

## **Environmental impact assessment of hydroelectric project “Santuario 20” located in Sumapaz river basin.**

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*Abstract:-* The Hydroelectric Project Santuario 20 is located between the towns of Icononzo and Pandi, in the departments of Tolima and Cundinamarca respectively. The project consists to get water of the Sumapaz river, which will be transported through a tunnel driving on a stretch of about 6.4 Km, its returned back into the river at a point downstream. At the last section of tunnel it will install the pressure line and then roundhouse, where power generation infrastructure will be available. Since 2008, the company EMGESA SA E.S.P. has applied to the Ministry of Environment, Housing and Territorial Development initiate the administrative procedure of environmental permit since the magnitude of the project is large scale; for this, the company EMGESA has made the past year socialization of the project to the community. However in the population and the mayors of these municipalities, is not clear the environmental involvement and the real benefits that this work will bring to people living in these municipalities, considering that the energy produced in the hydraulic unit will not be used in this region, this energy will be exported. In order to issue, a technical concept from the environmental point of view without conflict of interest is necessary, in this research was done the Environmental Impact Assessment of the area of influence of the project. We were used qualitative tools such as surveys and quantitative tools such as the matrix index of environmental significance, in which it was observed that affected components in the construction, commissioning and maintenance of the project and with very high environmental importance were: wildlife, hydrology and socio-economic component.

*KeyWords:* - Impact, Assessment, Hydroelectric energy, prevention, mitigation

### **1 Introduction**

Currently and since 2008, the company EMGESA SA E.S.P. has applied to the Ministry of Environment, Housing and Territorial Development initiate the administrative procedure for environmental license for the integrated mini power plants in the basin of the river Sumapaz. The project initially consisted of 14 mini power plants with reservoirs in the town of Cabrera, however, from a rethinking in technical studies, it was decided that three chains will give power generation (8 mini

power) without dam. At 2008 the company HVM Ingenieros Ltda; requested that Ministry, the definition of competition to begin the process of environmental license under Article 11 of Decree 1220 of 2005. At 2010, EMGESA SA ESP, performed the socio-environmental analysis of different mechanisms for project development and socio-environmental feasibility analysis, decides to develop the project into two phases; developing feasibility studies and environmental impact studies, is expected

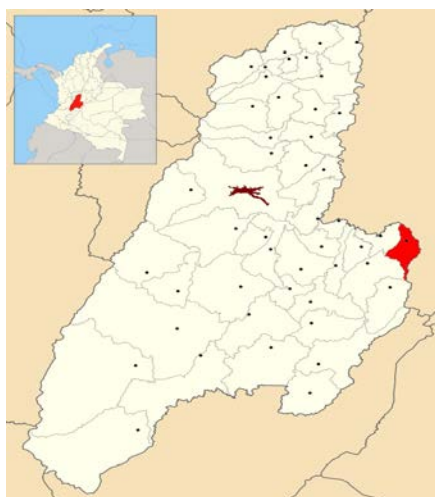
that the project begin construction in 2016 and commercial operation until 2019.

## 2. Project Description

### 2.1 Geographical Location of Project

The project is located to the southwest of the department of Cundinamarca, in the jurisdiction of the towns of Pandi and Icononzo, in the villages of El Meson, Sanctuary and Chaparro (Icononzo) about 90 km from the city of Bogotá. The project is located in the basin of the same name, natural border between the towns of Pandi and Icononzo in the departments of Cundinamarca and Tolima, respectively.

Figure 1. Location of project



### 2.2 Technique Description of Project

To implement the project, some existing roads in the municipality of Icononzo be used and will be held the adequacy of some sections to enter different project sites such as: the uptake site, gateway to the tunnel exit portal tunnel valve chamber and powerhouse. According to information provided by EMGESA SA E.S.P. [1] in Santuario 20 Hydropower project referred to the Ministry of Environment, Housing and Territorial Development, required for the project in each jurisdiction infrastructure can be summarized as follows:

Table 1: Infrastructure required for the development of the Project.

ACTIVITY	INFRASTRUCTURE	
	Tolima Department CORTOLIMA	Cundinamarca Department CAR
Catchment	Weir of catchment	Weir of catchment
	Sediment trap	...
	Sand trap	...
Water pipe	Tunnel of pipe	...
	Pressure pipe	....
	House Valves	....
Generation and distribution	Round House	....
	Electric Substation	....
	Transmisión lines	....
Ways of accesse	Way leading to the capture site and tunnel input portal	....
	Way to reach the powerhouse and construction of a bridge over the ravine La Laja.	....

