2015 TOUCHSTONE decides not to perform direct exploration with perforations complementary or confirmatory due to the change of corporate objectives (change of management) that they are oriented to the mining exploitation, with the objective of fulfilling the obligations of the resolutions mentioned and to close the process of temporary abduction. For this, he established office No. E1-2016-015632 (2016) before the Ministry of Environment requesting to close the theft of temporary areas and subsequently request the definitive removal of the El Pescado mining project in the mining concession 5969.

The mining concession 5969, object of this EIA, is registered in the National Mining Registry (hereinafter NMR) under the code HGKL-05 with a total area of 100 hectares (hereinafter ha) for exploration, exploitation and benefit of gold, granted by the ministries secretariat of the government of Antioquia, of according to the provisions of Law 685 of 2001 and the single regulatory decree of the administrative sector of mines and energy No. 1073 of 2015.

The legal mining situation of the 5969 concession is recorded in file H59690005, found on the website of the National Mining Agency (hereinafter ANM), where information is obtained basic information about the owner, mineral concession, validity of the concession and geographical location, as evidence in Illustration 1-2 and Illustration 1-3.





**Illustration 1-2.** Geographic information of the mining concession 5969.  
*Source: NATIONAL MINING AGENCY, 2016.*



Información General					
Código Expediente	H5969005	Clasificación	TITULO	Modalidad Actual	CONTRATO DE CONCESION (D 2655)
Estado Jurídico Actual	TITULO VIGENTE	Grupo de Trabajo	GOBERNACION DE ANTIOQUIA		
Detalle Expediente					
Fecha de Contrato	2006-05-30 00:00:00.0	Fecha Inscripción	2006-06-13 14:58:56.0		
Grupo de Trabajo	GOBERNACION DE ANTIOQUIA	Código RMN	HGKL-05		
Categoría		Código Anterior	5969		
Duración Total Meses	359	Duración Total Años	29		
Observación					
Información de Etapas					
Nombre		Duración Meses			
CONSTRUCCION Y MONTAJE					
EXPLOTACION					

Información de Tareas					
Proceso	Fase	Estado	Fecha Creación		
RADICACION DOCUMENTOS	Digitalizar Documento	NUEVA	2016-05-05 08:51:26.0		
RADICACION DOCUMENTOS	Digitalizar Documento	NUEVA	2016-01-06 14:23:05.0		
RADICACION DOCUMENTOS	Digitalizar Documento	NUEVA	2015-12-28 12:30:45.0		
RADICACION DOCUMENTOS	Digitalizar Documento	NUEVA	2015-12-22 09:31:25.0		
RADICACION DOCUMENTOS	Digitalizar Documento	NUEVA	2015-07-30 16:25:28.0		
RADICACION DOCUMENTOS	Digitalizar Documento	NUEVA	2015-07-29 10:47:02.0		
RADICACION DOCUMENTOS	Digitalizar Documento	NUEVA	2014-08-20 08:59:49.0		
RADICACION DOCUMENTOS	Digitalizar Documento	NUEVA	2014-07-16 11:39:06.0		
RADICACION DOCUMENTOS	Digitalizar Documento	NUEVA	2014-07-21 08:41:06.0		
RADICACION DOCUMENTOS	Digitalizar Documento	NUEVA	2014-04-22 09:54:21.0		
RADICACION DOCUMENTOS	Digitalizar Documento	NUEVA	2014-02-07 14:18:45.0		
RADICACION DOCUMENTOS	Digitalizar Documento	NUEVA	2014-02-14 09:32:20.0		
RADICACION DOCUMENTOS	Digitalizar Documento	NUEVA	2011-07-12 14:57:13.0		
RADICACION DOCUMENTOS	Digitalizar Documento	NUEVA	2011-04-13 14:03:57.0		
RECURSO REPOSICION	Digitalizar Recurso Reposicion	NUEVA	2010-03-30 16:46:40.0		
Información Modalidades					
Nombre	Fecha Creación	Fecha Modificación	Duración		
CONTRATO DE CONCESION (D 2655)	2006-06-13 14:58:56.0				
Información Titulares					
Nombre(s)	Primer Apellido	Segundo Apellido	Razón Social	Tipo Identificación	Número Identificación
JOSE LEONARDO	RINCON	GIRALDO	COLGOLD INC COLOMBIA	CEDULA	3608599
JAIRO	TORRES	JHON		NIT	9000646048
GUSTAVO	SALAZAR	GARCIA		CEDULA	15535666
TOUCHSTONE COLOMBIA SUCURSAL EN COLOMBIA DE LA SOCIEDAD TOUCHSTONE GOLD HOLDINGS S.A.				NIT	9002982951

Información Minerales					
Nombre	Fecha Creación	Fecha Modificación			
METALES PRECIOSOS	2006-06-12 09:20:16.0				
ASOCIADOS	2006-06-12 09:20:16.0				
Municipios Asociados					
Departamento	Municipio	Porcentaje Participación			
ANTIOQUIA	SEGOVIA	100.0			
Información Geografica					
Área Otorgada	1000000.0	Área Definitiva	1000000.0		
Detalle de Áreas					
Sistema Origen	Área	Perimetro	Cota	Punto Arclfinio	Descripción P.A.
BOGOTA	1000000.0	0.0	0	18409	PUNTO UNO DE LA ALINDERACION

Illustration 1-3. General information of the mining file H5969005.  
Source: NATIONAL MINING AGENCY, 2016

From the previous illustrations, it can be seen that the title is duly legalized (See Annex 1.4. NMR).

The social background between 2008 and 2013 shows that TOUCHSTONE developed a good relationship and community strengthening with the direct and indirect influence paths and the local administrations during the exploration stage, through the execution of various projects and programs that benefited the target population (between 250 and 300 people), among them:

- Improvement of educational equipment in the village of Cuturú bajo (low).
- Delivery of school kits for students during the years 2008 to 2013 for 115 children in stage school of the villages El Pescado, Cuturú Abajo (Bajo), Cuturú Arriba (Medio), Laureles and Chorro Lindo (Juan Tereso).
- Adequacy and improvement program for the access road in the Laureles village sector.
- Support with materials or economic resource of community treats for road arrangements.
- Delivery of seeds, tools, fertilizers, fertilizers, agricultural lime and mesh for the enclosure of twenty-five (25) home gardens.
- Economic support for celebrations of special dates such as Mother's Day, Father's Day, peasant, child and Christmas where about 50 people participated for celebration.
- Educational workshops for the population El Pescado and Cuturú Arriba (Medio), Abajo (Bajo) and Laureles, directed to the 115 children of school age and to the 30 mothers who are heads of family of these villages, in various environmental issues and self-care.
- Halloween celebration (sweets, lunch and costumes).
- Celebration of grades at school (refreshments for graduates).
- Christmas gifts (custard, donut, details for children and J.A.C).

It is important to mention that the INCODER in the year 2015 (Annex 1.5) determines that the title area 5969, do not intersect, intersect or overlap with indigenous reservations and/or black communities.

## 1.2 OBJECTIVES

Below are the general and specific objectives proposed for the development of the "El Pescado" mining project in the mining concession 5969.

### 1.2.1 GENERAL OBJECTIVE OF THE PROJECT

Define, plan, execute, monitor and control a set of processes aimed at developing a mining project with responsibility and transparency; that integrates the abiotic, biotic and to mitigate, compensate for and contribute to regional development through the use of a mineral resource, by means of responsible methods and techniques that must be taken into account in all the phases associated with the life cycle of a mining project.

### 1.2.2 SPECIFIC OBJECTIVES OF THE PROJECT

- Exploit through techniques based on engineering and good industrial practices used worldwide in the exploitation, sustainable, of a gold deposit located in the municipality of Segovia, northeast Antioquia.
- Assume the responsibility of contributing to change the paradigm that exists in the social field regarding the direct and indirect effects produced by a developed mining project on an industrial scale.
- Comply with the commitments acquired with Colombian laws to develop a project mining on legality and responsibility.
- Contribute to social, economic, local, municipal and departmental development through the medium-scale exploitation of a gold deposit, which will boost the economy of the region, will contribute taxes and royalties to the territory, through a company legally constituted, that will be willing to be monitored in matters concerning practices environmental and social responsibility, as required by Colombian laws.

### 1.2.3 GENERAL OBJECTIVE OF THE EIA

Conduct the environmental impact study, in accordance with the guidelines required by the National Agency of Environmental Licenses (ANLA), which allows to identify, assess, mitigate and control all aspects that may have an impact due to the development of a mining project located in the El Pescado, Municipality of Segovia, and Department of Antioquia.

### 1.2.4 SPECIFIC OBJECTIVES OF THE EIA

- Construct the Social and Environmental Baseline (LBSA) of the abiotic, biotic and socioeconomic environment that allows to know the current state of the ecosystems, natural resources and communities affected by the project, as well as the potential and limitations of intervention.

- Prepare an environmental analysis of the area to be explored and eventually to be exploited, which includes identification and qualitative evaluation of all the possible impacts that the development of the El Pescado mining project.
- Design measures that mitigate, prevent and correct the possible effects caused to the environment all the activities developed as part of the mining project.
- Establish a Compensation and Restoration Plan for the resulting residual impacts of the execution of the mining project in question.
- Define plans to measure indicators, establish procedures that allow perform an adequate follow-up and monitoring of the activities that are proposed to be carried out to control the affectations,
- Identify threats and environmental susceptibilities.
- Propose an Environmental Zoning (hereinafter ZA), an integrated product of the characterization.
- Obtain the approval of the EIA for the mining concession 5969, in order to obtain the LA to request to CORANTIQUEJA.

### 1.3 SCOPE

This document aims to comply with the guidelines indicated by the ANLA to develop a mining project that allows the exploitation of sustainable gold with the environment, means of identifying and characterizing the possible effects that allow design, initially, plans that control such affectations and allow to take advantage of the opportunities social and environmental factors that imply the responsible exploitation of a deposit by a company committed to good industrial practices.

For the abiotic, biotic and social characterization, a description was made on the stage without a project mining, this characterization was achieved through the integration of data obtained in the field, primary information medium, in the area of direct influence of the project; this information served as basis to project all the variables in time, and infer their possible effects, for the scenario with mining project. The public and private initiatives that are being developed in the project area and can represent "progress" for the community.

A characterization of the generated impacts is done, categorized and classified to identify in what degree they affect the ecosystem; In response to controlling the impacts generated, a proposal is made to environmental management plan and a monitoring and control plan that can be updated and improved during the life of the project, contains the actions that must be executed and controlled by of the company to minimize the possible negative impact on the ecosystem.

An economic valuation is made of the higher-level environmental impacts that occur for the change derived from the modification in environmental goods and services.

#### 1.4 PROFESSIONAL TEAM

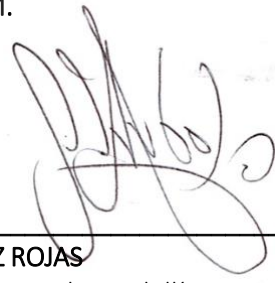
The collection, collection and analysis of the information for the EIA was consolidated by a group of multidisciplinary professionals and was supported by laboratories for the analysis of air, water, geotechnical, geoelectrical, taxonomy of flora, fauna and soils. Below are each of them:

##### MANAGEMENT AND TECHNICAL TEAM.



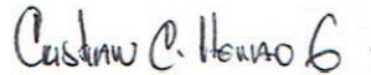
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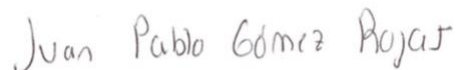
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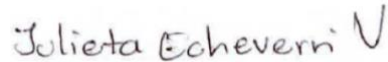
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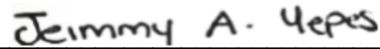
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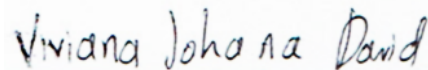
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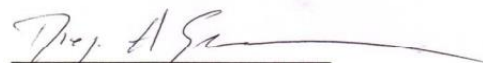
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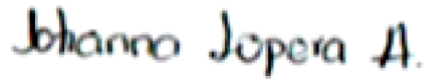
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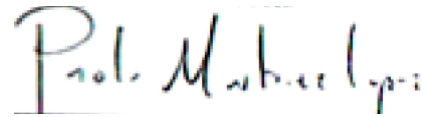
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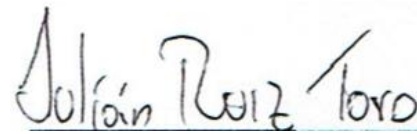
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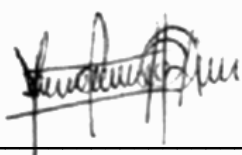
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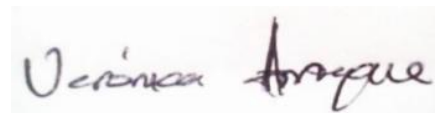
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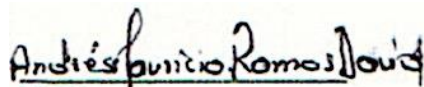
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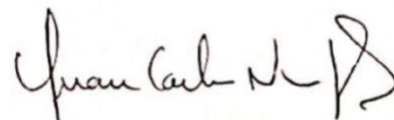
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**JUAN C. NAVARRO FLOREZ**

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**LABORATORIES AND / OR CONTRACTORS:****SOIL ANALYSIS**

Antek Laboratory S.A.S  
Pontificia Bolivariana University Laboratory  
Doctor Calderón Laboratory Technical Assistance  
Agrícola Ltd.

**GEOTECHNICAL ANALYSIS**

IDEAR S.A.S.  
In Situ Engineering S.A.S

**GEOELECTRIC ANALYSIS**

ARCE GEOFISICS S.A.

**TAXONOMIC IDENTIFICATION OF FLORA**

Tolima University

**TAXONOMIC IDENTIFICATION OF FAUNA**

Laboratory of Herpetology of the University of  
Antioquia

**1.5 METHODOLOGIES**

The present study contains primary information according to the methodological or technical scope required for the presentation of environmental studies. Information was used secondary school corresponding to the Basic Territorial Planning Plan (hereinafter PBOT) of the municipality of Segovia, Plan of Management and Management of the Hydrographic Basin of the Bagre River (hereinafter POMCHB), Aqueduct and Sewerage Master Plan (hereinafter PMAA), Municipal Development Plan (in forward PDM), geology of the exploration phase, ancient environmental studies of TOUCHSTONE and cartographic information.

The cartographic base used corresponds to plate 106-IV-B at 1: 25,000 scales elaborated by the Geographic Institute Agustín Codazzi (hereinafter IGAC), image and topographic surveys by total station for generation of contours and drains with high precision and aerial photographs. This cartographic information was used following the guidelines for the management and presentation of cartographic information as stipulated by resolutions No. 1415 of August 17, 2012 and No. 188 of February 27, 2013.

The spatial reaches, that is, the extensions of the land to study by component, were defined based on the methodology of areas of influence of the MADS - ANLA. These are presented with their due arguments in chapter No. 3. Areas of influence.

The biotic medium component was raised in the field in 2012 by TOUCHSTONE according to the collection permit granted by CORANTIOQUIA through administrative act No. 160-1409-321, file CAD2-2011-25, and was reinterpreted and reprocessed by Ingex Mining Group S.A.S.



### **1.5.1 METHODOLOGIES OF GEOLOGY**

For the elaboration of the local geology, exploratory journeys were made in the Areas of Influence (AIs) in order to find rock exposures on the drainages and slopes to know the lithological characteristics of the units that are in the study area. In addition to the lithological information obtained in each of the outcrops visited, it became necessary to measure structures to build structural information. The scale for the cartography was 1: 10,000, it is say the information was geo-referenced every hundred (100) meters with the help of a GPS device, correctly configured with the Magna Sirgas coordinate system originating in Bogotá and projection cross-section of Mercator with origin of coordinates Bogotá.

Once the coordinates of the outcrops were obtained for analysis, a physical map was drawn on the basic cartographic information (level curves, drainages, known points, roads, among others) to an appropriate scale with the help of a scale meter; This ensures that the work is carried out within the area of interest, besides helping the graphic understanding of local geology. In each one from the outcrops visited a general photographic record and important details were taken (Illustration 1-4), hand samples were taken to analyze the physical characteristics of the rock to proceed to its classification, and representative structural data.

Numerous cartographic mapping points were taken, and interpretations were carried out relevant to correlate lithology, structures and areas of interest that make up the local geology.

#### **1.5.1.1 Collection and bibliographic review**

The search for available information was based on the review and analysis of technical reports, articles, theses, research projects, maps, books, publications and websites of entities such as the SGC, AGUSTÍN CODAZZI GEOGRAPHIC INSTITUTE (IGAC) and universities.

For the analysis of the nomenclature of the lithological units and geological structures in the area, as well as its characteristics, Plan 106 - Liberia (González, 1988) and the catalog of lithostratigraphic units (Gonzalez & Londoño, 2002), an area that includes the work zone.

#### **1.5.1.2 Review and complementation of the topographic and hydrographic base**

For the field work, the cartographic bases available at the 1: 25,000 scales available were used in the IGAC.



Illustration 1-4. Image of outcrop in stream.

Source: INGEX, 2015.

### 1.5.1.3 Photointerpretation

As a basis for the interpretation of the field work, the information of the cartography used was available geological analysis and interpretation and interpretation of spatial information, including numerical terrain models (DEM), and remote sensor images.

In support of the process of photointerpretation, the geological map of griddle 106-Liberia was used (González, 1992), the geological map of Antioquia (González, 1996) and the geological map of Colombia (Gómez et al., 2007; Gómez et al, 2015).

In the process of photointerpretation, the DEM was used, which has a resolution of 30 m, as well as the model number available for study area version 4.1 of the Shuttle Radar Topography Mission - SRTM -, with a resolution of 90 m; Landsat images that allowed us to delimit some quaternary deposits and regional guidelines that, in this case, may correspond to regional failures associated with Out's fault.

#### **1.5.1.4 Field work**

Taking into account the final objective of the project, which is to determine the technical feasibility for a mining operation in title 5969 from the perspective of geological exploration, a planning of exploratory works, these were based on the characterization of previous works made by settlers in the area in abandoned tunnels, then proceeded to the execution of this planning.

#### **1.5.1.5 Planning**

In order to identify and increase the geological knowledge of the area and the gold anomalies present in the title 5969 the elaboration of a regional and local cartography was planned, to characterize structures with the potential to be mineable and increase the tonnage of structures previously exploited. As part of this planning, a working structure based on the revision was proposed detail of regional information, published by different mining companies and institutions scientific studies, which would allow obtaining a detailed knowledge of the structures identified regionally in the Segovia-Remedios mining district and in the detailed cartography of the works underground.

Finally, a dense perforation mesh was planned that sought to ensure the continuity of the observed structures and in turn allowed to classify the quantity of ounces as resources and not as exploration information.

#### **1.5.1.6 Execution**

As part of the execution work, all the mining works present in the area were mapped of the license, after having been surveyed its topography by planimetric methods, we proceeded with the cartography, the cartography was executed in parallel with a systematic sampling to know the Geochemical behavior of metallic minerals, geological faults were located and characterized. Regional cartography works were also developed that characterized the present structures in the area and allowed to identify the differentiation of mineralogical facies present; In addition to the surface works, sampling of soils and active sediments was carried out, all these exploratory works served as the basis for planning a drilling program that ensure the continuity of these anomalies in their course and dip. As a complement to these Direct exploration work was carried out an indirect exploration by geophysical methods.

The final cartography was complemented with a final interpretation on the present structural model in the area and that, possibly, controls the presence of mineralized structures at a regional level.

The geological logging served as a tool for the characterization of the present lithological column, in addition, it provided information on lengths, textural, structural, petrological characteristics and metal.

#### **1.5.1.7 Development of the geological model**

The interpretation of the data collected serves as an input for the modeling and subsequent calculation of resources; the modeling is elaborated in Surpac with the ordinary kriging method; the estimate of the resources is obtained by obtaining the weighted tenor of the mineralized blocks, this is the decided method as one of the estimation methods because it weights the relationship between lengths and tenors, since an arithmetic average, for this case, does not show the reality of the behavior and nature of the deposit. Once the weighted wording was obtained, the number of ounces in each one of the blocks, taking into account the density of the rock.

All these data are articulated so that later an efficient mining planning can be elaborated sustainable and sustainable environmental technical development over time; each of the steps in the development of this project are described individually; this document contains, in addition, the general conclusions and recommendations for the subsequent exploration based on the observed in the field stages and in the information analyzed.

### **1.5.2 GEOMORPHOLOGY AND GEODYNAMICS METHODOLOGY**

For the elaboration of geomorphology and geodynamics, the existing bibliographic information was revised, Field trips were carried out and the information was processed and interpreted. Next, they detail each of the stages that make up this methodology.

#### **1.5.2.1 PRELIMINARY BIBLIOGRAPHICAL REVISION**

Prior to the field work, geological and geomorphological studies were reviewed and analyzed previous elaborated at different scales within and / or near the area of interest. Next, List the documents analyzed:

- Carvajal J., et al, 2011. Proposal of standardization of geomorphological cartography in Colombia. Republic of Colombia Ministry of Mines and Energy, Colombian Institute of Geology and Mining (Ingeominas).
- Carvajal J., et al, 2004. Methodological proposal for the development of cartography geomorphological for soil mechanics zoning. Ministry of Mines and Energy, Institute Colombian Geology and Mining (Ingeominas), Colombian Geological Service.
- Feininger T, Borrero D. Geology of the departments of Antioquia and Caldas, Quadrangle I-9 and Part of the Quadrangles H-9, H-10, I-10, J-9 and J-10 Plates 132 Yolombó -148 San Carlos 168 Algeria (Aquitania) -188 La Dorada 117 - Amalfi Scale 1: 100,000 Explanatory Memory.

Aerial photographs were consulted in the IGAC, departmental cadaster and blue print data bases. There is a shortage of this information and even more with the specification of three dates with a difference of 10 years including the actual. Therefore, the multi-temporal analysis was carried out with available information, that is, with a photography of the year 2005, year 2012 and the cartography raised in the field in 2015, which likewise is representative and is considered sufficient for this component.

#### **1.5.2.2 FIELD WORK**

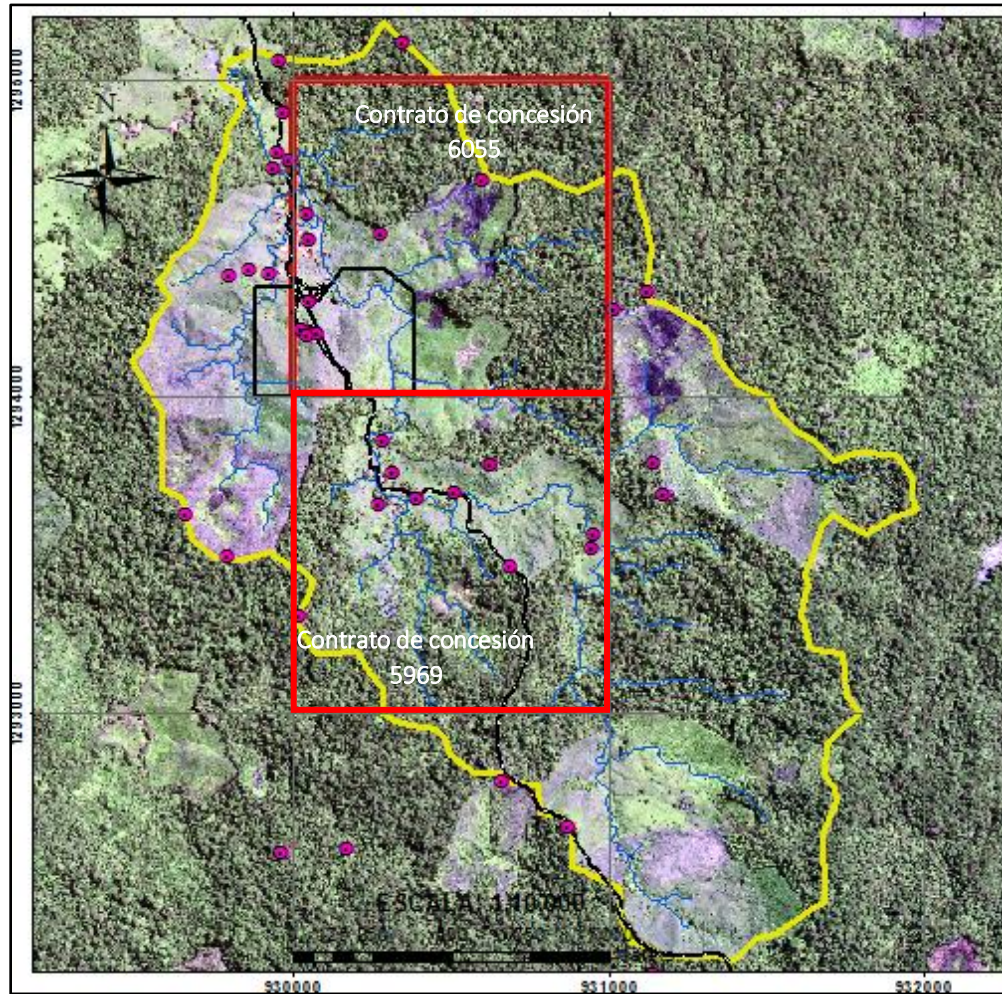
This component was based on various routes to the interior of the area corresponding to the Area of Direct Influence (AID) and the Indirect Influence Zone (AII) of the mining concession 5969. The objective was to detail the different geomorphological units and identify and demarcate morph dynamic processes, degree of weathering and measurement of structural elements at a detailed scale (1: 10,000). HE performed 37 geomorphological control points (Illustration 1-5), panoramic photographs were taken and the material for the classification of the different geo-forms was characterized.

#### **1.5.2.3 PREPARATION OF REPORT**

With the information gathered in the previous stages, the technical document was elaborated where the geomorphological units of the area are detailed; for this the methodology was used by the geomorphological survey system of the Survey Institute Aerospace and Earth Sciences (hereinafter ITC) implemented the INGEOMINAS (2011).

The different morphological units of the terrain are associated with an origin, related to processes natural so-called exogenous and endogenous. Bearing in mind that the origin of the geo-forms is of great importance for its classification, the methodology was adopted for the present study called a geomorphological survey system, established by the ITC, in Enscheda, Netherlands (Verstappen and Van Zuidam, 1991), recognized as a useful strategy for the delimitation of physical-environmental units; besides being considered as one of the main sources of data for the integral understanding of the environment for territorial planning purposes (Verstappen, 1977, 1983; Van Zuidam and Van Zuidam-Canceled, 1979; Verstappen and Van Zuidam 1991). It was also complemented with a multi-temporal analysis based on aerial photographs and satellite images. The system of geomorphological survey of the ITC is based on a landscape approach, taking into account the origin of the units, be it structural, denudation, fluvial, wind, volcanic, among others. Table 1-2 describes each of the units according to their origin.





**Illustration 1-5.** Location of geomorphological control points in the field trips.

Source: INGEX, 2015

**Table 1-2.** Description of the geomorphological units according to their origin

Main source	Example of geo-forms with a specific origin
FLUVIAL: Fluvial Erosion and sedimentation	Geo-form: Alluvial, transitional and erosional plains, terraces, fans, cones, active channels, etc.
LAKE: Marine Erosion and Sedimentary	Geo-form product of high water levels (terraces), bottoms of lakes: Plain lagoons, tidal, evaporite deposits, etc.
MARINE: Marine Erosion and Sedimentary	Geo-forms of high energy environments (coarse-grained materials); of environments low energy (fine grain materials); associated with complex surveys: Abyssal fans, turbidities, etc.
VOLCANIC: Volcanic activity	Geo-forms of cones, craters, volcanic scarp, lava flows and carved in pyroclastic materials.
DENUDEATION: Weathering, transport in mass, linear erosion	Geo-forms associated with wear, no greater lithological effects. Geo-forms influenced by linear lithology and fluvial erosion and associated with processes specific denudation: Movements of mass removal, denuded hills and residuals, slopes and denuded scarp, etc.
STRUCTURAL: Failures	Geo-forms associated with stratified rock layers or structurally controlled, related to folds, failures and uprisings: fault scarp, triangular facets, fault hooks, isolated hills, etc.

Main source	Example of geo-forms with a specific origin
STRUCTURAL DENUDATION	Denudation and structural associations: Structural depression, structural slope, etc.
KARSTIC: Solution and re-scaling	Positive (hills), negative (depressions), structures and other (complex) geo-forms: Caves, sinkholes, karren, etc.
GLACIAL: Erosion by the wind and Sedimentation	Accumulation geo-forms (Active / Non-active) and deflation: Dunes, sand dunes, etc.
ANTHROPOGENIC	Those forms of relief that are the product of modifications caused by the intervention of man: terraced hillside, top esplanade, anthropic, etc.

*Source: ITC Geomorphological Survey System.*

For the scale of work different geomorphological components (units) were to an intermediate unit that can be mapped at 1: 10,000 scales, taking into account the processes morph dynamics and the incidence to the generation of mass movements. Table 1-3 shows the Geomorphological hierarchy.

**Table 1-3.** Geomorphological hierarchy according to the scale.

Scheme of geomorphological hierarchy Scale		
scale	< 1:2.500.000 1:1.500.000	Geostructural zone
	1:1.000.000 -1:500.000	Geomorphological Province
	1:250.000 - 1:100.000	Geomorphological Region
	1:50.000 - 1:25.000	Geomorphological Subunit
	> 1:10.000	Geomorphological Component

*Source: Velázquez, Ingeominas 1999.*

In addition, the homologous geomorphological units were identified between the ANLA (2010) and INGEOMINAS (2011), in order to fill the cartographic domains required by resolution 1415 of 2012 (Table 1-4).

**Table 1-4.** Comparative classification Ingeominas and ANLA.

Geomorphological units					
INGEOMINAS, 2011	Zone Geostructural	Province Geomorphological	Region Geomorphological	Subunit Geomorphological	Component Geomorphological
Scales INGEOMINAS, 2011	< 1:2.500.000 - 1:1.500.000	1:1.000.000 -1:500.000	1:250.000 1:100.000	1:50.000 25.000	> 1:10.000
Domains of the ANLA, 2010	Geostructural	Province	Landscape	Relief type	

*Source: INGEX, 2015.*

For a better understanding about the location of the photographs that are exposed in the present Chapter, is shown schematically in Illustration 1-6, the location of the collection point and direction of the panoramic photograph, the foregoing in order to describe in detail the different geomorphological units present in the study area.



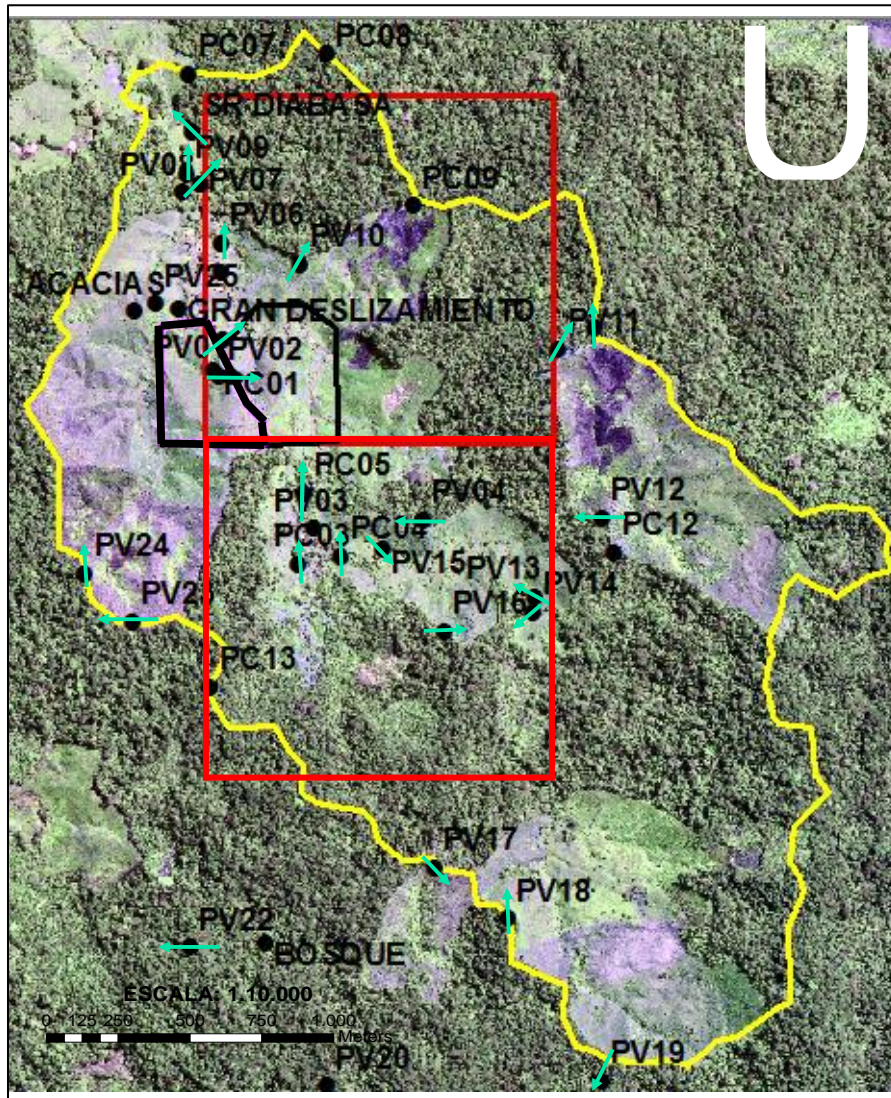


Illustration 1-6. The green arrows indicate the direction of the photographs taken in the project area.

For the characterization and classification of mass processes and movements in the field, a technical format in which all its features are consigned, namely: location, type of process, material involved, morphometric data and observations on the causes, contributing factors and affectations (Table 1-5). Once the field information was collected, the database was elaborated and Subsequent to this, where each of the erosive processes identified is recorded.



Table 1-5. Format of mass movement survey for the mining concession 5969.

<b>FORMATO DE LEVANTAMIENTO DE MOVIMIENTOS EN MASA</b>											
REGISTRO											
Estación No	Fecha del evento			Fecha de registro			Localización Geográfica			Coordenadas Geográficas	
	D	M	A	D	M	A	Departamento: Antioquia	Municipio: Segovia	Vereda: El Pescado	Latitud:	Longitud:
CARACTERÍSTICAS DEL MOVIMIENTO						CARACTERÍSTICAS DEL MOVIMIENTO					
Estado	Edad	Estilo	Descripción (Litología)			Tipo	Clasificación del Movimiento en Masa				
Activo	> 1 Año	Complejo				Caida	Subtipo				
Inactivo	1 - 6 Años	Compuesto				Deslizamiento	Desliz Cuña				
Reactivo	6 - 10 Años	Múltiple				Flujo	Flujo de detritos				
	< 10 Años	Único				Volcamiento	Flujo lodo				
						Reptación	Desliz Rotacional				
						Socavación	Volcam roca				
							Desliz Planar				
							Reptación suelo				
CARACTERÍSTICAS GEOMÉTRICAS DEL MOVIMIENTO EN MASA						CAUSAS DEL MOVIMIENTO EN MASA					
Dimensiones (Metros)			Humedad	Plasticidad	Detonantes			Cobertura del suelo (%)			
Ancho (Corona)			Mojado	Alta	Lluvias						
Profundidad			Húmedo	Media	Sismos						
Longitud total			Seco	Baja	Erupción volcánica						
Volumen (m3)				No plástica	Socavación lateral de ríos o Oda						
					Erosión fluvial						
					Erosión pluvial						
					Escapes de agua (tubería)						
TIPO DE EROSIÓN											
Superficial			Subsuperficial			Estado			Edad		
Tierras malas			Cavernas	Bajo							
Carcavas			Turbificación	Moderado							
Surcos				Severa							
Hondonadas											
Laminar											
TIPO DE EROSIÓN											
Superficial			Subsuperficial			Estado			Edad		
Tierras malas			Cavernas	Bajo							
Carcavas			Turbificación	Moderado							
Surcos				Severa							
Hondonadas											
Laminar											
AFECTACIÓN			OBSERVACIONES			FOTOGRAFÍAS					
Población			Infraestructura			Fecha			Fotografía No		
Heridos			Vía	Puente							
Desaparecidos			Ins. Educa	Hospital							
Vidas			Vivienda	Edificio							
			Acueducto								
ESQUEMA DEL MOVIMIENTO EN MASA											
Esquema en Perfil						Esquema en Planta					

Source: INGEX, 2015

### 1.5.3 METHODOLOGY OF HYDROGEOLOGY

To carry out the hydrogeological analysis, the methodology presented by the MADS is taken as a reference (2014) in its "Methodological Guide for the formulation of environmental management plans for aquifers". This methodology is adapted for the particular conditions of availability of information in the study area; It also tries to comply with the terms of reference established for this type of studies, however, and according to the evolution of the component analysis hydrogeological and the results that were obtained, some activities proposed in the guide methodological changes were modified according to their applicability.

Establishing the hydrogeological model of a zone implies integrating geological information, geomorphological, geophysical, hydrological, hydrochemical and groundwater hydraulics, all this with In order to be able to represent in a simplified way through maps, profiles or block models, the behavior of identified aquifers: the flow of groundwater; or the configuration of hydrogeological units other than aquifers in the case that the latter are not present in the area of influence defined. Table 1-6 shows the components that are integrated for conform the hydrogeological analysis.

**Table 1-6.** Components of the hydrogeological analysis.

Geological model	Geological units. Structures Geomorphology Geophysics. Hydrogeological units.
Hydrological model	Hydric balance. Precipitation. Evapotranspiration. Runoff. Infiltration
Hydraulic characteristics	Hydraulic conductivity Transmissivity Storage coefficient.
Water quality	Inventory of groundwater collection points. Physicochemical characterization.

Source: INGEX, 2015.

In order to achieve the conceptual hydrogeological model according to the adopted methodology, the next activities.

#### 1.5.3.1 DELIMITATION OF THE INFLUENCE AREA

The area of influence is demarcated taking into account aspects of geological and hydrological type. HE delimits a watershed that contains the area where the mining activity takes place, taking into account include in it the geological units that are intervened.

#### 1.5.3.2 IDENTIFICATION OF REGIONAL AQUIFER SYSTEMS

To initiate the identification of local aquifer systems that may be present in the area of study, a hydrogeological regional context should be made where it is located in said area of influence. This is achieved by identifying regional aquifer systems. For this one the project uses the homogeneous hydrogeological zones of Colombia to locate the hydrogeological area of interest, located in an area of scarce aquifer potential.

#### 1.5.3.3 IDENTIFICATION OF WATER POINTS

An inventory is made to begin the recognition of the hydrogeological characteristics of the land of the groundwater collection points and of the springs present, through the implementation of the National Single Form for the Inventory of Water Collection Points Underground For the specific area, the births of the streams were inventoried in view of the absence of civil works to collect groundwater such as wells and reservoirs. These births, although they cannot be considered lightly as springs of groundwater, must be taken into account for the analysis and construction of the conceptual hydrogeological model.

#### **1.5.3.4 IDENTIFICATION AND CLASSIFICATION OF HYDROGEOLOGICAL UNITS**

Based on the local geological model developed, and based on its textural characteristics, a reclassification of said units as hydrogeological units, which have similar hydraulic characteristics, that is, responds similarly to the flow and interaction with groundwater. For this reason, hydrogeological units composed of several geological units can be obtained differently, or the same geological unit can be divided into several different hydrogeological units.

#### **1.5.3.5 ANALYSIS OF THE POTENTIAL OF INFILTRATION OF THE TERRAIN**

As a complement to the definition of the hydrogeological units, an analysis of the potential of infiltration that these can have considered two main factors, the terrain slopes and the average permeability of the hydrogeological unit. This analysis allows us to identify how much potential may be that it is possible to store groundwater in the hydrogeological units identified.

#### **1.5.3.6 PHYSICOCHEMICAL ANALYSIS OF UNDERGROUND WATER**

Generally, the physicochemical analysis of groundwater is done to determine the ions majority and allow to achieve a water classification according to the Piper or Stiff diagrams. But in the case of the mining project, it is possible that this analysis cannot be developed due to the fact that it was not possible to find underground bodies of water to which analyzes of this type could be carried out.

#### **1.5.3.7 ANALYSIS OF INTRINSIC VULNERABILITY**

There are several methods to establish the degree of intrinsic vulnerability of an aquifer to the contamination. The method to choose depends mainly on the information that is available, which varies according to the degree of detail you have.

#### **1.5.3.8 GEOPHYSICAL ANALYSIS**

This type of analysis in hydrogeology refers mainly to geoelectrical studies, which are the most used to detect levels of water saturation in the subsoil. However, the method depends on the morphological characteristics of the terrain. In this particular case, they have developed electrical tomographies which result in iso-resistivity profiles of a cross section in order to have a greater coverage than those with electric probes vertical.

#### **1.5.3.9 PERFORATION ANALYSIS**

The input information was the exploration received by TOUCHSTONE with the laboratory analyzes. According to this it was not possible to show the presence of groundwater in the area, and the conditions Hydrogeological units suggest a low potential for groundwater, they do not install piezometer pipe and less pumping, due to lack of water level evidence underground and even less that can be useful to enrich the conceptual model. I also know used the results of laboratory permeability tests of the unaltered nucleus obtained in the perforations received by TOUCHSTONE. These permeability tests allow know the hydraulic conductivity parameter of the soil to feed the conceptual model and numeric.

### **1.5.3.10 DEFINITION OF THE UNITS HYDRAULIC PARAMETERS HYDROGEOLOGICAL**

Based on the results obtained from the permeability tests carried out in the laboratory at the undisturbed samples from the geotechnical studies, you can only set a hydraulic parameter corresponding to the hydraulic conductivity of the residual soil. This parameter is sufficient for the construction of the conceptual and numerical hydrogeological model.

