E842
Volume 1

# Amoyá River Hydroelectric Project

## Synthesis of Environmental Studies

for

**Generadora Unión S. A.**

by

**Luis Carlos García Lozano**

**Medellín, Colombia**

**June 29, 2003**

## Acronyms and abbreviations

| | |
|---|---|
| ARESP | Amoya River Environmental Services Project |
| ARHEP | Amoya River Hydroelectric Project |
| ARPP | Amoya River Power Plant |
| CDM | Clean Development Mechanism of the Kioto Protocol for greenhouse gases emission reduction |
| CERC | Carbon Emission Reduction Certificate |
| CI | Conservation International |
| CORTOLIMA | Tolima region environmental authority |
| EEPPM | City of Medellin owned Electrical Power Works |
| EIS | Environmental Impact Study |
| EMP | Environmental Management Plan |
| GHEG | CO2, CO and other green house effect gases |
| GUSA | Generadadora Union S. A. |
| ICAN | Colombian National Anthropological Institute |
| IGAC | Colombian National Geographic Institute *Agustín Codazzi* |
| ISAGEN | Colombian government owned electrical power generation corporation |
| LCSES | Latin America and the Caribbean Region Environmentally & Socially Sustainable Development |
| MoE | Ministry of Environment of Colombia |
| NNP | Natural National Park |
| PFC | Prototype Carbon Fund |
| QAT | Quality Assurance Team (from LCSES) |
| UPN | Colombian national parks administrative unit |
| WB | World Bank |

# 1 Introduction

The present document synthesises the main environmental issues related to the Amoya Hydroelectric Project, which is the main component of the Amoya River Environmental Services Project. This synthesis is based upon a long, in-depth environmental analysis carried out by Sedic in 1999 and presented as Amoya's EIS for approval to CORTOLIMA, the regional environmental authority of Tolima Province where the project is located.

A number of themes were subjected to a review and further analysis during this first half of the current year, upon request from the LCSES-QAT; précis of those points considered relevant for the present synthesis were integrated to main document where appropriate[1]. The complete analysis of the issues raised by LCSES-QAT is included as an appendix.

The synthesis is organised in the traditional form of an EIS and follows closely the original documents[2]:

- project description, centred around the environmentally meaningful aspects
- physical, ecological and social characteristics of the areas likely to be related to the project construction and operation
- main effects of the project's activities and processes on the regional and local environment and peoples
- recommendations for an environmental management plan.

There are no major discrepancies between the analysis of the different issues EIS carried out by Sedic and those done afterwards, including the QAT analysis, although it ought to be pointed out that the hydrology of the Amoya river has been particularly studied more in depth since then (Restrepo, 1998; Saldarriaga, 2002; and Deeb, 2003). The gain in precision has not affected though the general considerations regarding the environmental implications of the project. Some minor points in these regards are indicated in the document.

This synthesis and complementation was carried out by ecologist Luis Carlos García Lozano. Several people were helpful in many ways, but bear no responsibility in the results nor are they to be held responsible for the lateness of this report: Civil engineer David Puerta Zuluaga prepared earlier drafts of the project synthesis and of the hydrological aspects. Agricultural economist Iván Darío Pineda Londoño prepared a synthesis of social and economical aspects. Cartography from Autocad files to MapGrafix, a GIS for MAC OS, was prepared by geologist Pedro de Greiff Gautier. Biologist Adriana Morales Mira helped with literature searches and summaries. All contributions were useful but not all materials were used for the final version and those taken, were freely edited.

1 QAT concerns regarding the ARHEP are of an environmental nature and are related to particular aspects of the natural or cultural setting of Amoyá river project, therefore, it was considered more appropriate to articulate those concerns to the particular topic in the synthesis, including an outline to the recommendations for mitigation.

2 Sedic's EIS for the Amoyá hydroelectric project were presented in two volumes, the first one deals with the environmental evaluation per se and the second presents the environmental management plan.