Branching will be made from the construction of a weir specifically about 5 m high and 30 m long on the riverbed, which will on the left side (municipality of Icononzo). The harvesting will be on the left side of the dam, of rectangular openings, made to derive the flow to the conduction system, then will be found a sediment trap. The tunnel will be on the left bank of the river (jurisdiction of Icononzo) will be excavated from the rock, shielded, with steel supports, anchor bolts and concrete, will have an effective diameter of 3 m, a slope of 2 % and an approximate length of 4700 m, with an

alignment parallel to the Sumapaz. At the last 100 m of the tunnel exit will be there a concrete plug.

The powerhouse of the project will be superficial conventional and will be located on the left bank of Sumapaz River in the municipality of Icononzo, about 80 m upstream of the confluence of the creek the Laja with the Sumapaz river. The powerhouse will have two generating units horizontal axis, equipped with Francis type turbines, which are connected to the synchronous type generators with an installed capacity of 20 MW. According Viejo, [2] the Francis turbines are used for medium loads (about 30-400 meters), although also used to lower expenses, depending on the load can choose between several types of impellersie, slow, normal, based on denomination specific speed and not on the angular velocity.

The substation will be built in the vicinity of the powerhouse, the substation yard will have two transformers and switchgear required for connection to the network 115 kV to 12.5 MVA, 13.8 / 115 kV. It has been considered that the plant will connect to the existing system by building a line of 115 kV and 44 Km, until the substation to Fusagasugá.

### 2.3 Environmental characterization of the area of influence

The area of influence of the project is located in a premontano wet forest characterized by the following limits: Thermal Floor, Temperate Precipitation: 1200 mm, annual average temperature: 20 to 24° C and Altitude: 900 m. The hydrology of the region depends primarily on the Sumapaz River. This river originates in the Eastern Cordillera in the moor of Sumapaz at the height of 3800 meters and is part of the basin of the Magdalena River.

This basin has an area of approximately 1741.5 square kilometers, a length of the

main channel of 57 Km, serving as a boundary between the departments of Tolima and Cundinamarca, in this area the rainfall is bimodal character with a first Figure 2. Photography Sumapaz river and Area of influence



rainy season between March to May and the other from September to November. The driest period is from December to February, at southeastern and northern Sumapaz river basin , rainfall is between 900-1200 mm per year.

Morover average temperatures ranging between 22 and 24 °C are recorded; in the municipality of Pandi average temperature is 24 °C and the municipality of Icononzo 21°C in general the relative humidity is above 65%.

The relief genetic units located in the basin are the alluvial piedmont and structural mountainous, folding basin landforms show that it is a territory consisting of slopes that have a strong susceptibility of erosion for the runoff and surface waters.

### 3. Environmental Impact Assessment

Based on International Commission on Large Dams (ICOLD) and the World Bank [3], ten categories of environmental impacts have been established. These are the impacts on the natural environment (flora, fauna, and aquatic fauna), social/economic/cultural aspects (resettlement), land, dam construction activities, sedimentation of reservoirs, downstream hydrology, water quality, tidal barrages, climate, human health. The Environmental impacts predicted in the Area of Influence are the following:

Table 2. The expected relate Environmental Impacts during project

Environmental Component	Environemntal Impact
Geology	-Erosive processes. -Removal of rocks. -Changing the landscape. -Soil removal. -Altered soil properties.
Hidrology	-Sediment to the channel. -Alterations physicochemical water quality. -Flow reduction. -Allocation Pattern groundwater tunnel construction catchment. -Modification of aquatic ecosystems.
Air Quality	-Particle emissions. -Noise emission.
Flora	-Loss of vegetation cover.
Wildlife	-Alteration of habitats.

Socioeconomic	-Demand for labor. Increased demand for goods and services. -Involvement of local and regional mobility.
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#### 3.1 Methodology of Environmental Impact Assessment

The environmental Impact Assessments (EIA) has been designed with the objective of planning and establishing policies to follow, optimizing the use of natural resources, reducing social, economic and regional dysfunctions in order to achieve a balanced development project. According to Canter [4], socioeconomic factors more used in the environmental impact assessment are: the demographic aspects (infraestructure, movility), economic aspects and employment (solid uses, costs and taxes), social aspects and public services (home, health, educacion and tranSPORT). There is a need to incorporate the environmental dimension from governance, which is why territorial policies must be associated or coordinated with sectoral policies. Identifying classes of facilities with environmental advantages or disadvantages, according to Gleick [5] will permit development decisions to be made with far more environmental sensitivity than has been shown to date.