### **1.5.3.11 DEVELOPMENT OF THE CONCEPTUAL MODEL**

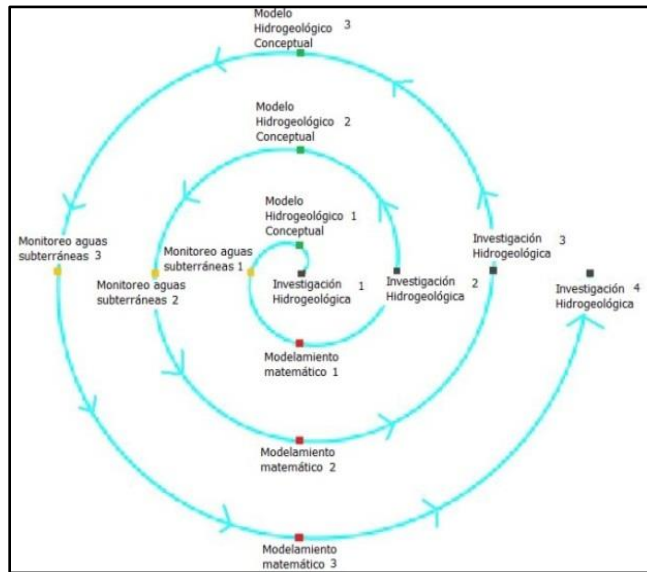
A conceptual hydrogeological model is a series of hypotheses that reduce the problem of the flow of underground water and the real mastery of the subterranean environment, to a simplified version of reality. HE formula to understand the circulation of groundwater in the geological environment and involves the identification of the hydrogeological units and the respective local conditions; finally, adequately represent the disposition, status and relationship of said units in the area and the groundwater recharge, transit and discharge mechanisms.

The conceptual hydrogeological model takes into account geological, geomorphological aspects, hydrogeochemical, hydrological, hydrogeological and climatic. It is important to note that these models are dynamic because they contain temporal variables such as climatological, hydrological and hydraulics, and as new information becomes available, it must be reevaluated and adjusted (Vélez 2010). In Illustration 1-7, an outline of the theory of increasing cycles in the management process is presented of basins (IDEAM, 2004), adapted for the hydrogeological analysis.

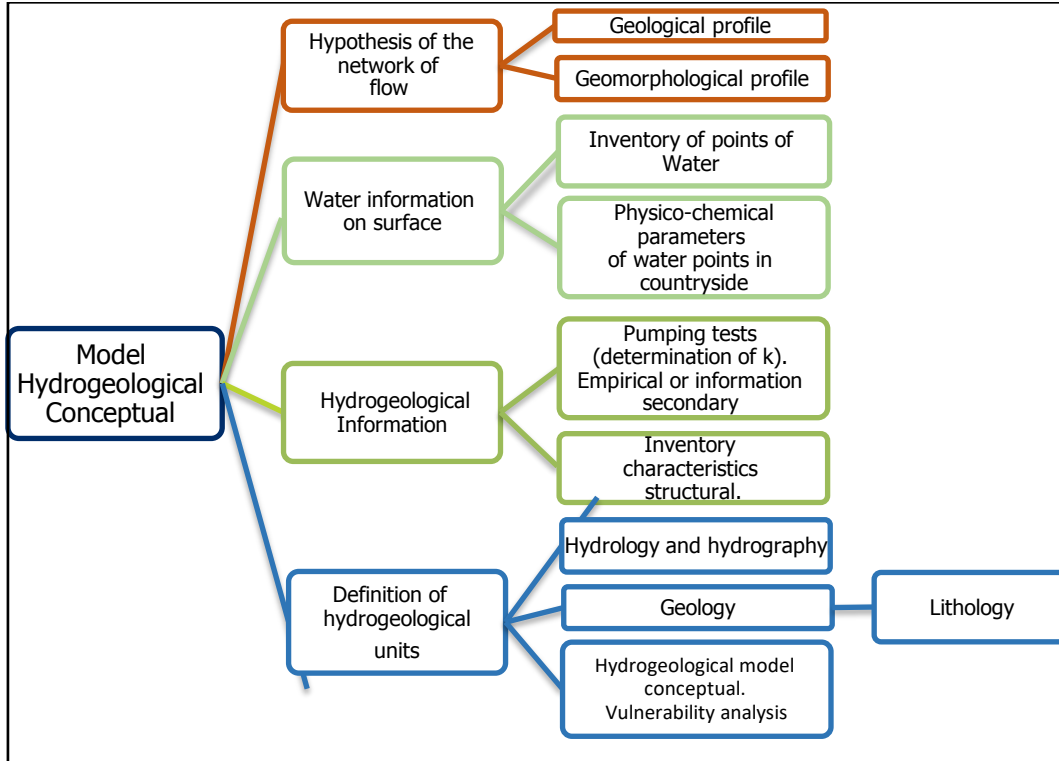
In Illustration 1-8 the methodological scheme of construction of the hydrogeological model is presented conceptually. This methodology is based on the methodological guide for formulating plans for environmental management of aquifers, published by the Ministry of Environment, Housing and Development Territorial (Vélez, 2010) MADS today, adjusted to the study area according to the available information.

### **1.5.3.12 DEVELOPMENT OF THE NUMERICAL MODEL**

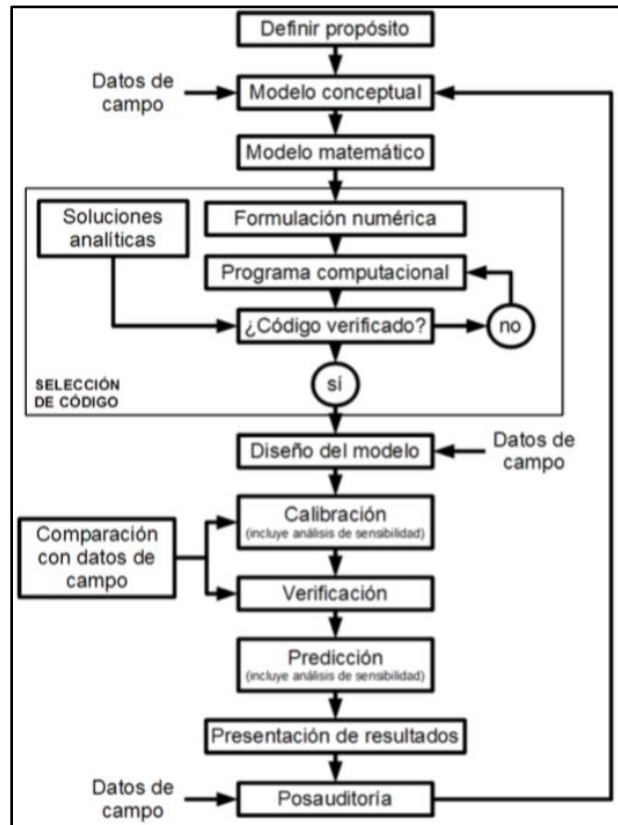
Once the conceptual hydrogeological model was built, the model was elaborated numerical hydrogeological Numerical modeling is an activity that only takes place from the conceptual model since this is what allows the definition of the area of interest and the scope of the simulations Once determined the need to build a numerical model and its purpose, it uses the following protocol adapted from (Anderson & Woessner, 2002) to design and implement the model (Illustration 1-9).



**Illustration 1-7.** Theory of increasing cycles in groundwater systems.  
*Source: IDEAM, 2004.*



**Illustration 1-8.** Methodological diagram of the construction of a conceptual hydrogeological model (MHC).  
*Source: Acuífero environmental management plans, published by the Ministry of Environment (Vélez, 2010).*



**Illustration 1-9.** Diagram of the protocol for numerical modeling.  
 Source: Own elaboration adapted from (Anderson & Woessner, 2002).

The protocol for the elaboration of the numerical model consists of the following procedures.

#### 1.5.3.12.1 Purpose of the model

Determine the equations that govern the phenomenon and the computational code to choose for solve it.

#### 1.5.3.12.2 Conceptual model

Identification of the hydrogeological units and the boundaries of the system. The data of field, including water balance information together with the data required to assign values to the parameters of the aquifer.

#### 1.5.3.12.3 Select the equations and the computational code

The code refers to the computer program that contains the algorithm to solve the mathematical model numerically. Both the equation and the code must be verified. Verification of the equation shows that it accurately describes the physical process that occurs in the porous medium. The Code verification refers

to the comparison of the numerical solution generated by the model with other solutions, whether analytical or numerical.

#### 1.5.3.12.4 Design of the model

The conceptual model is suitable for numerical modeling. This step includes the design of the network, the selection of time intervals, the configuration of borders and initial conditions, and the Preliminary selection of values of aquifer parameters and water stress.

#### 1.5.3.12.5 Calibration

The purpose of the calibration states that the model can reproduce the measurements taken in the field on hydraulic heads and flows. During the calibration there is a set of values for the parameters of the aquifer and water stress, which approximate the measurements taken in the field of heads and flows.

#### 1.5.3.12.6 Calibration sensitivity analysis

The calibration of the model is influenced by the uncertainty due to the inability to define a exact spatial and temporal distribution of the values of the parameters in the study region. There is also uncertainty about the definition of boundary conditions and water stress. HE Sensitivity analysis is performed to determine the effect of such uncertainty on the model calibrated.

#### 1.5.3.12.7 Verification of the model

Its purpose is to establish greater confidence in the model through the use of a set of calibrated values for the parameters, to reproduce a second set of data taken in countryside.

#### 1.5.3.12.8 Prediction

It quantifies the response of the system to future events. The model runs under calibrated parameters for the parameters.

#### 1.5.3.12.9 Sensitivity analysis of the prediction

It is done to quantify the effect of the uncertainty of the values of the parameters on the prediction. The ranges of future estimates of water stress are simulated to examine the impact on the prediction of the model.

#### 1.5.3.12.10 Presentation of the model design and results

It is a clear presentation of the design of the model and the results obtained with it.

#### 1.5.3.12.11 Post-audit

The post-audit is done several years after the modeling study has been completed. It requires the collection of data in the field to determine if the predictions were correct. If the Prediction of the model was successful, the model is validated for the particular site. The post-audit it must be done sufficiently later so that the prediction is made to ensure that there has been an adequate time for significant changes to occur.

#### 1.5.3.12.12 Design of the model

The post-audit leads to new information about the behavior of the system which may lead to changes in the conceptual model or in the parameters of the model. For this reason, it is necessary redesign the model and perform the whole process again.

The execution of all the steps contained in the previous protocol is an ideal state, commonly the Generic and interpretive studies do not perform activities beyond step 6 (Sensitivity analysis of the calibration). Because hydrogeological research does not have piezometers for absence of groundwater in the study area, which account for the spatio-temporal variation of groundwater levels, it is not possible to carry out calibration and verification processes of the model; instead, it works establishing different scenarios of the state of the system.

Groundwater flow can be represented by differential equations that combine the use of Darcy's law and the principles of mass balance. The mass balance involves considerations of entry and exit of flows, and changes in storage. To solve these equations, it requires assigning initial and frontier conditions, which refer to groundwater levels in an initial time at the beginning of the simulation, and the allocation of limits where there is no water flow underground These conditions are obtained from the conceptual hydrogeological model.

The computer code chosen is the PMWIN version 5.3, which uses the numerical method of finite differences that is a method to solve differential equations by using a mesh reticular composed of cells distributed in rows and columns. The adaptation of the model is done concept in the PMWIN program, by defining the mesh grid, the number of rows and columns, the size of the cells, the amount of layer, the distribution of the hydraulic parameters and the assignment of initial conditions and border. Once the code and the equation have been determined mathematical, the code is run to obtain the numerical model.

Based on the conceptual and mathematical hydrogeological model, and with the physiographic information, pedological, hydrological, geological and hydrogeochemical available, one of the methodologies is chosen to exist to determine the intrinsic vulnerability of aquifers to pollution. Based on this analysis builds the vulnerability map of the aquifers and determines the risk that they have to be contaminated by the mining activities that are planned to be carried out.



### 1.5.3.13 DEFINITION OF THE MONITORING NETWORK

The groundwater monitoring network has two purposes, one is to monitor the amount of water, it is say, periodically measure the levels to detect affectations due to the mining activities, and the other is to monitor the physico-chemical and microbiological quality of the water, also by sampling newspapers to establish the impact produced by mining activity. It should be noted that said monitoring is only valid when hydrogeological resources are available, and water is present underground, otherwise, as there is no underground water object of the analysis, it is not justified implementation of a monitoring network.

### 1.5.4 GEOTECHNICAL METHODOLOGY

#### 1.5.4.1 METHODOLOGY - EVALUATION OF SUSCEPTIBILITY BEFORE MOVEMENTS IN DOUGH

Generally, the methods used to evaluate the susceptibility to mass movements contain as one of its fundamental elements the knowledge of the occurrence of the processes of instability in the study area and related factors.

The qualitative or empirical methods are based on the opinion of experts, this method proposes perform landslide inventories in order to identify other places with geological properties and similar geomorphological, which allows us to suppose similar future behaviors.

For the evaluation of the susceptibility by mass movements, the heuristic method, which is based on categorizing and weighing the factors causing instability, according to the influence expected from these in the generation of mass movements (Brabb et al., 1972; Nilsen et al., 1979; Anbalagan, 1992 in Suarez, 2008).

These are known as indirect methods, with results that are extrapolated to areas without movements in mass with a combination of factors similar to that of land where there are mass movements. For this is used as weighting factors weights to each one of the categories of the variables analyzed, performing summation of weights calculating them in a quantitative way for each of the categories related to the occurrence of mass movements, which are assigned according to observations carried out in the field and in the criteria of the experts involved.

#### 1.5.4.2 THEORETICAL FRAMEWORK

Next, each of the terms used for the zoning of susceptibility are defined before movements in mass.

**Mass movement:** Movement downhill of a mass of rock, debris or earth (Cruden and Varnes, 1996).

**Zoning:** Varnes, (1984) in Ingeominas (1990) defines zoning as the division of land in areas and classification according to the degree of threat by landslides or other movements in mass on the slopes.

**Susceptibility of slip:** Express the ease with which a phenomenon can occur on the basis of the local conditions of the land. Susceptibility is a property of the land that indicates what so favorable or

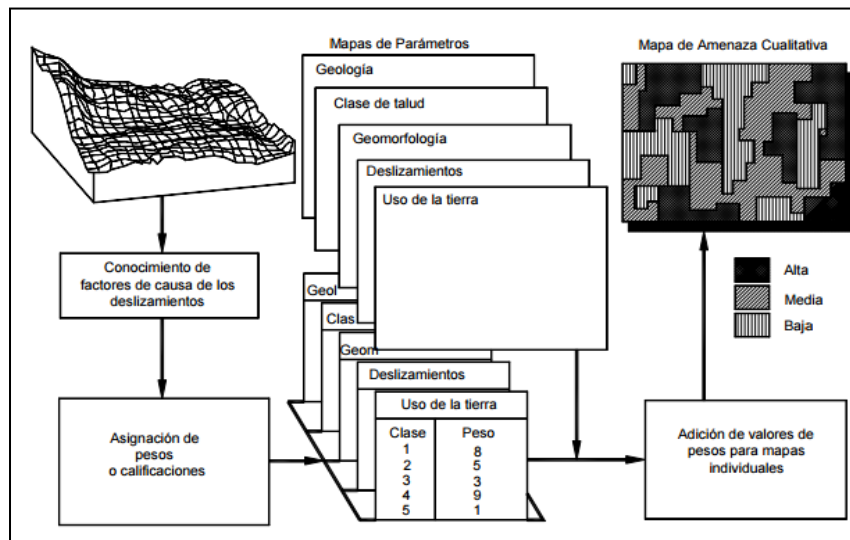
unfavorable are the conditions of it, so that landslides may occur. The susceptibility map classifies the relative stability of an area, in categories ranging from stable to unstable. The susceptibility map shows where there are or not, conditions that can create landslides. The probability of occurrence of a detonating factor such as a rain or an earthquake is not considered in a susceptibility analysis (Suarez, 2008).

**Threat:** Event, phenomenon or activity that can cause damage, loss of life, damage to property, interruption of social and economic activities or environmental degradation (ISDR, 2002).

The threat is a condition with the potential to cause an undesirable consequence. A description of threat to landslides must include the characteristics of these, the volume or areas of movements, depths, speeds and their probability of occurrence. The threat is the probability of a particular slip occurring in a given time (Suarez, 2008).

**Heuristic Method:** Heuristic methods are based on categorizing and weighing the causative factors of instability, according to the expected influence of these, in the generation of mass movements (Brabb et al., 1972; Nilsen et al., 1979; Anbalagan, 1992 in Suarez (2008). They are methods known as indirect, with results that are extrapolated to areas without mass movements with a combination of factors similar to that of land where there are mass movements.

The allocation of weights in the GIS is used as a tool to quantify the terrain. The criteria with which classes are designated may vary from polygon to polygon. The analysis can be performed using the values of the weights in each map to be evaluated, carried out by the specialized professional based on their experience (Illustration 1-10).



**Illustration 1-10.** Use of GIS, for combination or qualitative map.  
(Soeters and Van Westen, 1996 in Suarez, 2008).

## 1.5.5 METHODOLOGY OF HYDROGRAPHY AND HYDROLOGY

Below is the base information and methodology used to estimate the Model Digital Terrain (hereinafter MDT) as an input of the morphology of the basin. Also, the hydrological information and methodologies for flow calculations.

### 1.5.5.1 DIGITAL MODEL OF THE TERRAIN

The cartographic information used for the morphological analysis was obtained from the generation of the MDT of a Lidar image, with elevation information of the terrain every two meters.

This cartographic information was processed using the ARCGIS software. The procedure consisted of interpolate the contour lines by means of the construction of the "Triangular Irregular Network" (for its acronym in English, hereinafter TIN) and after that proceeded to generate a Raster with a resolution (pixel size of 10 m).

For the application of flow estimation methodologies, some parameters were determined morphometric of the basins or sub-basins of interest, such as the area of the basin (A) and the slope mean of the basin (S). The morphometric parameters for the basins in the points of interest in this study were obtained from the MDT, through the software HidroSIG 4.0. For this, the application of two operations: the estimation of drainage directions and the automatic plotting of basins.

Next, it shows how drainages, basins and patterns were determined.

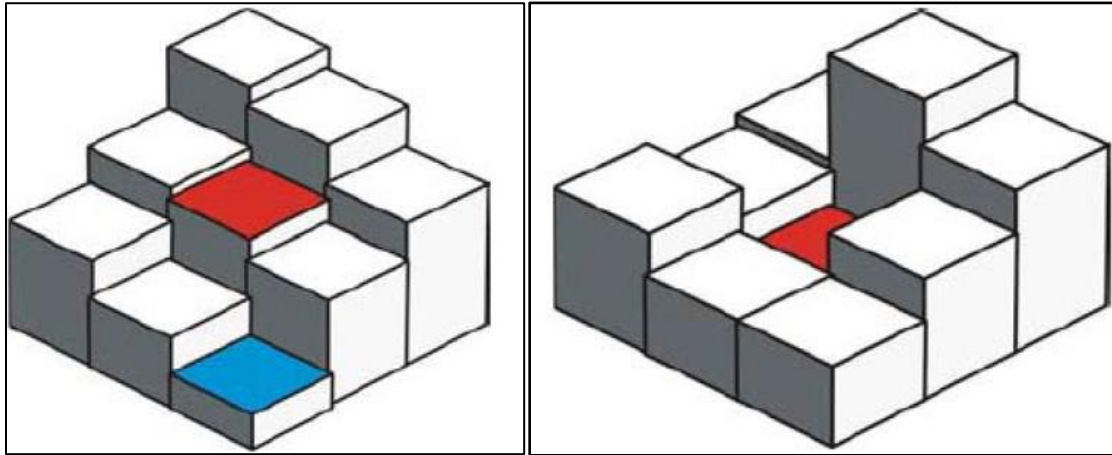
#### 1.5.5.1.1 Estimation of drainage networks

Using HidroSIG, the addressing model D8 proposed by Jenson and Domingues was used (1988), in UNAL (2003). According to this model, the direction of drainage of a pixel coincides with the direction maximum downward slope, taken between the eight possible directions determined by the eight adjacent pixels (Illustration 1-11).

#### 1.5.5.1.2 Automatic basin mapping

So that the methodology can be used repeatedly, on arbitrary basins and with results reproducible, the strategy of automatic extraction of basins using digital models is used of land that is implemented in HidroSIG 4.0 in its current support in free software MapWindows (NET platform).

The automatic basin layout consists of georeferencing on the bed of a main stream the exit point of the desired basin. HidroSIG through iterative processes calculates the division of waters of the basin.



**Illustration 1-11.** Assignment of drainage directions according to model D8. The red pixel is assigned the direction corresponding to the blue pixel. b) Pixel without drain direction.

Source: INGEX, 2016.

#### 1.5.5.1.3 Drainage patterns

According to the IDEAM, to ensure a systemic management of watershed management, it is necessary to define three (3) units that organically make up the system, which are: the hydrological region, the basin and the microbasin as the basic minimum unit. For this purpose, the IDEAM developed the coding of watersheds to facilitate the management exercise, the systematization of information and the spatial agreement of the hydrological models that are generated in the regional exercises and local.

The local classification of basins was carried out by the Garvellius method (1914), in which that the largest river is of order one (1) and the tributaries that reach it are of order two (2) and so successively.

#### 1.5.5.2 AVAILABLE HYDROLOGICAL INFORMATION

The study streams are not instrumented with flow measurement stations, and there is also no precipitation measurement station inside it, therefore it was made necessary the acquisition of hydrological information of a basin of the region so be a little withdrawal of these.

This search of the nearby basin that meets these characteristics is complex, given that there is a poor instrumentation with flow and precipitation stations in the municipalities of Segovia, Zaragoza, Vegachí and other nearby municipalities. The information used for this study is described continuation by variable.

### 1.5.5.2.1 Precipitation

To estimate the precipitation field in the area of interest, given the scarcity of stations, recourse was to the use of secondary information, by the location of precipitation stations is not possible make a map for this variable, which subsequently allows an adequate water balance. In this way, the precipitation fields calculated for the department of Antioquia were used according to Álvarez (2007). The generalities of the precipitation stations can be found in Table 1-7.

**Table 1-7.** Generality of precipitation stations near the study area

Code	Type	Name	Current	Municipality	Lat	Lon	Cota (m)	Date start	Date end	Years
27030090	PM	The Forest	Doña Teresa	Zaragoza	7°19'N	74°50'W	220	1970	2015	45
27030140	PM	Coconut palm's	Pocune	Segovia	7°14'N	74°48'W	100	1974	2015	41
27011100	PM	Las Brisas	Mata	Segovia	7°09'N	74°49'W	600	1983	2015	32
27030130	PM	El Londre	Tigui	El Bagre	7°28'N	74°39'W	1000	1974	1987	13

*Source: INGEX, 2016.*

### 1.5.5.2.2 Evapotranspiration

Evapotranspiration is one of the most important components of the water balance. Represents the amount of water leaving the system into the atmosphere in the form of water vapor, for a combination of physical evaporation and transpiration of vegetation. Evapotranspiration depends mainly on climatic conditions that in turn are a function of the characteristics of the atmosphere that is close to the ground and the vegetation, it also depends on the quality of water and surface water area.

For the calculation of this variable there are several empirical methods, most of them based on formulas that have been obtained in climatic conditions different from the tropical, so it is necessary to do the calculation with different expressions and be able to compare them to see which of them better represents the variation of evapotranspiration in the study basins.

In the estimation of this variable was made based on rainfall information and through the Turc equation.

Its formulation (equation 1) is based on a mass balance, based on elements meteorological conditions such as temperature and rainfall in the basin, applied to measures of long term (Barco y Cuartas, 1998).

$$ETR = \frac{P}{\sqrt{0.9 + \frac{P^2}{L^2}}} \quad (1)$$

Where, ETR is the real evapotranspiration (mm / year), P is the average precipitation in the basin (mm / year), T the average annual temperature in ° C.

For  $P / L > 0,316$ , where L is expressed as:

$$L = 300 + 25 * T + 0.05 * T^3 \quad (2)$$

If  $P/L < 0,316$ :

$$ETR = P \quad (3)$$

The generalities of the station, which measures the evaporation parameter, are shown in Table 1-8.

**Table 1-8.** Generalities of the stations with evaporation information near the study area.

Code	Type	Name	Current	Municipality	Lat	Lon	Cota (m)	Date start	Date end	Years
27035020	CO	El Boquete	Nechí	Segovia	7°08'N	74°39'W	450	1970	1975	5

*Source: INGEX, 2016.*

#### 1.5.5.2.3 Mass curves

The information quality of the precipitation stations was validated through a curve analysis of simple masses. This consists in accumulating the monthly precipitation as the time, expecting this accumulated mass curve to conform to a straight line with constant slope, in a certain period.

The sections with slope change in the mass curve were analyzed in detail. Having in account that if the slope of the curve increases abruptly, it indicates that the precipitation increased of this period, in this case it must be analyzed if it was due to natural phenomena or to bad operation of the measuring station. There may also be the case in which the slope of the mass curve store to zero, indicating that the measurement station stopped working in the period and therefore the data in that time interval should not be taken into account.

The mass curves of rainfall stations Las Brisas, The East, El Londre, the forest and coconut palm, in general, the information of precipitation stations is reliable, and the slope of their cumulative mass curve is approximately constant.

#### 1.5.5.2.4 Homogeneity

The homogeneity analysis consisted in applying tests to determine if there is a change in the average or in the variance of the data series at monthly level. The tests applied to analyze changes in the mean are: Mann-Whitney test, simple T-test, modified T-test and sign test, while those used to detect change in variance are: simple F test, modified F test, Ansari-Bradley test, Barlett test, and Levene test. All these methodologies are they are described in Electrical Interconnection S. A.-UNAL (1995), and Ceballos and Goes (2003).

This analysis applies to precipitation stations. Table 1-9 summarizes the conventions adopted to accept or reject any of the aforementioned hypothesis tests previously; Table 1-10 shows the results for the Las Brisas, The East stations, coconut palm, the forest and the Londre. The results show that all the stations present changes in the mean and in the variance.

**Table 1-9.** Reliability analysis Seasons PM Las Brisas, El Oriente, Coconut Palm, El Bosque and El Londre.

Half	Test	Convention
1 -	Mann-Whitney	A: Accepts stationary average
2 -	Simple T	
3 -	Modified T	R Rejects stationary average
4 -	Sign	
Variance	Testing	Convention
1 -	Simple F	A: Accepts stationary variance
2 -	Modified F	
3 -	Ansari-Bradley	R: Rejects stationary variance



Half	Test	Convention
4 -	Barlett	
5 -	Levene	
# -	The size of the series is not enough to apply the test	

*Source: INGEX, 2016*

**Table 1-10. Results of the analysis - PM stations Las Brisas, El Oriente, Coconut Palm, El Bosque and El Londre.**

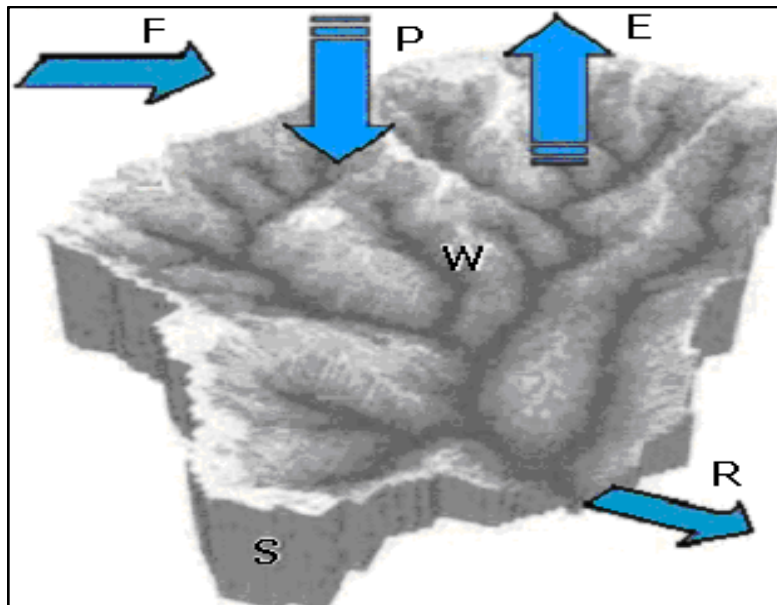
Station		Average				Variance						
Name	Code	Date of change	1	2	3	4	Date of Change	1	2	3	4	5
The Forest	27030090	May-1998	A	R	A	R	Feb-2003	R	R	R	R	R
Coconut palm's	27030140	Nov-1981	A	A	A	R	Apr-1984	A	A	R	A	R
The East	27030220	Jun-1975	A	A	A	R	Apr-1984	A	A	R	A	R
Las Brisas	27011100	May-1995	A	R	R	R	Feb-2007	A	A	R	R	R
El Londre	27030130	Jun-1975	A	A	A	R	Sep-1979	A	A	R	A	R

*Source: INGEX, 2016*

#### 1.5.5.2.5 Water balances and average flows

In the estimation of average flows, the long-term hydrological balance is used, which is implemented in the HidroSIG 3.1 program, developed in the Graduate Course on Achievement of Resources of the National University.

The hydrological balance is carried out in a control volume by means of the conservation equations of mass, which includes the columns of water and soil between the watershed, the upper edge of the atmosphere and a waterproof layer at the bottom of the ground, where the variables that involved in the process are: The moisture flow in the atmosphere (F), Precipitation (P), Evaporation (E), Direct runoff (R), storage of water in the atmosphere (W) and storage of water in the floor (S), see Illustration 1-12.



**Illustration 1-12. Hydrological balance diagram.**

*Source: INGEX, 2016.*

In the atmosphere, the water balance in the atmosphere and in the soil is given by the expressions (4) and (5), respectively.

$$F + E - P = \frac{dW}{dt} \quad (4)$$

$$P - E - R = \frac{dS}{dt} \quad (5)$$

If we combine both expressions, equation (6) is obtained for the water balance in the whole volume of control:

$$F - R = \frac{d(W + S)}{dt} \quad (6)$$

Considering a long-term balance (of the order of years), changes in the storage of water in the atmosphere (W) and in the storage of water in the soil (S) are despicable, therefore, of the expression (5), it can be said that the atmospheric influx must be equal to long-term average runoff, i.e.  $F = R$ . Thus, we can express the water balance to long term as shown in expression (7).

$$R = P - E \quad (7)$$

Being the variables R, P and E averages taken over a long time and per unit area.

For a given basin, equation (7) is applied in each interior point of this, in our case, how are you working with a Raster type MDT. In this way you get the column of water in each cell this contributes to surface runoff. Finally, the average flow is obtained by adding all these contributions of the cells to surface runoff.

#### 1.5.5.2.5.1 Dimensionless duration curve

Due to the little information available in the study area, to analyze the hydrological regime of affected currents, the flow station closest to the study area was used, which was located in the municipality of Vegachi (Table 1-11).

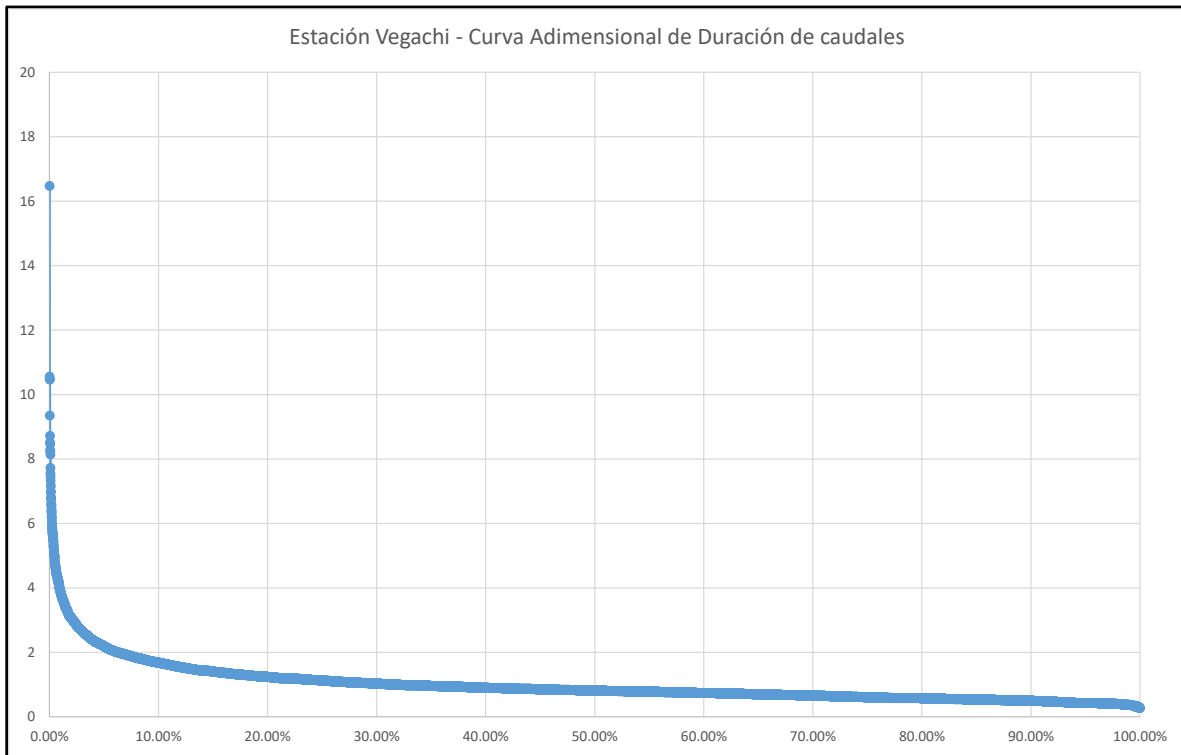
**Table 1-11.** Average monthly flows of Vegachi station.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DIC
1975							9.6	11.1	16.0	12.0	11.6	9.1
1976	7.5	5.8	6.1	6.4	7.4	7.6	5.7	7.2	5.4	11.7	8.8	5.1
1977	3.7	3.1	3.8	5.2	6.9	6.6	7.1	8.0	7.4	8.8	6.9	5.2
1978	4.0	4.8	4.9	9.7	10.1	12.0	7.8	6.1	10.0	10.7	9.2	6.7
1979	4.3	3.5	3.7	5.3	9.8	8.3	5.9	7.7	8.7	14.2	8.7	6.3
1980	5.0	4.0	4.4	3.6	6.3	6.1	6.1	4.2	4.4	8.0	5.3	4.4
1981	3.6	3.5	3.3	7.0	13.0	11.7	8.6	6.5	6.3	6.7	5.7	4.9
1982	3.8	4.2	3.9	9.2	11.5	6.6	7.4	8.2	14.3	10.8	8.0	5.9
1983	4.9	3.5	3.9	4.2	7.3	4.4	5.0	6.9	7.3	6.6	4.3	4.0
1984	3.5	3.2	3.1	2.9	5.4	5.0	5.2	5.3	14.1	13.7	17.0	6.6
1985	4.8	3.7	3.8	5.1	8.1	7.5	9.8	5.9	11.3	10.8	8.8	6.1
1986	4.6	4.0	3.8	6.1	9.7	7.0	5.7	8.2	7.7	11.3	7.0	5.8
1987	4.5	3.6	3.4	5.5	8.2	6.0	8.1	6.7	5.9	14.6	10.3	7.8
1988	4.9	4.2	3.9	5.6	6.2	5.6	5.1	11.9			11.2	8.8
1989	7.4	2.8	4.9	6.1	6.0	7.9	5.7	9.9	11.6	8.8	8.1	9.6

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DIC
1990	6.3	4.7	5.1	6.7	9.7	7.5	5.6	4.9	7.8	14.4	8.4	7.4
1991	5.2	3.8	4.6	7.4	8.6	6.4	6.2	5.2	7.4	8.7	6.9	5.5
1992	4.8	4.2	5.1	5.8	6.1	5.0	7.3	6.3	9.7	9.0	7.4	6.4
1993	5.8	4.7	5.4	9.2	8.7	6.2	8.5	9.3	16.3	11.9	10.6	9.0
1994	7.3	6.6	7.3	10.2	10.8	10.5	8.6	9.1	12.6	11.1	12.7	8.5
1995	7.7	6.7	7.1	8.8	10.2	11.9	12.2	14.2	12.6	22.4	11.1	11.5
1996	8.8	8.4	10.0	10.6	13.3	13.8	14.1	12.7	14.2	15.3	12.9	10.3
1997	8.6	7.8	9.1	9.4	8.8	12.3	7.9	7.8	11.3	12.2	11.9	7.3
1998	6.6	5.5	6.1	8.9	13.5	14.0	12.0	12.5	9.7	9.2	7.2	8.2
1999	6.9	7.5	7.8	14.2	14.3	15.8	14.1	11.8	14.4	16.4	11.1	9.9
2000	4.3	4.0	4.6	5.2	8.3	6.1	7.7	10.3	17.6	11.4	9.9	6.8
2001	5.5	4.2	5.2	5.2	5.7	7.5	11.4	5.1	10.2	12.0	10.7	7.0
2002	5.0	4.0	7.4	7.6	9.4	11.2	6.2	6.4	6.0	5.7	5.9	8.4
2003	4.8	4.5	4.9	8.0	9.7	10.7	7.0	10.3	11.6	12.0	8.2	9.2
2004	5.0	4.2	4.9	5.8	10.7	6.8	10.3	6.4	14.5	14.2	13.2	7.3
2005	6.8	5.0	5.6	8.8	8.2	8.6	7.6	8.1	8.6	11.9	10.7	8.2
2006	6.9	5.4	7.3	7.0	9.5	0.8	7.1	7.7	0.9	1.5	4.8	7.3
2007	6.0	5.0	4.8	6.6	7.5	9.5	8.3	9.0	10.3	8.3	12.7	10.4
2008	7.7	6.0	7.0	6.2	8.1	9.0	9.3	11.9	6.0	15.5	13.7	8.1
2009	6.5	5.7	7.0	6.5	8.7	10.9	7.6	8.0	6.5	7.3	8.7	5.8
2010	4.7	4.3	5.4	9.2	10.3	12.9	17.4	17.3	18.6	18.2	19.3	18.0
2011	13.9	11.0	12.3	20.0	22.5	17.0	16.4	15.8	15.4	16.5	14.9	11.6
2012	9.4	7.4	8.6	10.3	13.9	9.2	9.8	11.4	7.5	10.9	8.6	7.3
2013	6.9	5.9	7.2	7.4	14.2	8.9	9.4	13.9	17.0	10.4	9.4	7.5
2014	6.9	5.7	6.2	7.9	9.1	8.2	7.8	8.3	7.0	11.3	8.9	8.7
average	6.0	5.0	5.7	7.6	9.6	8.8	8.6	8.9	10.4	11.4	9.8	7.8

*Source: INGEX, 2016.*

With the data from the Vegachi station, the dimensionless duration curve was drawn (Illustration 1-13) and this information was used to characterize the hydrological regime of the intervened basins, multiplying the dimensionless duration curve by the average flow of each stream.



**Illustration 1-13.** Non-dimensional curve of duration of flows.  
 Source: INGEX, 2016.

Of the curve of dimensionless duration that was extracted from the volcano current in the municipality of Vegaci, it can be seen that the average flow of the basin is exceeded 30% of time, behavior typical of incipient currents in mountain sectors. The duration curve is not appreciated atypical behaviors in the average flows.

#### 1.5.5.2.6 Maximum flow rates

Below are the methodologies of the variables needed for flow calculations maximum.

##### 1.5.5.2.6.1 Concert time

The duration of the rain is equal to the concentration time of the basin, since it is for this duration when the entire area of the basin is contributing to the runoff process, therefore, it is to be expected that the maximum flows will be presented. In the literature there are multiple expressions for the calculation of the time of concentration, among them those proposed by: Temez, William, Kirpich, Johnstone and Cross, California Couverts Practice, Giandotti, S.C.S, Ventura-Heras. Its foundations Theoretical studies can be reviewed in Campo y Múnera (1997). Because of the different expressions for the calculation of the concentration time, there is a strong variability in the results from one to the other, which makes it necessary to appropriately choose the time of concentration and discard those methods that do not conform to the local morphometric conditions of the basin.

The expressions used to estimate this parameter were the following:

- Témez (1978) 
$$T_c = 0.3 \left( \frac{L}{S_o^{0.25}} \right)^{0.75}$$

T<sub>c</sub>: concentration time in hours.

L: length of the main channel in kilometers.

S<sub>o</sub>: Difference of heights between the extreme points of the current on L in%.

- Williams (1922) 
$$T_c = \frac{LA^{0.4}}{DS_o^{0.2}}$$

T<sub>c</sub>: Time of concentration, in hours.

A: Area in square miles.

L: Distance in a straight line from the site of interest to the highest point of the basin in miles.

S<sub>o</sub>: Difference of heights between the extreme points of the basin divided by L, in%.

D: Diameter of a circular basin, with area A, in miles.

- Kirpich (1990) 
$$T_c = 0.066 \left( \frac{L}{\sqrt{S_o}} \right)^{0.77}$$

T<sub>c</sub>: Time of concentration, in hours.

L: length from the gauging station to the boundary, following the main channel, in kilometers.

S<sub>o</sub>: Difference of heights between the extreme points of the current on L in m / m.

$$T_c = 0.01 \left( \frac{L^3}{H} \right)^{0.385}$$

California Culverts Practice

T<sub>c</sub>: Concentration time in hours

L: Length of the main channel in kilometers

H: Difference of heights between the point of interest and the divide in km.

- Giandiotti

$$T_c = \frac{4\sqrt{A} + 1,5L}{25,3\sqrt{LS_o}}$$

T<sub>c</sub>: Concentration time in hours

L<sub>c</sub>: Distance from the site of interest to the point at which the main current cuts the Divide in km

H: Difference of heights between extreme points of the current in meters

- S.C.S-Ranser

$$T_c = 0.947 K^{0.385} \quad (13)$$

$$K = \sqrt{\frac{L_c^3}{H}}$$

$$T_c = \frac{L}{72 \left( \frac{Ae}{L} \right)^{0.6}}$$

T<sub>c</sub>: Time of concentration, in hours.

L<sub>c</sub>: Distance from the site of interest to the point at which the main current cuts the Divide, in kilometers.

H: Difference of heights between the extreme points of the current, in feet.

#### 1.5.5.2.6.2 Intensity of rains

It is assumed for the estimation of hydrological events of a certain magnitude in the basin, that the occurrence of the design flow has a frequency equal to the design storm. To determine the intensity of rain, the IDF curves (hereinafter Intensity-Duration-Frequency) are used, which they relate their duration to the intensity associated with different periods of return.

The study basin does not have hydrological records that allow determining the IDF curve; for this reason, it is necessary to infer them from neighboring basins by means of regional analyzes. To determine the precipitation histograms on this basin, the precipitation records of the station used coconut palms (27030140).

The design intensity for the basin of interest was determined from the coconut palm's station, once the IDF curve is constructed based on the monthly maximum rainfall records of said station (Wilches, 2001).



#### 1.5.5.2.6.3 Rational method

The method assumes that runoff is directly proportional to effective precipitation and although this is not true in reality, errors in such small basins (less than 8 km<sup>2</sup>) are not significant.