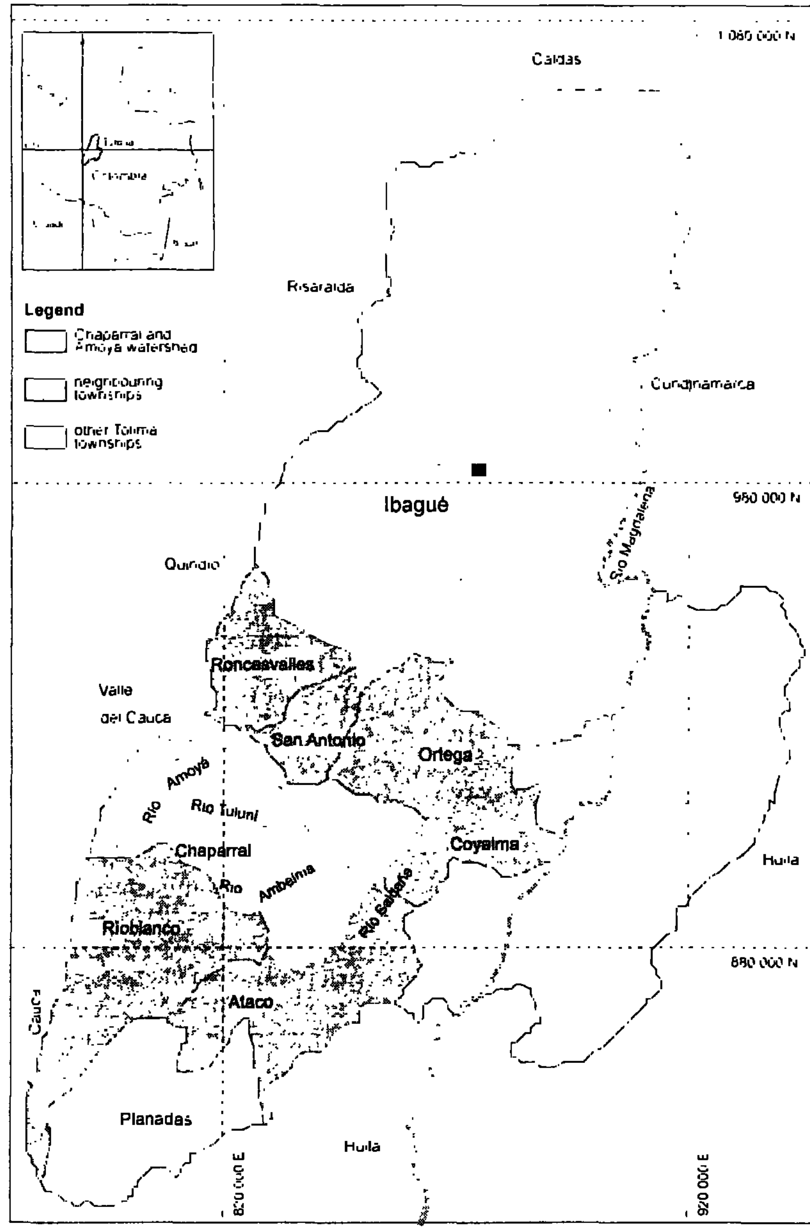
# 2 The hydroelectric project

## 2.1 Development objective

The development objective of the Amoya River Environmental Services Project is to contribute to the reduction of greenhouse gas emissions from the electrical energy sector in Colombia through the promotion of 80 MW run-of-river generation facility. The project is expected to displace on the average 0,39 million metric tons of carbon dioxide equivalent (mt$CO_2$e) per year for a total of 7,87 mt$CO_2$e until year 2025. The project will also support an environmental programme for the protection of Paramo Las Hermosas, a unique, high-mountain biotope, upstream from the hydroelectric facility, and a key component for the water regulation of the watershed, and a social program that will contribute to improve the welfare of the local rural community in the municipality of Chaparral.

The basic component is a small, run-of-river hydroelectric generating facility to be constructed on the Amoya River, with a nominal power capacity of 80 MW to generate around 568 GWh/year. ARHEP is located in the middle stretch of the Amoya River (between 1.460 m elevation at the intake, and 930 m at discharge), in Chaparral, a small city in Tolima province, South Central Colombia, 141 km to the south of Ibague, the provincial capital. (Map 1).