In the case of the Hydroelectric Project Santuario 20 the methodology to be implemented is based on a matrix of Environmental Impact Assessment that will achieve the identification of environmental impacts generated by the different stages of the project. It is based on the identification made in the inspection visits to municipalities and managed information obtained through research. Were used the following rating criteria:

### 3.1.1 Qualitative rating

The qualitative classification is performed using as only criterion the theoretical nature of the impact, which is defined as the change produced by an action of the project on the environment, can be positive when the impact produces a beneficial or negative effect when the impact produces an effect detrimental to the component analyzed. Regarding the Santuario 20 hydroelectric project, the researchers decided to study the perceptions of the inhabitants of the municipalities in the area of influence of the project through the implementation of a survey. The sample population was defined based on the last census conducted by DANE (National Statistics department), with this data were calculated the population by 2013 and the parameters of the group of people who were able to answer were defined. The sample was 183 residents between the towns of Pandi and Icononzo.

### 3.1.2 Quantitative Rating

The quantitative rating of impacts, called Environmental Importance Index (IIA), is obtained by decomposing the theoretical impact on their characteristic factors: Probability, Severity, Coverage Degree of recovery, Duration and Development, this elements are integrated to determine the impact rating. Quantification was performed in order to transform a subjective opinion, based on environmental characterization, in a number allowing interrelating factors and obtain a relative measure of the severity of impact considered.





It is the result obtained by integrating factors by applying the following formula taken from Canter [4]:

$$I.I.A = Pr * [(Co * Gr)*0,6 + (Rec)*0,2 + Du*0,1 + De*0,1] \quad (1)$$

In an excellent review of Perdicou´ lis, he gives great importance to Establishing

causality across the hierarchy of impacts can also reduce uncertainty by providing linkages between impacts and their significance [6]. The score can range from 10 to 100, and in accordance with this result the impact is classified according to the following table:

Table 3 Environmental Criteria Importance

Very High	80-100	
High	60-79	
Medium	40-59	
Down	< 40	

## 4. Results

### 4.1 Social Component

Social research is an important part of this research because the communities of the two municipalities are those who receive the benefits and drawbacks of the project. The treatment of the social dimension usually ends minimized or absent, its participation in the environmental analysis as mentions Partridge [7], results in the failure of several projects that have strong environmental impact on the social components. A survey was used to collect the perception of the public about the project, then was analyzed the results among those that stand out : The 45% of respondents are in the range of 15 to 20 years, 11% are in an age range from 21 to 30 years, 10% are in an age range of 31 to 40 years, and 12% are in an age range of 41 to 50 years. The 55% of respondents indicated no prior knowledge of the possible construction of a hydroelectric project within their municipalities while the remaining 45% said if they have knowledge of it. The 49% of respondents say they disagree with the construction of the hydroelectric project Santuario 20 in the towns of Pandi (Cundinamarca) and Icononzo (Tolima), while 51% of

respondents say they agree with and support the construction of same.

As to the possible negative impacts that can be generated as a result of the construction of the hydroelectric project, 46% indicated that these impacts will be reflected in the environmental, 21% in social, 20% on economic issues and 13% remaining indicates that the project will not bring negative impacts on municipalities under study. About possible Positive impacts that can be generated by the construction of the hydroelectric project, 49% indicated that these impacts will be reflected in economics, 26% in social, 19% on environmental issues and 6% remaining indicates that the project will bring positive impacts on municipalities under study.

If the Sanctuary 20 hydroelectric project will be build, 84% of respondents would not agree that this project will make by a foreign company, the remaining 16% indicated they would prefer it to be developed by foreigners, because they trust on their delivery times, quality of work and experience in similar projects. The 89% of respondents believe that implementation of the project will bring employment and business to the region, while the remaining 11% indicate they will not see these benefits or at least not the inhabitants of the municipalities under study. The 73% of respondents consider that if the hydroelectric project is carry out, it could generate strong negative impacts to the environment, especially in the components associated with the hydrology and geology of the area of influence.