With this method you can find the flow with the following expression:

$$Q = \frac{C * i * A}{3.6}$$

Where A is the area of the km<sup>2</sup> basin, i is the rainfall intensity in mm / h that depends on the period of return just like the runoff coefficient C and 3.6 is a unit conversion value. The value of the runoff coefficient for each return period that is proposed for a basin with forests and mountains with slopes greater than 7% in which sub-basins can be classified of study (Chow, 1994).

#### 1.5.5.2.7 Minimum flows

For the estimation of the minimum flows, the following regionalization methodologies were chosen.

##### 1.5.5.2.7.1 Regionalization of average characteristics

In the estimation of the minimum flows the same concept used in the maximum flows was used, that is, the statistical parameters scale with the drainage area and the climatic information. Without However, an important diversity of research (Vogel and Sankarasubramanian, 2000; Gupta and Waymire, 1990; Goodrich et al, 1997; Gupta, 2004) have shown that scale parameters  $\theta_1\mu$ ,  $\theta_2\mu$ ,  $\theta_1\sigma$ ,  $\theta_2\sigma$  are equal and take the value of one. That is, they scale simply with the average flow.

The above is true for all types of drainage area, since the minimum flows are a consequence of droughts that can be representative in a wide range of drainage areas and where the zones are hydrologically homogeneous. In the case of the study it is clear that this hypothesis is fulfilled and therefore the estimates were made available information.

$$\mu_{\min} = 0.361 * (P - E) * A \quad \sigma_{\min} = 0.179 * (P - E) * A$$

Additionally, the regionalization equations obtained by *Empresas Públicas de Medellín* (hereinafter EPM) for Antioquia. The minimum flows were calculated by method I and III proposals by EPM.

Método I:

$$\mu = 0,01114 * A^{1,087}$$

$$\sigma = 0,002948 * A^{1,087}$$

Método III:

$$\mu = 10^{-5,281} * A^{0,903} * Pma^{1,086}$$

$$\sigma = 10^{-5,257} * A^{0,944} * Pma^{0,9027}$$

With the values obtained for the mean and multi-year standard deviation, the equation is used proposed by Chow (1951), using the distribution of GEV type extreme values (Heo and Salas, 1996, Chow et al., 1994), namely; Gumbel, the minimum flow values were obtained with a period of associated return for the streams.

$$Q(Tr) = \mu_{Q_{min}} + K(Tr, \gamma) * \sigma_{Q_{min}}$$

#### 1.5.5.2.8 Ecological flows

For the estimation of the ecological flow, it is proposed that it be considered as 25% of the flow average of the driest month (resolution 0865 of 2004, Numeral 3.4.2 M.A.V.D.T.).

#### 1.5.5.2.9 Sedimentological regime

To perform an adequate morphological classification of the basin, which allows inferring how are the transport processes in it, the proposal of Flores et al. (2006), in which they establish 4 basic types of bed classification: cascade, step - pool, plane bed, pool - riffle.

The annual average rate of soil loss due to laminar erosion is estimated based on the Universal Equation of Soil Loss:

$$E = RKLSCP$$

Where:

**E** is the loss of soil per unit area [ $T (m^2 \text{ year})^{-1}$ ]

**R** is the erosivity factor of rain [ $MJ \text{ mm} (m^2 \text{ h})^{-1}$ ]

**K** is the soil erodibility factor [ $T m^2 \text{ h} (m^2 \text{ MJ h})^{-1}$ ]

**LS** is the topographical factor [dimensionless]

**C** is the coverage factor for handling [dimensionless]

**P** is a factor for conservation practice [dimensionless]

This equation describes the relationship between laminar erosion caused by rain and the main factors who control it.

The erosivity factor,  $R$ , evaluates the potential capacity of the rain to produce erosion in given circumstances. According to Pérez (2001), the rainfall erodability factor for Colombia can be calculate according to the following expression:

$$R = 1.193 \times 10^{-8} PMA^{1.70148}$$

Where  $PMA$  is the average annual rainfall [mm/year] and  $R$  is the rainfall erosivity factor [ $MJ \text{ mm} (\text{m}^2 \text{ h})^{-1}$ ]. For the basin defined up to the catchment site, values for  $R$  that oscillate between  $1.54 \times 10^{-2}$  y  $1.40 \times 10^{-2}$  [ $T \text{ m}^2 \text{ h} (\text{m}^2 \text{ MJ h})^{-1}$ ].

The soil erodibility factor,  $K$ , represents the degree of natural resistance that the soil offers to act other erosive factors. The value of this factor was taken from the Hydrological Atlas of Colombia (Poveda et al., 2007). In this study, a  $K$  map was obtained for all the soil based on the texture of the soil. Colombian territory with a resolution of 120 seconds of arc (pixels of 3.7 km approximately). It must be taken into account that for the elaboration of this map only account for a reduced number of textures for soil classification and scale of information used was 1: 3'400 000, however due to the lack of data, we chose to work with this information. For the study area, a value for  $K$  of  $7.192 \times 10^{-2}$  was estimated [ $T \text{ m}^2 \text{ h} (\text{m}^2 \text{ MJ h})^{-1}$ ].

The LS factor is the product of the slope ( $L$ ) and slope ( $S$ ) sub factors, which are calculated with the following expressions (McCool et al., 1987 and 1989 and Foster et al., 1977, cited by Barrios, 2000):

$$L = (\lambda / 22.13)^m$$

$$m = \beta / (1 + \beta)$$

$$\beta = \left\{ (\text{sen } \theta / 0.0896) / [3.0(\text{sen } \theta)^{0.8} + 0.56] \right\} \times r$$

$$S = 10.8 \text{sen } \theta + 0.03; \text{ para } p < 9\%$$

$$S = 16.8 \text{sen } \theta - 0.50; \text{ para } p > 9\%$$

Where:

$\lambda$  slope length (m)

$m$  variable exponent according to  $\beta$

$\beta$  relation erosion in furrow to erosion in spacing of furrows

$\theta$  terrain inclination angle

$p$  slope of the land (%)

$r$  coefficient equal to: 0.5 in forest land or pasture; 1.0 on agricultural land; and 2.0 in sites of building.

The spatial distribution of  $\lambda$  within the basin was estimated by the TDM according to the CALSITE model (Bolton et al., 1995, cited by Barrios, 2000):

$$\lambda = (A / \pi)^{0.5}$$

Where A is the accumulated area of drainage. Finally, the coverage resulting from applying the equation, is updated to consider  $\lambda = 0$  in the pixels that correspond to the drainage network of the basin.

The factor C has been defined as the relationship between the loss of soil of a plot subject to determined use and management, and losses corresponding to uncultivated land. They have drawn a lot of tables to determine the value of the coefficient C depending on the type and coverage of the vegetal cover. Considering that land use in the analyzed basin corresponds mainly to forests and pastures and taking as a reference the classification proposed in the Hydrological Atlas of Colombia (Poveda et al., 2007), a value of 0.12 was assumed for the study zone.

To obtain the values due to conservation practices, *P*, the parameters of the slope map (the P factor varies depending on the slope), since there is no measurement information direct of this variable.

By integrating the laminar erosion map in the flow direction, the annual sediment rate is obtained produced in the currents inside the AID and the All by laminar erosion.

It must be taken into account, that within the estimate made, important processes were not considered in the production of sediments, such as the formation of gullies and furrows in the upper parts of the basin, the erosion in the pews of the channels and the mass removal.

### 1.5.6 SOIL METHODOLOGY

To carry out the environmental study of the soil component, the bibliographic revision phases were carried out and planning, recognition and field phase, laboratory phase and information analysis phase.

#### 1.5.6.1 BIBLIOGRAPHICAL REVISION

To carry out the survey of the information of the component soils, an initial revision was made bibliography of the existing soil studies in the area of influence of the project, finding on a scale of 1: 100,000 the RMe1 Association (Association Remedios, slightly steep phase, slightly eroded), the RMd1 Association (Association Remedios, strongly wavy phase, slightly eroded) and the IVA Association (ITE Complex). (IGAC, 2007).

Then it proceeded to perform recognition of the points to be sampled in the AID and study area, to which was taken into account two main components of the cartography maps raised by the project: The Geomorphology and Vegetable Coverage component. The first one extracted the following units:

- Hills (DC): There are two geographically separated zones.
- Moderate Hillside (DLM): There are four geographically separated zones.
- Steep Slope (DLE): There are two geographically separated zones.
- Structural Loin (SLE): One area.
- Loin (DL): One area.
- Terrace (FT): Four terrace areas, separated and continuous geographically.

And the coverage component present in the AID areas and study area were taken into account five units of vegetable coverages.

- Dense forest under solid ground (Bdbtf)
- Low secondary vegetation (Vsb)
- Clean Pasture (PL)
- Cocoa cultivation (CC)
- Cultivation of Banana and Yucca (CPY)

#### 1.5.6.2 FIELD PHASE

In the areas selected for sampling as indicated above, studies of soil profiles by opening pits of 1 m<sup>3</sup>, (Illustration 1-14) and observations with drilling and trunks or small pits, these three methods were performed at a depth of 1 m per site is sampled. At each point, geo-referencing with GPS was carried out, taking coordinates of latitude and altitude in linear meters, photographic records and the description of the profile or the observations using in the "Edaphology format and description of soil profile".

For the opening of pits and sampling, the following materials and implements were used: shovel, pigeon, pike, hammer, machete, plastic bags of 2kg capacity, tape, meter, markers, notebook, maps, plans and aerial photographs of the study area, camera, GPS, field formats, sacks, Munsell table and hydrochloric acid. And in the observation places it was used the helical hole for soil.

In each elaborated pit of 1 m<sup>3</sup> identification was made in the field structure according to the aggregation and the shear planes of the peds and/or resistance to breakage, the wet consistency and in dry, the texture by the touch method and the wet color with the Munsell table.

##### 1.5.6.2.1 Determination of soil structure

The structure is a physical property of the soil that indicates the ordering of individual grains (sands, silts, clays) in secondary particles or aggregates (peds) and the pore space associated with these (Porta, 2003). Its formation is possible due to the physicochemical interactions between clays and matter organic, clays and minerals and by the action of flocculating agents. Therefore, a good soil structured will have a porous space that favors the infiltration of water, air circulation and proper growth of the roots of the plants; In addition, it is more resistant to erosion because it has its particles well adhered. To determine this property in the field, samples of the horizons in the soil profiles of the pit, the drills and the trunks, the key of the USDA was used (Soil Survey Division Staff, SSDS, 1993, cited by Jaramillo, 2002) to describe the type, class and degree of aggregates development (Table 1-12).





Illustration 1-14. a) Drilling taken in the project area b) Removal of soil with borehole. c and d. Measurement of horizons.

Source: INGEX, 2016.

Table 1-12. Determination of type of soil structure.

CLASE (Tamaño de los agregados) ( mm )	TIPO (Forma y disposición de los agregados)						
	Laminiforme	Prismas		Poliedros		Esferoides	
	Orientación en un plano horizontal	Orientación alrededor de un eje vertical y caras verticales bien definidas		Orientación alrededor de un punto		Orientación alrededor de un punto	
		Sin redondeamiento en partes superiores	Con redondeamiento en partes superiores	Vértices angulosos	Vértices redondeados	Muy poco porosos	Porosos
	LAMINAR	PRISMÁTICA	COLUMNAR	BLOQUES ANGULARES	BLOQUES SUBANGULARES	GRANULAR	MICAJOSA
MUY FINA	<1	<10	<10	<5	<5	<1	<1
FINA	1 a 2	10 a 20	10 a 20	5 a 10	5 a 10	1 a 2	1 a 2
MEDIA	2 a 5	20 a 50	20 a 50	10 a 20	10 a 20	2 a 5	2 a 5
GRUESA	5 a 10	50 a 100	50 a 100	20 a 50	20 a 50	5 a 10	
MUY GRUESA	>10	>100	>100	>50	>50	>10	



<p>Nº DE PERFIL _____</p> <p>FECHA _____ OBSERVACIÓN Nº _____</p> <p>OBSERVADOR _____</p> <p>UBICACIÓN _____</p> <p>DEPARTAMENTO _____</p> <p>MUNICIPIO _____</p> <p>ALTURA _____</p> <p>(MSNM) _____ TEMPERATURA _____</p> <p>COORDENADAS _____</p> <p>Tº PROMEDIO _____ PRECIPITACIÓN _____</p> <p>GEOFORMA _____</p> <p>RELIEVE _____</p> <p>PENDIENTE _____</p> <p>HUMEDAD ACTUAL: SECO _____ CM,</p> <p>HÚMEDO _____ CM</p> <p>EVIDENCIAS DE EROSIÓN _____</p> <p>MATERIAL SUBYACENTE _____</p> <p>VEGETACIÓN, USO ACTUAL _____</p> <p><b>INTERPRETACIÓN</b></p> <p>MATERIAL PARENTAL _____</p> <p>REGIMEN DE HUMEDAD _____</p> <p>PROFUNDIDAD EFECTIVA _____</p> <p>LIMITANTE DE PROFUNDIDAD _____</p> <p>INUNDACIONES, FRECUENCIA _____ AÑOS _____</p> <p>DRENAJE NATURAL _____</p> <p>PROF AGUA, NIVEL FREÁTICO _____</p> <p>CLASE Y GRADO DE EROSIÓN _____</p> <p>GRAN GRUPO _____</p> <p>SERIE _____ CONJUNTO _____</p> <p>POSICIÓN GEOMORFOLÓGICA _____</p>	<b>PROFUNDIDAD Y NOMENCLATURA</b>	<b>COLOR (MUNSELL)</b>	<b>TEXTURA (FRAGMENTOS % VOL)</b>
	0		
	10		
	20		
	30		
	40		
	50		
	60		
	70		
	80		
	90		
	100		
110			

Source: INGEX, 2016.

Eipedón: \_\_\_\_\_ Horizonte \_\_\_\_\_  
 superficial \_\_\_\_\_  
 Unidad de mapeo: \_\_\_\_\_

Clasificación  
 agrológica \_\_\_\_\_  
 Formaciones  
 especiales: \_\_\_\_\_

Estructura			Consistencia			Reacción		Observaciones
Tipo	Clase	Grado	Seco	Húmeda	Moj.	HCL	H2O2	

Source: INGEX, 2016.

#### 1.5.6.2.2 Determination of soil consistency

According to Jordán (2005) the consistency of the soil can be defined as "the resistance that this one opposes to the deformation or rupture ". And it is related to other physical properties such as structure, texture and moisture and chemical properties such as organic matter content, and plasticity.

In the field, from the horizons of the soil profiles, the boreholes and the trunks, samples were taken, and it was evaluated both in dry, wet and wet state, the resistance that opposes the soil to be crumbled (hardness), its friability and its degree of stickiness, respectively; As it shown in Table 1-13).

**Table 1-13.** Soil consistency classification in the field, according to SSDS (1993).

Soil consistency in state		
Dry	Wet	Wet
Loose	Loose	Stickiness
Soft	Very friable	Not sticky
Slightly hard	Friable	Slightly sticky
Hard	Very firm	Moderately sticky
Very hard	Extremely firm	Very sticky
Extremely hard		

*Source: Jaramillo, 2002.*

#### 1.5.6.2.3 Determination of texture in the field

Texture is that physical property that establishes the composition of fine particles and inorganic in the soil according to its size, that is, its granulometry (Jordán, 2005). In field was determined in the sites sampled (Calicata, blasted and trunks) by the method of tact and was complemented with the physical-chemical results of the laboratory, this first one, has in the sensation between the fingers of a sample (touch), the ease with which it forms circles and spheres and their adhesiveness to a surface (Table 1-14).

**Table 1-14.** Key to the classification of soil texture by the touch method.

Texture	Touch	Circles	Spheres	Adhesive
A (Sandy)	Rough	No	No	No
AF (Arene-Free)	Rough	Very bad	Bad	Very little
FA (Sandy loamy)	Rough	Bad	Bad	Little
F (Free)	Very soft	Bad	Hardy	Little
FL (Silt-loam)	Soft	Curly	Good	Media
L (Silty)	Harpy	Curly	Regular	Little
FArA (Sandy clay loam)	Little rough	Regular	Good	High
FAr (Clay Loam)	Soft	Regular	Good	High
FArL (Silty Clay Loam)	Soft	Curly	Good	High
ArA (Argilloarenaceous )	Little rough	Good	Good	High
ArL (Silty clay)	Soft	Good	Good	High
Ar (Argillaceous)	Soapy	Good	Firm	Very High

*Source: Jaramillo, 2002*

#### 1.5.6.2.4 Determination of color

To the horizons found in the three methods used, for the study of soils, the wet color identification using the Munsell color card, which includes nuance, purity and intensity of color (Illustration 1-15) The color symbol for each horizon is presented described.



**Illustration 1-15.** Munsell color chart.

*Source: Kaplán et al, 2011.*

#### 1.5.6.2.5 Measurement of water infiltration

In order to determine the level of water infiltration in the soil, the cylinder method was used concentric in each site where the profile with pits was described, for which measurements of the water column in double PVC rings for one hour (Illustration 1-16). The result allowed to obtain the infiltration curve, the theoretical infiltration in time and per hectare. This process explains the vertical penetration of water from the surface into the soil, which is affected by characteristics such as texture, type of clay, slope of the terrain, structure, compaction, moisture content existing at the time of measurement, land use, among others According to Pizarro et al. (2002) the velocity and volume of infiltration, determine the amount of surface runoff water and the risk of water erosion.



**Illustration 1-16** Infiltration rings used in the field.

*Source: INGEX, 2016.*

### 1.5.6.3 LABORATORY PHASE

For samples from the study area, 11 composite samples were sent to laboratory analysis by the horizons of the profiles for physical-chemical parameters. In order to ensure traceability of the samples, these were remitted with the chain of custody of the laboratory. In addition, the geographical location map of samples is presented. In the particular case of mineralogy (mineral composition in the textural fraction), four samples; one per horizon and per type of soil.

For soil analyzes in the project area, samples were taken for physical parameters chemical for each soil horizon, such as texture, mineralogy in textural fractions, quantities of mineral elements such as Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Iron (Fe), Interchangeable aluminum (Al), Organic Carbon (CO) content, Acidity or basicity reaction through pH, electrical conductivity (EC), salinity, porosity and cation exchange capacity (CIC). For this purpose, composite samples of 1kg of floor packed and labeled in double closing bags. In the case of bulk density (Dap), real density (Dr) and humidity retention, samples were taken with 5 cm PVC cylinders in each profile described (Illustration 1-17 a). The samples were sent labeled according to the area geomorphology and the vegetation of the sampling site, whose information was also completed in the chains of custody of the laboratories selected to carry out the analyzes.

In the study area, simple soil samples were also taken for fats and hydrocarbons in plastic containers of 250 g labeled (Illustration 1-17. b), and for heavy metals Mercury, Manganese, Nickel, Silver, Copper and Lead, and for Cyanide the sample size was 1kg of soil sent in plastic bag. For these parameters, 11 samples were sent.

To take the samples, observations were made every 100 m, making a zig-zag route (Illustration 1-17), in flexible mesh, in order to obtain a scale map of 1: 10,000. Which according to the Regional Autonomous Corporation of Cundinamarca and the IGAC (2012), this corresponds to a study detailed, fundamental in the planning of Territorial Planning and in the identification of the Agrological classes.

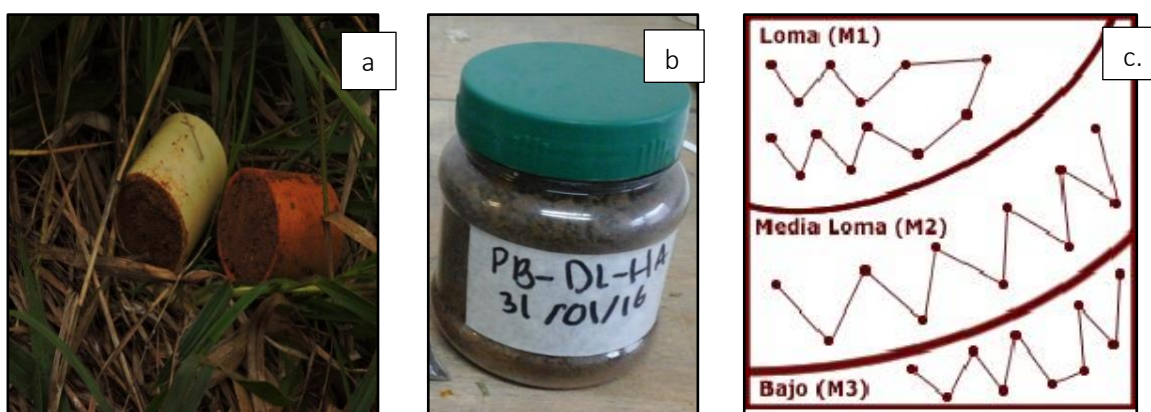


Illustration 1-17 a. Dap samples. b. Sample for fats. c. Zig-zag route according to topography.

Source: INGEX, 2016.

All the samples were kept in a refrigerator at 4°C while their field shipment was made in the laboratory. Below are the parameters accredited by the IDEAM that were sent to the laboratories for analysis (Table 1-15).

#### 1.5.6.3.1 Parameters to be analyzed in the AID

Below are the parameters and the method used by the laboratory to be analyzed in the area of study influence.

**Table 1-15.** Parameters analyzed, and extraction methods used by the laboratory.

Parameter	Method used by laboratory
Texture	Bouyoucos method
Apparent and real density (Dap and Dr)	Waxed lump
Humidity	Calculation by difference
Mineralogy	Microscopy
Organic Carbon (CO)	Walkley - Black
pH	Electrometric - pH with water
Nitrogen (N)	Digestion - Distillation.
Phosphorus (P)	Bray II Method
Potassium (K)	Extraction with 1 N Ammonium Acetate, pH 7
Calcium (Ca)	Extraction with 1 N Ammonium Acetate, pH 7
Magnesium (Mg)	Extraction with 1 N Ammonium Acetate, pH 7
Iron (Fe)	
Electrical conductivity (CE)	Determination of electrical conductivity
CIC (Cation exchange capacity)	Cationic Exchange Capacity 1N Ammonium Acetate, pH 7.
Greases and oils	Ultrasound / infrared extraction
Total hydrocarbons (HT)	Ultrasound extraction / infrared partition - hydrocarbons
Cyanide	Colorimetric-Title metric
Mercury (Hg)	Digestion - Cold Steam
Manganese (Mn)	Acid digestion - Atomic absorption
Nickel (Ni)	Digestion nitric acid-hydrogen peroxide / ICP
Silver (Ag)	Digestion nitric acid-hydrogen peroxide / ICP
Lead (Pb)	Digestion nitric acid-hydrogen peroxide / ICP
Copper (Cu)	Digestion nitric acid-hydrogen peroxide / ICP
Aluminum (Al)	) Determination of interchangeable acidity

*Source: INGEX, 2016.*

The mineralogy studies were made for each textural fraction (gravel, sand, silt and clay) performed the laboratory by counting the minerals, which were expressed in terms of relative frequency of abundance for each mineral species in percentage. According to the IGAC (2007), the mineralogical composition is the result of the alteration of the parental materials exposed to weathering, weathering, erosion, accumulation and other phenomena on the surface of the Earth. It enables us to know the current and potential fertility conditions for agriculture to establish the pedogenetic processes and define the taxonomic classification of them.

#### 1.5.6.3.2 Parameters to be analyzed in IIA

For the IIA samples, 22 samples composed of horizons of the profiles for physical-chemical parameters described in the following table. With the final purpose to ensure the traceability of the



samples, they were sent with the chain of custody of the laboratory. In addition, the geographical location map of samples is presented.

**Table 1-16.** Physical-chemical parameters of soils.

Texture	Potassium (K)
Apparent and real density (Porosity)	Calcium (Ca)
Humidity.	Magnesium (Mg)
Organic Carbon	Iron (Fe)
pH	Aluminum (Al)
Nitrogen (N)	Electric conductivity
Phosphorus (P)	CIC

*Source: INGEX, 2016.*

#### 1.5.6.4 PHASE ANALYSIS OF INFORMATION

With the data taken in the field and based on the information delivered by the laboratory, proceeded to run the USDA key (2010) for soil classification up to the subgroup level, there They described the modal profiles for each type of soil. This also allowed to present the map of soils by associations, as well as agrological classification and potential use and conflicts in the land use related to the project.

The delivered results of the physico-chemical characteristics were analyzed based on the levels defined as optimal at the vegetal level. And the cationic Ca / Mg, Ca / k, Mg / k ratios were calculated and Ca + Mg / k, in order to establish if these were balanced.

The contents of heavy metals, fats and hydrocarbons were compared with the limits established for soils in Louisiana Protocol 29B and EPA (1992) in order to establish whether the current quantities were in the allowed ranges.

##### 1.5.6.4.1 Soil associations

The soil associations presented were classified based on the structural variable of Geomorphology combined with a functional variable such as vegetation. Selecting one of the variables with which units can be defined as indicated by Velasquez et al. (2004) in the Illustration 1-18.

##### 1.5.6.4.2 Current use, agrological classification and conflicts of land use

The current land uses were determined with the vegetation cover and the observations in the Project study area. For each one, the percentage of area was determined. The potential use is made based on the agrological classification modified by the Geographical Institute Agustín Codazzi "IGAC" of the system of the Department of Agriculture of the United States of America (INCORA, nineteen ninety-five); in which there are eight agrological classes represented with Roman numerals, where higher numerical grade lower soil aptitude for use and handling. In addition, the subclasses by means of letters that indicated their limitation, defined by the MADS (2012) as follows:

Limitations in the root zone; **e**: erosion or susceptibility to it; **h**: excess moisture in the ground resulting from flooding and / or flooding; and **c**: limitations by climate.

To determine conflicts in land use, current use was compared with the potential use generated with the agrological classification, which allowed to establish if there was a correspondence between the vocation of the land and its current use, in such a way that the conflicts of land use.

VARIABLE DE DELIMITACIÓN	UNIDADES CARTOGRÁFICAS
<b>POR ESTRUCTURA</b>	
Clima	Climosecuencia. Suelos zonales
Geología	Litosecuencia. Litosuelos
Edad de los materiales o suelos	Cronosecuencia. Geocronología de los suelos
Geomorfología	Toposecuencia. Unidades pedogeomorfológicas
<b>POR COBERTURA Y FUNCIONALIDAD</b>	
Uso de la tierra	Zonas urbanas, industriales, agrícolas o pecuarias, áreas de vegetación secundaria en diversos estados de sucesión, plantaciones forestales u otras áreas alteradas que se observan en el paisaje con un mosaico de contornos geométricos típicos de actividades humanas.
<b>OTROS</b>	
Combinaciones de las anteriores. Zonas agrícolas según tipos de suelos, uso del suelo de acuerdo con la zonalidad climática, entre otros.	

**Illustration 1-18.** Categories for the cartographic delineation of the soil units.  
*Source: Velásquez et al, 2004.*

### 1.5.7 WEATHER METHODOLOGY AND CLIMATE

For the elaboration of this component sources of information were used, in order to determine the following study variables.

#### 1.5.7.1 PRECIPITATION

To estimate the precipitation field in the area of interest, given the scarcity of stations, recourse was to the use of secondary information, by the location of precipitation stations is not possible make a map for this variable, which later allows a suitable water balance. In this way, the precipitation fields calculated for the department of Antioquia according to Álvarez (2007). The generalities of the precipitation stations are in Table 1-17

**Table 1-17.** Generalities of precipitation stations near the study area.

Code	Type	Name	Current	Municipality	Lat	Lon	Cota (m)	Date	Date	Years
							(m)	Start	End	
27030090	PM	El Bosque	Doña Teresa	Zaragoza	7°19'N	74°50'W	220	1970	2015	45
27030140	PM	Palma de Coco	Pocune	Segovia	7°14'N	74°48'W	100	1974	2015	41
27011100	PM	Las Brisas	Mata	Segovia	7°09'N	74°49'W	600	1983	2015	32
27030130	PM	El Londre	Tigui	El Bagre	7°28'N	74°39'W	1000	1974	1987	13

*Source: INGEX, 2016.*

### 1.5.7.2 EVAPOTRANSPIRATION

Evapotranspiration is one of the most important components of the water balance. It represents the amount of water leaving the system into the atmosphere in the form of water vapor, for a combination of physical evaporation and transpiration of vegetation. Evapotranspiration depends mainly on climatic conditions that in turn are a function of the physical characteristics of the atmosphere that is close to the ground and vegetation, it also depends on the water quality and water surface area.

For the calculation of this variable there are several empirical methods, most of them based on formulas that have been obtained in climatic conditions different from the tropical, so it is necessary to do the calculation with different expressions and be able to compare them to see which of them better represents the variation of evapotranspiration in the study basins.

In the estimation of this variable was made based on the precipitation information and through the Turc equation.

Its formulation (equation 1) is based on a mass balance, based on elements meteorological conditions such as temperature and rainfall in the basin, applied to measures of long term (Barco y Cuartas, 1998)

$$ETR = \frac{P}{\sqrt{0.9 + \frac{P^2}{L^2}}} \quad (1)$$

Where, ETR is the real evapotranspiration (mm / year), P is the average rainfall in the basin (mm / year), T the average annual temperature in ° C.

For  $P / L > 0,316$ , where L is expressed as:

$$L = 300 + 25 * T + 0.05 * T^3 \quad (2)$$

Si  $P/L < 0,316$ :

$$ETR = P \quad (3)$$

The generalities of the station, which measures the evaporation parameter, are shown in the Table 1-18.

**Table 1-1.** Generalities of the stations with evaporation information near the study area.

Code	Type	Name	Current	Municipality	Lat	Lon	Cota (m)	Date	Date	Years
							(m)	Start	End	
27035020	CO	El Boquete	Nechi	Segovia	7°08'N	74°39'W	450	1970	1975	5

*Source: INGEX, 2016.*

### 1.5.7.3 RELATIVE HUMIDITY

The relative humidity of the study area was obtained from El Boquete station, which is the only station with records of relative humidity in the study sector. The generalities of the station used are shown in Table 1-19.

**Table 1-19.** Generalities of the stations with relative humidity information close to the study area.

Code	Type	Name	Current	Municipality	Lat	Lon	Cota (m)	Date start	Date end	Years
27035020	CO	El Boquete	Nechí	Segovia	7°08'N	74°39'W	450	1970	1975	5

*Source: INGEX, 2016.*

### 1.5.7.4 TEMPERATURE

Due to the scarcity of information in the basin, to know the spatial variability of temperature indirect estimation was used by the equation proposed by Cenicafé (Chávez and Jaramillo, 1998). In this methodology, regionalization is variable with height above sea level from monthly average surface temperature records for different geographical regions in the country. The equation used belongs to the Andean region and is of the form:

$$T = 29.42 - 0.0061 * h \quad (4)$$

Where: h= height above sea level

### 1.5.7.5 SOLAR BRIGHTNESS

The solar brightness of the study area was obtained from El Boquete station, which is the only station with records of relative humidity in the study sector. The generalities of the station used are shown in Table 1-20.

**Table 1-20.** Generalities of the stations with solar brightness information next to the study area

Code	Type	Name	Current	Municipality	Lat	Lon	Cota (m)	Date start	Date end	Years
27035020	CO	El Boquete	Nechi	Segovia	7°08'N	74°39'W	450	1970	1975	5

*Source: INGEX, 2016.*

#### **1.5.7.6 SOLAR RADIATION**

For the analysis of solar radiation in the AID and All, the re-analysis of NCEP / NCAR was used (Kalnay et. Al., 1996), which has data from 1948 to 2015, in a grid of 2.5 ° x 2.5 °, with a resolution of four daily data. For this study, only the last 10 years of information. Illustration 1-19 shows the location of the point closest to the study area. The point for the analysis corresponds to "solar radiation 1".

#### **1.5.7.7 ATMOSPHERIC PRESSURE**

For the analysis of atmospheric pressure in the AID and All, the re-analysis of NCEP / NCAR (Kalnay et. Al., 1996), which has data from 1948 to 2015, in a grid of 2.5 ° x 2.5 °, with a resolution of four daily data. For this study, only the last 10 years of information. Illustration 1-20 shows the location of the point closest to the study area. The point for the analysis corresponds to "atmospheric pressure 1".

#### **1.5.7.8 CLOUDINESS**

For the analysis of cloud cover (or cloud cover) in the AID and All, the re-analysis of the NCEP/NCAR (Kalnay et al., 1996), which has data from 1948 to 2015, in a grid of 2.5 x 2.5, with a resolution of four daily data. For this study only, the last ones were taken 10 years of information. In it shows the location of the point closest to the study area. He points for the analysis corresponds "Cloudiness 1" (Illustration 1-21).

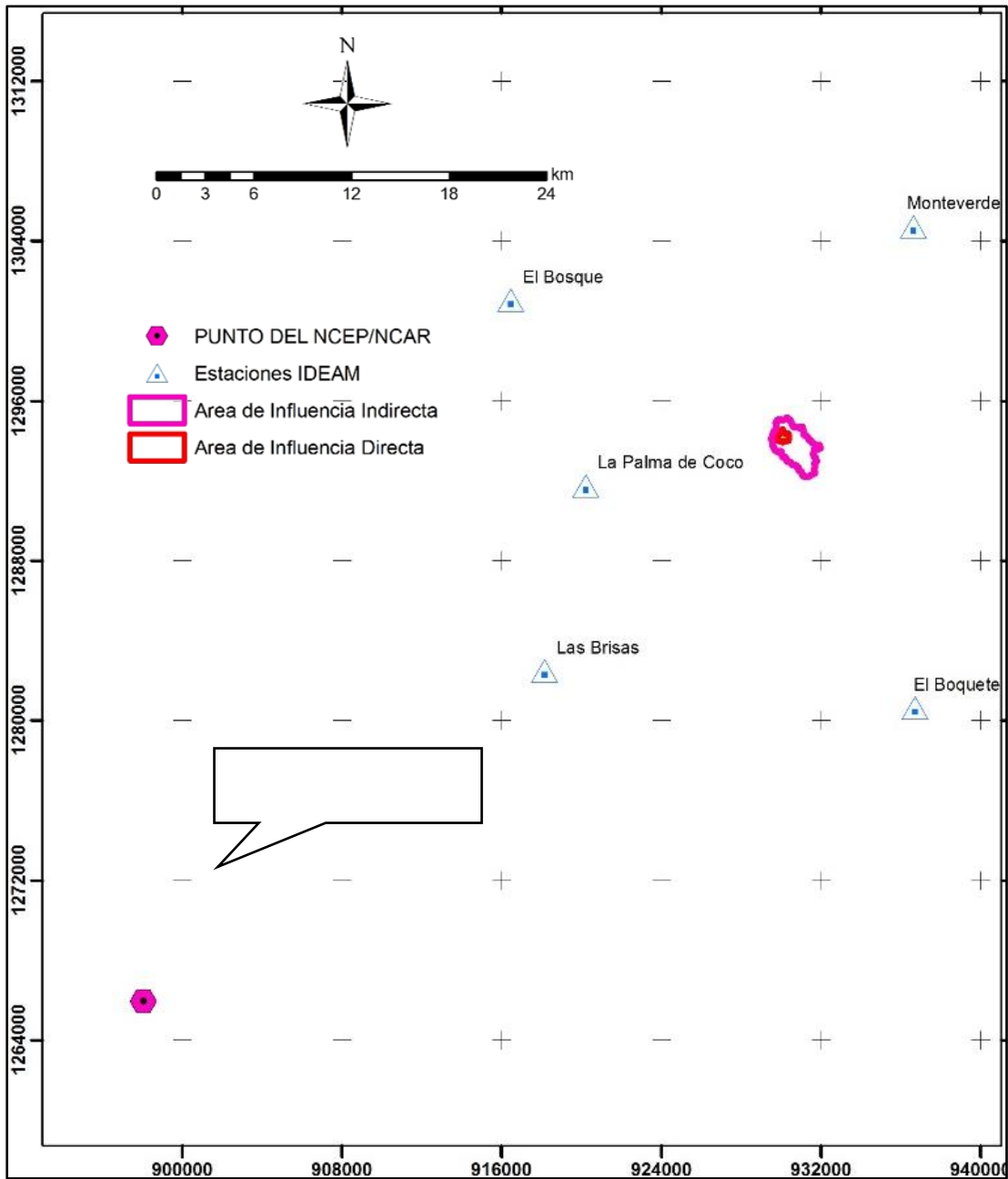


Illustration 1-19. Location of NCEP / NCAR point to obtain solar radiation data.

Source: INGEX, 2016.

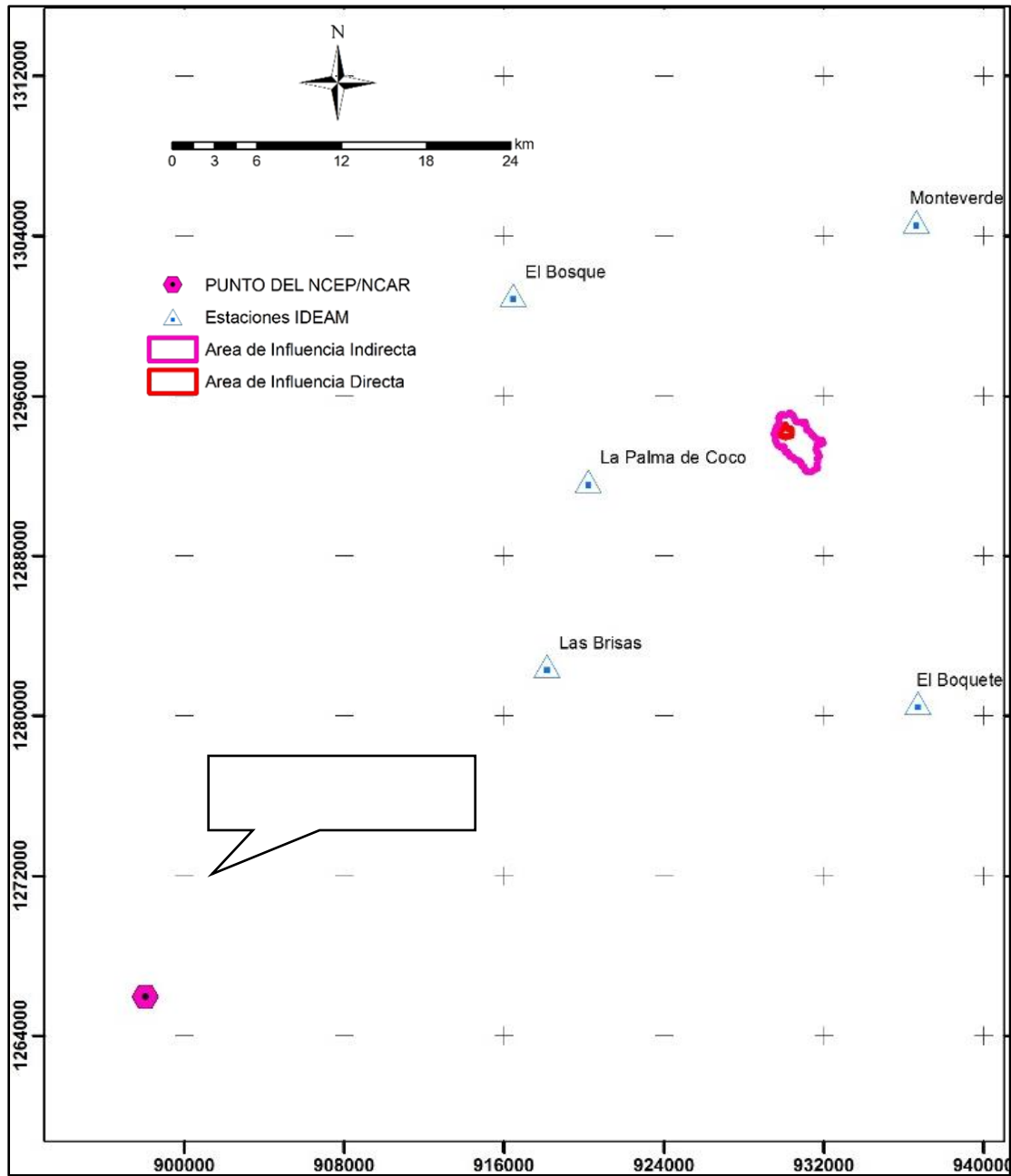


Illustration 1-20. Location of NCEP/NCAR point to obtain atmospheric pressure data.  
 Source: INGEX, 2016.



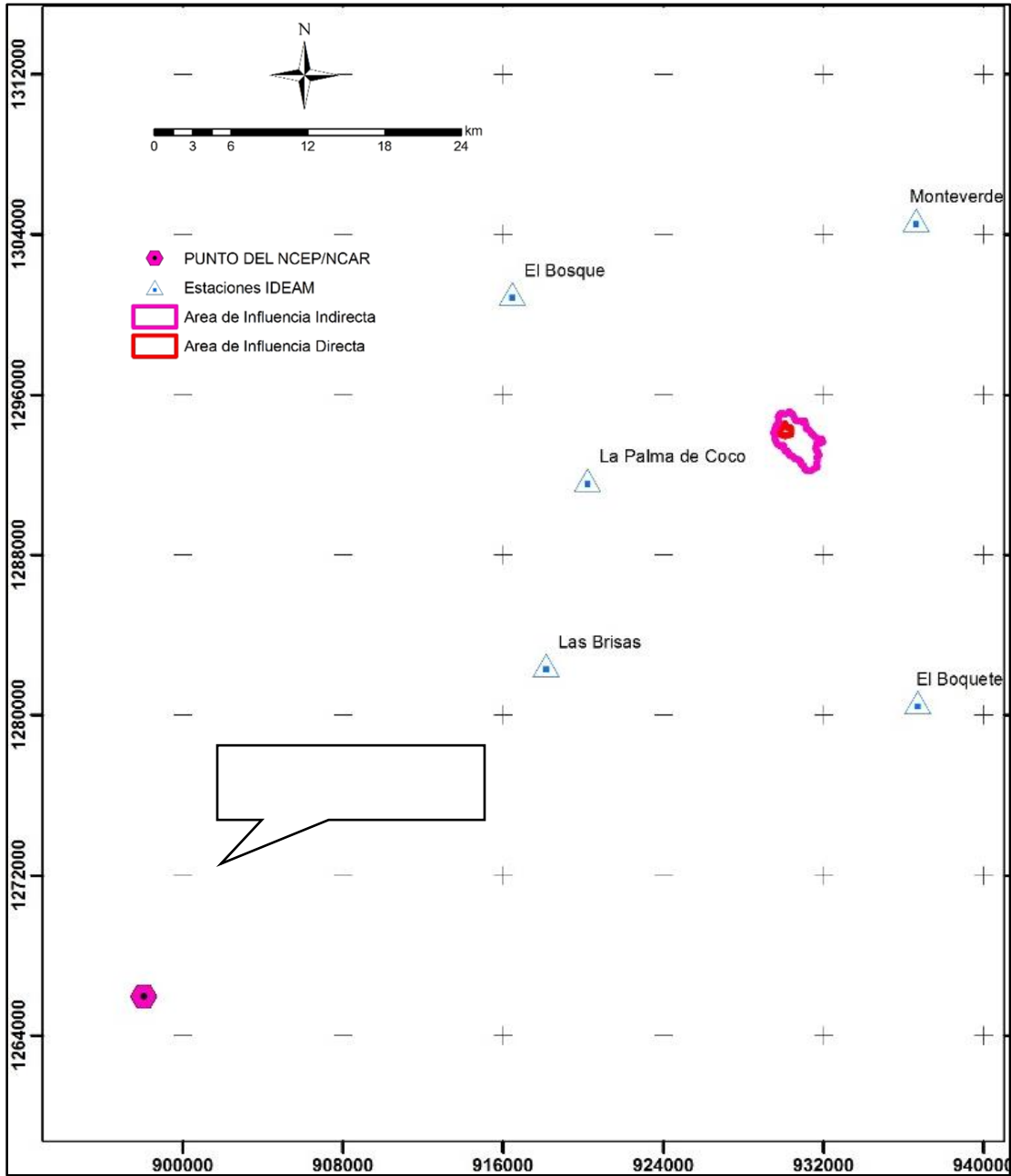


Illustration 1-21. Location of NCEP / NCAR point to obtain the cloud data.  
Source: INGEX, 2016.