AREHP construction, to be initiated in December, 2003 ought to conclude 28 months later in April 2006. The overall investments would total some $97 million. This figure does not include the costs of construction of the 18 km transmission power line (ca. $7 million), neither the conservation nor the social development components of ARESP.[3]



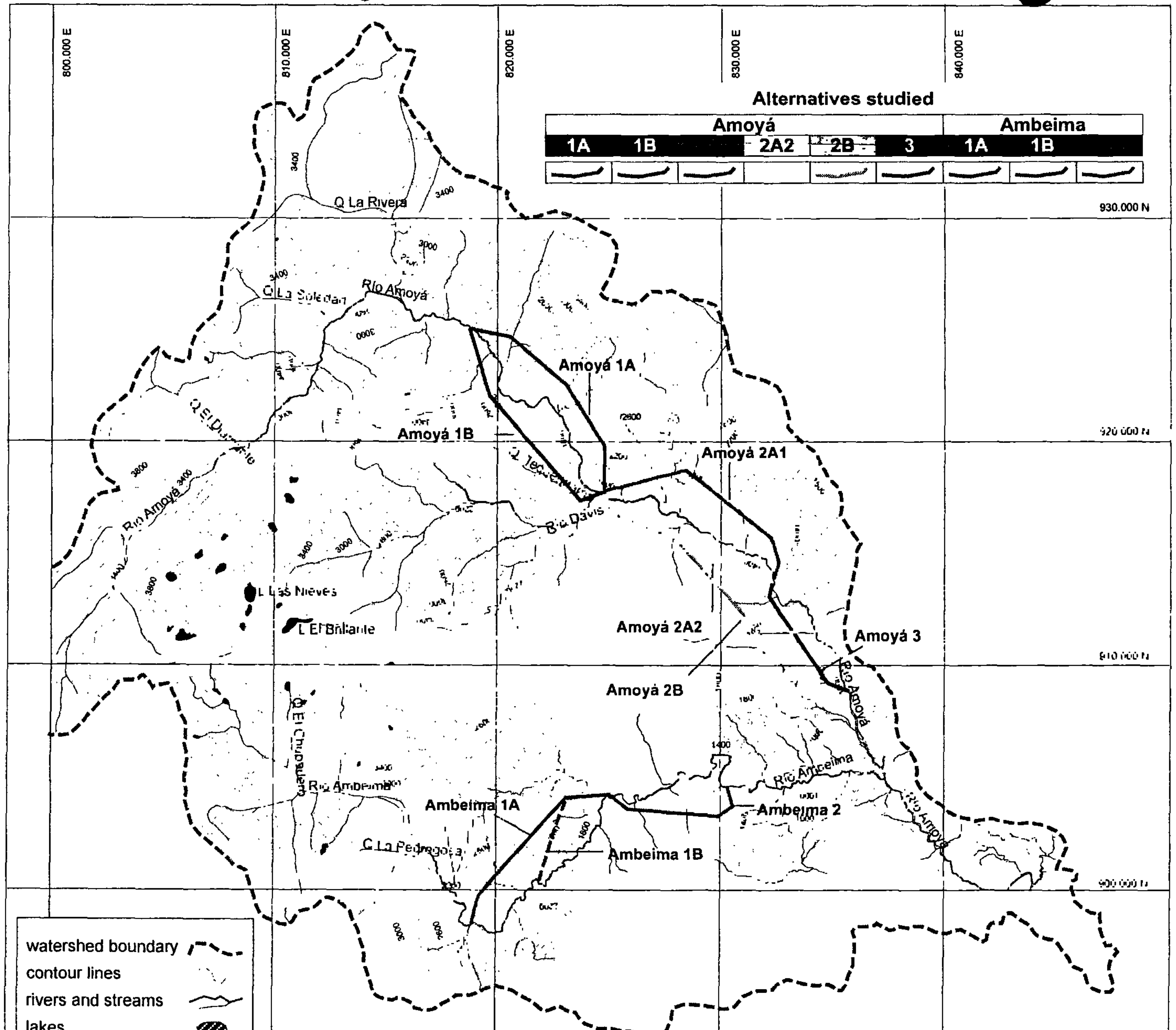

Map 1. Location of ARHEP region: Chaparral and Amoyá river watershed in Tolima province

## 2.2 The hydroelectric project component

The definition of the technical, financial and environmental feasibility, is the result of a series of studies carried out by five different consulting firms between 1994[4] and 1999. Table 1 synthesises the characteristics, the selection criteria -technical, economic and environmental- for the 9 alternatives analysed during the feasibility phase, and their final ranking, in order of eligibility. Map 2 shows their location in the watershed.

[3] The general data for the project hydroelectric as well as conservation and social components might differ slightly from those reported in other documents. This discrepancy obeys to the permanent refining of two basic parameters: mean water flow of Amoya River, which defines annual energy production and $CO_2$ reduction capacity and the dollar value per metric ton of reduced $CO_2$.