Of the total respondents, 34% believe that their standard of living will improved with the construction of the hydroelectric project, 37% indicated that see no change in their quality of life and the remaining 29% indicated that their living standards will down by building it.

## 4.2 Environmental Component

Was used the environmental Importance Index matrix for the analysis of environmental component , was analyzed that the components that will be affected according to their importance (Very High, High and Medium) are:

### 4.2.1 Very High Environmental Significance

- Fauna: Alteration of habitats and species loss Fauna
- Hydrology: Modification of aquatic ecosystems and Flow Reduction
- Socioeconomic: Demand for labor, increased demand for goods and services and involvement of local and regional mobility.

### 4.2.2 High Environmental Importance

- Geology: erosive processes, rock removal, modification of the landscape, soil removal and alteration of soil properties.
- Hydrology: Contribution to the riverbed sediments, physicochemical alterations affecting water quality and groundwater pattern through the tunnel catchment.
- Air Quality: Emission of particulate material, PM 10 – PM 2.5.
- Flora: loss of plant cover and species loss Flora

### 4.2.3 Medium Environmental importance

- Air Quality: Noise Emission

The performance of EIAs around the world is continually improving and the increasing use of the EIA process has placed more emphasis on improving the identification of potential impacts. Whereas McAllister says, hydroelectric project might be described as ‘‘threatening’’ should an EIA not be conducted, prepared too quickly, or offer no mitigation options [8].

## Conclusions

Upon completion of this investigation and in order to issue a technical concept from the environmental point of view, was realized the environmental impact evaluation of the hydroelectric project Santuario 20; so the research team can issue the following conclusions:

After analyzing the technical component of the project and taking into account the headworks, driving, construction of the powerhouse and substation and transmission lines, without neglecting the paths, it can be concluded that the social and environmental variables that may be affected by the implementation of hydropower project are mainly associated with the following components:

**Geology:** this environmental component can be affected by erosion due to the removal of rock and soil, this will be necessary for the construction of the tunnel driving, which can result in the modification of the landscape, altering the properties and use of soil.

**Hydrology:** during construction and operation of the project will can generate sediment to the river, physicochemical changes of water quality, reduced flow, pattern affected groundwater by the construction and maintenance of the tunnel uptake, that can generate changes in aquatic ecosystems.

**Air Quality:** In the construction phase of the project can alter air quality due to the emission of particulate matter and noise generation.

**Flora and Wildlife:** Due to the modification of the landscape and land use change can present scenarios where vegetation cover is lost, which immediately generate a significant

alteration of habitats, so that their study should be taken into account.

**Socioeconomic:** There is a high possibility that the socio-economic component will have a positive impact, given that the construction of the hydroelectric project will generate demand for local, national and even international work, as well as increased demand for goods and services at the economic community.

Finally, the researcher believes that Municipal Administrations head Mayors and Councillors of Municipalities of Pandi and Icononzo should have clear that the use of water and land are interrelated. It is likely that decisions on the use of water in one part of the watershed, present opportunities and constraints for users elsewhere. These circumstances constitute an argument in favor of integrated planning watershed, to ensure that water in the basin is not too compromised and the project growth keep up an equilibrium in the water resources of the region.

There are tools and expertise needed to achieve such planning and management; the difficulties generally are institutional, water resources do not respect political boundaries, so that an institution with sufficient capacity to influence decisions about land use and water in the two jurisdictions is necessary. As Desiree [9] says, the EIA process can potentially go a step further by playing a fundamental role in the design process as well as advancing the science and improving interdisciplinary communication of large hydroelectric project impacts.

## Recomendations

After analyzing the results of this research, the researcher suggests to Municipal Administrations of Pandi and Icononzo head of Mayors and Councillors, consider

the following recommendations associated Hydroelectric Project Sanctuary 20.

If it is true, the energy industry is one of the most important drivers of the economy, the hydroelectric issue in Colombia give work opportunities for economic development, wealth creation and employment, however the past experiences in other Hydroelectric projects has revealed serious problems in the territories and population where they have established. The rapid development requirements of the region caused radical changes economically, socially, and environmentally. Also the strong desire for development in the region resulted unplanned and uncontrolled use of the project outputs according to Karadeniz [10].