### 1.5.7.9 ARIDITY INDEX

The aridity index is the relationship between average precipitation and evapotranspiration potential of the study area. This relationship is described by the following equation:

$$Ia = \frac{P}{ETP} \quad (5)$$

Where:

$$ETP = 1700.17 * e^{-0.002*h} \quad (6)$$

Being:

h: height above sea level

### 1.5.8 FLORA METHODOLOGY

The objective of the characterizations for the flora component is to know the type of coverage plants, the predominant species of the area and the distribution pattern in the spatial dimension, is the definition of ecosystems and / or biomes, besides establishing the relationship between rarity; A) Yes like the actions directed to the conservation, preservation, and / or restoration of the natural environment. On the other hand, it allows knowing the diversity patterns of the site, the connection between coverages or patches of forest, state of conservation, plant succession, ecosystem services that are derive from them and their multiple uses.

The Northeast part of Antioquia is, in contrast to the mining activity that takes place there as, a region of great interest and importance in conservation, due to the remnants of humid lowland forest that presents, to the high rates of endemism, that have led to define it as the area of endemism of the Nechi lowlands (EBA 037) (Stattersfield, Crosby, Long & Wege, 1998), which is part of the biogeographic province of the Magdalena basin and the northernmost piedmont of the Central and Western Cordilleras of Colombia (Hernández- Camacho, 1992), added to the fact of the potential presence of the distribution of species with some degree of threat regarding its conservation refers to various parameters.

In the study area for the "El Pescado" mining project, immersed in the forest reserve of the Magdalena (law 2nd of 1959 of the Ministry of Environment), is not alien to this situation; since for the year 2005 it was estimated that only 10% of its original habitat remained, because its economy It is mainly based on mining, timber trade, extensive livestock farming and agricultural practices, being by anthropic intervention relicts of the original ecosystem as a fragmentation; from Likewise, semiconexous forest patches are evidenced by narrow to medium to high strips intervened as it was found in the field trips, additionally an accelerated change of vegetation coverage to create pastures through the use of slash and burn method, this alteration can be developed in the short term, as evidenced in Illustration 1-22, Illustration 1-23 and Illustration 1-24.

Colombia is making a big effort led by the Institute of Natural Sciences, to document all the species of native plants, both vascular and non-vascular, through the project "Catalog of Plants of Colombia". This project is being advanced in two stages: the initial production of fairly elaborate lists of each

family, with which it was obtained in August 2006 a first version of the catalog, and the final purification of these lists by the respective specialists, with whom it is expected to have a final version of the catalog in 2009 (Bernal, Robbert & Celis, 2007).



**Illustration 1-22.** Overview of the accelerated change in vegetables cover  
*Source: TOUCHSTONE, 2012.*



**Illustration 1-23.** Changes in land use.  
*Source: TOUCHSTONE, 2012.*



**Illustration 1-24.** Burning to expand paddocks for livestock.  
*Source: TOUCHSTONE, 2012.*

Below is the methodology used for the determination of ecosystems, plant cover, elaboration of thematic cartography, vegetation characterization, information processing, 100% inventory and sample collection.

#### **1.5.8.1 DETERMINATION OF ECOSYSTEMS**

The national map of marine and terrestrial ecosystems prepared by the Institute was used of Hydrology, Meteorology and Environmental Studies (hereinafter IDEAM), Institute of Pacific Environmental Research (IIAP), Amazon Research Institute (in forward SINCHI), Research Institute of Biological Resources Alexander von Humboldt (in forward IAvH) and Agustín Codazzi Geographical Institute (hereinafter IGAC), 2008.

#### **1.5.8.2 DETERMINATION OF VEGETABLE COVERAGE**

The classification of plant cover was based on the adapted Corine Land Cover methodology for Colombia (2010) through the interpretation of orthophotos and their respective field trip, in order to validate the information.

Initially, a preliminary map of vegetation coverage was prepared from an orthophoto of the year 2012 and with secondary information obtained in previous studies. Later it was updated based on field work.

The Corine Land Cover methodology allows to describe, characterize, classify and compare each one of the coverage there, in addition to updating the data found there. Within the Coverages found were identified (See Table 1-21):

**Table 1-21.** Units of Covers of the earth (Corine Land Cover, 2010).

Level 1	Level 2	Level 3	Level 4	Level 5	Abb.
1 TERRITORIES ARTIFICIALISED	1.1. Urbanized areas	1.1.2. Urban fabric discontinuous			Tud
2. AGRICULTURAL TERRITORIES	2.2 Permanent crops	2.2.1. Crops permanent herbaceous	2.2.1.3 Banana and Yucca		
		2.2.2. Crops permanent bush	2.2.2.3. Cocoa		C
	2.3 Pastures	2.3.1. Clean pastures			Pl
		2.3.1. Woodland pastures			Pa
3. FORESTS AND AREAS SEMI NATURALES	3.1. Forest	3.1.1. Dense forest	3.1.1.2. Forest dense low	3.1.1.2.1. Forest dense ground firm	Bdbtf
	3.2. Areas with vegetation herbaceous and / or shrubby.	3.2.3. Vegetation secondary or in transition.	3.2.3.2. Vegetation low secondary		Vsb

*Source: Corine Land Cover Methodology (modified by TOUCHSTONE, 2012).*

#### 1.5.8.2.1 Discontinuous urban fabric

They are spaces made up of buildings and green areas. The buildings, roads and infrastructure built cover the surface of the land in a dispersed and discontinuous manner, since the rest of the area it is covered by vegetation. This unit may present difficulty for its delimitation when other coverings of natural and semi-natural type are mixed with areas classified as urban areas.

#### 1.5.8.2.2 Permanent herbaceous crops

Coverage mainly composed of permanent crops of herbaceous habit such as cane sugar, banana, banana and tobacco. Herbaceous plants are plants that do not have organs woody, they are green and with an annual vegetative life cycle.

#### 1.5.8.2.3 Banana and Yucca

Coverage dominantly composed of cultivation of banana (*Musa sapientum L.*) and/or banana (*Musa paradisiacal L.*), giant perennial herbaceous plant of the family Musaceae, with short rhizome and Apparent stem, which results from the union of the leaf sheaths, of conical shape and with varying height between 3.5 and 7.5 m high, which ends in a crown of leaves. The leaves are very large and arranged in a spiral.

#### 1.5.8.2.4 Permanent Bush crops

Permanent coverings occupied mainly by shrub crops such as coffee, cocoa, coca and vineyards. A shrub is a perennial plant, with a woody stem structure, with a height between 0.5 and 5 m, strongly branched at the base and without a defined cup (FAO, 2001).

#### 1.5.8.2.4.1 Cocoa

Coverage in which the cultivation of cocoa (*Theobroma cacao* L.), perennial shrub plant, predominates of woody stem, reaching heights of up to 4.5 m. Its cultivation is established mainly in regions of warm and temperate climate (0-1.500 m.a.s.l). Grows to free exposure or under shade, requiring an optimum rainfall that varies between 1,800 to 2,500 mm / year, with high relative humidity.

#### 1.5.8.2.5 Clean Pastures

This coverage includes lands occupied by clean pastures with a percentage of coverage greater than 70%; carrying out management practices (cleaning, liming and / or fertilization, etc.) and the technological level used prevents the presence or development of other coverages.

#### 1.5.8.2.6 Wooded pastures

Coverage that includes lands covered with pastures, in which pastures have been structured with presence of trees with a height greater than 5 meters, distributed in a dispersed manner. The coverage of trees must be greater than 30% and less than 50% of the total area of the pasture unit.

#### 1.5.8.2.7 Dense forest of dry land

Corresponds to areas with arboreal vegetation characterized by a more or less stratum continuous whose area of tree coverage represents more than 70% of the total area of the unit, and with height of the canopy between 5 and 15 meters, and that is located in areas that do not present periodic flooding processes.

#### 1.5.8.2.8 Low secondary vegetation

Are those areas covered by mainly shrub and herbaceous vegetation with irregular canopy and occasional presence of trees and vines, which corresponds to the initial stages of the plant succession after presenting a process of deforestation of forests or afforestation of the pastures. It develops after the original intervention and, generally, they are conformed by communities of shrubs and herbaceous formed by many species.

### 1.5.8.3 DEVELOPMENT OF THE THEMATIC CARTOGRAPHY

Plant covers were delimited from an orthophoto of the year 2012, through an analysis multi-temporal data were verified in the field, making a tour through points of control in strategic places, where the changes generated by activities were visualized anthropic (artisanal mining, urban and agricultural expansion, burning, logging, pasture expansion for livestock, wood extraction, among others) or natural (thunderstorms, lightning and fire forestry). The determined changes were georeferenced, and the relevant information was updated through a new map of coverage according to the legend of the Corine Land Methodology Cover adapted for Colombia (2010).



This methodology allows to describe, characterize, evaluate, classify and compare each and every one of the coverage of the land once they are identified in the field.

A multi-temporal analysis of coverage with photointerpretation of aerial photographs of the years 2005, at the beginning of 2012 and cartography raised or updated in the year 2012.

#### 1.5.8.4 CHARACTERIZATION OF VEGETATION

The methodology to develop the data gathering in the field was the one required by the terms of reference corresponding to resolutions No. 1526 of 2012 (Annex 1.1) and No. 1274 of 2014 (Annex 1.2) and the methodology for the presentation of environmental studies.

These methodologies are framed in the characterization of high forest vegetation (trees and palms) and early regeneration (saplings and stand of trees). This vegetal characterization aims at collecting basic information to know the status, evaluate, and carry out feasibility studies and forest potential on a large scale and of general interest.

##### 1.5.8.4.1 Sampling

To design the proposed vegetation inventory of the study area, the representativeness in the amount of data to be taken in the field, the characteristics of each of the individuals and the environment where they are found, as well as the existence of maps and cartography updated digital.

For the selection of sampling sites in the characterization of forest ecosystems in each One of the plant covers, a first sector of points for each of them was made, mainly in those that are within the study area. For this, resources were available technologies and cartographic inputs such as forest inventory sampling points previous made for TOUCHSTONE. The methodologies for the establishment of the plots was at random within the study area for the biotic component, taking into account that the intensity sampling rate of 95% and an error rate of 15%. These values were determined after performing the pre-field phase and use the statistician to establish the number of parcels to be made by coverage, using the following equation.

$$n = \frac{t^2 * CV\%^2}{E^2} \quad n = \frac{t^2 * CV\%^2}{E^2 + \frac{t^2 * CV\%^2}{N}}$$

n= Number of plots.

t= t- student with a 95% probability.

CV= Covariance.

N= Total area (ha) by vegetation cover.

E= Sampling error.

Finally, according to decree 1791 of 1996, the forest inventory was carried out at 100% of the trees to take advantage as only time, for the establishment of the necessary infrastructure of the project, in that inventory the measurement of each of the individuals with a DAP was made (Diameter at breast height) greater than or equal to 10 cm, taking the necessary field records as total height,



commercial height and geographical location of each of the individuals in closed critical, dangerous or vulnerable, in order to determine with their location (Table 1-22).

**Table 1-22.** Inventory field inventory 100% of individuals reason for use.

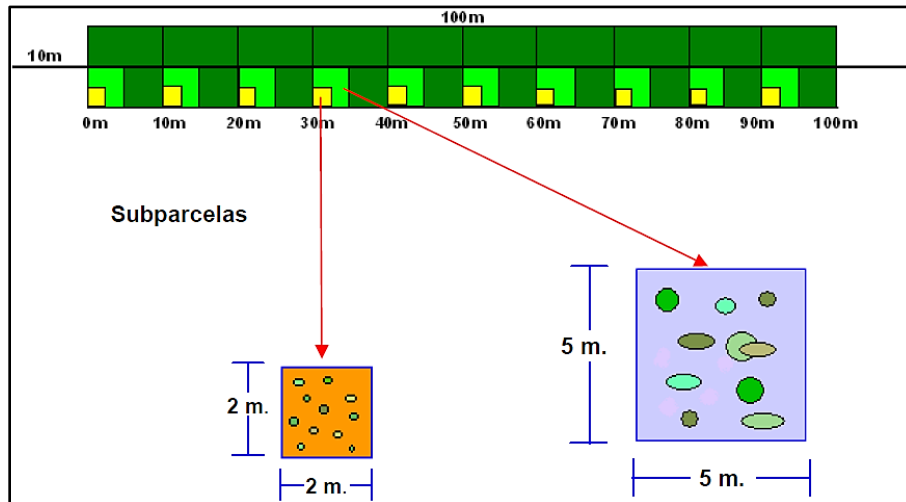
FECHA: _____		DEPARTAMENTO: _____		MUNICIPIO: _____		VEREDA: _____		
COORDENADAS: N (Y) _____		E (X) _____		ALTURA SOBRE EL NIVEL DEL MAR (m.s.n.m): _____		PARCELA _____		
SUBPARCELA: _____		ANOTADOR: _____						
PLANILLA DE CAMPO								
N°	NOMBRE COMÚN	NOMBRE CIENTÍFICO	INDIVIDUOS	DAP (cm)	ALTURAS		COORDENADAS	
					H <sub>c</sub> (m)	H <sub>t</sub> (m)	NORTE (Y)	ESTE (X)

Source: TOUCHSTONE, 2012.

#### 1.5.8.4.2 Sampling units

For field data collection, plots of 0.1 ha were defined as sampling units, depended on the shape of the fragment, i.e. 10 m x 100 m or 20 m x 50 m (separated yes at least 200 meters to avoid replicas between them), in these the characterization was carried out of the forests, oriented towards a cardinal point or perpendicular to a channel (Illustration 1-25).

The assembly of each of the plots was initiated once the pre-field phase was completed, where located by random coverage, the sampling point indicated in the base map and later with the help of a precision compass was located north and from this point were located the delimiters of the plots initially in the east or in a clockwise direction (Illustration 1-26).



**Illustration 1-25.** Size of plots for the characterization of forest ecosystems.  
 Source: Project General Plan of Forest Management for the Department of Tolima, 2008.



**Illustration 1-26.** Scheme assembly of plots for the characterization of forest ecosystems of the study area.  
 Source: TOUCHSTONE, 2012.

The sampling of vegetation was carried out by the method of establishment of random plots and following the methodology proposed by Rangel and Velasquez (1997), which proposes to carry out a characterization for plant coverings and in plots of 10 x 100 m (separated from each other by at least 200 m avoid replicas among them), within which the different ages are evaluated as they are high forest (plots of 10 x 10 m), stand of trees (plots of 5 x 5) and saplings (plots of 2 x 2). In the area of in the study of the project, 35 sampling plots were carried out, in order to know and analyze the structure of the forest, its species and its behavior, in the different types of coverages (See Table 1-23).

**Table 1-23.** Location of plots.

Plot N°	Coordinates	
	Y	X
1	1293341	931511
2	1293397	931393
3	1293514	931281
4	1293202	931256
5	1292990	931321
6	1293082	931881
7	1292831	930765
8	1293413	930797
9	1292837	930538
10	1292968	930576
11	1293100	930597
12	1293538	930583
13	1293790	930096
14	1293831	930852
15	1294283	931009
16	1292549	930830
17	1292241	931387
18	1292479	931308
19	1292821	931119
20	1293702	931254
21	1293407	930945
22	1293661	930496
23	1293524	930313
24	1293744	930202
25	1293673	929941
26	1294285	930190
27	1294676	929945
28	1294691	929749
29	1294545	929612
30	1294448	929502
31	1294136	929269
32	1293850	929540
33	1293494	929637
34	1293419	929474
35	1293183	930009

Source: TOUCHSTONE, 2012.

The characterization of terrestrial flora with primary information was carried out in the area of biotic study of the mining concession 5969 of the "El Pescado" project. This comprises approximately 395 ha, with an altitudinal range that goes from 170 to 340 m.a.s.l. meters above sea level and is supported in chapter 3. Areas of Influence.

The first point was located to the north, there the first delimiter was established and the points of georeferencing in the field spreadsheet (See Table 1-24), where it will be replaced by location of the quadrant of 50 x 20 m or 10 x 100 m.

**Table 1-24.** Field sheet for high forest

FECHA: _____		DEPARTAMENTO: _____		MUNICIPIO: _____		VEREDA: _____								
COORDENADAS: N (Y) _____		E (X) _____		ALTURA SOBRE EL NIVEL DEL MAR (m.s.n.m): _____		PARCELA _____								
SUBPARCELA: _____		TIPO DE COBERTURA: _____		ANOTADOR: _____										
Planilla de Campo														
Nº Ind	Nombre Común	Nombre Científico	DAP	Alturas			Coordenadas		Diámetro de copas				Usos y Observaciones	
				H <sub>r</sub>	H <sub>c</sub>	H <sub>copa</sub>	X	Y	X1	X2	Y1	Y2		

*Source: TOUCHSTONE, 2012.*

#### 1.5.8.4.2.1 Natural regeneration

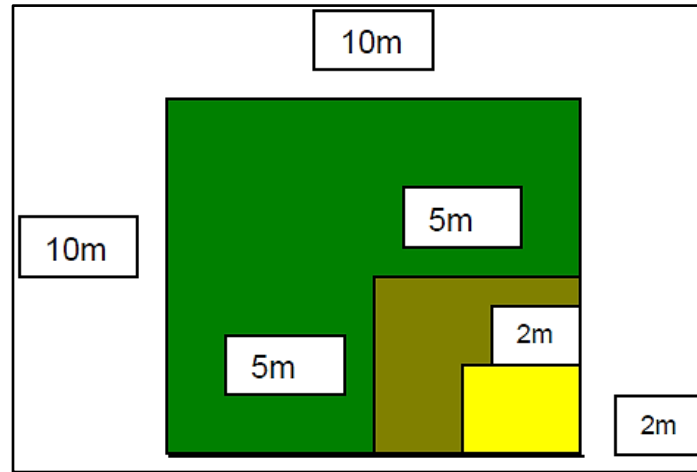
Natural regeneration was evaluated following the diagnostic sampling methodology for the natural regeneration implemented by Dubois (1980), who establishes a detailed division for the lower categories of this one. The first corresponds to the shoots or saplings (R), in which include all individuals of tree species between 0 and 30 cm in height.

The second category corresponds to the seedlings (U), which are subdivided into lower seedlings (U1), with heights between 30 - 150 cm and the upper seedlings (U2), with heights between 150 cm and 300 cm.

A third category corresponds to the established ones (E), they have an ecological definition, because it is considered that an individual when he reaches this category has exceeded the competence and for that reason has the highest probability of becoming an adult tree, those established correspond to individuals with heights greater than 300 cm and less than 5 cm in normal diameter.

The stand of trees (L), correspond to individuals with diameters between 5, above this category the different types of high forest or trees themselves are located, which include higher categories of regeneration.

For inventory purposes, category R is evaluated in plots of 2 x 2 m, while categories U and E, are recorded in plots of 5x5 m. The other categories were evaluated in the 10 m plots x10 m (Illustration 1-27).



**Illustration 1-27.** Size of plots for the characterization of the natural regeneration of forest species in the area study.  
Source: Project General Plan of Forest Management for the Department of Tolima 2008.

#### 1.5.8.4.2.2 Method registration variable

In each of the plots, all the individuals with a diameter at the height of the chest (DAP) greater than or equal to 2.5 cm, to which they were registered in their respective form (See Table 1-25) the following parameters: total height, height of the shaft and commercial height, description of the state of the shaft (inclined, crooked, bifurcated, fallen, dead or with disease) and common name, between other relevant parameters of each tree for the category high forest and stand of trees.

In each of the inventory plots the variable of the number of fallen trees and observations regarding changes in vegetation structure and physiography. The data was recorded in a form of inventories of the high forest. Another type of vegetation is the natural or early regeneration conformed by saplings and stand of trees, these determined by DAP < 10 cm. However, there are two types of saplings and two types of stand of trees of the following shape.

#### Saplings

**Table 1-25.** Field sheet for saplings

FECHA:	DEPARTAMENTO:	MUNICIPIO:	VEREDA:	
COORDENADAS: N (Y)	E (X)	ALTURA SOBRE EL NIVEL DEL MAR (m.s.n.m):	PARCELA	
SUBPARCELA:		ANOTADOR:		
Nº	NOMBRE COMÚN	NOMBRE CIENTÍFICO	INDIVIDUOS	H <sub>TOTAL</sub> (m)

Source: TOUCHSTONE, 2012.

- R: Trees with height between 1 and 30 cm high
- U1 Trees with height between 1 and 30 cm high.

Stand of trees

In units of 5 x 5 m. the species and the amount of stand of trees, determined according to the following categories of Tree Size:

- U2: Individuals between 150 and 300 cm in height
- E: Individuals with height  $\geq$  500 cm. of and DAP  $\leq$  9.9 cm.

Base information was recorded (Table 1-26) as topography of the terrain, height above sea level, slope, area of the plot, date, annotation, plus the parcels were georeferenced at their central point and the locality of the same was indicated (department, municipality and village). On the other hand, the observations of habits of growth and were the object of direct observation.

**Table 1-26.** Field sheet for stand of trees

FECHA: _____		DEPARTAMENTO: _____		MUNICIPIO: _____		VEREDA: _____	
COORDENADAS: N (Y) _____		E (X) _____		ALTURA SOBRE EL NIVEL DEL MAR (m.s.n.m): _____		PARCELA _____	
SUBPARCELA: _____		ANOTADOR: _____					
N°	NOMBRE COMÚN	NOMBRE CIENTIFICO	INDIVIDUOS	DAP	H <sub>TOTAL</sub> (m)		

Source: TOUCHSTONE, 2012.

### 1.5.8.5 METHODS OF TABULATION OF FIELD INFORMATION

The measurement for the DAP was made with diametric tape at 1.30 m from the ground. This measurement tool is practical since it only requires a single measurement and does not present difficulty with trees of thick bearing.

The measurement of the heights was made under the use of SUUNTO clinometer which has high precision, in addition to taking the slope measurement and its percentage of inclination.

For the location and georeferencing of the sampling plots a GPS device was used Garmin eTrex 20, with which the geographic coordinates of the initial points for the Assembling the plot, this throws the starting point for the orientation of the geographic north and as such the construction of the plot. In the same way, the device was used for the determination altitude of the sites where the plots are established, and in the rectification of the dimensions and extension of the sample units.

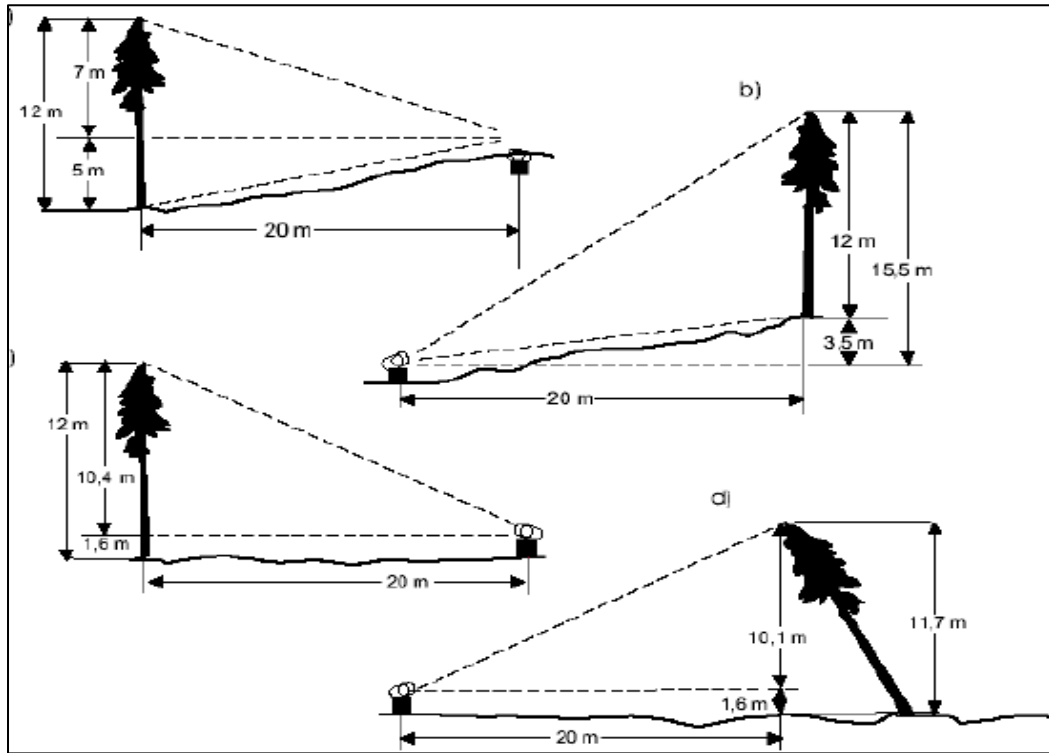
In obtaining the data, the measurement of total heights must be taken into account when Different relief conditions that may occur as indicated in Table 1-27 and Illustration 1-28.

Table 1-27. Field spreadsheet for land characterization.

<b>FECHA:</b> _____		<b>DEPARTAMENTO:</b> _____	
<b>MUNICIPIO:</b> _____		<b>VEREDA:</b> _____	
<b>COORDENADAS: N (Y)</b> _____		<b>E (X)</b> _____	
<b>ALTURA SOBRE EL NIVEL DEL MAR (m.s.n.m):</b> _____			
<b>PARCELA</b> _____		<b>SUBPARCELA:</b> _____	
<b>TIPO DE COBERTURA:</b> _____		<b>ANOTADOR:</b> _____	
<b>TOPOGRAFÍA</b>	<b>DRENAJE</b>	<b>TIPO DE BOSQUE</b>	
1. Terreno llano	1. Excesivo.	1. Alto.	
2. Laderas.	2. Bueno.	2. Medio.	
3. Terreno Ondulado	3. Pobre.	3. Bajo.	
4. Terreno Montañoso	4. Nulo o negado.	4. Muy bajo.	
5. Terreno Escarpado			
<b>ESTADO DE INTERVENCIÓN DEL BOSQUE.</b>		<b>PENDIENTE:</b> _____	
1. Natural sin señas de intervención.			
2. Natural con poca intervención.			
3. Natural con señal de aprovechamiento.			
4. Natural con señales de incendio.			
5. Natural con dosel abierto.			
6. No hay bosque			
<b>ILUMINACIÓN DE LA COPA.</b>	<b>LIANAS</b>		
1. Emergente.	1. No visibles en fuste y copa.		
2. Plena vertical.	2. Sueltas en el fuste, no copa		
3. Vertical parcial.	3. Sueltas en el fuste y copa		
4. Iluminación oblicua.	4. Apretando el fuste presentes o no en Copa.		
5. Nada directa.			
<b>ESTADO FUSTAL.</b>			
1. Torcido.			
2. Bifurcado.			
3. Caído.			
4. Muerto.			
5. Presencia de enfermedad.			
6. Aprovechado.			
<b>OBSERVACIONES.</b>			

Source: TOUCHSTONE, 2012.



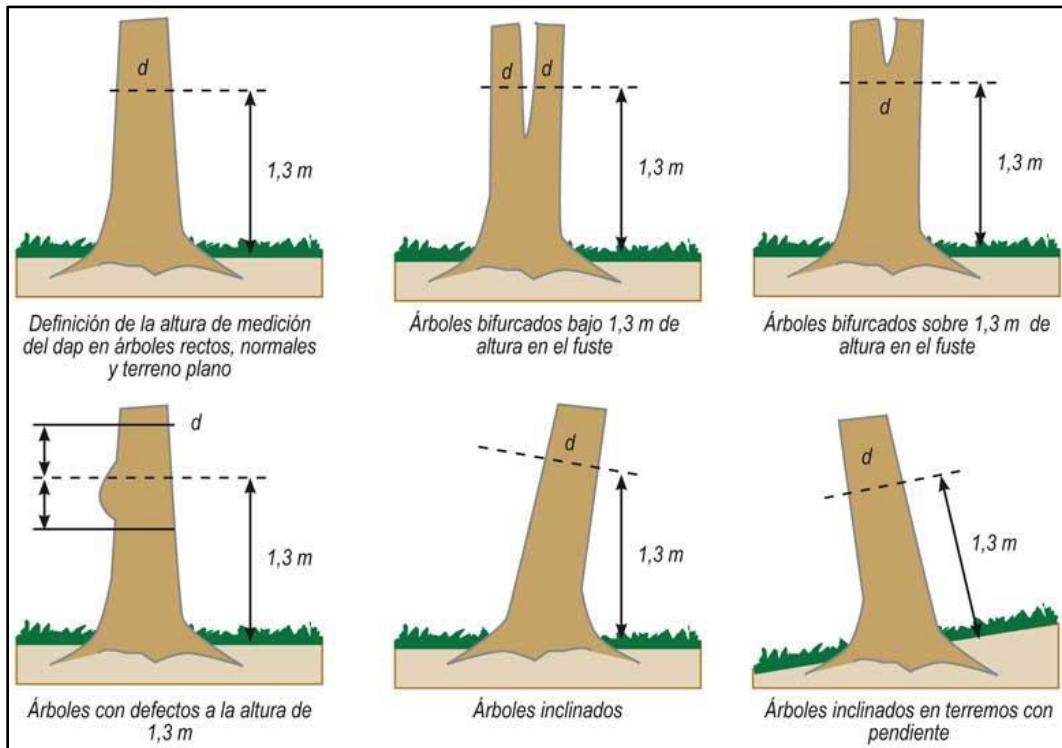


**Illustration 1-28.** Considerations in the measurement of heights for the characterization of forest species in the area of study.

Source: CONIF, 2013.

As well as for the taking of height, the field registration of the DAP must take into account the different possible situations that arise in the field as shown in Illustration 1-29.

In order to speed up the work in the field, the forms previously carried out for the individuals high forest and natural regeneration, filling in the necessary and sufficient information for the generation of results in office, therefore it was very important to review and verify the information to collect before leaving for sampling.



**Illustration 1-29.** Considerations in the measurement of the diameter at chest height (DAP) for the characterization of forest species within the study area in the study area.

Source: CONIF, 2013.

The forms mentioned above were completed in pencil to facilitate the correction in field and to prevent possible difficulties with the climate, the following concepts are described they took into account for the completion of the respective forms:

**Relief Topography:** This consists of schematizing and conceptualizing the set of particularities that occur in the field, in this way the following are considered by relief topography types:

**Slopes:** From each slope point there is a single line of maximum slope going up and another going down.

**Flat land:** The one with smooth slopes, without sudden changes from one to another.

**Wavy terrain:** That with elevations and depressions of little importance. The movement does not it presents great difficulties.

**Mountainous terrain:** The slopes have a steeper slope and the differences in height between troughs and the divide is more noticeable. The places through which to cross or cross must be known.

**Steep terrain:** It has slopes of great slope, even vertical and almost inaccessible. Sudden changes of slopes.

**Slope:** this is determined with the abney level, to represent the height or elevation of each one of the points with respect to a reference plane.

**High Forest State:** the high forest state is elaborated under observation criteria, accepting the methodology raised by the ministry the following states are described: I = Inclined; T = Twisted; B = Forked; C = Fallen; M = Dead; E = Presence of disease.

For these tasks of measurement in the field, we worked with a work group or group formed by three (3) people, among which is the baquiano or person from the support zone in the opening roads that in turn act as an empirical recognizer of tree species in the field its vulgar name, and between the two supports the collection of botanical samples. On the other hand, a forest engineer leader of the crew and trained in the management of equipment and tools support and finally a field assistant who will support the activities of measurement, data collection, collection of botanical samples and their subsequent management.

Once the characterization of the flora was done, the tabulation of the data collected was made in the field, in order to perform the respective analyzes of each of the biodiversity indices, vertical structure, horizontal structure, dispersion of cups, alpha, beta and gamma diversity, between other relevant aspects.

#### 1.5.8.5.1 Methods of Calculation of Indicators and Outputs

##### 1.5.8.5.1.1 Horizontal structural analysis

The evaluation of the horizontal structure allows us to characterize the behavior of the species in the surface of the land, indicates the behavior of the dominant species, importance ecology of the species and expresses the homogeneity of the forest mass (Rangel J.O & Velásquez). In this process, the following indices and graphs will be used:

With the registered data, the structural analysis, composition and diversity of the flora in the study area. For this analysis, the diametric and altimetric classification of the plants. We also found the conventional indexes that include the abundances, frequencies and dominances. The index of importance value (IVI) is obtained as derived indexes and the mixture ratio (CM).

To categorize the abundance of each of the species, the following criteria were used:

- Abundant Species, species with frequencies of occurrence greater than 10%
- Common Species, species with frequencies of occurrence between 2-10%
- Uncommon Species, species with frequencies of occurrence between 0.1-2%
- Rare species, species with frequencies of occurrence between 0-0.1%

Importance Value Index (I.V.I.): The importance value index is determined with the sum of the abundances, frequencies and relative dominances of each of the species found in the sampling, can be represented in tables or histograms, extended IVI, predominance index physiognomic IPF and mixing ratio. (See Table 1-28).

**Table 1-28.** Determination of the IVI Index of the forest species of the area under study.

<b>Especie</b>	<b>Abundancia absoluta</b>	<b>Abundancia relativa</b>	<b>Frecuencia absoluta</b>	<b>Frecuencia relativa</b>	<b>Dominancia absoluta</b>	<b>Dominancia relativa</b>	<b>I.V.I</b>
.							
.							
.							
<b>Total</b>							

Source: CONIF, 2013.

By grouping the individuals of a forest, the aim is to analyze the behavior of the frequencies in each of the intervals coming to visualize the degree of intervention to which the forest and the existing possibility that individuals of low diameter classes may occupy upper diameter classes. This analysis is represented in tables and illustrations.

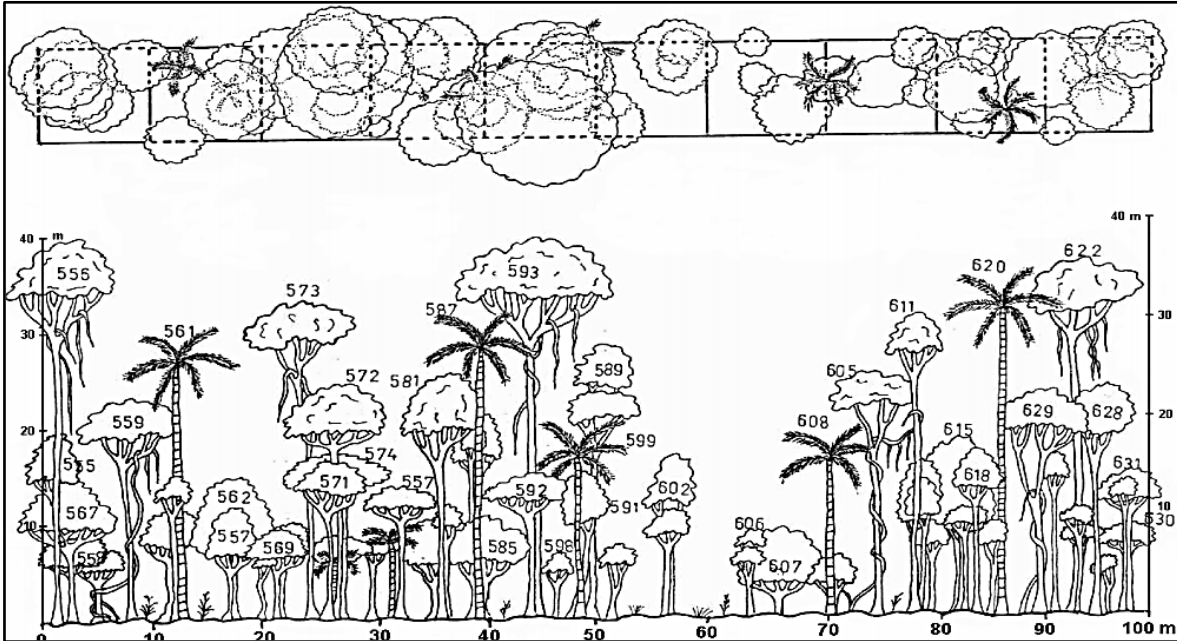
Spatial distribution of the species. Because the communities are constituted by a variable set of species with a greater or lesser degree of interaction and with variable abundance, from common until rare and given that the phytosociological studies are based on the comparison of floristic censuses coming from the communities studied, it is important to know some characteristics of the vegetation linked to the spatial pattern of the species and the frequency distribution. The boss spatial of a species refers to the distribution on the forest surface of individuals belonging to this one.

In the same way, to evaluate the sampling effort, an accumulation curve was carried out. Species with a nonparametric statistic (CHAO) which tells us the number of species expected with the sampling effort. Each curve is accompanied by intervals of confidence from the 95% If the confidence intervals of the accumulation curve and the nonparametric estimator are overlap, indicates that the sampling effort is representative.

#### 1.5.8.5.1.2 Vertical structural analysis

The objective of the vertical structure analysis is to characterize the morphology of the vegetation say the architecture of the forest, it is possible to establish the successional state in which the vegetation at the time of the measurements, one can also deduce the complexity of the structure (Illustration 1-30). This is achieved with the implementation of the following analyzes.

- Vegetation profile diagram



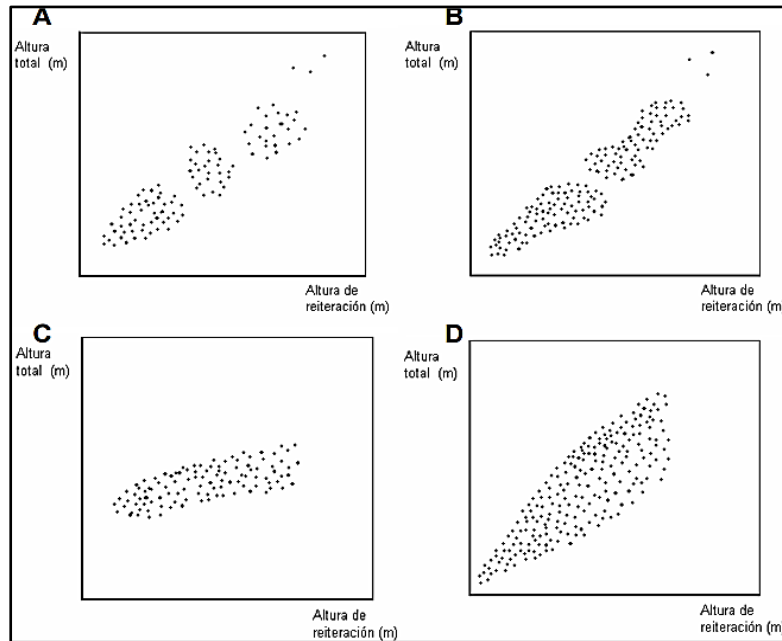
**Illustration 1-30.** Example of Vertical structure for forest species.

Source: *Ecological and Silvicultural Evaluation of Forest Ecosystems.* (MELO AND VARGAS 2003).

- Cup dispersion diagram (Illustration 1-31).

#### 1.5.8.5.2 Evaluation of floristic diversity

A correct use of the soil is only possible with an adequate knowledge of the communities that exist in the area where you want to work, for this reason you must have a notion of the potential of diversity in the different ecosystems present in the department to be able to apply management methodologies; because the best use of a soil is that which makes nature itself, hence the importance of knowing the dynamics of vegetation when man has not intervened because it serves as a tool for planning the territory. The evaluation aims to characterize the floristic richness of one of the ecosystems (alpha diversity) in order to compare the characteristics similar or differences that may be found between them (beta diversity).



**Illustration 1-31.** Example of the tree dispersion diagram for forest species.  
*Source: Ecological and Silvicultural Evaluation of Forest Ecosystems. (MELO AND VARGAS 2003).*

#### 1.5.8.5.2.1 Evaluation of alpha diversity

The study of the diversity within the parcels of characterization or alpha diversity is carried out with the in order to characterize the richness of species present within the work units and for this the purpose is to use density indexes, abundance indexes and graphic representations of relative abundances such as the abundance models described below:

- Margalef species density index (DMg)

$$Dmg = \frac{S-1}{\ln(N)}$$

Where: S = Number of species

N = Number of individuals

- Indices based on the relative abundance of species:

Shannon-Wiener Index (H')

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

$$E = \frac{H'}{\ln(S)}$$

Where: H' = Diversity of Shannon

pi = (ni / N) = Proportional (relative) abundance

E = Uniformity of Shannon

S = Total number of species in the sample.

#### 1.5.8.5.2.2 Beta-diversity evaluation

The evaluation of beta diversity is carried out in order to compare plant communities different geographically, but contiguous in the territory where there are different species and very probably common species. Beta-diversity is related to the rate of change in species of two adjacent plant communities. It reflects, therefore, the difference in composition of the two communities and ultimately the heterogeneity of the landscape. This can be obtained with the implementation of indexes that compare communities and have been called metric and non-metric measures:

- Measures of Similarity or Metrics, Jaccard Index ( $C_j$ ):

$$C_j = \frac{j}{a+b-j}$$

Where: a = Number of species in ecosystem A

b = Number of species in ecosystem B

j = Number of species shared by the communities.

The range of values for this index goes from zero (0) when there are no shared species between both sites and one (1) when the two sites have the same species composition.

- Measures of Dissimilarity, Percentage of dissimilarity (PD)

$$PD=100-PS$$

$$PS=200 \frac{\sum \min (X_{i1}; X_{i2})}{\sum (X_{i1}+ X_{i2})}$$

Where: PD = Percentage of dissimilarity

PS = Percentage of similarity

Min ( $X_{i1}; X_{i2}$ ) = The minimum of the abundances of species i between the two communities

#### 1.5.8.5.2.3 Evaluation of Gamma-Diversity.

Total wealth of species within several units of the landscape or between various types of cover or habitats and is the result of the diversity of each of the communities (alpha diversity), as well as the degree of differentiation that has developed between them (beta-diversity).

- Gamma Index (Schluer and Ricklefs, 1993)

Gamma = diversity of average alpha x diversity beta x dimension of the sample.



To make comparisons between plant coverings and indices, Analysis of Variance was used (ANOVA) and a Chi-square test when it was the case. For comparison between groups, a Tukey test based on the ANOVA performed. To identify if there were differences a significant level of 0.05 was used.

#### **1.5.8.6 INVENTORY TO 100% FOR SPECIES OBJECTIVE OF EXPLOITATION**

The inventory of 100% of the forest species is carried out in order to know each of the target species for exploitation as stipulated in Decree 1791 of 1996 "Through which the regime of forest exploitation is established "in chapter IV (Forest uses only), by means of a statistical inventory with sampling error not exceeding fifteen percent (15%) and a probability of ninety-five percent (95%).

This inventory should generate information about the topography of the land, the location of all the trees with diameter equal to or greater than 10 cm (DBH), species, diameters and volume of trees to take advantage.

To carry out the census in the sites where the open pit mines will be established, and the benefit opens a lane or baseline in a strategic location over the area of use, then secondary lines are opened perpendicular to it, covering all the area to inventory in order to know the terrain (slopes, drainages, topographic features, among others).

In a second moment it proceeds to collect the relevant information for the target species of utilization (> 10 cm DAP) or lifting the census of the predetermined trees.

For each tree, the data referring to species, diameter, total height, commercial height are collected and location. This information is recorded in field notebooks or in a form previously structured, in addition to assigning a correlative number with colorful spray oil paint striking Each tree registered must be listed in a visible place on the shaft and always on a specific orientation to facilitate its later location.

Once the information is collected, a map of the location of trees in the field is prepared, in addition to elaborate lists of remaining species and cutting trees, with their respective species and commercial volume the remaining trees can come from three main sources: a) percentage of reserve by species, b) trees of rare species and c) protected species by the Environmental Authorities.

Once the number of individuals and the volume of wood found there is determined, performs the program of use and compensation according to the requirements established by CORANTIOQUIA and MADS, according to the characteristics of the use and with native species.

In the same way, the bibliographic review established by international agreements, book is carried out red of forest species, resolution 0192 of 2014 of the MADS and resolution 10194 of 2008 issued by CORANTIOQUIA, in order to categorize each of the species and/or individuals found in endemic, closed, critical, endangered and/or vulnerable.

#### **1.5.9 FAUNA METHODOLOGY**

INGEX GRUPO MINERO S.A.S. complemented and corroborated, through observations in the field, the characterization of the terrestrial fauna that was carried out during the year 2012 by TOUCHSTONE

in the study area according to the collection permit granted by resolution No. 1202-16599. The duration of the field work in the different coverages of the study area, corresponded to 26 net days of sampling with the exception of avifauna with 31 net days.

### 1.5.9.1 SAMPLING AREA

Said region comprises approximately 395 ha, with an altitudinal range that goes from 170 up to 500 meters above sea level.

The study area is located in the zone of life corresponding to tropical humid forest (bh-T), this is characterized by having an average temperature of 24°C, and a range of precipitation that it varies between 2,000 and 4,000 ml per year (Holdridge, 1967). The landscape within the sampling area it is dominated by large areas of pasture for livestock use and forest fragments dense connected to each other. It is also worth mentioning the presence of some areas with vegetation secondary in transition and some small crops of cocoa, cassava and banana.

### 1.5.9.2 SAMPLING POINTS

During the year 2012 and in order to characterize the terrestrial fauna within the study area, took a total of 188 sampling points of birds and mammals, these correspond to tours free of registration, trap installation sites, cameras and fog networks, in addition to occasional observation censuses (See Table 1-29).

**Table 1-29.** Bird and mastofauna sampling points in the study area of the mining concession 5969.

Sampling Point	Coordinates		Type	Coverage
	X	Y		
PML014	931514,457	1293219,65	Census	Bdbtf (3.1.1.2.1)
PML016	931312,231	1293134,54		
PML015	931392,739	1293050,93	Transect	
	931219,104	1293117,42		
PML044	930955,722	1293215,55	Census	Cpha (2.2.2.3)
PML011	930982,239	1293383,95	Transect	Bdbtf (3.1.1.2.1)
	931175,156	1293365		
PML012	931099,357	1293339,33	Transect	
	931072,73	1293171,15		
RBDA1	931103,604	1293215,34	Fog nets	
RBDA2	931150,571	1293235,96		
RBDA3	931047,334	1293175,5		
PML017	931055,193	1293107,58	Transect	
	931251,151	1293131,31		
AVI7	930709,272	1294695,37	Transect	
	930963,712	1294686,06		
AVI8	930976,315	1294695,22		
	931119,227	1294536,65		
RBDB1	931090,683	1294660,34	Fog nets	
RBDB2	931098,805	1294624,16		
RBDB3	931109,04	1294597,71		
RBDB4	931117,746	1294584,54		

Sampling Point	Coordinates		Type	Coverage
	X	Y		
RDBB5	931121,092	1294527,91		
PML030	931133,323	1294507,76	Transect	
	931128,153	1294361,78		
AVI10	931013,345	1294077,92		
	930916,737	1294097,96		
TSH16	930993,123	1294069,54	Sherman Traps	
TSH17	930973,587	1294078,19		
TSH18	930942,818	1294110,09		
TSH19	930921,263	1294096,74		
TSH20	930902,818	1294095,21		
AV11	930799,705	1294043,6	Transect	Bdbtf (3.1.1.2.1)
	930908,669	1294093,88		
TSH30	930805,556	1294041,71	Sherman Traps	Bdbtf (3.1.1.2.1)
TSH29	930816,262	1294036,94		
TSH28	930831,383	1294030,06		
TSH27	930848,492	1294023,51		
TSH26	930859,423	1294021,61		
TSH25	930868,267	1294027,35		
TSH24	930881,199	1294034,97		
TSH23	930884,091	1294049,89		
TSH22	930883,334	1294061,62		
TSH21	930888,988	1294077,43		
AV12	931014,512	1294123,26	Census	
PML022	930062,398	1293409,23	Transect	Vst (3.2.3)
	930068,66	1293227,17		
PML021	930133,121	1293199,66		
	930326,086	1293214,76		
AVI15	930252,704	1292862,94	Census	
PML019	930386,84	1292904,11		
	930239,41	1292992,58		
PML032	931006,27	1294073,06	Transect	Bdbtf (3.1.1.2.1)
	930808,526	1294033,41		
PML033	930742,515	1293976,76		
	930943,66	1293919,97		
PML045	929736,895	1293309,81	Census	Cphy (2.2.1)
RTUD2	930062,606	1294665,41	Fog nets	Tud (1.1.2)
RTUD3	930038,323	1294674,85		
RTUD5	930075,693	1294467,75		
RTUD4	930063,716	1294511,46		
RTUD1	929977,231	1294424,87		
PML023	929736,906	1293475,27	Transect	Bdbtf (3.1.1.2.1)
	929560,695	1293279,09	Transect	
RB12	929619,275	1293389,83	Fog nets	
RB11	929670,022	1293428,47		
CAM3	929696,204	1293433,52	Trap camera	
BDRB10	929707,494	1293450,98	Fog nets	Bdbtf (3.1.1.2.1)
PML038	930195,62	1293350,09		
	930315,8	1293522,02		
PML036	930178,467	1293563,46	Transect	Vst (3.2.3)
	930302,224	1293369,3		

Sampling Point	Coordinates		Type	Coverage
	X	Y		
PML039	930378,223	1293300,51		
	930537,385	1293390,43		
PML040	930368,456	1293504,25		
	930333,33	1293500,65		
AVI24	930311,893	1293571,68		
	930316,479	1293613,59		
TSH50	930156,836	1293574,88	Sherman Traps	Bdbtbf (3.1.1.2.1)
TSH70	930063,567	1293455,46		
RVSA2	930042,585	1293456,7	Fog nets	Vst (3.2.3)
RVSA3	930028,239	1293465,24		
RVSA4	929972,065	1293494,85		
TSH99	929949,99	1293504,5	Sherman Traps	Bdbtbf (3.1.1.2.1)
RVSA5	930054,563	1293413,66	Fog nets	Vst (3.2.3)
RVSA1	930097,943	1293475,87		
TSH101	929591,861	1294472,52	Sherman Traps	Bdbtbf (3.1.1.2.1)
TSH102	929573,975	1294476,2		
TSH103	929577,09	1294492,67		
TSH104	929566,725	1294503,86		
TSH105	929555,472	1294512,94		
TSH106	929536,484	1294517,95		
TSH107	929524,009	1294521,17		
TSH108	929510,328	1294531,14		
TSH109	929504,561	1294514,12		
TSH110	929509,526	1294510,57		
TSH111	929514,238	1294484,02		
TSH112	929531,797	1294483,67		
TSH113	929529,686	1294474,82		
TSH114	929539,058	1294463,75		
TSH115	929532,44	1294469,95		
TSH116	929526,34	1294451,71		
TSH117	929531,842	1294437,22		
TSH118	929533,478	1294422,17		
TSH119	929530,023	1294400,5		
TSH120	929529,349	1294391,98		
TSH121	929526,791	1294379,6		
TSH122	929567,653	1294378,55		
TSH123	929573,397	1294379,76		
TSH124	929571,314	1294390,71		
TSH125	929577,5	1294391,36		Bdbtbf (3.1.1.2.1)
TSH126	929575,966	1294400,32		
TSH127	929575,994	1294420,12		
TSH128	929573,561	1294417,91		
TSH129	929581,853	1294423,76		
TSH130	929580,324	1294436,26		
TSH131	929589,826	1294439,01		
TSH132	929586,52	1294444,22		
TSH133	929588,966	1294456,16		
TSH134	929583,004	1294457,16		
PML004	929778,796	1294443,73	Census	PI (2.3.1)

Sampling Point	Coordinates		Type	Coverage
	X	Y		
	929601,545	1294369,32		
RB13	929610,746	1294472,61	Fog nets	Bdbtf (3.1.1.2.1)
RB14	929703,873	1294569,47		
AVI27	929722,462	1294594,66	Transect	
	929804,499	1294737,77		
AVI28	929554,985	1294244,74		
	929338,613	1293919,22		
PML026	929417,706	1293930,83		
AVI30	929259,537	1293997,42	Census	
AVI31	929160,849	1294030,07	Transect	
	929318,503	1294381,44		
PML024	929473,226	1294299,93		
	929583,51	1293717,03		
AVI32	929508,767	1293500,58		
PML025	929495,391	1293491,53		
	929262,205	1293383,59		
PML031	930932,927	1294305,75		
	930683,719	1294266,06		
PML034	930465,62	1293883,69		
	930260,728	1293946,68	PI (2.3.1)	
RPA4	930299,832	1293396,51	Fog nets	Vst (3.2.3)
RPA3	930339,284	1293414,04		
RPA2	930353,882	1293428,18		
RPA1	930360,741	1293436,57		
AVI34	930344,98	1293538,79		
AVI36	930331,643	1293558,27	Transect	
	930242,477	1293529,64		
RPA5	930321,851	1293346,82	Fog nets	
AV37	930339,405	1293341,6	Transect	
	930324,201	1293527,2		
AVI38	930284,698	1293473,18		
PML005	930152,381	1294339,79		
	930321,6	1294198,43		
PML035	930239,773	1293888,21		
	930092,218	1293963,4		
PML042	930280,637	1293809,51		
	930524,878	1293689,51		
PML041	930349,7	1293677,14		
	930447,922	1293466,76		
PML018	931023,161	1292944,49		
	930898,314	1293151,48		
CAM1	931705,541	1293394,8	Trap camera	Bdbtf (3.1.1.2.1)
RBB1	931693,511	1293401,01	Fog nets	
RBB2	931671,328	1293412,32		
RBB3	931651,567	1293418,32		
RBB4	931634,422	1293399,1		
RBB5	931619,793	1293362,29		
TSH1	931619,086	1293329,33	Sherman Traps	
TSH15	931623,627	1293257,66		
PML007	930496,527	1294031,3	Transect	

Sampling Point	Coordinates		Type	Coverage
	X	Y		
PML008	930688,764	1294001,83	Fog nets	PI (2.3.1)
	930739,004	1293833,87		
	930492,079	1293850,03		
PML006	930358,002	1293929,18		
	930309,241	1294126,78		
RPE1	930063,686	1293857,48		
RPE2	930055,014	1293815,69		
RPE3	930025,237	1293767,51		
RPE4	930017,116	1293724,83		
RPE5	929998,407	1293693,23		
PML001	930050,118	1293869,23	Transect	PI (2.3.1)
	929891,049	1293923,97		
PML002	929780,242	1293741,86		
	929851,367	1293900,36		
PML003	929861,994	1293996,35		
	929824,767	1294227,55		
CAM2	930999,323	1293278,64	Trap camera	Bdbdtf (3.1.1.2.1)

Source: TOUCHSTONE, 2012.

All sampling points were randomly distributed within the study area, where it was tried that each coverage obtained a representative sampling.

In the area, a total of six (6) plant coverings were registered following the CORINE methodology LAND COVER (IDEAM 2010), these are: Discontinuous urban fabric (1.1.2), Permanent crops herbaceous products of cassava and plantain (2.2.1), permanent crops of shrubby cocoa (2.2.2.3), pastures clean (2.3.1), dense lowland forest (3.1.1.2.1) and secondary or transition vegetation (3.2.3). For the herpetofauna (amphibians and reptiles), up to 45 transects were made (See Table 1-30)

**Table 1-30.** Amphibian and reptile sampling points in the study area of the mining concession 5969.

Transect	Coor_x_ini	Coor_y_ini	Coord_x_fi	Coor_y_fin	Vegetal cover
1	930050	1293869	929891	1293924	2.3.1
2	929780	1293742	929851	1293900	
3	929862	1293996	929825	1294228	
4	929602	1294369	929779	1294444	
5	930322	1294198	930152	1294340	
6	930358	1293929	930309	1294127	
7	930689	1294002	930497	1294031	
8	930739	1293834	930492	1293850	
9	931393	1293397	931281	1293514	
10	931281	1293514	930945	1293407	3.1.1.2.1
11	931175	1293365	930982	1293384	
12	931073	1293171	931099	1293339	
13	931362	1293257	931223	1293301	
14	931514	1293220	931376	1293210	
15	931393	1293051	931219	1293117	
16	931312	1293135	931151	1293236	
17	931251	1293131	931055	1293108	

Transect	Coor_x_ini	Coor_y_ini	Coord_x_fi	Coor_y_fin	Vegetal cover
18	931023	1292944	930898	1293151	
19	930239	1292993	930387	1292904	
20	930387	1292904	930253	1292863	
21	930133	1293200	930326	1293215	
22	930062	1293409	930069	1293227	
23	929737	1293475	929561	1293279	
24	929584	1293717	929509	1293501	
25	929495	1293492	929262	1293384	
26	929418	1293931	929161	1294030	
27	929473	1294300	929319	1294381	
28	929510	1294511	929722	1294595	
29	930966	1294477	930653	1294475	
30	931128	1294362	930933	1294306	
31	930933	1294306	930684	1294266	
32	930809	1294033	931006	1294073	
33	930944	1293920	930743	1293977	
34	930466	1293884	930261	1293947	
35	930092	1293963	930240	1293888	
36	930178	1293563	930316	1293614	
37	930098	1293476	930312	1293572	
38	930196	1293350	930316	1293522	
39	930378	1293301	930333	1293501	3.2.3.2
40	930368	1293504	930537	1293390	
41	930448	1293467	930350	1293677	
42	930525	1293690	930281	1293810	
43	930038	1294675	929977	1294425	1.1.2
44	930956	1293216	930956	1293216	2.2.2.3
45	929737	1293310	929737	1293310	2.2.1.3

Source: TOUCHSTONE, 2012.

### 1.5.9.3 MASTOFAUNA METHODOLOGY

During the year 2012 and in order to characterize the terrestrial fauna within the study area, performed the characterization of mammals by field sampling. For this study, they chose representative sites where the success of capturing mammals was greater, that is, the Forest cover predominated in sampling. The sampling of flying mammals was carried out in all coverages present within the study area (See Table 1-29).

#### 1.5.9.3.1 Medium and small mammals

For the sampling of this type of mammals, a total of 135 Sherman type traps were installed with sweet bait (peanut butter, flaky oatmeal and vanilla essence for 9 days divided into 3 sampling stations (45 traps for each station), in the corresponding vegetation cover a dense low forest of the mainland (3.1.1.2.1). These traps were reviewed during the hours of the morning and barley in the afternoon hours.

The capture success is greater in this type of plant unit, due to the ecological requirements of mammals collected with this type of traps.



#### 1.5.9.3.2 Large mammals

For the observation of large mammals, it was freely traversed inside each of the vegetable coverings present in the study area, always trying to ensure that these routes were representative for the total sampling area. During the tours, an active search for evidence of mammals (vocalizations, feces, tracks, burrows); these were included within of the photographic record of the faunal characterization.

Additionally, 4 tracking cameras were installed in places where it was considered feasible to pass through some kind of mammal.

#### 1.5.9.3.3 Flying mammals

To sample these mammals, AXT fog nets of 12 m long X 5 m width and 36 mm mesh eye, which were located in strategic sites of passage of bats, in all coverages present within the study area, for 15 nights.

With all the species of mammals sighted and / or captured, sex data were taken, state of maturation, if it was sighted in groups or solitary and diet (to specimens that allowed its visualization in the field). Each captured specimen was released near the place of capture.

Finally, some surveys or conversations with inhabitants of the area were carried out in order to complement the list of mammal species for the study area.

#### 1.5.9.3.4 Sampling efforts

Below are the sampling efforts and the capture success for the different methodologies implemented for the characterization of the mastofauna within the study area.

##### 1.5.9.3.4.1 Sampling effort and capture success for Sherman traps

In the study area, 45 Sherman-type traps were installed per sampling station within the vegetation cover corresponding to low dense forest of the mainland (3.1.1.2.1), for the capture of small mammals. Sampling was done at each station for 3 days, for a period total of 9 days. Although each trap was installed in the afternoon hours and were checked in the hours of the morning, they were active throughout the day, for a sampling effort in each station equal to 1080 hours and a total of 3240 sampling hours.

Through this method, 4 individuals were captured for a total capture success equal to 0.123%.

*Sampling units:* 45 traps per plant cover.

*Sampling effort:* 12 hours / trap / day or 36 hours / trap / vegetation cover.

Biologist's dedication in Sherman traps: The revision of the total traps by him avifauna biologist, took 1 hour with the support of auxiliaries.

##### 1.5.9.3.4.2 Sampling effort and capture success for the active search method of mammals

*Sampling units:* 4 to 6 routes per plant cover.

*Sampling effort:* 6 hours / night or 18 hours / plant cover.

Biologist dedication in search: 6 hours per night, approximately. **In total the mastofauna demanded 9.5 hours between morning and night.**

#### 1.5.9.3.4.3 Sampling effort and capture success for tracking cameras

A total of four Moultrie M-550 type tracking cameras were installed in the study area during 26 days, for a sampling effort of 2496 hour. Through this method 4 records were obtained in total, for a capture success of 0.160%.

*Sampling units:* 4 Tracking cameras per sampling areas.

*Sampling effort:* 24 hours / day / camera or 24 hours / day / sampling area.

*Biologist's dedication in tracking camera:* The review of the photos is done the last day before finish the shift, to get out to rest. That is to say that there is no demand for time to develop this activity.

#### 1.5.9.3.4.4 Sampling effort and successful capture of chiropter for the network method of fog.

*Sampling units:* 60 meters of networks or 5 networks per vegetation cover.

*Sampling effort:* 6 hours / nights or 18 hours / plant cover or 3 nights / plant cover.

*Biologist's dedication in fog networks:* The revision of a network by the same biologist avifauna, it took 10 minutes and for the total of revisions (15), this professional dedicates 150 min or 2.5 hours a day to review networks with the support of auxiliaries.

### 1.5.9.4 AVIFAUNA METHODOLOGY

The Aves class constitutes one of the most diverse biological groups within the tetrapods with about 9000 described species (Clements et al 2015; Ziswiler, 1980), which are present in all the continents where they can live, reproduce and feed in a large part of the habitats existing (Naranjo et al 2012). This enormous diversity is the result of the great radiation of birds, 145 million years ago at the beginning of the Cretaceous, when one of the most important characteristics of most of the current birds: the flight (Padian & Chiappe, 1998). The flight as a result of evolution from a common ancestor of reptiles and current birds, brought with it a set of synapomorphies or unique and excluding characters for birds such as Presence of feathers, aerodynamic bones, internal air sacs, pectoral muscles developed, among others (Hilty & Brown, 1986). It should be noted that the presence of wings, despite being the main characteristic that evolved from the flight, this is not exclusive to birds, since that other vertebrates, like chiropter, also have wings. There is another set of characteristics of the birds that they share with reptiles; the group  $\bar{i}$  surviving more closely related to birds: the legs and fingers of birds are covered with scales and nails similar to the reptiles, additionally in both groups the skull is articulated to the column vertebral by a single occipital

condyle, the ribs have uncinated processes, the eyes possess nictitating membranes and erythrocytes are nucleated (Kardong, 2006).

The diversity and composition of birds of Colombia is unique in the world, in its territory, corresponding to 0.7% of the world landmass houses around 1900 species of birds (Clements et al 2015), corresponding to 19% of all bird species on the planet (Hilty & Brown, 1986; Cooper, 2011; Clements et al 2015), situation that places the country as the first in the world. This diversity is mainly due to the fact that Colombia is a tropical country and has a large diversity of ecosystems and habitats that offer multiple niches for the birds (Cooper, 2011).

Additionally, Colombia has a huge rate of endemic and almost endemic species, due to especially its geographical heterogeneity and the existence of biomes and ecosystem units unique in the world, as is the case of the Sierra Nevada de Santa Marta, the biogeographical Chocó and the Andes, which are divided into a complex series of three mountain ranges more or less parallel and oriented from north to south and that are separated by two large and deep valleys, the Cauca between the western and central mountain range; and Magdalena between central and eastern (Hilty and Brown, 1986). The Colombian Andes are recognized as strategic ecosystems that harbor a high diversity of bird species (Lentijo & Kattan, 2005). Because this region of the country is the one it has the greatest demographic, economic and industrial development, faces the biggest problems fragmentation and loss of ecosystems and species, so it is urgent to concentrate different conservation efforts in these sites (Armenteras et al 2003, Fahrig, 2003, Harper et al 2005;).

For the elaboration of the baseline, the characterization of avifauna was included, since the study of bird communities are useful for designing and implementing conservation and management policies ecosystems and habitats. They also provide technical information for the identification of communities that need protection and scientific information for the development of studies in biogeography, systematic, ecology and evolution (Villareal et al 2004).

The study of the structure of bird communities provides a quick, reliable and replicable assessment of the conservation status of most terrestrial and aquatic habitats and also allows comparisons along climatic and ecological gradients to be made to wealth, change and abundance of species. These inventories can also be documented some aspects of the natural history of the species such as diets, reproductive periods, migrations, social structures, habits among others (Villareal et al 2004).

Bird samplings are useful in the design of the implementation of policies for conservation and management of ecosystems and habitats; these are a fast, reliable and replicable means of evaluation, as they provide technical information for the identification of communities vulnerable or important. It also allows comparisons to be made along gradients climatic and ecological in terms of wealth, turnover and abundance of species (Villareal et al 2006).

To characterize effectively the community of birds present in the area of influence of the mining project "El Pescado" in concession 5969, the methodological proposal has been adopted stipulated in the Manual of methods for the development of biodiversity inventories of the IAVH (Villareal et al 2006), with certain modifications that are dependent on the area that is going to be sampled and the type of records that will be taken later. In this way, different types of independent but complementary activities were executed each.

In this way, different types independent activities were executed, but complementary to each other.

#### 1.5.9.4.1 Sampling by relay of visual and auditory encounters (REV)

To register the bird species, present in the area, we proceeded with visual identification and auditory in free and random routes, to the interior of the different vegetal coverages of the area of study, trying to cover the largest representative area in each plant unit. The length and the number of transects per coverage varied according to the topography of the land and the total area of the coverage to be sampled, being the forest cover the one that greater number of transects obtained (See Table 1-29). Additionally, visual and auditory census points of specimens were established, in specific sites of interest or with a set of favorable attributes for direct bird's observation.

The routes were made between the busiest hours for birdlife in general, from 6:00 to 12:00 and from 2:00 to 6:00. Once an individual was sighted, they proceeded with its taxonomic determination up to the species level in cases where it was possible and if it was feasible his photographic record was taken.

The sightings were made with Bushnell 20X50 binoculars and the photographic record was captured with a Nikon Coolpix P600 compact camera. It is important to mention that at the moment to carry out the tours, we tried to reduce the disturbance within the environment, this in order to that the fauna moved freely, and its visualization was facilitated.

#### 1.5.9.4.2 Sampling with fog nets

To complement the list of species of birds registered from direct observation, they used fog nets, made with very thin and resistant fibers (nylon, polyester or cotton). Due to the fineness of the threads and their color (black, gray and Havana, among others), these networks pass almost unnoticed in the habitat, so they successfully catch the birds that are entangled to the flight (Villareal et al 2006).

Within the area of direct influence, a total of 5 were installed during the 26 sampling days fog nets in each vegetation cover. These networks were of type AXT 12; that is, 12 meters of long by 5 meters wide; with extended mesh of 30 to 36 mm, which were placed on sites and strategic transects for the passage of birds during the sampling day.

The registered specimens besides being photographed determined from taxonomic keys and field guides (Hilty & Brown, 1986; Peña & Quirama, 2014), defined attributes such as sex, size, weight, location in which the capture was made, coordinates of the observation, altitude, date and time, number of observation sequences, among others.

For rare species, with a certain degree of endemism, in closed or in danger of extinction and migratory, they deepened in data of specific behaviors, eating habits, nesting, among others. These annotations were consigned in notebooks and field formats.

Surveys were eventually conducted to the inhabitants of the area, in order to obtain information additional information about some species and the uses they received from these people.

The methodology carried out for the sampling of the avifauna has been complementary when combining different strategies that each one contributes key elements not only to elaborate a list full of species, but also a characterization of the different populations in the area. The visual and auditory bird sightings allow to cover a wide sampling area to elaborate not only a complete list of species, but also the data collection of the general biology of the species, on the other hand catches with fog nets allow, among other things, to characterize the state of maturity and the rate of males and females of some populations.

To complement the information on behavioral data, conservation status and biology in general of some species, a bibliographic search was carried out for each family and Each species. (Hilty & Brown, 1986, Naranjo et al 2012, AviBase 2014, Cites 2014, IUCN 2014).

#### 1.5.9.4.3 Sampling effort

Below are the sampling efforts and the capture success for the different implemented methodologies for the characterization of avifauna within the study area of the mining project "El Pescado", mining concession 5969.

##### 1.5.9.4.3.1 Effort and success of capture for the sampling of birds by relays of visual and auditory encounters (REV)

In the study area, sightings and active bird searches were conducted for 26 net days; these samplings were carried out by two people (professional and auxiliary) between 6:00 and 12:00 hours and 14:00 and 18:00 hours for an effort of 260 hours per observer and a total of 520 hours.

In the area a total of 961 individuals of different bird species were registered by means of methods direct (visual and auditory record), for an average capture success of 1.84 individuals per hour. It is noteworthy that the largest number of individuals was registered by this method.

*Sampling units:* 4 to 6 tours per plant cover and 2 to 8 bird census points.

*Sampling effort:* 9 hours / day or 27 hours / plant cover.

*Biologist dedication in REV for avifauna:* **9 hours a day approximately simultaneously with the review of fog networks**

##### 1.5.9.4.3.2 Capture effort and success for bird sampling using the network method fog

In the study area, 5 mist nets were installed for vegetation cover, type AXT 12 (12x5) meters) with 36 mm mesh eye. Each network remained open during 6:00 and 18:00 hours, during 26 days of sampling for a capture effort equal to 312 network hours and a total of 1560 sampling hour.

Through this method a total of 160 individuals were captured, thus the total capture success, that is, the relationship between the number of individuals captured and the sampling effort is 0.1026 (10%).

It is important to mention that the 160 individuals captured with this method correspond to the 16.65% of the total avifaunal records within the study area; this is an indirect proof of the validity of the use of this method for the knowledge of avifauna composition in a zone.

*Sampling units:* 60 meters or 5 networks per plant cover.

*Sampling effort:* 10 hours / network / day or 30 hours / network / vegetation coverage.

*Biologist demand in fog nets for avifauna:* Review every 30 or 40 minutes, after doing REV. The review of a network takes 10 minutes and for the total of revisions (15) this professional dedicates 150 min or **2.5 hours a day to review the networks with the support of auxiliaries.**

#### 1.5.9.5 METHODOLOGY OF HERPETOFAUNA

The sampling methods mainly used for the registration or capture of Herpetofauna are: direct (observation of the animal with capture or without capture) or indirect (the animal is not seen but detected by vocalizations or traces). Specifically, in this project methods were used Directives that provide quantitative information and were taken from Heyer et al 1994 and Angulo et al. to the 2006.

##### 1.5.9.5.1 Survey by Visual Encounters (REV)

The Survey by Visual Encounters, Visual Encounter Survey (hereinafter referred to by its initials) in English, REV) is very appropriate for the study of inventory and monitoring. It consists of one limited search per unit of effort time. A search of individuals is done through of an area or habitat for a predetermined period of time looking for animals so systematic review of all available habitats. The limitation of this technique is that not all Habitats and microhabitats can be sampled with the same efficiency and relative abundance of species can only be compared between sites with the same habitat type (Heyer et al., 1994, Angulo et al. 2006). The advantages of using the REV are that both species and Individuals of each species have the same probability of being observed during the survey. East Sampling can provide us with quantitative information to estimate species richness and abundance relative, but it is not adequate to estimate densities.

For this technique there were three basic sampling designs that depend on the objective of the study. For this case the Transect Design was used since it is suitable for sampling potentially different habitats (Heyer et al 1994). A transect is drawn with a length determined and you walk along this. For large areas, it is appropriate to establish 10 or more transects of 100 m in length, although this may vary according to the investigator's criteria (Heyer et al. 1994, Angulo et al. 2006).

##### 1.5.9.5.2 Sampling

The field work was carried out in 22 days of sampling. Because the amphibians and reptiles have diurnal and nocturnal habits were searched both day and night with the participation of a field manager who in this case is a herpetologist and an assistant field, for a total of two people per sampling event or per day.

The sampling area was chosen by the field manager, taking into account the coverages available vegetables that for this case were delimited by the flora professional: Denso Forest Low of Firm Earth, Secondary vegetation or in transition, Clean Pastures, Permanent Crops herbaceous, Cocoa Farming, Cultivation of Banana and Yucca and Discontinuous urban tissue.

During this study there were tours in the schedules: 8:00 - 12:00 in the morning 15:00 - 17:00 in the afternoon and 6: 30-22: 30 at night. In the sampling area, transects were established with a length of 200 meters measured with a synthetic fiber rope of that length. He took the initial coordinate and the final coordinate of each transect, 60-minute journeys were made for each of these. During this time, all the observed individuals were recorded to simple sight and vocalizations (in the case of amphibians); they also carefully reviewed all the available microhabitats (litter, trunks and stones, cracks, caves, roots and branches of shrubs and trees).

A review of two 200-meter transects was conducted per day, using 60-minute tours for each one, however, some days only one or two transects were carried out, due to the size of the vegetation cover, the topography where they were and the logistics to access the place of study.

A 200-meter transect was covered by dedicating two hours in the morning, one hour in the afternoon and two hours in the night for a total of five hours. How two transects per day were made, then both transects were covered in a total of ten hours. In this order of ideas, the sampling effort was ten hours per person per day for transects of 400 meters, that is to say in total 20 hours a day were used by 2 people for 400 meters.

For the capture of individuals, a herpetological clamp or hook was available for the case of Snakes and clean hands for the case of amphibians and lizards. For storage it they used cloth bags for reptiles and Ziploc bags for anurans. Registered individuals for this work was identified in the field, some were only observed, and others were captured to make the photographic record. The species that presented taxonomic uncertainty were collected, and those who were identified were immediately released. For all species you registered data on location, plant cover, microhabitat, time and number of individuals.

#### 1.5.9.5.3 Interviews

During the sampling, interviews were also conducted with the guides to establish that individuals of the herpetofauna they knew or had seen in the mining title area. Through photographs and images certain species that were not seen during the fieldwork were identified. The category taxonomic that could be reached in certain species was only up to order, some up to genus and few until species.

#### 1.5.9.5.4 Collection

During the year 2012 and according to the collection permit granted by resolution No. 1202-16599, the collection of 11 individuals was carried out, 2 of the order Tailless (frog), 6 of the suborder Serpent (snakes) and 3 of the suborder Saurian (lizards), because they presented taxonomic uncertainty. The individuals were transported from the field to the camp in cloth bags for reptiles' case and in Ziploc bags for the case of amphibians. A photographic record of these was made in and then they were sacrificed with an injection of 2% lidocaine in the cardiac region. Once the death of the individual was confirmed, they were fixed in 10% formaldehyde and left for 3 to 5 days. Once the time in formalin was complete, the individuals were stored in 96% Ethanol within a hermetic plastic container. The individuals were transported to Medellin in a refrigerator



of polystyrene. These were taken to the laboratory of Herpetology of the University of Antioquia, with the taxonomic register, where they were reviewed and stored.

#### 1.5.9.5.5 Sampling units and efforts

##### 1.5.9.5.5.1 Survey by Visual Encounters (REV)

**Sampling units:** 1 hour/1 Transect/Vegetation cover (the amount and extent of transects were defined during the REV in the field, where they tried to make them between 200 and 100 meters as suggests the methodology).

**Sampling effort:** 5 hours / Transect / Vegetable covers and 2 Transects / day.

Biologist dedication in REV for herpetofauna: *approximately 10 hours a day.*

#### 1.5.9.6 STATISTICAL ESTIMATES

For the study of each of the faunal groups (birds, mammals, amphibians and reptiles) they followed a particular methodology explicit in each respective section, this varied according to the characteristics ecological of said groups; However, for the treatment of the information obtained, it was applied some ecological parameters common to all groups.

##### 1.5.9.6.1 Alpha diversity indices ( $\alpha$ )

These are Indicators that combine wealth as the Shannon-Wiener diversity index, Simpson's Dominance Index and Margaleff's Wealth Index.

##### 1.5.9.6.2 Shannon-Wiener diversity index

For the calculation of this index the function ( $H'$ ) of Shannon-Wiener was used:

$$H' = - \sum p_i (\log_{10} p_i), \text{ where}$$

$H'$  = Diversity Shanon-Wiener

$p_i$  =  $n_i/N$

$n_i$  = Number of individuals per species

$N$  = Total number of individuals.

The Shanon-Wiener index is one of the simplest and most widely used indexes, it measures the average degree of uncertainty to predict the species to which an individual chosen belongs to chance within the community. This index is a measure of diversity and, at the same time, of frequency, this increases with the number of species and the number of individuals. A high diversity indicates a high degree of development and stability of biota (Magurran, 1988, Moreno, 2001).

##### 1.5.9.6.3 Simpson's dominance index.

Simpson's function was used for this calculation:

$\lambda = \sum pi^2$ , where:

pi= relative abundance for each species within a unit sampled

$\lambda$ = Simpson's Index

The Simpson index measures the probability that two individuals, taken at random within a sample, belong to the same species. This index varies between 0 and 1. If the probability is high, the predominance becomes greater, while diversity decreases, which would indicate the dominance of certain groups (Moreno, 2001).

#### 1.5.9.6.4 Margaleff Index

The D function of Margaleff was used:

$$D = \frac{(S-1)}{\ln N}, \text{ where}$$

S= Number of species

N= Total number of individuals.

This index is based on the relationship between the number of species and the number of individuals observed, which increases with the size of the sample.

The values of this index vary from 0 to infinity.

#### 1.5.9.6.5 Equity

For the estimation of this index the function J 'of Pielou was used, which is a relation between the index of diversity of Shannon H 'and the maximum expected diversity H'max:

$$J = H/H'max, \text{ where}$$

H'= Shanon-Wiener diversity index

H'max= Natural Logarithm of S

S= number of registered species.

This index shows how abundance of species is found within the community. Each index varies between 0 and 1, where higher values indicate that there are no dominant species (Moreno, 2001).

#### 1.5.9.6.6 Beta diversity ( $\beta$ )

In beta diversity, indicators of similarity are combined between several sites or sampling points.

#### 1.5.9.6.7 Jaccard Index

Function (J) was used, which relates the number of shared species with the total number of Exclusive species:

$$J = l/(a + b + c), \text{ where}$$

l= number of common species in the different sampling sites

a= number of species in site 1

b= number of species in site 2

c= number of species in site 3

#### 1.5.9.6.8 Cluster analysis

Cluster comparisons were made to establish the degree of similarity between coverages. in the Bray-Curtis index.

The indices described above were calculated by using the statistical program Biodiversity Pro LNK (McAleece et al 1997) and PAST (Hammer et al 2001). On the other hand, the graphs they were made using the Microsoft Excel program (2010).

### 1.5.10 METHODOLOGY OF HYDROBIOLOGY

Hydrobiological studies were developed based on the scope of the terms of reference for the SDA and the manual for the presentation of environmental studies. For these, a sampling campaign in 2012 after the granting of the specimen collection permit of wild species.

#### 1.5.10.1 STUDY ZONE AND SAMPLING STATIONS

In 2012, the reconnaissance and sampling visit of the hydrobiological variables was carried out with the double purpose of identifying the hydrographic network of the micro-basin and eleven (11) points of monitoring (See Table 1-31).

The eleven sampling points were selected taking into account the following criteria:

- Topography and ease of access to the monitoring point.
- Section of the stream with the appropriate conditions to carry out gauging by means of floating through the area-velocity methodology.
- Possible incidence (pollution or deterioration of water quality) by activities generated in the study area.
- Suitable conditions for taking hydrobiological samples.

**Table 1-31.** Geographic location of the sampling stations.

Monitoring point	East	North
P-01	929897	1293967
P-02	929835	1294248
P-03	929988	1294547
P-04	930350	1293575
P-05	930973	1293276
P-06	930621	1293966
P-07	930353	1294082
P-08	930337	1293999
P-09	930180	1294290
P-10	930100	1294551
P-11	929963	1294706

*Source: TOUCHSTONE, 2012.*

### 1.5.10.2 METHODOLOGIES FOR HYDROBIOLOGICAL SAMPLING

The characterization was carried out by multiple qualified professionals in the field of pollution environmental and hydrobiology according to the water sampling manual, taken from Standard Methods for the examination of water and wastewater (2005) and Ramírez & Viña (1998) respectively.

Below is a description of the methodology that was taken to each hydrobiological community for its taking shows:

#### 1.5.10.2.1 Periphyton

The sample was taken by means of a removal of material adhered to stones, trunks and leaf litter that are submerged in surface water sources. For this purpose, it was scraped with a plastic brush an area chosen of 234 cm<sup>2</sup> per sampling point.

The samples were fixed with a solution of 10% Lugol in 100mL opaque plastic containers duly labeled.

For the analysis of the peripheral samples, an inverted microscope was used, according to the guidelines proposed by Wetzel & Likens (1990) for the purpose of making comparisons valid among the quantitative analyzes. To carry out the counting, 30 fields of observation, following a random sampling system, where the data obtained is the density of algae per unit volume (ind/mL), which was related to the sampling area (234 cm<sup>2</sup>) (Uehlinger, 1964).

#### Sampling units and effort

For the collection of the quantitative and qualitative sample of periphyton, one hour was available and average for both. Taking into account that the qualitative sample was scanned 100 meters in different substrates during (45 minutes) for quantitative sampling, by using a 7.8 cm<sup>2</sup> slide frame 30 scrapes per station (45 minutes) were made.

**Removal by quadrant (Quantitative)**

*Sampling units:* 30 stones to be scraped equivalent to 234 cm<sup>2</sup> / 100m walk / station sampling.

*Sampling units:* 45 minutes / 30 stones to be scraped equivalent to 234 cm<sup>2</sup>. Travel (Qualitative).

**Travel (Qualitative)**

*Sampling units:* 1 Route / sampling station.

*Sampling units:* 45 minutes / Route / sampling station.

**1.5.10.2.2 Phytoplankton**

The quantitative sample collection of phytoplankton consisted of filtering 50 liters of water through of a phytoplankton network 10 $\mu$ m in diameter. While for the qualitative sample was left the network for ten minutes against the current. The samples were deposited in opaque plastic bottles (100 mL), fixed with lugol's solution.

An inverted microscope was used to observe the samples. Following the established by Uehlinger (1964), 30 observation fields were defined with a sinusoidal trajectory in a 40x lens magnification.

**Sampling units and effort**

*Phytoplankton network*

*Quantitative*

*Sampling units:* 50 liters filtered in phytoplankton net (30 $\mu$ m) / sampling station.

*Sampling effort:* 30 minutes / sampling station.

*Qualitative*

*Sampling units:* 1 30 $\mu$ m network / sampling station.

*Sampling effort:* 6.5 hours / day / sampling station.

**1.5.10.2.3 Zooplankton**

The procedure for the collection and analysis of quantitative zooplankton samples and qualitative is done in the same way as phytoplankton, to differentiate that these samples are they were fixed with 70% alcohol and a 60 $\mu$ m network was used.