In the execution of the works of construction and the commissioning of the plant, appear different impacts on watersheds: the deterioration of water quality, sedimentation increases with nutrient accumulation that encourage algal blooms sometimes toxic, serious effects on flora and fauna due to the requirement of a source of fresh water flowing unobstructed to breed and spawn; for example the fishes that live in the Sumapaz river and loss of ecosystems with high biodiversity. As Carvalho says [11], when it comes to determining a river's vocation for generating electricity, basic environmental constraints should be properly examined.

Consequently, each and every one of these impacts on ecosystems result in social, economic, and cultural impacts on the health of the communities around which hydropower projects are implemented. The loss of water quality causes serious health problems, food sovereignty is threatened by the alteration of reproduction and migration of species, as well as damage to agricultural crops by variations in microclimate and natural cycles rivers.

More serious is the often forced displacement that are subjected entire populations being seriously violated their human rights, particularly the right to freedom of movement, property, housing and consultation to develop projects of direct affectation.

In this scenario the Shrine 20 hydroelectric project no slouch because as this research shows there are many social and environmental components that will be affected by the construction, commissioning and maintenance of the project. It is extremely important that the Municipal Administrations of Pandi and Icononzo Mayors and Councillors demand to the consultant and the company that aims to develop the project, inform the community that will be affected on the progress of the project. This is important due that the 55% of respondents don't has knowledge of project progress, how will build the project, changes in land use, the deviation of Rio Sumapaz, the construction of tunneling , how it will be handled the demand for drinking water in times of drought and other relevant topics, they should do action plans with the community to address duly these situations when they arise. According to Diducka [12], this could be seen in other parts of the world, results of EIA confirmed a lack of meaningful opportunities for participation in the planning and assessment of these projects, and revealed a similar shortcoming with respect to mitigation.

Finally, the investigators consider that Municipal Administrations request to the competent environmental authorities in each Department and the Regional Autonomous Corporations corresponding, the hiring a team of professionals associated with the nature of the project for the purpose of exercising one auditing at the stages of planning, construction and maintenance. The principal job will be



exercise functions of inspection, supervision and control over the progress of the project and the impacts generated in the catchment area and the implementation of preventive measures and remedial action to ensure the conservation of the environment and the populations in the catchment area.

#### References:

- [1] Emgesa S.A. E.S.P., *Desarrollo Hidroeléctrico Santuario 20-Río Sumapaz*, Emgesa publicaciones: Bogotá, 2008.
- [2] Viejo zubicaray Manuel, Editorial Limusa, *Energías Eléctricas y Renovables, turbinas y plantas generadoras*: Mexico D.F, pp. 76-93, 2001.
- [3] World Commission on Dams, *Dams, Ecosystem Functions and Environmental Restoration. Thematic Review Environmental Issues*. WCD publications: Berkeley, 2000.
- [4] Canter I, Mc Graw-Hill, *Manual de Evaluación de Impacto Ambiental. Técnicas para la elaboración de los estudios de impacto*: Madrid. pp.56-62, 1998.
- [5] Gleick Peter H., Environmental consequences of hydroelectric development: the role of facility size and type. *Energy*, 17(8), pp. 735-747, 1991.
- [6] Perdicou 'lis, A, Hanusch, M., Kasperidus, H., Weiland, U., The handling of causality in SEA guidance. *Environmental Impact Assessment Review* 27, pp. 176–187, 2007.
- [7] Partridge, W, LATEN Banco Mundial, *Participación Popular en la Evaluación Ambiental en América Latina*. Nota de Divulgación n° 11 Department of environmental: United States, pp. 34-45, 1994.
- [8] McAllister, D., Craig, J., Davidson, N., Delany, S., Seddon, M., World Commission on Dams, *Biodiversity impacts of large dams*: Berkeley, pp. 35-47, 2000.
- [9] Desiree Tullos, Assessing the influence of environmental impact assessments on science and policy, An analysis of the Three Gorges Project: *Journal of Environmental Management* 90, pp. 208–223, 2009.
- [10] Karadeniz Mehmet Berkun, Hydroelectric potential and environmental effects of multidam hydropower projects. *Energy for Sustainable Development*, 14, pp. 320–329, 2010.
- [11] Carvalho Osmar Abilio, Waleska Valenca Manyaria, Environmental considerations in energy planning for the Amazon region, Downstream effects of dams, *Energy Policy*, 35, pp. 2007.
- [12] Diducka Alan Paul, Perceptions of impacts, public participation, and learning in the planning, assessment and mitigation of two hydroelectric projects in Uttarakhand, *Land Use Policy*, 33, pp. 170–182, 2013.