**Sampling units and effort**

*Quantitative*

*Sampling units:* 50 liters filtered in phytoplankton net (60 $\mu$ m) / sampling station

*Sampling effort:* 30 minutes / sampling station.

### *Qualitative*

*Sampling units:* 1 60µm network / sampling station.

*Sampling effort:* 6.5 hours / day / sampling station.

#### 1.5.10.2.4 Macrophytes

The identification of aquatic plants or macrophytes was done by direct observation in situ, however, those that could not be identified in the field were photographed.

### **Sampling units and effort**

According to the above, in total 8.5 hours were used per sampling station for all the hydrobiological communities. This in order to cover all periods of time and routes for the collection, capture and partial identification of species from different communities hydrobiological. It is worth mentioning that hydrobiological sampling was assisted by two auxiliaries of the area, who were trained in the collection and collection of samples hydrobiological in order to comply with the given times.

#### *Manual collection (Qualitative)*

*Sampling units:* 1 radial distance of 100 m / sampling station.

*Sampling units:* 1 hour / 1 radial run of 100m.

#### 1.5.10.2.5 Aquatic macroinvertebrates

The capture of aquatic macroinvertebrates was carried out by qualitative sampling and another quantitative. For the qualitative sampling a sweep was made on the edges by means of a triangular network, another method was the collection of organisms that were attached to rocks and leaf litter that were immersed in the current. The quantitative sampling was done by means of a surber network with a specific area of 1 m<sup>2</sup>.

### **Sampling units and effort**

#### **Surber net (Quantitative)**

*Sampling units:* 1 Surber network of 1 m<sup>2</sup> / sampling station.

*Sampling effort:* 1 hour / 1 surber network of 1 m<sup>2</sup> / sampling station.

#### **Triangular network collection (Qualitative)**

*Sampling units:* 1 100 m route with triangular network / sampling station.

*Sampling effort:* 1 hour / 1 100 m route with triangular network / sampling station.

#### **Manual collection (Qualitative)**

*Sampling units:* 1 100 m route with manual collection / sampling station.

*Sampling effort:* 1 hour / 1 100 m route with manual collection / sampling station.

#### 1.5.10.2.6 Ichthyofauna

The catch for the fish or fish communities used was the one suggested in the methodology for the presentation of environmental studies (2010), the collection of these organisms was through hooks and nets (triangular and from fishnets), after the capture, we proceeded to make a photographic study of individuals for their identification and early release.

#### **Sampling units and effort**

##### **Fishnets (Qualitative)**

*Sampling units:* 3 routes / 20 castings of fishnets / sampling station.

*Sampling effort:* 1 hour / 3.100-meter course with 20 castings of fishnets / station sampling.

##### **Capture with hook (Qualitative)**

*Sampling units:* 3 routes / 60 castings of fishhook / sampling station.

*Sampling effort:* 1 hour / 3.100-meter course with 60 castings of fishhook / station sampling.

##### **Triangular network (Qualitative)**

*Sampling units:* 2 100 m routes with triangular net / bank / sampling station.

*Sampling effort:* 1 hour / 2 100-meter routes 2 100-meter routes with triangular network / bank / sampling station.

### **1.5.10.3 CALCULATIONS FOR RESULTS ANALYSIS**

After the individual interpretations of each community, ecological indexes were built (diversity, abundance, equity, dominance and wealth) for communities hydrobiological (periphyton, phytoplankton, zooplankton and aquatic macroinvertebrates), In addition, the Biological Monitoring Working Party index (hereinafter referred to as its acronym in English BMWP) in Antioquia de Roldán (2003) for the determination of water quality and the Bray-Curtis similarity analysis for the aquatic macroinvertebrate community with the to determine the quality of the water and the similarity between the different stations evaluated. Likewise, the presence or absence of the hydrobiological communities was identified (macrophytes).

For the analysis of spatial information, diversity indices and their components were applied which includes the diversity of Shannon-Weaver, Margalef's wealth, Simpson's dominance and equity of Pielou from the hydrobiological composition of periphyton, plankton and benthos through the Biodiversity Pro program.

These indexes are formulated by means of mathematical equations in which there are three elements in the structure of biotic communities such as wealth, equity and abundance. Where the



wealth is the number of different organisms found in the sample, equity constitutes the distribution of organisms in the taxa and abundance is the number of organisms found in the sample.

The diversity indices that were used are expressed below:

1.5.10.3.1 The diversity indices that were used are expressed below

$$H' = -\sum \frac{(ni)}{(N)} \ln \frac{(ni)}{(N)}$$

Where:

H': Shannon-Weaver diversity index

ni: number of individuals for each of the taxa

N: total number of individuals

ln: natural logarithm

Values between 0.0 and 1.0 indicate highly contaminated environments, between 1.0 and 3.0 correspond to waters of moderate contamination and from 3.0 onwards, good quality waters (Wilhm & Dorris, 1968). For Magurran (1988) the range of values ranges between 1.5 and 3.5.

1.5.10.3.2 Equity index of Pielou (1966)

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

Where:

H: Shannon-Weaver diversity index

Hmax: Maximum value of H (Ln S).

The Pielou equity index measures the proportion of observed diversity with the proportion of the maximum diversity achieved. Its value goes between 0 and 1.0, where the value of 0 represents the lowest equity and 1.0 the maximum.

1.5.10.3.3 Simpson's dominance index (1949)

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

Where:

D= Simpson's dominance index

ni = number of individuals for each of the taxa or gender

N = total number of individuals in the station

The values for this index vary between 0 and 1. As you approach 1 indicates greater dominance, that is, diversity decreases and therefore points to a polluted environment.

#### 1.5.10.3.4 Margalef's wealth index (1983)

$$Dmg = (S - 1) / \ln N$$

Where:

S= Number of taxa or species

N= Number of individuals or organisms

Used to estimate the biodiversity of a community based on the numerical distribution of the individuals of different species in algebraic function. Dmg <2.0 are areas with low biodiversity and Dmg > 5.0 are areas with high biodiversity.

In this research, the BMWP/Col modified biotic index for Antioch was also applied Roldán (2003). In Table 1-32 and Table 1-33, information regarding this biotic index is presented.

**Table 1-32.** Points assigned to the different families of aquatic macroinvertebrates to obtain the BMWP / COL (modified from Roldán, 2003 by Alvarez, 2006)

Aquatic macroinvertebrate family	Score
Anomalopsychidae, Atriplectididae, Blephariceridae, Ptilodactylidae, Chordodidae, Griptopterygidae, Lampyridae, Odontoceridae, Perlidae Polymitarciidae, Polythoridae, Psephenidae	10
Coryphoridae, Ephemeraeidae, Euthyplociidae, Gomphidae, Hydrobiosidae, Leptophlebiidae, Limnephilidae, Oligoneuriidae, Philopotamidae, Platystictidae, Polycentropodidae, Xiphocentronidae	9
Atyidae, Calamoceratidae, Hebridae, Helicopsychidae, Hydraenidae, Hydroptilidae, Leptoceridae, Limnephilidae, Lymnaeidae, Naucoridae, Palaemonidae, Planorbidae (cuando es dominante Biomphalaria), Pseudothelphusidae, Saldidae, Sialidae, Sphaeriidae	8
Ancylidae, Baetidae, Calopterygidae, Coenagrionidae, Dictyriidae, Dixidae, Glossosomatidae, Hyalellidae, Hydrobiidae, Hydropsychidae, Leptohiphidae, Lestidae, Pyralidae, Simuliidae, Veliidae	7
Aeshnidae, Ampullariidae, Caenidae, Corydalidae, Dryopidae, Dugesidae, Elmidae, Hyriidae, Limnichidae, Lutrochidae, Megapodagrionidae, Mycetopodidae, Pleidae, Staphylinidae	6
Ceratopogonidae, Corixidae, Gelastocoridae, Glossiphoniidae, Gyrinidae, Libellulidae, Mesoveliidae, Nepidae, Notonectidae, Tabanidae, Thiaridae	5
Belostomatidae, Chrysomelidae, Curculionidae, Ephyridae, Haliplidae, Hydridae, Muscidae, Scirtidae, Empididae, Dolichopodidae, Hydrometridae, Noteridae, Sciomyzidae	4
Chaoboridae, Cyclobdellidae, Hydrophilidae (larvas), Physidae, Stratiomyidae, Tipulidae	3
Chironomidae (cuando no es la familia dominante, si domina es 1) Culicidae, Psychodidae, Syrphidae	2
Tubificidae	1

*Source: modified by Roldán, 2003 by Álvarez, 2006*

**Table 1-33.** Class, quality and scale of values, color, and their respective environmental significance of the BMWP.

Class	Quality	Value	Meaning	Color
I	Good	>150, 101-120	Very clean to clean waters.	Blue
II	Acceptable	61-100	Lightly contaminated waters.	Green
III	Doubtful	36-60	Moderately polluted waters.	Yellow
IV	Criticism	16-35	Very polluted waters.	Olive
V	Very critical	<15	Heavily polluted waters.	Red

Source: Alba-Tercedor, 1996; Roldán, 2003

For the analysis of the results, the Bray-Curtis similarity dendrogram was also applied.

### 1.5.11 ECOLOGICAL CONNECTIVITY METHODOLOGY

The vision and interpretation of connectivity is developed from the ecology of the landscape and based on an approximation of structural-morphological and functional at the same time; that is to say, the structural and morphological characteristics that make up a territory and its ecosystems at a given time, and / or their evolution over time or product of a transformation, inferring at the same time its incidence at the level of ecological functionality (Forman & Godron, 1986).

In order to interpret each of the plant coverages present in the site and their interaction through photographs from 2005 to 2012, in addition to a multi-temporal analysis and evaluation of the anthropization effect in the area.

In the basin (largest area of influence used for connectivity analysis), identified six (6) types of coverages, according to the Corine Land Cover methodology, classified for the case of natural and semi-natural, up to the fourth sub-level, from an orthophoto of the year 2012 and with update with field trips in 2016 by Ingex. The visualization and distribution of Coverages in the form of a map.

**Table 1-2.** Coverage of the earth.

Level				ABB
1	2	3	4	
1.TERRITORIES ARTIFICIALISED	1.1. Areas	1.1.2. Urban fabric discontinuous		Tud
2. AGRICULTURAL TERRITORIES	2.2 Permanent crops	2.2.1. Crops permanent herbaceous	2.2.1.3 Banana and Yucca	Cph
		2.2.2. Crops permanent bush	2.2.2.3. Cocoa	Cpa
	2.3 Pastures	2.3.1. Clean pastures		PI
3. FORESTS AND AREAS SEMI NATURALES	3.1. Forest	3.1.1. Dense Forest	3.1.1.2. Forest dense low	Bdbtf
	3.2. Areas with vegetation herbaceous and / or shrubby.	3.2.3. Vegetation secondary or in transition.	3.2.3.2. Vegetation low secondary	Vsb

Source: Modified from Ingex 2016, according to the Corine Land Cover methodology.

The methodology for the structural analysis of the landscape is based on the coverage layer, in a visual review with high resolution images of Google Earth®; this in order to corroborate and refine the work in the field. Topological errors were corrected, such as the overlapping of coverages and the existence of gaps between them, through the use of GIS tools. Later the area was calculated by type of coverage to proceed with the calculation of the area, shape, edge, ecotone indices, neighborhood and diversity. These indices were calculated by using the Fragstats 4.0 tool, a patch level, class and landscape.

In the calculations of the connectivity of the landscape the layers of roads, drainage, coverage and pending. The track layer was completed with manual scanning with a buffer of 3.5 m so that corresponded with what was observed in the high-resolution images. After obtaining the Euclidean distances were calculated for the area of analysis. Also, a buffer of 5m was made in the layer of rivers to obtain the polygons corresponding to the courses of water

For the calculation of the friction model by connectivity, a layer was obtained with different levels of resistance or dislocation cost. Areas with high viability values present a cost of smaller resistance, with values from 1 to 100. These values are added in order to obtain a map friction with values from 1 to 100, where 1 corresponds to the source areas and 100 to the areas with a greater friction of the mobility of animal species in the landscape. This calculation was made for both the current coverage, as for the change of coverages with the projected extraction area.

#### **1.5.11.1 Structural connectivity**

Understanding fragmentation as "Dynamic process by which a certain habitat goes being reduced to patches or islands of smaller size, more or less connected to each other in a matrix of habitat different from the original "(Forman, 1995). It is taken into account that these patches do part of a chain that structurally exceeds the basin, which does not happen with the other types of coverage, immersed in the matrix.

With the clarity of the context in which the matrix is found, the following indices are calculated:

- Index of area and number of patches: The area by type of patch corresponds to the calculation of the area corresponding to the set of fragments that constitute a certain class.
- Average size of patch: It is related to the area occupied by each of the plant covers identified in the field.
- Index of form: As its name is specific, are based on the characteristics of form of the fragments or patches. This type of calculation is based on the relationship between area and perimeter and facilitates the understanding of this fundamental factor at a morphological and functional level. Calculate the complexity of the shape of the fragments compared to a standard form, as would be the circumference in the vector environment or the pixel in the Raster environment (Vila Subirós et al., 2006).
- Distance to the nearest neighbor: Calculates the distance from the edge habitat and ecotone of a fragment to the nearest fragment of the same type. These are fundamental indexes for be able to assess the degree of isolation or structural connectivity between the different fragments, on the

basis that greater isolation implies a reduction in possibilities of harboring or maintaining a greater degree of biological diversity (Forman, 1995; Hilty et al. al., 2006).

- Ecotone and interior habitat indices: Allows calculations on the extent of the ecotone or Edge habitat in relation to the interior habitat. This type of habitat is considered essential for the presence and maintenance of fauna and flora specialist, that is, more demanding in their ecological requirements, while the edge habitat facilitates the presence of species generalists (Forman, 1995).

#### **1.5.11.2 Functional connectivity**

The approach to functionality continues the territorial and socio-ecological approach in which frames the delimitation of the area of influence. They are recognized as characteristics of the approach territorial, that their level of resilience or ability to absorb disturbances, maintaining their structure, functioning and dynamics, are their own and are attributed to a hierarchical organization, that in the case of the area of indirect influence represents the interaction of the space scales temporary and translates into ecological integrity (Martín-López, 2013), and that is what you are looking for Stay through the analysis of the connectivity model.

Within the framework of functionality, the provision of habitats and the favoring of a structure that confluence in a less impermeable or fragmented matrix, the ability to reorganize a territory, is favored (from different degrees of socio-ecological heterogeneity), after being subject to a disturbance regime. When the intensification of uses is low (a), the reorganization is faster and more effective, in case of not organizing and regulating the activities that already there presented (c), deforestation rates would continue to increase fragmentation and disadvantaging the connectivity and provision of ecosystem services.

Following with this conceptual framework and to analyze the functionality in the identified ecosystem, Landscape metrics and the applied connectivity model are presented below, accompanied by friction maps and costs, which indicate the mobility of the species, to close with a synthesis connectivity associated with ecosystem services.

- Indexes of landscape diversity: These indexes provide relevant information to be able to compare different landscapes or the evolution of a landscape at different historical moments (Vila Subirós et al., 2006). Therefore, landscape diversity is understood as the heterogeneity of coverage that can be found in this and given that heterogeneous landscapes harbor a greater amount of biodiversity, it is necessary to analyze these aspects of functional connectivity, in light of the structural, taking into account that the matrix is not too rough to allow the flow of species and ecological processes.

- Binary connectivity model with friction: It is an indicator of the degree of permeability that presents the territory. These are calculated from two friction values, one for the sectors favorable to mobility and another for hostile sectors (binary resistance surfaces). The assignment of friction values is based on land uses as favorable dispersive media for animal species (Ruiz-González et al., 2010).

The model presents an indicator of the degree of permeability in the area of influence; this approach it allows to know the movement capacity and dispersion patterns through the zone of study.

#### **1.5.12 SOCIOECONOMIC METHODOLOGY**

The socio-economic environment was developed according to the methodology for the presentation of studies environmental the methodology for characterization and participation is presented below community.

This medium was developed from a process of information and characterization, with the participation of professionals with specific experience in participatory methodological strategies (diagnosis situational, social maps, thematic tables to identify impacts, among others).

##### **1.5.12.1 SOCIOECONOMIC CHARACTERIZATION**

House was visited home from the study area, to characterize primarily through forms, demographic, spatial, economic, cultural, political-organizational, trends of the development, history of colonization, environmental significance and possible population to resettle. This it was also done for the study area but based on official secondary and primary information by filling out forms with community leaders.

##### **1.5.12.2 COMMUNITY PARTICIPATION**

This process was carried out multipurpose in order to inform about the SDA and the Studies of Environmental impact in the area under study.

The following topics were socialized with the communities of the AIs (JAC, Community Groups, among others):

- Announcement of the LBSA.
- LBSA results.
- Technical presentation of the project, evaluation of socio-environmental impacts and plan of driving.
- Socializations with the City Halls, Curia, Corantioquia, Personality and ONGs.
- Socialization of the SDA.

##### **1.5.12.3 SOCIAL FEASIBILITY**

Consultations were also held with the Ministry of the Interior and Justice, and with INCONDER, in order to identify the existence of indigenous, Afro-descendant communities in the area of influence of the draft.

#### 1.5.12.4 ARCHEOLOGY

The reconnaissance and prospecting phase of the preventive archeology plan was developed presented to the Colombian Institute of Archeology and History (hereinafter ICANH) with file 1046 of March 4, 2016 (see Annex 1.3). The study was conducted in order to identify if in the ground are archeological assets, importance and correct way to prevent or mitigate destruction or deterioration, covered by the special protection regime of (Laws 397 of 1997, 1185 of 2008, decree 763 of 2003).

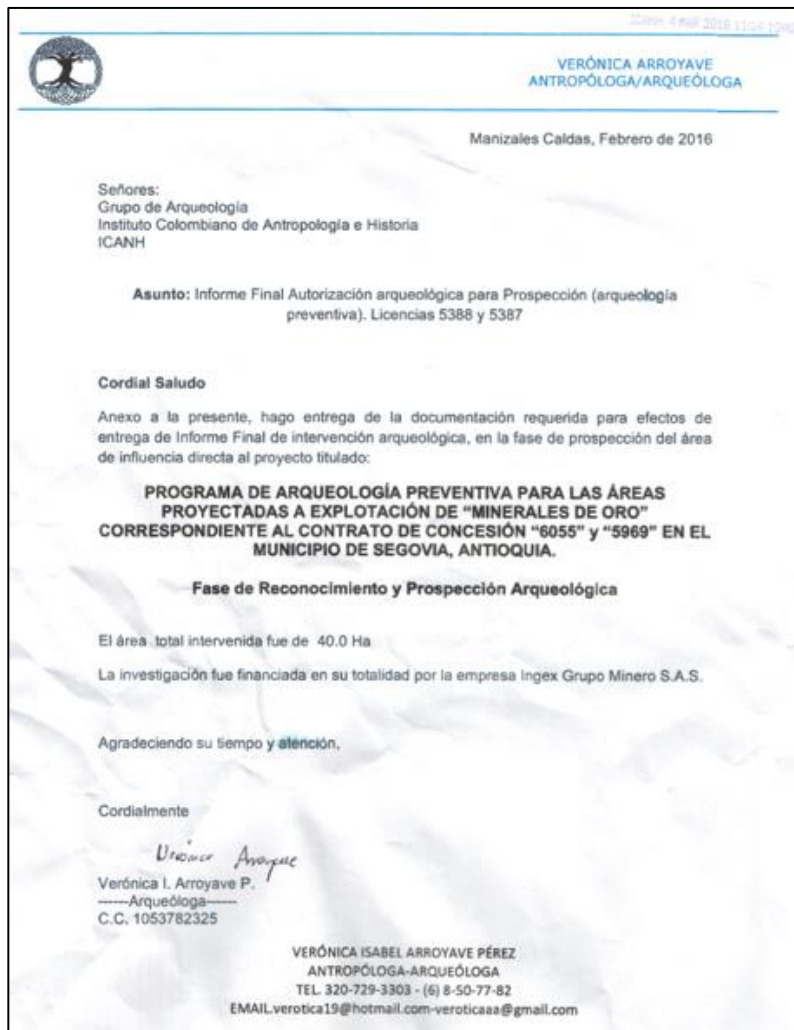


Illustration 1-32. ICANH certificate.



## 1.6 NORMATIVE FRAMEWORK

### 1.6.1 NATIONAL CONSTITUTION

It contemplates a model of sustainable development, recognizes the collective right to enjoy a healthy environment, sustains any policy of environmental protection in the participation citizen and tends to a greater degree of autonomy of environmental authorities.

### 1.6.2 MINES CODE

- Law 685 of 2001, by which the mining code is issued.
- Decree 1073 of 2015, by which the sole regulatory decree of the sector is issued administrative of mines and energy.

### 1.6.3 LAW 99 OF 1993

"By which the Ministry of the Environment is created, the public sector in charge of the management and conservation of the environment and renewable natural resources, the National Environmental System, SINA and other provisions are dictated".

Its purpose is the planning of projects, including environmental criteria for design, construction and operation and provide the terms of reference for the preparation of the environmental studies.

### 1.6.4 CODE OF NATURAL RESOURCES

- Decree 2811 of 1974, national code of renewable natural resources and protection of environment. In which many of the rules and regulations in force are established in Colombia, in relation to the environment.
- Decree 1076 of 2015, by which the sole regulatory decree of the sector is issued environment and sustainable development.

### 1.6.5 NATIONAL HEALTH CODE

Law 9 of 1979 of the Congress of Colombia "By which sanitary measures, of protection of the environment, which are included in this code and whose applicability for the issuance of permits in terms of water concession, disposal of liquid and solid waste. Regarding permits of emissions, the Ministry of the Environment, through Law 99 of 1993 grants powers to Regional Autonomous Corporations to grant said permission.

### 1.6.6 NATIONAL CONTINGENCY PLAN

Decree 919 of 1989, which organizes the National System for the Prevention and Attention of Disasters and other dispositions are dictated.

### 1.6.7 SPECIAL AREAS

- Decrees 2278 of 1953 Article 4, Decree 2811 of 1974, Article 83 and Decree 1449 of 1977, Article 3 that regulate protective forest areas.
- Law 2 of 1959, whereby regulations are issued on the national forest economy and conservation of renewable natural resources.
- Decree 2857 of 1981, Article 5 and Article 6, which regulate activities in watersheds hydrographic.
- Decree 622 of 1997, Article 30, "Creation of the Natural Parks System", and Political Constitution, Article 63.
- Decree 2372 of 2010. By which Decree-Law 2811 of 1974 is regulated, Law 99 of 1993, Law 165 of 1994 and Decree-Law 216 of 2003, in relation to the National System of Protected Areas, the management categories that comprise it and other dispositions.
- Resolution 1526 of 2012, which establishes the requirements and the procedure for the subtraction of areas in the national and regional forest reserves, for the development of activities considered of public utility or social interest, the activities are established subject to temporary subtraction and other determinations are adopted.
- Resolution 1274 of 2014, by which Resolution 1527 of 2012 is modified.

### 1.6.8 LEGAL FRAMEWORK OF THE TERRITORIAL ORDER

Table 1-35 lists the normative framework consulted in relation to the ordering territorial.

**Table 1-35.** Normative framework of territorial ordering.

Standard	Date	Entity	Regulates
Law 9	11/01/1989	Congress of Colombia	It was an antecedent with urban emphasis in aspects related to reserves of urbanized land, housing of social interest, development zones progressive, restricted and concerted, protection to residents affected by urban development and renewal processes, compensation mechanisms for urban obligations, etc.
Law 152	15/07/1994	Congress of Colombia	It establishes that the municipalities, in addition to the development plan, have a territorial arrangement planning. It requires forming systems of participation in planning, creating instances or spaces such as Territorial Planning Councils; principles of organization and articulation with levels of regional planning, national and higher standards hierarchy.
Law 388	18/07/1997	Congress of Colombia	Modifies Law 9 of 1989 and Law 3 of 1991 (specific housing) and determines that the urban territory is not ordered but also rural, conceiving an intervention framework that accounts for a permanent transformation stress of rural and urban areas. Identify that the planning implies a set of actions, proposals, activities of management and regulatory elements. It presents a series of differentiations as the hierarchy of urban planning norms in: general and complementary structural, pointing to long-term validity medium and short term for each of them.
Decree 1729	06/08/2002	Presidency of the republic	Watershed management and protection.
Decree 4002	30/11/2004	Ministry of Environment, Housing and	Establishes conditions, requirements and procedures for review and adjustment of Territorial Ordinance Plans (hereinafter POT), new

Standard	Date	Entity	Regulates
		Development Territorial	definitions of high impact services and incompatibility of uses and repeals Decree 932 of 2000.

*Source: INGEX, 2016.*

### 1.6.9 LEGAL FRAMEWORK - PERMITS OF USE AND USE OF RESOURCES NATURAL

Table 1-36 lists the normative framework consulted in relation to the use, exploitation, and affectation of natural resources.

**Table 1-36.** Normative framework for the use and exploitation of natural resources.

Standard	Date	Entity	Regulates
<b>Forestry exploitation</b>			
Decree 1791	4/10/1996	Ministry of Environment, Housing and development Territorial	By means of which the regime of forest use.
Resolution 0192	10/02/2014	Ministry of Environment and Development Sustainable	By which the list of wild species is established threatened by the Colombian biological diversity that found in the national territory, and other dispositions.
Resolution 10194	10/04/2008	Corantioquia	Prohibition and restriction of the use of threatened forest and wild flora species in their jurisdiction.
<b>Occupation of channels</b>			
Decree 1541	26/07/1978	Ministry of farming	By which Part III of Book II of the decree-law is regulated 2811 of 1974: "Of the non-maritime waters" and partially the law 23 of 1973. Modified by the national decree 2858 of 1981
National Decree 2858	13/10/1981	Ministry of farming	Whereby Article 56 of the Constitution is partially regulated decree-law 2811 of 1974 and the decree 1541 of 1978 is modified
Decree 1594	26/06/1984	Ministry of farming	Current Articles 20 and 21 where the substances of health interest and the definition of user of health interest, respectively. Repealed by art. 79, national decree 3930 of 2010, except the arts. 20 and 21
National Decree 3930	25/10/2010	Ministry of Environment, Housing and development Territorial	By which Part I of Law 9 of 1979, as well as Chapter II of Title VI - Part III - Book II of the decree-law 2811 of 1974 regarding water and waste uses liquids and other provisions are dictated.
<b>Shedding of liquid waste</b>			
Decree 1594	26/06/1984	Ministry of farming	Current Articles 20 and 21 where the substances of health interest and the definition of user of health interest, respectively. Repealed by art. 79, national decree 3930 of 2010, except the arts. 20 and 21. .
Resolution 273	1/04/1997	Ministry of Environment, Housing and development Territorial	By which the minimum rates of the remuneration rates are fixed by liquid discharges for the parameters Demand Oxygen Biochemistry (BOD) and Total Suspended Solids (SST).
Resolution 372	6/05/1998	Ministry of Environment,	"By which the minimum rates of the rates are updated retributive payments for liquid discharges and dispositions are dictated ".

Standard	Date	Entity	Regulates
		Housing and development Territorial	
Decree 3100	30/10/2003	Ministry of Environment, Housing and development Territorial	"By means of which the remuneration rates are regulated by the direct use of water as a receiver of the shedding punctual and other determinations are made ". Repealed by National Decree 2667 of 2012
Decree 3930	25/10/2010	Ministry of Environment, Housing and development Territorial	By which Part I of Law 9 of 1979, as well as Chapter II of Title VI - Part III - Book II of the decree-law 2811 of 1974 regarding water and waste uses liquids and other provisions are dictated.
National Decree 2667	21/12/2012	Ministry of Environment and Development Sustainable	By which the remuneration rate is regulated by the use Direct and indirect water as a receiver of the shedding punctual, and other determinations are made. .
Resolution 631	17/03/2015	Ministry of Environment and Development Sustainable	By which the parameters and maximum limits are established permissible in the occasional discharges to bodies of water surface and to public sewage systems and dictate other provisions. .
<b>Water concession</b>			
Decree -Law 2811	08/12/1974	Congress of the Republic	National Code of Renewable Natural Resources and Environmental Protection.
Decree 1541	28/07/1978	Ministry of farming	By which Part III of Book II of the Decree - Law is regulated 2811 of 1974: "Of non-maritime waters" and partially the Law 23 of 1973.  Art. 44 to 53 Characteristics of the concessions, Art. 54 to 66. Procedures for granting surface water concessions and underground, Art. 87 to 97: Exploitation of material from trawl, Art. 104 to 106: Occupation of channels and permit occupation of channels, Art. 211 to 219: Control of shedding, Art. 220 to 224: Shedding for domestic and municipal use, Art. 225: Shedding for agricultural use, Art. 226 to 230: Shedding for industrial use, Art. 231: Regulation of shedding.
Decree 2858	13/10/1981	Ministry of Environment, Housing and development Territorial	By which Part 56 of the Regulation is partially regulated Decree-Law 2811 of 1974 and Decree 1541 of 1978
Decree 1594	26/06/1984	Ministry of farming	Current Articles 20 and 21 where the substances of health interest and the definition of user of health interest, respectively. Repealed by art. 79, National Decree 3930 of 2010, except the arts. 20 and 21
Law 373	6/06/1997	Congress of the Republic	By which the program is established for the efficient use and water saving. In order to protect the water resource and guarantee their rational use, imposes obligations on those who administer the resource and those who use it
Decree 475	10/03/1998	Ministry of Health Public	By which technical standards of water quality are issued potable. Repealed by art. 35, National Decree 1575 of 2007

Standard	Date	Entity	Regulates
Decree 1575	09/05/2007	Congress of the Republic	By which the System for Protection and Control is established of Water Quality for Consumption.
Resolution 2115	22/06/2007	Ministry of Environment, Housing and development Territorial	By means of which the characteristics, instruments are indicated basics and frequencies of the control and surveillance system for water quality for human consumption.
Decree 303	06/02/2012	Ministry of Environment and Development Sustainable	Whereby Article 64 of the Constitution is partially regulated Decree - Law 2811 of 1974 in relation to the Registry of Users of the Water Resource and other provisions are dictated
<b>Solid waste</b>			
Resolution 02309	24/02/1986	Ministry of Health Public	By which rules are dictated for the fulfillment of the content of Title III of Part 4a. of Book 1 of Decree-Law N. 2811 of 1974 and of Titles I, III and XI of Law 09 of 1979, insofar as to Special Waste.
Resolution 541	14/12/1994	Ministry of Environment, Housing and development Territorial	By means of which it is regulated the load, unload, transport, storage and final disposal of debris, materials, elements, concrete and loose aggregates, construction, demolition and organic layer, soil and excavation subsoil. .
Resolution 0058	21/01/2002	Ministry of Environment, Housing and development Territorial	By which maximum permissible limits of emission for incinerators and waste crematoria solids and liquids
Resolution 0886	27/07/2004	Ministry of Environment, Housing and development Territorial	By which Resolution number 0058 is partially modified of January 21, 2002 and other provisions are enacted.
<b>Special waste</b>			
Resolution 02309	24/02/1986	Ministry of Health Public	By which rules are dictated for the fulfillment of the content of Title III of Part 4a. of Book 1 of Decree-Law N. 2811 of 1974 and of Titles I, III and XI of Law 09 of 1979, insofar as to Special Waste.
Law 430	16/01/1988	Congress of the Republic	By which prohibitive norms are dictated in environmental matter relating to hazardous waste and other dispositions.
Law 55	02/07/1993	Congress of the Republic	Regulates the issue of chemical substances in relation to their classification, handling storage responsibility employees and employers. Regulates the security cards for the handling of chemical substances
Resolution 541	14/12/1994	Ministry of Environment, Housing and development Territorial	By which the load is regulated, unloaded, transported, storage and final disposal of debris, materials, elements, concrete and loose aggregates, construction, demolition and organic layer, soil and excavation subsoil
Decree 1609	31/07/2002	Ministry of transport	By which the management and land transport is regulated automotive dangerous goods by highway
Decree 4741	30/12/2005	Ministry of Environment, Housing	By which is partially regulated the prevention and managed of the waste or hazardous waste generated in the framework of integral management

Standard	Date	Entity	Regulates
		and development Territorial	Partially developed by the Resolution of the Min. Environment 1402 of 2006
Resolution 1402	17/07/2006	Ministry of Environment, Housing and development Territorial	By which Decree 4741 of September 30 is partially developed December 2005, on waste or waste dangerous
Resolution 1362	2/08/2007	Ministry of Environment, Housing and development Territorial	By which the requirements and procedure for the Registration of Hazardous Waste or Waste Generators, a referring to articles 27 and 28 of Decree 4741 of December 30, 2005.
Law 1252	27/11/2008	Congress of the Republic	By which prohibitive norms are dictated in environmental matter, regarding hazardous waste and waste and other dispositions.
Resolution 180005	05/01/2010	Ministry of Mines and Energy	"Whereby the Regulation for the management of radioactive waste in Colombia "
<b>1% investment</b>			
Decree 1900	25/09/2006	Ministry of Environment, Housing and development Territorial	By which the paragraph of article 43 (the owner of the project must invest this 1% in the works and actions of recovery, preservation and conservation of basin to be determined in the environmental license of the project), of Law 99 of 1993 and other dispositions are dictated. General Law of Culture. Art. 70 - 72 of the Political Constitution.  Law 99, Titles X and XI 12/22/1993 Congress of Colombia
<b>Community and citizen participation</b>			
Law 99, Titles X y XI	22/12/1993	Congress of the Republic	Among others, provisions are made about the modes of community participation throughout the processes of licensing and operation of development projects. .
Decree 1753	3/08/1994	Presidency of the Republic	Knowledge of the licensing status by the citizens. Replaced by Decree 1728 of 2002
Decree 1728	08/06/2002	The Minister of the Environment	By which is regulated Title VIII of Law 99 of 1993 on the Environmental License Repealed by art. 29, National Decree 1180 of 2003
Decree 1180	05/10/2003	Ministry of Environment, Housing and development Territorial	By which is regulated Title VIII of Law 99 of 1993 on Environmental Licenses. Repealed by art. 41, National Decree 1220 of 200
Decree 1220	21/04/2005	Ministry of Environment, Housing and development Territorial	By which is regulated Title VIII of Law 99 of 1993 on environmental licenses. Repealed by art. 52, National Decree 2820 of 2010
Law 134	31/05/1994	Congress of the Republic	By which rules are issued on participation mechanisms citizen

Standard	Date	Entity	Regulates
Decree 1320	1998	Ministry of Inside	Regulates prior consultation with indigenous communities and for the exploitation of natural resources within his territory.
Decree 330	8/02/2007	Ministry of Environment, Housing and development Territorial	Regulates public hearings.
Decree 2820	5/08/2010	Ministry of Environment, Housing and development Territorial	Reiterates as a binding element the "Participation of communities "(Art. 15).
Resolution 1544	06/08/2010	Ministry of Environment, Housing and development Territorial	By which the terms of reference for the preparation of the Study of Environmental Impact for drilling projects exploratory Hydrocarbons and other determinations are made.
<b>Archaeological heritage</b>			
Political Constitution of Colombia	06/07/1991	Congress of the Republic	Art 63 and 72 through which it is established that the Cultural Patrimony of the Nation and public goods are of unalienable, imprescriptible and no forfeitable character and they are under the protection of the State and belong to the Nation
Law 163	30/12/1959	Congress of the Republic	Whereby measures are issued on defense and conservation of Historic, Artistic and Public Monuments of the Nation. Article 11º. Any application for a license for exploration or archaeological excavations, as well on public lands such as private property, must be submitted to the Colombian Institute of Anthropology, entity that will attend to such requests, taking into account the scientific solvency of the interested parties and the strictly cultural motives of such explorations. Regulated by National Decree 264 of 1963
Regulatory Decree 264	12/02/1963	Presidency of the Republic	By which is regulated Law 163 of 1959 on defense and conservation of historical, artistic and monumental heritage public of the Nation.
Law 397	07/08/1997	Congress of the Republic	General Law of Culture. Partially regulated by National Decrees 833 of 2002, 763 and 2941 of 2009. Modified by means of Law 1185 of 2008. The regulation of Decree 833 of 2002, refers to the Archaeological Heritage; of Decree 763 of 2009, as regards concerning the Cultural Patrimony of the Nation of nature material and the Special Regime for the Protection of the Property of Cultural interest. For its part, Decree 2941 of 2009, regulates what corresponds to the Cultural Heritage of the Nation of immaterial nature.
Decree 833 del 2002	26/04/2002	Ministry of Culture	Regulates Law 397 of 1997, in terms of terms, management of goods.
Decree 2941	06/08/2009	Ministry of Environment, Housing	by which Law 397 of 1997 is partially regulated amended by Law 1185 of 2008, as regards the Cultural Heritage of the Nation of immaterial nature.



Standard	Date	Entity	Regulates
		and development Territorial	
Law 1185 del 2008	12/03/2008	Congress of the Republic	Modifies Law 397 on the integration of heritage archaeological and cultural.
Decree 763 de 2009	10/03/2009	Ministry of Culture	By which are partially regulated Laws 814 of 2003 and 397 of 1997 modified by means of Law 1185 of 2008, in what corresponds to the Cultural Patrimony of the Nation of material nature. Modifies Law 1185 on special regime of assets of cultural interest
General scheme and technical guidelines of the programs preventive archeology In colombia	15/07/2010	Group of Archeology - Office Legal Sub-management ICANH Scientific	Technical guidelines of archeology programs preventive in Colombia
<b>Threatened species and collection of specimens of wild species</b>			
Law 17	22 /01/1981	Congress of the Republic	By which the "Convention on Trade" is approved International Convention on Endangered Species of wild Fauna and Flora ", subscribed in Washington, D.C. on March 3, 1973.
Law 165	9/11/1994	Congress of the Republic	By means of which the "Agreement on the Biological Diversity ", made in Rio de Janeiro on June 5, 1992 Regulated by National Decree 2372 of 2010
Decree 2372	01/07/2010	Ministry of Environment, Housing and development Territorial	By which Decree-Law 2811 of 1974, Law 99 is regulated 1993, Law 165 of 1994 and Decree-Law 216 of 2003, in relationship with the National System of Protected Areas, Management categories that make up and dictate other dispositions.
Resolution 383	23/02/2010	Ministry of Environment, Housing and development Territorial	By which the wild species that are found are declared threatened in the national territory
RESOLUTION 584	26/06/2002	Ministry of the Environment Ambient	By which the wild species that are found are declared threatened in the national territory and other dispositions
RESOLUTION 572	04/05/2005	Ministry of Environment, Housing and development Territorial	By which Resolution number 0584 of the 26th of June 2002 and other determinations are adopted.
Resolution 10194	10/04/2008	Corantioquia	Prohibition, prohibition and restriction of the use of threatened forest and wild flora species in their jurisdiction.
Decree 3016	27/12/2013	Ministry of Environment and Development Sustainable	Collection of specimens of wild species for the purpose of environmental studies.
Resolution 0192	10/02/2014	Ministry of Environment and	By which the list of wild species is established threatened by the Colombian biological diversity that found in the national territory, and other dispositions.

Standard	Date	Entity	Regulates
		Development Sustainable	
<b>Others</b>			
Decree 1715	04/08/1978	Ministry of farming	By which the Decree - Law 2811 of 1974, Law 23 of 1973 and Decree-Law 154 of 1976, in Regarding landscape protection.
Law 388	18/07/1997	Congress of the Republic	By which Law 9 of 1989 is modified, and Law 2 of 1991 is amended and dictate other provisions. Chapter III Planning Plans Territorial (regulated by Decree 879 of 1998)
Resolution 1503	04/08/2010	Ministry of Environment, Housing and development Territorial	By which the General Methodology is adopted for the Presentation of Environmental Studies and other determinations
Resolution 1415	07/08/2012	Ministry of Environment and Development Sustainable	By which the storage model is modified and updated geographical (Geodatabase) content in the General Methodology for the Presentation of Environmental Studies adopted through Resolution 1503 of August 4, 2010.
Resolution 188	27/02/2013	Ministry of Environment and Development Sustainable	By which the Environmental Monitoring Manual of Projects adopted by Resolution number 1552 of 20 October 2005
Resolution 1517	16/09/2012	Ministry of Environment and Development Sustainable	By which the Manual for the Assignment of Compensation for Loss of Biodiversity.

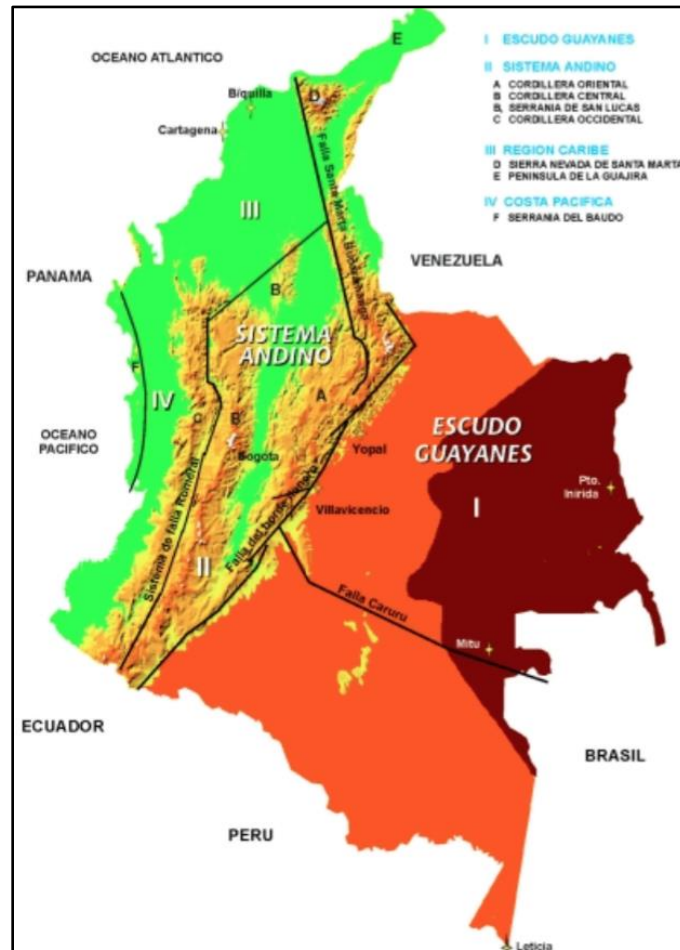
## 1.7 IMPORTANCE OF THE ACTIVITY CONSIDERED OF PUBLIC UTILITY OR INTEREST SOCIAL

Below is the importance of the mining activity declared as public utility and social interest, sustained under the following geological and mining, economic considerations, historical, legal and social and environmental; in the national, regional and local context.

### 1.7.1 GEOLOGICAL AND MINING CONSIDERATIONS

#### 1.7.1.1 GEOLOGICAL AND MINING CONSIDERATIONS

Mining in Colombia is one of the main productive engines of the country, as it is located in a privileged way from the metallogenic point of view in four (4) different systems morphotectonics, characterized by "sui generis" geological - mining indicators in the environment South American. Mainly two (2) of these environments (Illustration 1-33) are constituted as sources important mineral resources with a high probability of generating large-scale projects importance, through the application of modern and sustainable techniques.



**Illustration 1-33.** Morphotectonic systems of Colombia.  
*Source: Strategic minerals for the development of Colombia - MEDC, 2000.*

The first geological environment is defined as an Andean system made up of mountain ranges Western, central and eastern. The second is the Guayana system constituted by the shield of the same name.

These two (2) training environments are homologous to those of other countries, where they have been identified, deposits of minerals and precious stones, base metals, industrial mining products, rocks ornamentals, uranium and coal; factors that attract foreign investment to perform work of exploration and exploitation.

In detail the potentialities of the subsoil in the western and central mountain ranges, which they cross the department of Antioquia (Illustration 1-34, Table 1-37 and Table 1-38, Illustration 1-35).

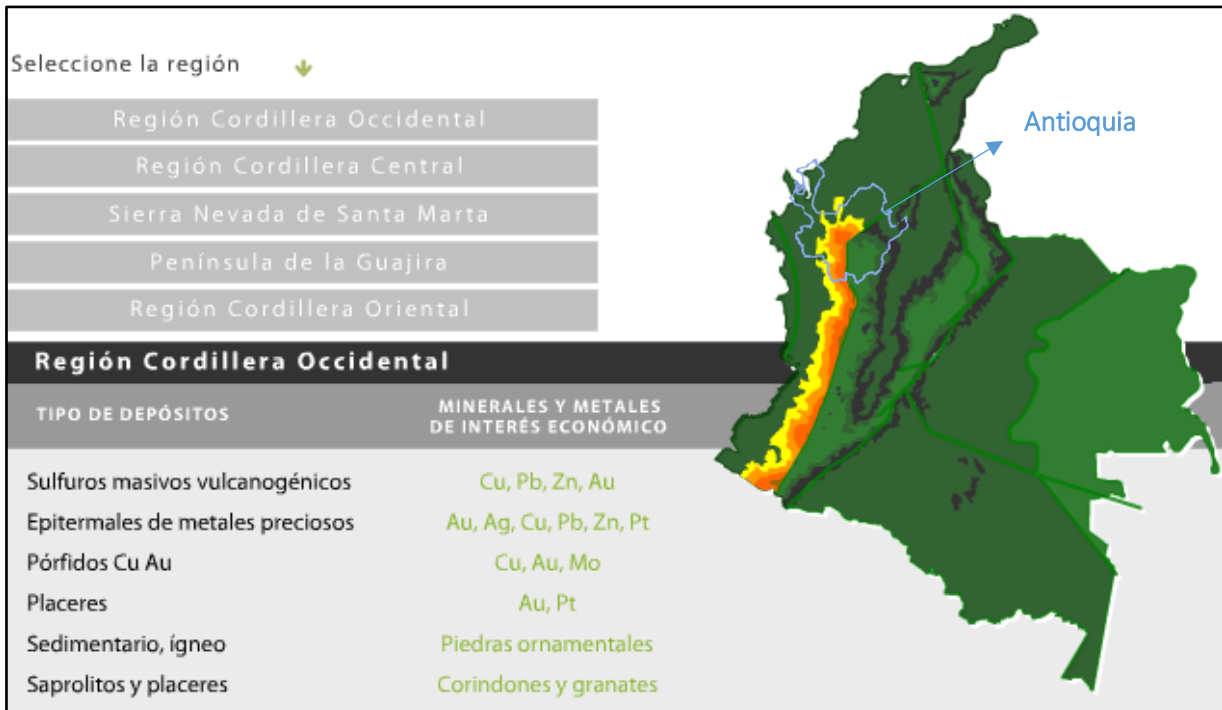
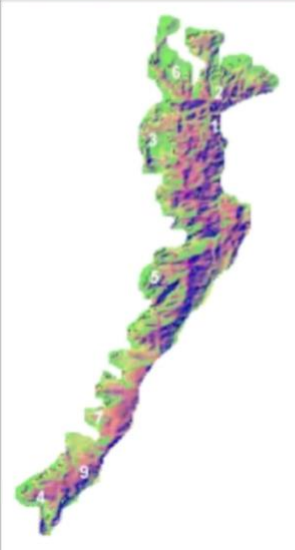


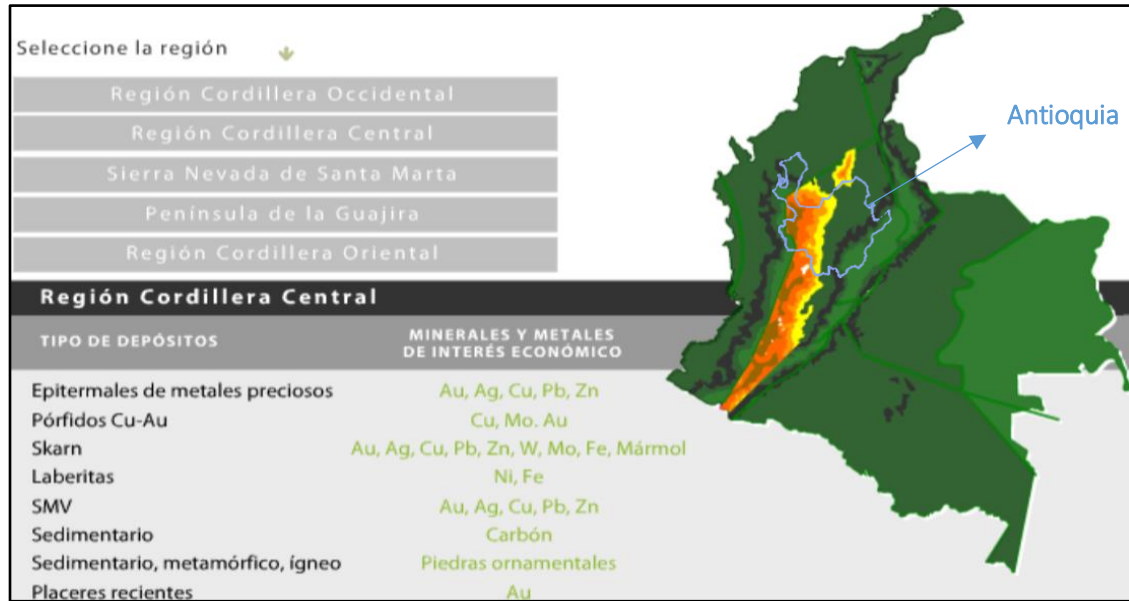
Illustration 1-34. Potentialities of minerals and metals of economic interest, in the western cordillera - Sistema Andean.

Source: Strategic minerals for the development of Colombia - MEDC, UPME, MINERCOL, INGEOMINAS, 2000.

Table 1-3. Potentials of Minerals and Metals of Economic Interest in the Western Cordillera - Andean System.

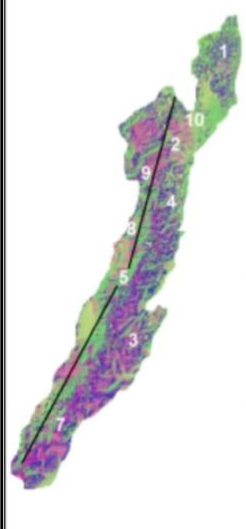
CORDILLERA OCCIDENTAL	OBJETIVOS DE EXPLORACION (TARGETS)	CARACTERIZACION GEOLOGICA	TIPOS DE DEPOSITOS	MINERALES Y METALES DE INTERES ECONOMICO	PRIORIZACION
	1 Cañas Gordas (Cretáceo)	Basamento oceánico, intruido por tonalitas y pórfidos dacítico-andesíticos	Sulfuros masivos volcanogénicos (SMV) Epitermales de metales preciosos	Cu, Pb, Zn, Au Au, Ag, Cu, Pb, Zn	Alta
	2 Liborina - Ituango (Cretáceo - Terciario)	Secuencias ofiolíticas en contacto con metamorfitas a lo largo de la paleosutura de Romeral e intruidas por sidos graníticos	Epitermales de Metales Preciosos	Au, Ag, Cu, Pb, Zn	Alta
	3 Batolito de Mandé (Cenozoico)	Magnetismo calcioalcalino con facies subvolcánicas tardías	Pórfidos Cu-Au Epitermales de Metales preciosos	Cu, Au, Mo Au, Ag, Cu, Pb, Zn	Alta
	4 Batolito de Piedrancha - Cumbitará (Cenozoico)	Secuencias volcanosedimentarias oceánicas intruidas por el Batolito de Piedrancha	Pórfidos Cu-Au Epitermales de Metales preciosos	Cu-Au, Mo Au, Ag, Cu, Pb, Zn	Alta
	5 San Juan Atrato (Terciario Sup. - Cuatern.)	Aluviones recientes Intrusiones zonadas Ipo Atalca	Placeres Epitermales de metales preciosos	Cu, Pb, Zn, Au Au, Pt Pt, Au	Alta Media Baja
	6 Atrato - Riosucio (Cuaternario)	Aluviones recientes	Placeres	Au, Pt Pt, Au	Media
	7 Timbiquí (Cuaternario)	Aluviones recientes	Placeres	Au, Pt	Media
	8 Barbacoas (Cuaternario)	Aluviones recientes	Placeres	Au, Pt	Media
	9 Río Mayo - Volcán Doña Juana (Paleozoico-Cuaternario)	Metamorfitas, saprolitos de rocas volcánicas e aluviones recientes	Saprolitos y placeres	Corindones y granates	Baja

Source: Strategic minerals for the development of Colombia - MEDC, 2000.



**Illustration 1-35.** Potentialities of minerals and metals of economic interest, in the central mountain range-Andean system  
Source: Strategic minerals for the development of Colombia - MEDC, UPME, MINERCOL, INGEOMINAS, 2000.

Table 1-4. Potentials of Minerals and Metals of Economic Interest in the Central Cordillera - Andean System.

CORDILLERA CENTRAL	OBJETIVOS DE EXPLORACION (TARGETS)	CARACTERIZACION GEOLOGICA	TIPOS DE DEPOSITOS	MINERALES Y METALES DE INTERES ECONOMICO	PRIORIZACION
	1 <b>Serranía de San Lucas</b> (Triásico-Jurásico - Cenozoico?)	Metamorfitas afectadas por magmatismo Triásico - Jurásico y Cenozoico.	Epitermales de Metales Preciosos	Au, Ag, Cu, Pb, Zn.	Alta
	2 <b>Batolito Antioqueño</b> (Cretáceo)	Magmatismo calcoalcalino con facies subvolcánicas tardías	Epitermales de metales preciosos	Au, Ag, Cu, Pb, Zn.	Alta
	3 <b>Batolitos de Ibagué-Mocóa y Terreno Payandé</b> (Jura-Triásico)	Magmatismo calcoalcalino con facies subvolcánicas tardías	Pórfidos Cu-Mo Epitermales de Au-Ag Skarn	Cu, Mo, Au Au, Ag, Cu, Pb, Zn Au, Ag, Cu, Pb, Zn, W, Mo, Fe, Marmol.	Alta Alta Meda
	4 <b>Aranzazu-Salamina</b> (Cretáceo)	Secuencia volcánico-sedimentaria intruida por plutones calcoalcalinos	Epitermales de Metales Preciosos	Au, Ag, Cu, Pb, Zn - Hg	Meda
	5 <b>Paleosutura de Romeral</b> (Cretáceo)	Zona tectónica que pone en contacto corteza oceánica y corteza continental	Lateritas	Ni, Fe.	Meda
	6 <b>Batolito del Bosque-Manzanares</b> (Cretáceo - Paleógeno)	Magmatismo calcoalcalino con facies subvolcánicas tardías	Epitermales de metales preciosos	Au, Ag, Cu, Pb, Zn.	Alta
	7 <b>Piedrasentada - Mercaderes - Suárez (Cenozoico)</b> (Cenozoico)	Sedimentitas y vulcanitas oceánicas y metamorfitas intruidas por stocks calcoalcalinos	Pórfidos Cu SMV Epitermales de metales preciosos	Cu-Au, Mo Cu, Pb, Zn, Au, Ag Au, Ag, Cu, Pb, Zn	Alta Alta Alta
	8 <b>Marmato - Titiribí - Anzá</b> (Cenozoico)	Metamorfitas y sedimentitas afectadas por pórfidos dacítico - andesíticos	Epitermales de Metales Preciosos	Au, Ag, Cu, Pb, Zn. Yeso	Alta
	9 <b>Cuenca de Amagá - Venecia</b>	Sedimentitas del Terciario y Cretáceo	Sedimentario	Carbon.	Meda
	10 <b>Nechi Bajo Cauca</b> (Cuaternario)	Aluviones recientes	Flaceres recientes	Au	Meda

Source: Strategic minerals for the development of Colombia - MEDC, 2000.

The country currently has thirty-four (34) Mining Districts (hereinafter DM) declared, and Antioquia has four (4) of these (Illustration 1-36).

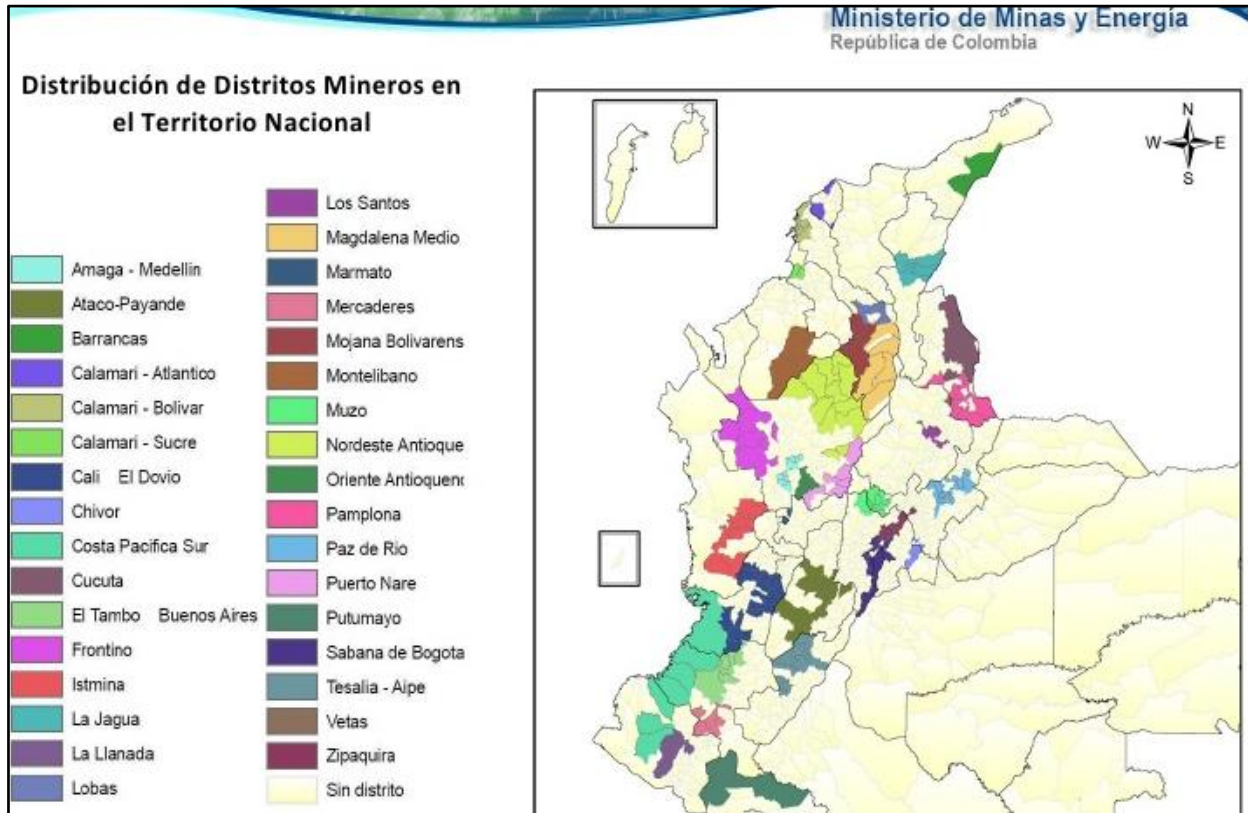
Among the main products of Antioquia mining are copper, silver, zinc, lead, gold, manganese, ornamental rocks, limestones, platinum, marble, calcareous, kaolin, clays, siliceous sands, feldspar, talc, coal and construction materials.

In the municipality of Urrao a deposit of massive sulfides is exploited from which copper concentrates are extracted. Porphyry copper deposits have also been identified in Murindó and in the area Pantanos - Pegadorcito. In some gold mines of Segovia and Remedios, they are also exploited as sulphurous byproducts of silver and zinc and lead sulphides.

Antioquia has two (2) manganese deposits, located in the municipalities of Dabeiba and Saint Barbara. This department has important reserves of calcareous rocks, mainly marbles, whose exploitation supplies the Antioquia cement industry, one of the most important in the continent.

Limestone is also exploited for agricultural and industrial uses and ornamental rocks. Old Calcareous deposits are located in the municipalities of Nare and Puerto Triunfo. It is estimated that the territory of Antioquia has reserves of 500 million tons of rocks calcareous to explode.





**Illustration 1-36.** Mining districts of Colombia.  
*Source: Colombian Mining Information System, 2008.*

There are extensive deposits of kaolin and kaolinitic clays that supply various industries of the region, which are exploited in the municipalities of La Unión and Carmen de Viboral. Equally It has siliceous sand mines in the municipalities of Amagá, Angelópolis, Titiribí and Amalfi, feldspar in the municipalities of Montebello, Alejandría, Bello, Envigado and La Ceja, of gypsum in the Anzá municipality and talc in the municipality of Yarumal, among others.

The coal deposits in Antioquia are located in five areas: Amagá - Sopetrán, Venecia - Titiribí, Purí - Cacerí, Tarazá - Man River and Urabá. The first two are the most important and they know with the name of Sinifaná coal basin. It is estimated that in these areas with reserves of 160 million tons to be exploited.

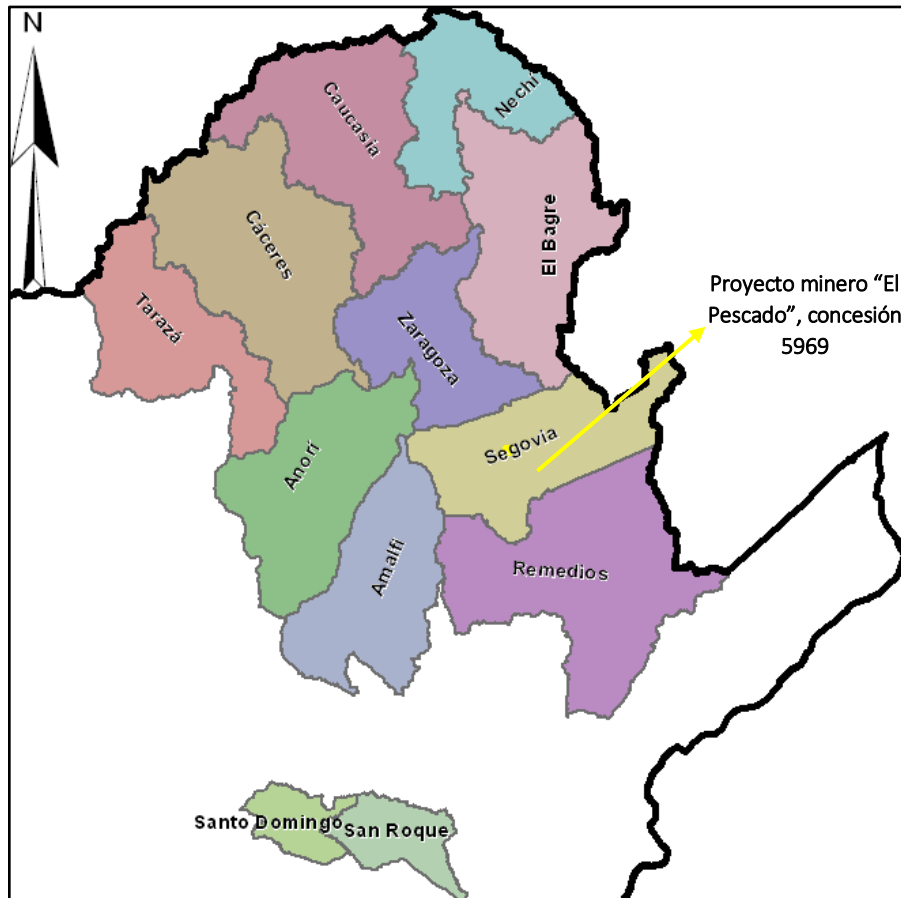
The exploitation of construction materials (stone aggregates, sands and clay for brick) takes place in different parts of the department, but especially in the Aburrá Valley, the Carmen del Viboral and the area of Amagá, for this purpose material from quarries and alluvial deposits.

Below are the local geological and mining considerations, which support the importance of the development of this project.



### 1.7.1.2 LOCAL CONSIDERATIONS

The mining concession 5969 "El Pescado" project to be advanced by TOUCHSTONE, will be developed in the municipality of Segovia belonging to the Mining District (DM) of the Northeast Antiquedom (Illustration 1-37). This DM, according to studies carried out by state entities and mining companies, owns large mining reserves of gold, silver and platinum, clays and limestones.



**Illustration 1-37.** DM North east of Antioquia, municipality of Segovia and mining project 5969.  
 Source: INGEX, 2016.

The DM of the northeast is considered as the main Philonian area in the department of Antioquia, since the social and economic development of the municipalities that compose it has always been linked to gold mining. In some areas of the DM of the Northeast mining is also developed alluvium, less frequently. For both types of mining, the benefit of gold is realized, in the majority of the cases, artisanally where the mining reserves are exploited.

The current technified mining in the municipality of Segovia, is developed in veins, on three fronts of work managed by the company Zandor Capital, who is exploiting the mines Sandra K, El Silence and Providence.

The previous mining potentials are located in several areas of the municipality of Segovia similar to the El Pescado village, where the project of interest of the present study is located.

The "El Pescado" mining project in the 5969 concession aims to achieve the highest standards of technological quality through equipment such as low profile loaders, jumbo, among others; to difference from the gold mining that historically has been developing in the region in a way handicraft the engineering techniques required by these mining-industrial activities, causing social and environmental impacts in the absence of effective and / or effective management measures, and without compliance with the regulations.

The project is focused on exploring, exploiting and efficiently benefiting the mineral deposit (mineral resource or ore with gold) in a technified form according to the current regulations (law 685 of 2001 and decree 1073 of 2015) in harmony with the environment and sustainable development as stipulated by the regulation of natural resources and protection of the environment (decree 2811 of 1974 and 1076 of 2015), once the present SDA and LA are obtained.

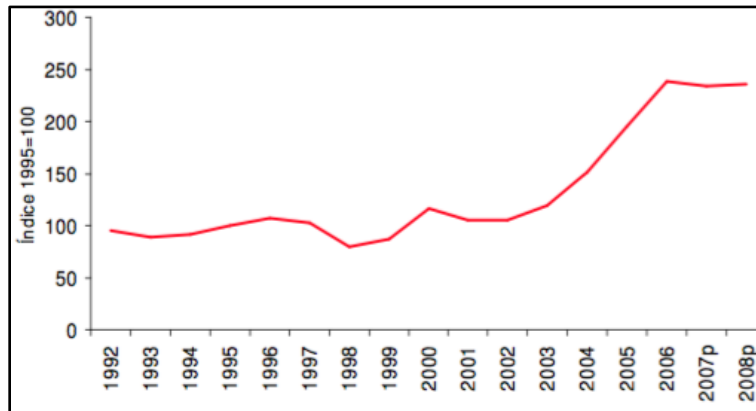
For the above, a Work and Work Plan (PTO) was designed covering all the mining planning and mineral benefit processes, according to mining and metallurgy engineering techniques conjugated with the results of the exploration campaign that investigated the geological resource.

The development of the "El Pescado" project in the mining concession 5969 will make it possible to extract efficiently mineral resources of 1.23 ha for pit 1 and 0.74 for pit 2, with a depth approximately 20 meters. (See Block model of reserves in the deposit with tunnels) and a content of 14,144 gold tons. However, this information geological may vary in greater depth according to findings in the extraction stage.

This project estimates to generate the first year of operation 14,144 ounces of gold, managing to extract efficiently 300 tons per day, as specified in chapter No. 2. Description of the project, framed in the sustainable development and community relation.

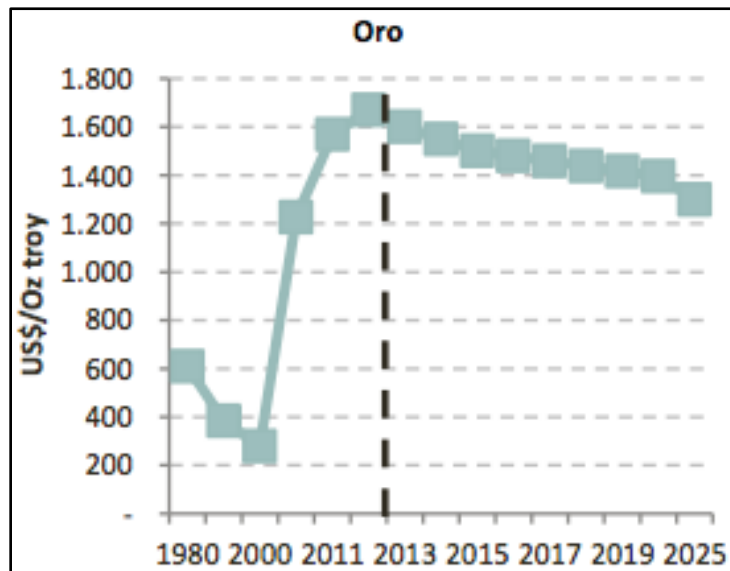
### **1.7.2 ECONOMIC CONSIDERATIONS**

Since 2002 there has been a global apogee of commodities or commodities (Illustration 1-38), which has meant that international gold prices have grown more than double and staying for longer with some slight but sustained falls, unlike of the averages recorded in past decades (Illustration 1-39).



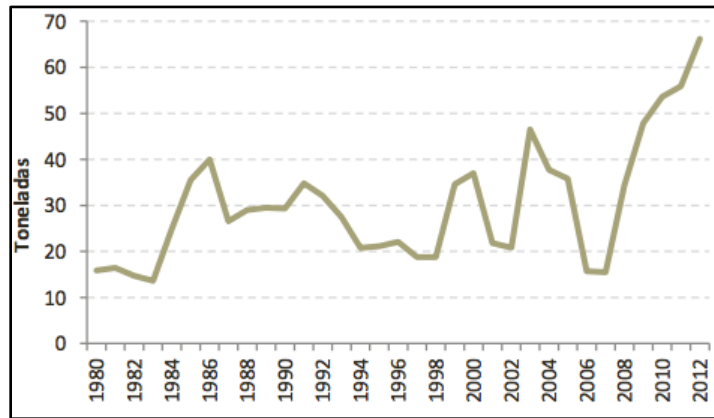
**Illustration 1-38.** International prices of commodities.  
*Source: International Monetary Fund.*

Gold prices show a sharp increase over the last decade due to their value as an active refuge in the global economy, mainly after the 2008 financial crisis where precious metals like silver and gold became a safer investment before the uncertainty about the performance of the US economy, the volatility of the stock markets values and fluctuations of the main currencies.



**Illustration 1-39.** International gold prices.  
*Source: World Bank - Global Commodity Prices.*

The future evolution of the prices of this metal, in the next two years, depends more on the monetary policies of developed and emerging countries than on the fundamental factors related to the economic dynamics that explain the demand for gold in normal times (Illustration 1-40).



**Illustration 1-40.** Gold production.  
 Source: SIMCO.

In the midst of this economic advantage, Colombia is not a major producer in the world, with the exception of the emeralds; mineral of which is the largest producer. However, it occupies the position No. 19 in the world as a gold producer (Reuters, 2011).

It is also likely that the price of gold will continue for some years, generating profitability for this activity of public utility or social interest, thanks to the sustained expansion of China and the growth prospects of India (ANDI, 2008).

Due to the foregoing, international mining companies have multiplied their investments in exploration and exploitation around the world. Global spending on mineral exploration does not ferrous metals has increased from 1,900 million dollars in 2002 to 5,000 million dollars in 2005 (Economist, 2006). Latin America has played a predominant role in the midst of the dynamism of exploration processes, to the point of being the fastest growing mining region in the world (Journal, 2002).

It also highlights the rest of Latin America, specifically for countries like Chile and Peru, which benefit from this sector, as one of the main engines of economic development, framed within sustainability.

This bonanza of the international market in relation to mining in Colombia, can be verified with growth rates higher than those presented by other productive segments such as manufactures, energy, personal services, agriculture, forestry and fishing (UPME, 2006).

There is currently uncertainty about whether the "energy mining sector boom" will remain or if you are beginning to moderate your growth. Despite its stabilization there are no clear signs of reduction in production in Colombia, new investments are announced, and others have gone by the lack of legal security mainly in environmental matters.

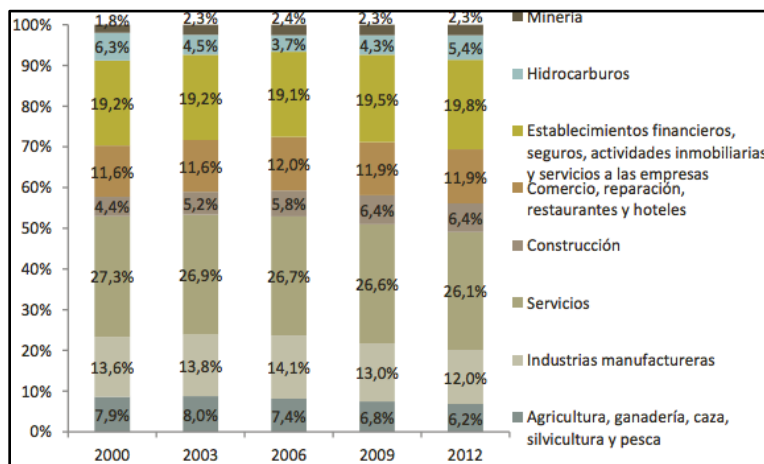
In accordance with the national development plan, the mining-energy sector is considered as a locomotive for the growth of the economy: The high production projections of oil and coal for the next few years, the upward estimates of the international prices of the mining-energy basket and the

increasing activity of exploration in the national territory, clearly show the crucial role that this sector will have in the Colombian economy in the next years".

Below are the contributions of mining in production and prices, exports, Foreign Direct Investment (hereinafter FDI), income to the nation, impact on the rest of the economics and local economic considerations that underpin the development of the mining project "El Pescado "in the mining concession 5969.

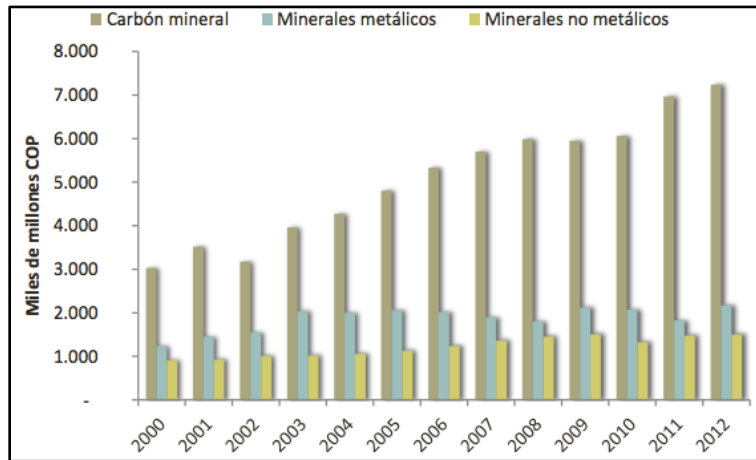
### 1.7.2.1 PRODUCTION AND PRICES

The participation of mining in the Gross Domestic Product (hereinafter GDP) in the last decade of the country, has been stable unlike the hydrocarbons sector. Giving a growth between the years 2000 and 2003 from 1.8 to 2.3% respectively (Illustration 1-41), the contribution being stable in GDP with around 2.3%. However, it is much lower compared to the countries in which mining has played a more important role in economic growth, as in the case of Chile and Peru.



**Illustration 1-41.** Evolution of the participation in GDP by sectors.  
 Source: Fedesarrollo calculations based on information from DANE.

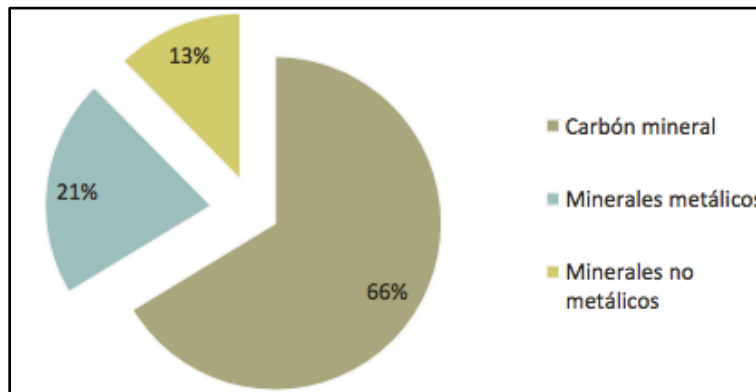
The behavior of the GDP by mining, increased from 5.2 trillion pesos in the year 2000, until 10.9 billion pesos in 2012 (Illustration 1-42).



**Illustration 1-42.** Evolution of mining GDP 2000-2012.

Source: DANE.

Illustration 1-43 shows the percentage share of the types of mining that contribute to the GDP, where metal corresponds to 21%.



**Illustration 1-43.** Composition of mining GDP 2012.

Source: DANE.

The records of gold production in Colombia show a very unstable behavior during the last three decades. Not necessarily by purely productive variables but by figures reported on the illegality of non-technified farms that go against development sustainable and this productive sector.

In 2010, the Ombudsman's Office reported that 28% of the mining units in fact (without mining title) are dedicated to the exploitation of gold. In addition, according to the Departmental Mining Census 2010-2011, of the 4133 Gold Mining Production Units surveyed, 86.7% did not have mining title.

### 1.7.2.2 EXPORTS

Exports of minerals in the year 2000 amounted to 1,237 million FOB dollars and reached 12,822 million FOB dollars in the year 2012 (Illustration 1-44), increasing its participation within of national exports, from 14.2% to 21.3% during the same period (Illustration 1-45).

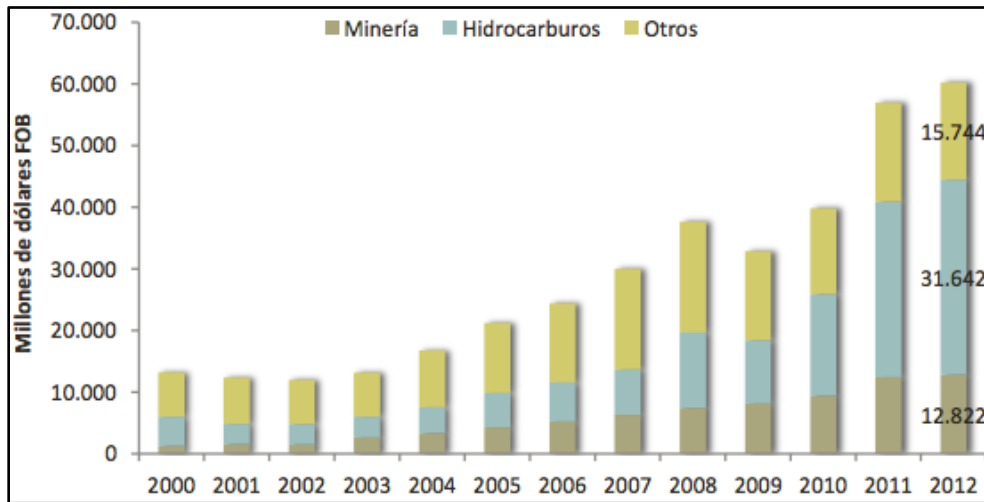


Illustration 1-44. Evolution of exports 2000-2012.  
 Source: Bank of the Republic.

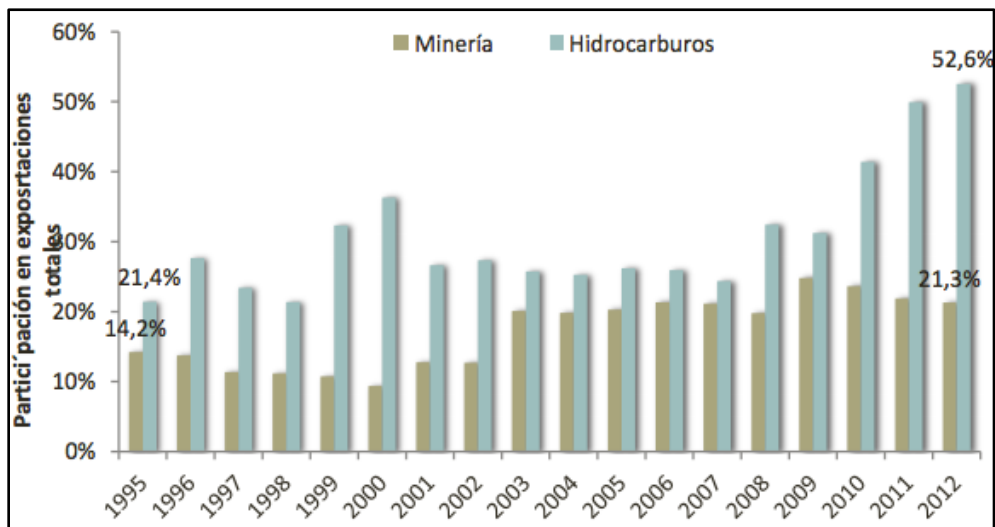


Illustration 1-45. Evolution of the participation of mining and hydrocarbons in exports.  
 Source: Bank of the Republic.



### 1.7.2.3 DIRECT FOREIGN INVESTMENT

FDI flows to the mining sector have increased from 507 to 2,250 million dollars between the year 2000 and the year 2012. Therefore, the mining participation in this area in the country, has been on average 24.5% (Illustration 1-46).

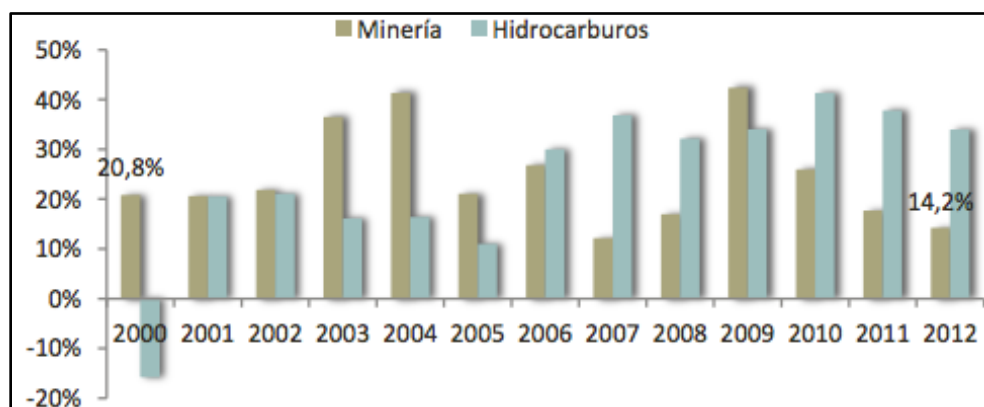


Illustration 1-46. Evolution of the participation of mining and hydrocarbons in total FDI.  
 Source: Bank of the Republic

#### 1.7.2.3.1 International perception

The mining countries attract FDI based on the explained geological considerations. But this IED it also obeys the tax and royalty system, the legal framework, the institutional framework that regulates activity and the security environment that surrounds the operations and that guarantees the life of the people.

Countries compete for risk capital and technology in an international arena. While the companies establish their own measures to objectively compare the attractiveness of different countries based mainly on opinion surveys, where investors report their perceptions for different categories of management in different countries, on the risks that it involves every mining project.

In the last decade the attractiveness of Colombia, according to these qualitative appreciations, is presented by the following surveys.

#### 1.7.2.3.2 Behre Dolbear Group Survey

The Behre Dolbear Group survey on attractive countries to invest in mining takes into account seven criteria that go from the economic and political system of the countries, to the competitiveness of the tax system. In it, Colombia remains since 2010 in position 7 among 25 countries (Illustration 1-47), with a score of 39 points (between 0 and 70).

Posición 2012	País	Puntos 2012	Puntos 2011	Puntos 2010
1	Australia	57	57	61
2	Canadá	52	52	56
3	Chile	51	51	49
4	Brasil	45	45	42
5	México	43	44	45
6	Estados Unidos	41	41	42
7	Colombia	39	39	39
8	Botswana	37	37	36
9	Perú	36	37	33
10	Ghana	36	34	36
11	Namibia	33	31	31
12	Tanzania	32	32	32
13	Mongolia	32	34	36
14	Argentina	30	30	31
15	Filipinas	29	28	26
16	India	29	30	29
17	China	28	31	35

Illustration 1-47. Colombia's position in the mineral production ranking.  
Source: Behre Dolbear Group Inc.

### 1.7.2.3.3 Survey of the Fraser Institute

While the Fraser Institute indicates the relative position of Colombia it is much less favorable and the improvement observed between 2007 and 2011 was partially reversed in the last two versions of the index (Illustration 1-48).

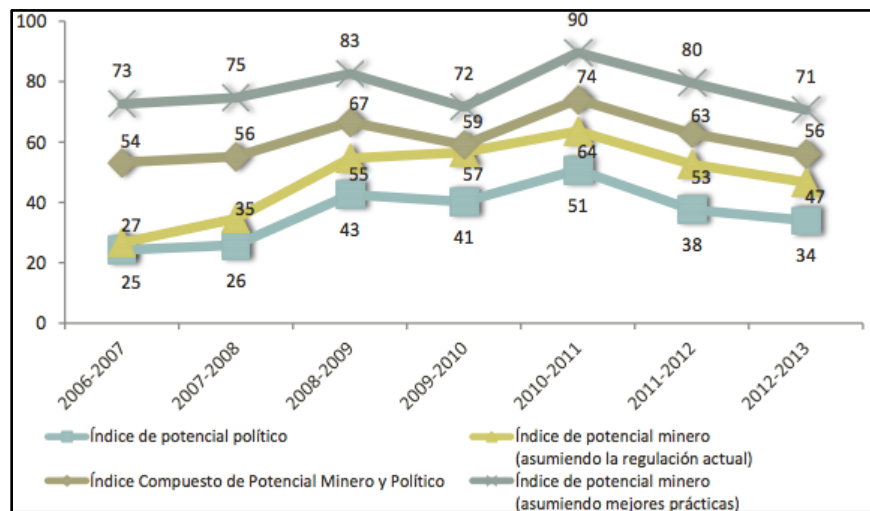


Illustration 1-48. Evolution of the indexes of mining potential, political potential and compound.  
Source: Fraser Institute.

When compared to some countries in the region, such as Brazil, Chile, Mexico and Peru; Colombia is located in a very unfavorable position, just above Brazil in the potential index mining, assuming the

current regulation and below all the countries mentioned in the index of political potential (Institute Fraser, 2011).

#### 1.7.2.4 INCOME OF THE NATION

Mining has a significant role because of its contributions to the current income of the nation and of some regions of the country. Specifically, mining contributes to public finances mainly with income taxes, equity and VAT, like the rest of the activities productive and additionally with a specific contribution constituted by royalties.

Mining contributes 2.3% of the nation's current income (DIAN, 2006). The Illustration 1-49 shows that the participation of the sector has grown steadily since 2002 and it presents a considerably high level in 2006 with a contribution of 1.17 billion pesos.

	2000	2001	2002	2003	2004	2005	2006
Ingresos corrientes de la Nación	20,126,537	25,177,166	27,393,539	31,578,625	36,937,140	42,517,876	51,475,000
Sector minero sin hidrocarburos	162,072	193,391	143,132	430,699	786,370	833,086	1,176,034
Participación sector	0.81	0.77	0.52	1.36	2.13	1.96	2.28

Illustration 1-49. Taxation of the mining sector.

Source: Fiscal measurements division. Office of economic studies, DIAN.

According to the UPME, the value that the Municipality of Segovia and the Department of Antioquia to the current revenue of the nation for the year 2009; is \$ 11,829,354,683 for the municipality and \$ 45,965,311,771 for the Department (Illustration 1-50).

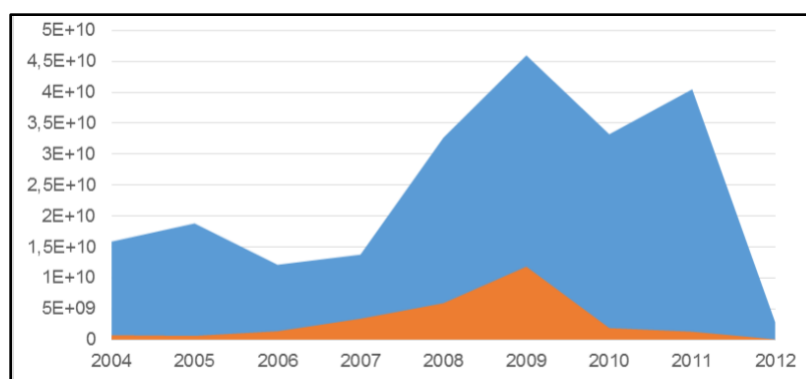


Illustration 1-50. Distribution of Royalties related to Precious Metals.

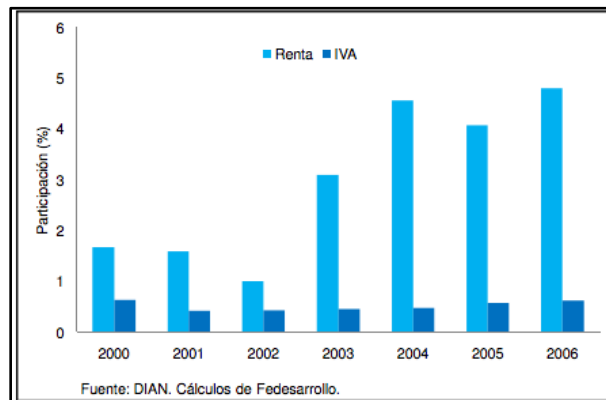
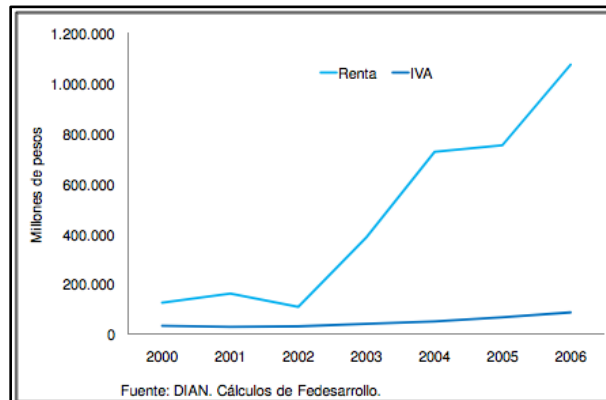
Source: [http://www.upme.gov.co/generadorconsultas/Consulta\\_Series.aspx?idModulo=4&tipoSerie=106&grupo=339](http://www.upme.gov.co/generadorconsultas/Consulta_Series.aspx?idModulo=4&tipoSerie=106&grupo=339)

Next you specify the income to the nation of mining conformed by income contribution and VAT, property tax and royalties.

##### 1.7.2.4.1 Income and VAT contribution

In 2000, the DIAN collection of contributions from the mining sector for rent was of \$ 125,781 million pesos, a value that has increased in subsequent years (Illustration 1-51).

This contribution doubled and continued to grow to reach \$ 1,074 billion pesos in 2006, which represents approximately 4.8% of the total collected in the country as income tax rent.



**Illustration 1-51.** Contribution in income collection and VAT and percentage of participation.  
 Source: DIAN, Calculus Fedesarrollo.

#### 1.7.2.4.2 Equity tax

Mining also makes contributions for the concept of property tax that was introduced in 2004. This represents 2.6% of the total collection of the DIAN as a tax on equity in the country. In less than two years that contribution doubled, going from 6.4 billion pesos in 2004 to 13,644 million pesos in 2006.

#### 1.7.2.4.3 Royalties

Royalties from mining have changed significantly since 2004 with 9.9% of the total royalties, while in 2012 they accounted for 18.7% of the same item Table 1-39.

Table 1-39. Payment of mining and hydrocarbon royalties 2004 and 2012.

Producto	Regalías 2004			Regalías 2012		
	Miles de millones de pesos	% PIB	% Total regalías	Miles de millones de pesos	% PIB	% Total regalías
Hidrocarburos	2.585	0,8%	90,1%	8.500	1,3%	81,3%
Minas	285	0,1%	9,9%	1.958	0,3%	18,7%
Total	2.870	0,9%	100,0%	10.458	1,6%	100,0%

Source: SIMCO y ANH.

That is, the value paid for royalties went from 285 billion pesos in 2004 to 1.96 trillion pesos in the year 2012 (Illustration 1-52). Gold mining has a stake of 10.3% for this item for that year.

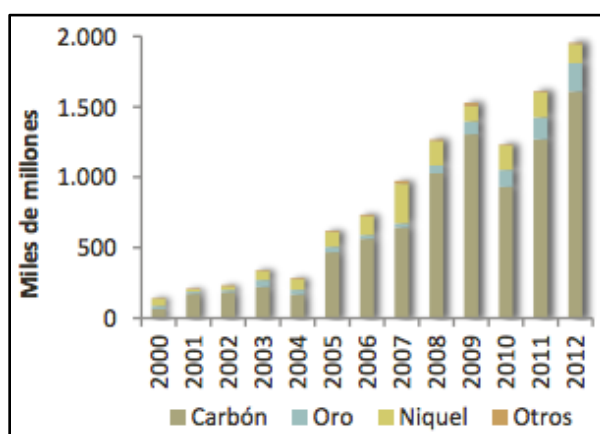


Illustration 1-52. Royalties of the mining sector. Source: Source: SIMCO and ANH.

According to the Medium Term Fiscal Framework (hereinafter MFMP) of 2012, income from royalties would go from 9.1 to 10.6 billion pesos between 2012 and 2020, which represents growth of 16.4% (Illustration 1-53).

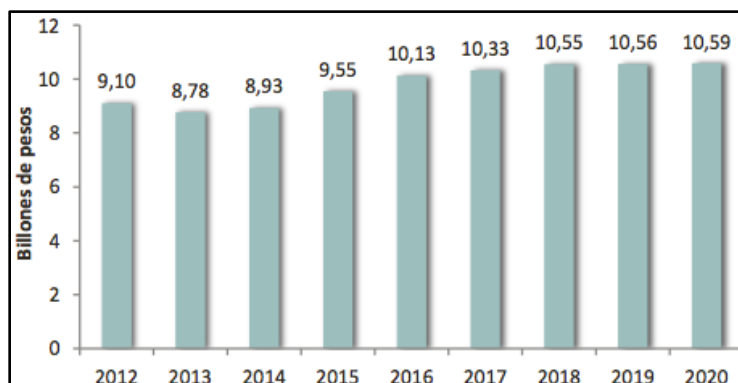


Illustration 1-53. Projection of royalty income.  
Source: MFMP 2012 (2012).

However, while hydrocarbon royalties show slight growth, the highest the growth of this item comes from mining royalties. It should be noted that the figures reported in the last year, they already surpass the projected figures in the Development Plan (Table 1-40).

**Table 1-40.** Royalties projected in the resource plan 2013-2022.

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Hidrocarburos	7,58	6,94	7,71	7,77	7,89	8,04	8,04	8,03	8,01	8,01
Minería	1,56	1,64	1,85	2,00	2,09	2,14	2,16	2,22	2,29	2,36
<b>Total</b>	<b>9,14</b>	<b>8,59</b>	<b>9,56</b>	<b>9,77</b>	<b>9,98</b>	<b>10,19</b>	<b>10,20</b>	<b>10,25</b>	<b>10,30</b>	<b>10,37</b>

Source: MHCP (2012).

Antioquia is the largest gold producer in Colombia (with approximately 68% of the production national level in 2006), and it is also the department that has the highest level of technology for the extraction of the mineral (Jaime Sierra, 1989). Next in importance Chocó, Bolívar and in minor Measure Cauca, Tolima, Santander, Nariño, Valle del Cauca and Risaralda.

In the precious metals subsector, the highest percentage of income from royalties receive the departments of Antioquia (46.09%) and Chocó (20.88%), which at the same time are the major gold producers. In a much smaller proportion, the distributions made to Caldas (7.76%), Bolívar (5.79%) and Córdoba (2.34%).

#### 1.7.2.5 IMPACT OF MINING ON THE REST OF THE ECONOMY

The "forward" linkages reflect the relationships established by the mining sector with the rest of the economy, by providing productive inputs for the production of other goods and services in other sectors locally or as exports.

More than 60% of mineral production is exported (See Table 1-41).

In the case of coal, that percentage is close to 94%. At the national level, the main the applicant is the basic metallurgical products sector with a participation of 18.9%, followed by construction with 10.3%. These milestones within the internal market are mainly in the metallic minerals sector, followed by non-metallic minerals.

Table 1-41. Conformation of the supply of the mining sector and subsectors.

	Carbón mineral		Minerales metálicos <sup>1</sup>		Minerales no metálicos <sup>2</sup>		Total minería	
	\$	%	\$	%	\$	%	\$	%
<b>Exportaciones</b>	<b>10.478</b>	<b>93,9%</b>	<b>1.999</b>	<b>33,6%</b>	<b>306</b>	<b>9,1%</b>	<b>12.783</b>	<b>62,4%</b>
<b>Formación bruta de capital</b>	<b>21</b>	<b>0,2%</b>	<b>52</b>	<b>0,9%</b>	<b>0</b>	<b>0,0%</b>	<b>73</b>	<b>0,4%</b>
<b>Demanda Intermedia</b>	<b>657</b>	<b>5,9%</b>	<b>3.905</b>	<b>65,6%</b>	<b>3.070</b>	<b>90,9%</b>	<b>7.632</b>	<b>37,3%</b>
<i>Productos metalúrgicos básicos</i>	23	0,2%	3.827	64,3%	14	0,4%	3.865	18,9%
<i>Construcción</i>	0	0,0%	0	0,0%	2.109	62,5%	2.109	10,3%
<i>Productos minerales no metálicos</i>	69	0,6%	11	0,2%	622	18,4%	702	3,4%
<i>Carbón mineral</i>	160	1,4%	0	0,0%	105	3,1%	265	1,3%
<i>Energía eléctrica</i>	182	1,6%	0	0,0%	0	0,0%	182	0,9%
<i>Sustancias y productos químicos</i>	9	0,1%	12	0,2%	111	3,3%	132	0,6%
<i>Productos refinados</i>	122	1,1%	0	0,0%	0	0,0%	122	0,6%
<i>Equipo de transporte</i>	0	0,0%	53	0,9%	1	0,0%	54	0,3%
<i>Minerales metálicos</i>	27	0,2%	0	0,0%	25	0,7%	52	0,3%
<i>Minerales no metálicos</i>	5	0,0%	0	0,0%	19	0,6%	24	0,1%
<i>Otros</i>	60	0,5%	2	0,0%	64	1,9%	125	0,6%
<b>Total Oferta</b>	<b>11.156</b>	<b>100,0%</b>	<b>5.956</b>	<b>100,0%</b>	<b>3.376</b>	<b>100,0%</b>	<b>20.488</b>	<b>100,0%</b>

Source: Fedesarrollo calculations based on the DANE (2010).

Therefore, there is an important space to expand the productive chains towards forward through the development of productive activities that demand minerals, taking advantage of to a greater extent, the national abundance of mining resources, particularly coal.

In 2010, the production of the mining sector amounted to \$ 19.4 billion, where \$ 5.25 billion they corresponded to purchases of inputs (intermediate consumption) and \$ 14,17 billion to value added. The Table 1-42 shows the composition of the production value of the mining sector and its subsectors.

Table 1-42. Composition of the production value of the mining sector.

	Carbón mineral		Minerales metálicos		Minerales no metálicos		Total minería	
	\$	%	\$	%	\$	%	\$	%
<b>Valor agregado</b>	<b>8.592</b>	<b>75,6%</b>	<b>3.890</b>	<b>66,8%</b>	<b>1.690</b>	<b>75,4%</b>	<b>14.172</b>	<b>73,0%</b>
<i>Remuneración a los asalariados</i>	1.493	13,1%	451	7,7%	537	24,0%	2.481	12,8%
<i>Excedente bruto de explotación</i>	6.913	60,8%	1.675	28,8%	264	11,8%	8.852	45,6%
<i>Ingreso mixto</i>	38	0,3%	1.698	29,2%	883	39,4%	2.619	13,5%
<i>Impuestos</i>	148	1,3%	66	1,1%	6	0,3%	220	1,1%
<b>Consumo Intermedio</b>	<b>2.773</b>	<b>24,4%</b>	<b>1.930</b>	<b>33,2%</b>	<b>551</b>	<b>24,6%</b>	<b>5.254</b>	<b>27,0%</b>
<b>Total producción</b>	<b>11.365</b>	<b>100,0%</b>	<b>5.820</b>	<b>100,0%</b>	<b>2.241</b>	<b>100,0%</b>	<b>19.426</b>	<b>100,0%</b>

Source: Fedesarrollo calculations based on the DANE (2010).

As shown in Illustration 1-54, an increase in mining production of 1 peso generates increases in gross national production of 2.44 pesos. Of these 2.44 pesos, 1 peso corresponds to the increase in sector production, 0.27 pesos to the increase in production generated by the direct suppliers of the mining



sector, 0.26 pesos to the increase in the production of suppliers of suppliers of the sector and 0.91 pesos to the effect induced by household expenditure.

In terms of added value, an increase in 1 peso in mining production induces an increase of the national added value of 1.3 pesos, of which 1 peso corresponds to remuneration to the capital, 0.27 pesos to the remuneration to work and 0.03 pesos to taxes.

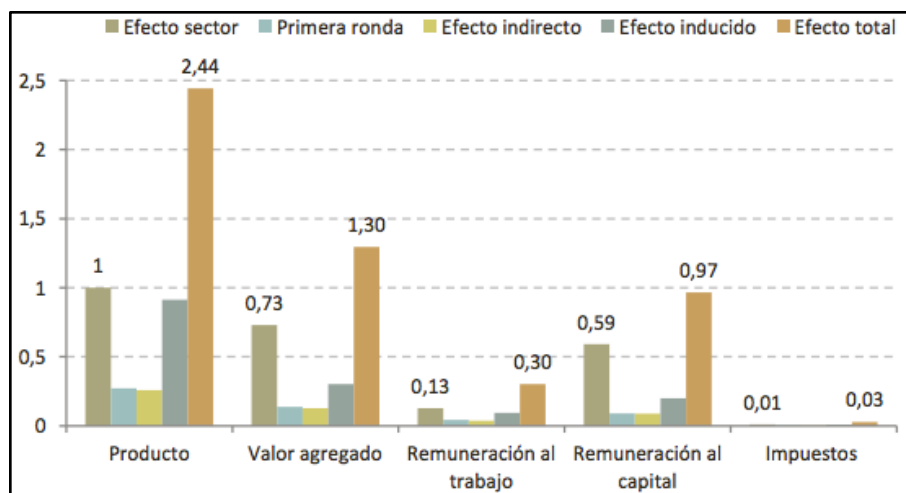


Illustration 1-54. Effect of the increase of a peso in the production value of the mining sector.  
Source: Fedesarrollo calculations based on the DANE (2010).

Indirect and induced effects are similar in mining subsectors. The multiplier of product amounts to 2.40 pesos for mineral coal, 2.46 pesos for metallic minerals and 2.96 pesos for non-metallic minerals. These figures are shown in Table 1-43.

Table 1-43. Summary of the effects of the mining sector and totals before an increase of \$ 1 in the production of the sector.

	Carbón		Minerales metálicos		Minerales no metálicos		MINERÍA	
	Efecto sector	Efecto total	Efecto sector	Efecto total	Efecto sector	Efecto total	Efecto sector	Efecto total
Producto	1,00	2,39	1,00	2,42	1,00	2,82	1,00	2,44
Valor agregado	0,76	1,30	0,67	1,24	0,75	1,43	0,73	1,30
Remuneración al trabajo	0,13	0,30	0,08	0,25	0,24	0,45	0,13	0,30
Remuneración al capital	0,61	0,97	0,58	0,96	0,51	0,96	0,59	0,97
Impuestos	0,01	0,03	0,01	0,03	0,00	0,02	0,01	0,03

Source: Fedesarrollo calculations based on the DANE (2010).

The linkages of the mining activity are superior to those of other extractive activities as oil production, the way to go in terms of strengthening the sticking of other economic activities is still very broad and of great importance. As mentioned by Martinez in a study by Fedesarrollo (2012), to the extent that the local content of the mining demand be greater, the positive effects of its growth in terms of

employment and value chains will be also older. The companies dedicated to mining exploration and exploitation are in the ability to contribute to the analysis of the difficulties of local suppliers and join the effort of the government to improve their skills.

Below are the local economic considerations, which support the importance of the development of this project.

#### **1.7.2.6 LOCAL ECONOMIC CONSIDERATIONS, WHICH SUPPORT THE IMPORTANCE OF THE DEVELOPMENT OF THE MINING PROJECT "EL PESCADO", CONCESSION 5969**

The "El Pescado" mining project in concession 5969, may generate approximate values in the first year of production of \$ 54,549,083,121 gross (\$ 99,909 / g Au) - Colombian Pesos. Value without even deducting the amortization of the investment during the useful life of the project, such as:

##### **Exploration stage**

- Acquisition of 5969 mining concession and/or negotiation.
- Surface canons.
- Easements and leases.
- Exploration campaign.
- Mining and environmental exploration permits.
- Studios of STA, SDA and EIA.
- PTO and engineering design for construction.

##### **Stage of operation and closure**

- Construction and assembly.
- Operating costs (extraction and benefit) - see chapter 2.
- Execution of the social and environmental management plan.
- Execution of the compensation plan for ecological restoration by the SDA.
- Execution of the 1% investment plan.
- Execution of the closure plan and others.

Below are the previous percentage-unified items (contributions to the State corresponding to 31.55%, utilities, among others - Illustration 1-55).

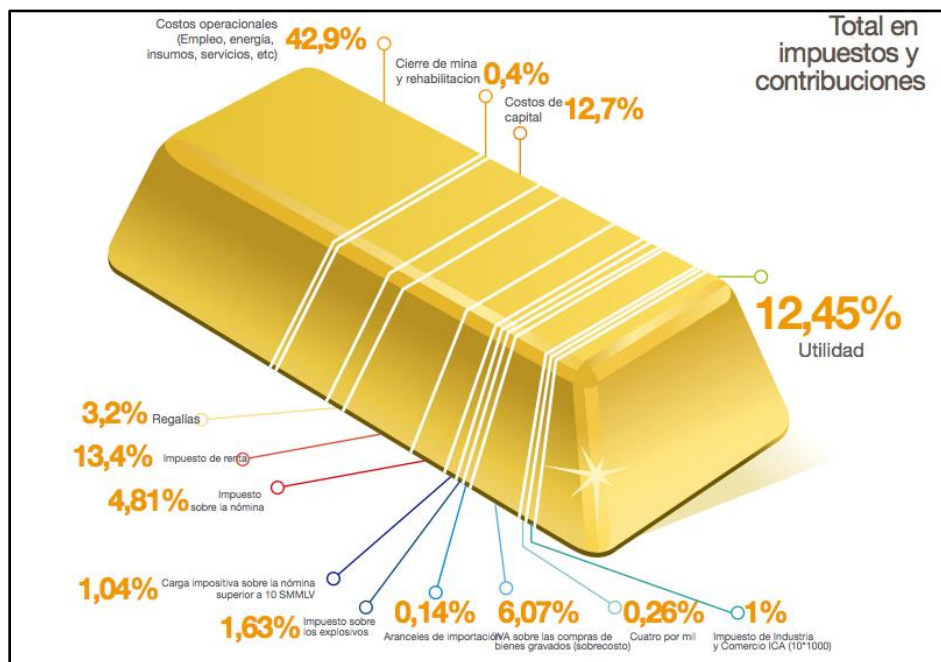


Illustration 1-55. Percentage distribution in the first year.

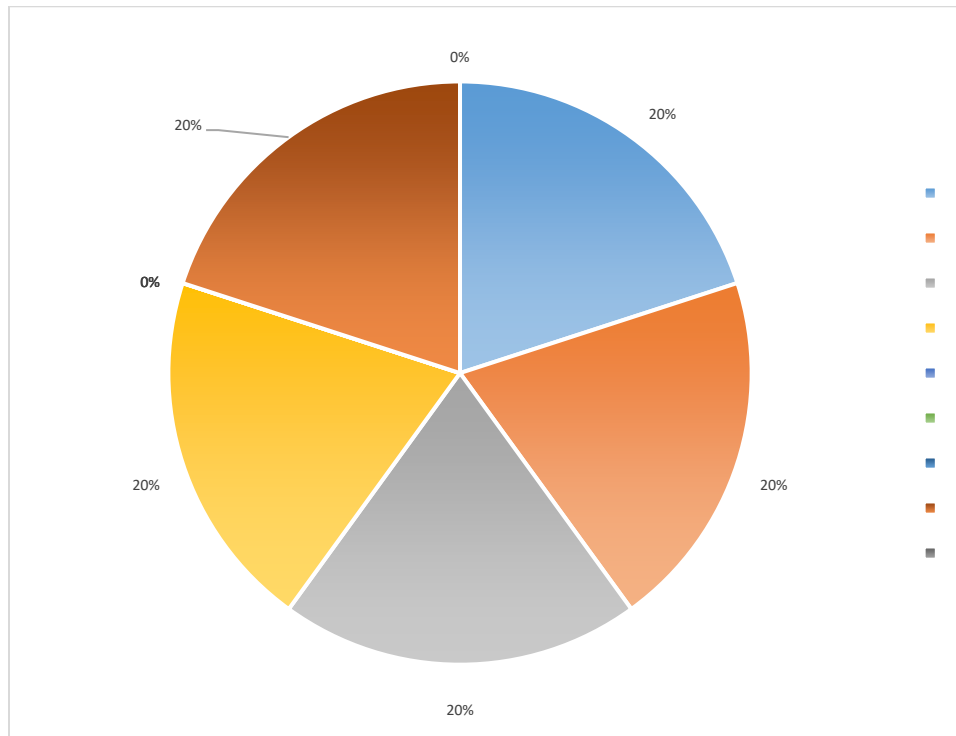
Source: INGEX, 2016.

In accordance with Illustration 1-55, taxes and contributions for the state are made up of: Royalties (3.2%), income taxes (13.4%), payroll tax (4.81%), tax burden on the Payroll > 10 SMMLV (1.04%), tax on explosives (1.63%), import duties (0.14%), VAT on purchases (6.07%), four per thousand (0.26%), industry and trade taxes (1%); will be contributed to the corresponding regulatory entities. These taxes and contributions are translated at approximately \$ 1,257,752,407 for the first year of production and unified for life useful for the project, approximately \$ 17,210,235,725 (see Table 1-44).

Table 1-44. Projection of taxes for the El Pescado project, concession contract 5969.

Type of collection	Rate of collection (%)	Taxes generated 1st year of production.	Taxes generated in life Useful of the project.
Royalties	3,2	127.569.182	1.745.570.660
Rent	13,4	534.195.951	7.309.577.138
Payroll	4,81	191.752.427	2.623.810.898
Payload	1,04	41.459.984	567.310.464
Explosive tax	1,63	64.980.552	889.150.055
Tariffs	0,14	5.581.152	76.368.716
VAT	6,07	241.982.793	3.311.129.345
4x1000	0,26	10.364.996	141.827.616
Industry and commerce tax	1	39.865.369	545.490.831
<b>TOTAL</b>	<b>31,55</b>	<b>1.257.752.407</b>	<b>17.210.235.725</b>

Source: Ingex Mining Group, 2016.



**Illustration 1-56.** Distribution of collections for taxes.

From the royalties, the municipality of Segovia will have access to the formulation of projects in the Collegiate Organs of Administration and Decision (hereinafter OCAD), who are in charge to define them, evaluate them, make them viable, prioritize them, approve them and designate the executor of them.

In addition to the percentage contributions that will be delivered to the state. The economy will be benefited through:

- Productive chains of alternative activities to mining, where communities of influence can provide goods and services to the mining project "El Pescado" in the mining concession 5969. Some of these may be direct sale of vegetables, eggs, meats, fruits and other foods for the restaurant and other marketing businesses, goods or services that communities can offer.
- Generation of multiple direct and indirect jobs, prioritizing in areas of influence, and the municipalities of Segovia and Remedios. Improving the economy of the families.

The presence of TOUCHSTONE, in the region of El Pescado village where the population lives from the livestock, small-scale agriculture, artisanal mining, makes the company become a potential driver of the economy and a resource factor as a product of the technified exploitation of the mineral. Therefore, the economic resources generated with this project are invested in the majority of the percentage in the development thereof, taxes and contributions to the state, and environmental and social investments.

### 1.7.3 HISTORICAL CONSIDERATIONS

Mining in Colombia is part of the main productive sectors that have come promoting the development of the national and regional economy and infrastructure. To understand the importance, you should know its historical role internationally, nationally and regionally. Next, presents a brief summary of the most significant events:

- "In the Middle East, humanity began to work metal 9,000 years ago. But in Colombia the oldest pieces date from 1500 b.c. For 2,000 years indigenous tribes of the country perfected the techniques of goldsmithing and knew how to mix perfectly different materials. Gold - bright and powerful - represented male and copper - red and changing - the feminine. The union of the feminine and the masculine produced new colors, smells and glitters that did not exist in nature, and that symbolized different aspects of indigenous cosmology. But with the arrival of the Spanish goldsmiths it ended almost completely "(Semana Magazine, 2014).
- Since pre-Colombian times, our aborigines had special appeal for the exploitation of gold and goldsmithing for ceremonial and ornamental purposes. In the conquest and settlement of our territory, the mineral was the main attraction for European conquerors and colonizers.
- Between the seventeenth and eighteenth centuries, the progress of mining was slow due to the exhaustion of numerous mines of pleasures, availability of veins but at great depths, health problems and rudimentary technology.
- Between 1800 and 1810 there was a fall of the Antioquia economy due to the wars of independence. But later the greatest benefit for mining in Antioquia was the disappearance of Spanish governmental control in the period 1810 to 1820, disappearing the real fifth, allowing gold traders to increase their profits and thus the department's great industry emerges.
- Between 1820 and 1830 Antioquia became the main gold region of the New Granada, surpassing the province of Cauca and reaching 50% of all gold of the country, highlighting the historical role of mining in the region.
- Between 1850 and 1855 there was a great movement of technification in mining and very especially in the vein.

The following are historical local considerations that support the importance of development of this project.

#### 1.7.3.1 LOCAL HISTORICAL CONSIDERATIONS THAT SUSTAIN THE IMPORTANCE OF THE DEVELOPMENT OF THE MINING PROJECT "EL PESCADO", CONCESSION 5969

Following are the following local historical records, which indicate that the municipality was formed by mining and is its main vocation.

- Around 1868 there were purchases of precious metals, located in the municipality of Segovia and the exploitation of the El Silencio mine, Manzanillo, Marmajito, Cogote, begins Córdoba later bought the mines of San Nicolas and Cristales from the French. He also acquired the La Italia, Tres y Media mines, as well as two alluviums: East Thread and the First Cecilia.

- Large investments were made to obtain water and build the road Yolombó-Remedios- Saragossa. The mining development in northeast Antioquia restored the level of production of that area, which had been declining since the beginning of the century.
- On August 24, 1865, the hamlet of Tierra Adentro, corregimiento de Remedios is founded, at that time it was inhabited by 500 people. On December 31, 1877 the corregimiento acquires the name of Segovia and already by then it had 2,500 population. On June 15, 1885, the decree was issued through which Segovia is founded municipality.
- The company Frontino (Hoy Zandor Capital) in recognition of the population decided legalize the properties and that is how, in 1888, they ceded under public free to the district of Segovia an area of 83.5 hectares to locate the settlements.
- The auriferous potential of this region, as well as the existence of platinum, attracted the first expert foreign miners who contributed capital and technology. With them came the Californian mill, amalgamation with mercury, cyanidation, dynamite, the Pelton wheel, the pump, the steam engine, the river dredger, the hydraulic monitor, and many others. The gold potential of this region, as well as the existence of platinum, attracted the first expert foreign miners who contributed capital and technology. With them came the mill Californian, amalgamation with mercury, cyanidation, dynamite, the Pelton wheel, hydraulic pump, steam engine, river dredger, hydraulic monitor and many others technological innovations that were appearing in the world mining. Emerging also entrepreneurs from Antioquia who founded their own mining companies and that with great success they managed to grow and adapt to the changing realities of the market.
- Thanks to the mining boom that occurred in the Antioquia region, and the arrival of capital abroad was given the opportunity to adopt technological advances "to change mining of alluvium by the vein and with this increase considerably the productive potential " (Romero, 2013). The development of business associations and the use of techniques administrative initiatives and entrepreneurship gives prestige to Antioqueno entrepreneurs with high capacity for capital accumulation, which allowed them to continue investing in the sector. "They saw a group interested in reinvesting instead of accumulating profits; in improving the exploitation of the mines; to open the lands bordering the Cauca River; in financing the settlers of the south and the southwest and in establishing commerce with the outside of the country without stopping doing it with the interior "(Romero, 2013).
- Given the mining strength in the department of Antioquia, the National School of Mine with the intention of educating and training professionals for mining and industry, "the training of the bullfighting or generalist engineer, allowed these professionals to face a work, such as a road or an electrical system. Especially, before the fall of mining in Antioquia, the demand for engineers is focused on planning and construction, and singularly to the management and maintenance of the railways, tasks that were led by Antioquia engineering or the best trained cohorts in Antioquia. " (Romero, 2013)
- The Segovia region has been one of the areas with the largest gold production in Colombia.

Gold mining has been the support in this region, the economy, infrastructure and settlement since its foundation. This project aims to contribute to these aspects through its development in sustainable way.

#### 1.7.4 LEGAL CONSIDERATIONS

According to the current mining code, that is, Law 685 of 2001, in the following articles establishes the importance of mining, which is an activity of public utility or social interest, for Economic development, generation of jobs and royalties:

(...) Article 13. Public utility. In development of article 58 of the Political Constitution, it should be public utility and social interest the mining industry in all its branches and phases. So, they can be decreed in their favor, at the request of the interested party and by the procedures established in this Code, expropriations of ownership of immovable property and other rights constituted about them, that are necessary for its exercise and efficient development. The expropriation enshrined in this article, in no case shall proceed on the goods acquired, constructed or destined by the beneficiaries of a mining title, for exploration or exploitation or for the exercise of their corresponding servitudes.

*Article 186. Condemnable. Because mining is an activity of public utility and social interest, the expropriation of immovable property by nature or permanent adhesion and of the other rights constituted on them, which are indispensable for buildings and facilities of the infrastructure and assemblies of the mining project, for the realization of the extraction or capture of minerals in the exploitation period and for the exercise of corresponding servitudes. Exceptionally, expropriation will also proceed for the benefit of the exploratory works.*

*Article 194. Sustainability. The duty to properly manage renewable natural resources and integrity and enjoyment of the environment, is compatible and concurrent with the need to promote and rationally develop the use of mining resources as basic components of the national economy and social welfare. This principle should inspire the adoption and application of the norms, measures and decisions that regulate the interaction of the two fields of activity, equally defined by law as of public utility and social interest.*

*Article 339. Character of the mining information. Declare the public utility to be obtained, Organization and dissemination of information related to the richness of the subsoil, the offer and status of mining resources, and the mining industry in general. As a result, title concessionaires miners or mine owners, are required to collect and supply, at no cost, such information at the request of the mining authority. (...)*

#### 1.7.5 SOCIAL AND ENVIRONMENTAL CONSIDERATIONS

##### 1.7.5.1 BACKGROUND

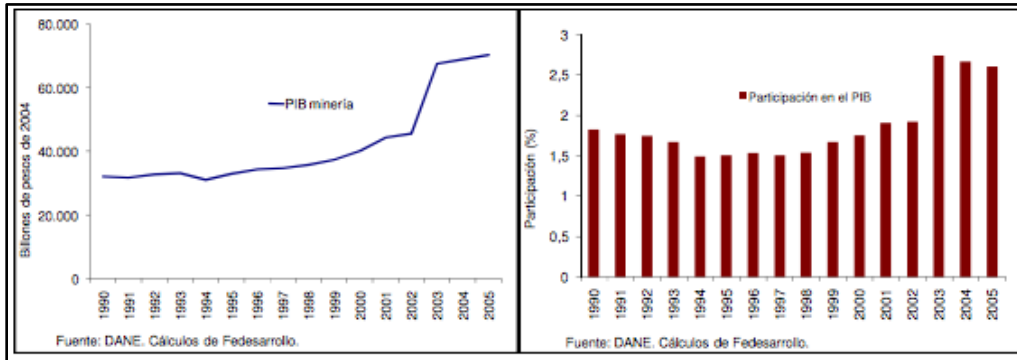
Mining generates jobs in remote areas for people with few opportunities, which is why it constitutes a motor of employment and economic activity of high benefit in some regions. Due to its linkages, mining production also generates indirect and induced effects in other sectors of the economy, which are by no means negligible and put once again in evidence the importance of the sector.

Although mining is an intensive activity in the use of physical capital and technology, the generation of highly remunerated employment by the sector, registered an increase of 120,000 jobs in Work in



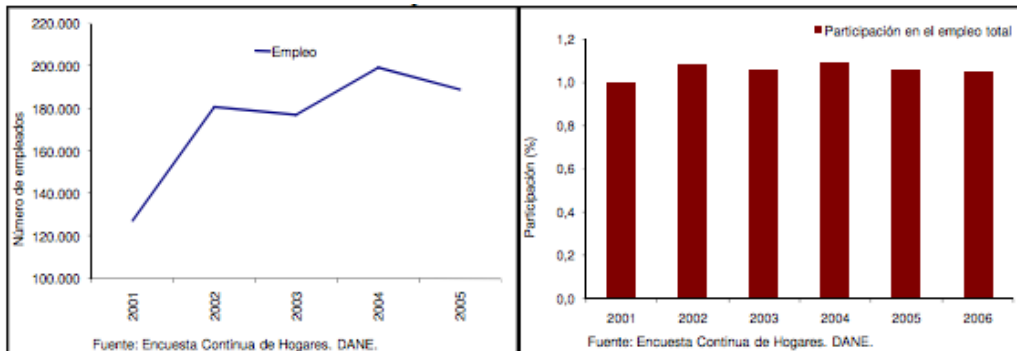
2001 to 180,000 in 2004 (ANDI, 2008). Mining exports amounted to 5,000 million dollars for the year 2006, which implies a contribution of 21% to exports totals.

As shown in Illustration 1-57, throughout the 1990s, mining production had a slow growth, which meant that the sector had a slight loss in its participation in the national GDP in some years of the middle of the decade. Improving notably since 2003, when the production value of the sector increased from 45.5 to 67.4 billion pesos constant in 2004.



**Illustration 1-57.** Billions of pesos in 2004 of mining and percentage of participation in GDP.  
*Source: DANE, Calculus Fedesarrollo.*

This notable increase in production meant that the contribution of the mining sector to GDP will pass from a level of less than 2%, registered for several years, to 2.8% in 2003. While employment mining industry increased by 50% between the first years of this decade in absolute terms, 120,000 to 180,000 jobs (Illustration 1-58).



**Illustration 1-58.** Employment of mining and percentage of total population participation.  
*Source: DANE, Calculus Fedesarrollo.*

Later in 2012, as shown in Table 1-45, the mining and oil sector it represented 7.7% of GDP and 1.2% of the number of employed persons of the national total.

**Table 1-45.** Participation in the GDP and the number of employed persons by branch of activity

Rama de actividad	Participación 2012 (%)	
	PIB	Ocupados
Establecimientos financieros	19,8	7,9
Servicios comunales, sociales y personales	15,1	19,1
Industria	12,0	12,8
Comercio, hoteles y restaurantes	11,9	26,7
<b>Minería y petróleo</b>	<b>7,7</b>	<b>1,2</b>
Transporte, almacenamiento y comunicaciones	7,4	8,3
Construcción	6,4	5,9
Agricultura y ganadería	6,2	17,4
Electricidad, gas y agua	3,6	0,5

Source: Fedesarrollo calculations based on the DANE (2010).

In particular, the number of jobs generated by the mining and hydrocarbon sector has increased in 37.7% during the last years, going from 175 thousand in 2005 to 24,118 thousand in the year 2012.

The mining sector is going through one of the most difficult moments of recent years, due to the lack of investment and technical support, the potential mineral deposits are unexplored and exploited under illegality in the absence of social and environmental responsibility, so much presents the following mainly environmental problems:

- Historically, there is an invasion of mining titles by illegal miners, due to which they do not have organizations and economic resources to transact and less to develop the technical activity, leaving social and environmental liabilities during its execution.
- The lack of promotion of productive linkages is the achievement of the lack of execution of projects that seek a better economic and technical use of the productive chain of gold.
- Small-scale miners do not have the technical and legal tools to perform legal and safe work. There has been an increase in the execution of unsustainable jobs that put risk their lives and the stability of their families. To the mining that welcomes the formalization and legalization, nor are they provided with the corresponding procedures.
- Illegal extraction generates poverty and violence; does not discriminate in using men, women, children, and adolescents as a workforce. Illegal extraction predates the environment and pollutes the waters. While technified and legal mining, offers job opportunities worthy, that improve the living conditions of families, reactivates the local economy, improves road infrastructure, contributes taxes and royalties to the state for investment project, and is responsible with the environment and the communities. To 2012, the legal extraction industry generated 30

billion pesos, which the national government has invested in social projects, transport and health (Fedesarrollo, 2012).

- In order to extract gold from the ore exploited by illegal mining, they are presented in the region multiple rural sites where they carry out grinding, cyanidation and mercury amalgamation, breaching the regulatory and prohibitive regulations, and in absence of social and environmental responsibility. Also, in the urban area of the municipality is presented notorious pollution of the water resource.
- According to the United Nations Industrial Development Organization (hereinafter UNIDO), this municipality has the highest mercury air pollution in the world, with 67,188 ng / m<sup>3</sup>. Together with the municipality of Remedios it has approximately ninety-six (96) liabilities by illegal alluvial and reef mining.
- The sale of precious metals, mainly operate in places where it is not fulfilled the purchase obligation and other contributions with the state. In addition, processes of heating amalgam (Mercury with gold), its national use is prohibited, contaminating the air and water, and attacking human health.

#### **1.7.5.2 SOCIAL AND ENVIRONMENTAL CONSIDERATIONS THAT SUPPORT THE IMPORTANCE OF THE DEVELOPMENT OF THE PROJECT "EL PESCADO", MINING CONCESSION 5969**

The social and environmental impacts of illegal mining over time have caused significant damages in the region and has also insufficiently exploited mineral reserves. Thus, this project aims to develop a technified mining, framed with sustainable development and interested in continuing to benefit the communities in their operation phase, by:

- Generation of approximately 110 direct and 220 indirect jobs (contractors, subcontractors and suppliers) during the construction and assembly stage.
- Generation of approximately 96 direct and 180 indirect jobs during the stage of extraction.
- Corporate hiring of local labor within AIs, for presenting greater roots territorial and social. Who can also participate in the development of social projects and productive alternatives to mining.
- Productive chains of alternative activities to mining, where communities of influence can provide goods and services to the mining project "El Pescado" in the mining concession 5969. Some of these may be direct sales of vegetables, eggs, meats, fruits and other foods for the restaurant and other marketing businesses, goods or services that the communities can offer to both TOUCHSTONE and the contractors, subcontractors and suppliers.

During the exploration phase, we have been working with neighboring communities, through the inclusion in contracting, the formulation of projects and some improvements in equipment community this will continue to be done in the operation stage. To date, between projects

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in the RAs and the LBS diagnosis for the STA, SDA and the EIA, have been invested more than \$ 500,000,000 in the social environment.

The "El Pescado" project in the mining concession 5969 will also allow investment environmental: through the compensation plan of 1% on the cost of the construction stage and mounting.