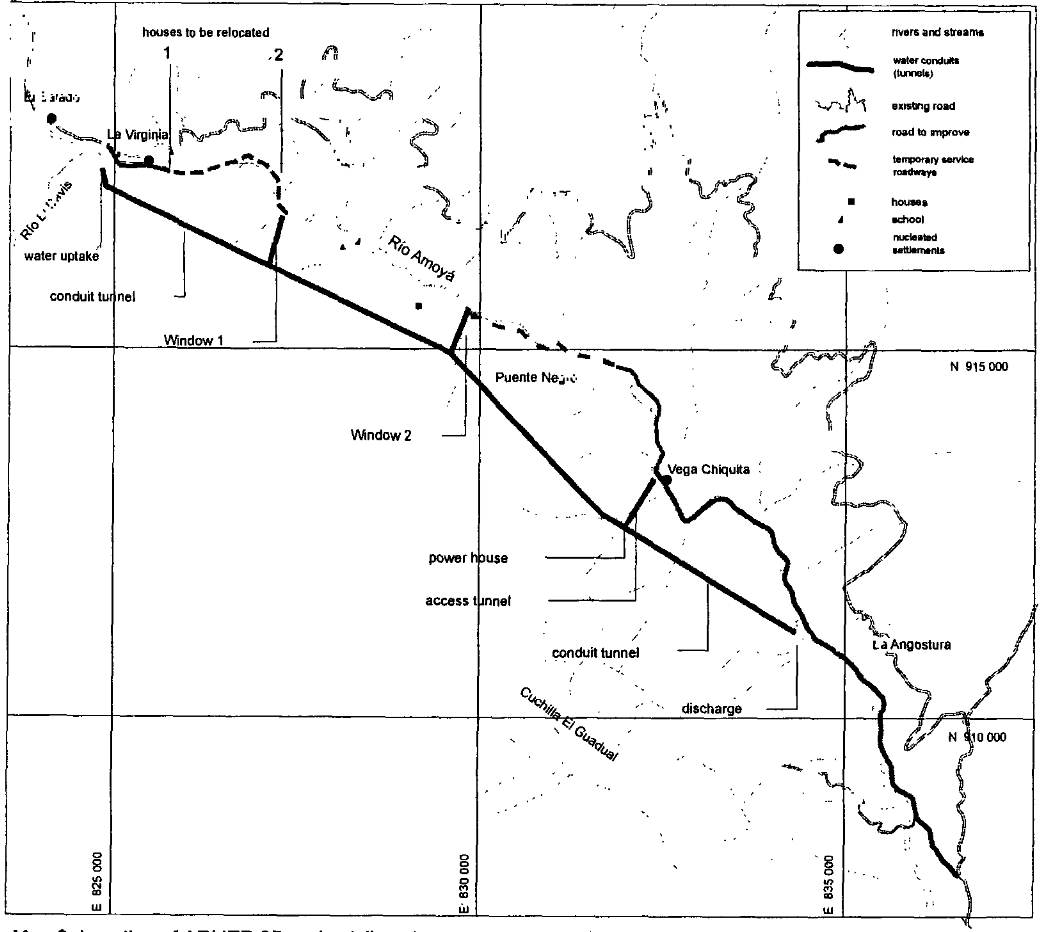
[4] The identification of the hydroelectric potential of the Amoyá river was derived from a roadway study in a trans-cordillera corridor, in-charged by the Ministry of Transportation in 1994. Hydroelectric an other particular studies began in 1997.




Map 2. Alternatives of hydroelectric development in Amoyá watershed, considered in the feasibility study. Characteristics are presented in table 1. Modified from INGETEC, 1998

Table 1. Comparison of alternatives of hydroelectric development in Amoya and Ambeima Rivers (Taken form INGETEC, 1998)

| parameter | unit | Amoya | | | | | | Ambeima | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1A | 1B | 2A1 | 2A2 | 2B | 3 | 1A | 1B | 2 |
| **I Technical Considerations** | | | | | | | | | | |
| River bank | | left | right | left | right | right | right | left | left | right |
| Water uptake altitude | m asl | 2.000 | 1.950 | 1.460 | 1.460 | 1.460 | 1.030 | 2.010 | 1.800 | 1.480 |
| Discharge altitude | m asl | 1.460 | 1.460 | 1.030 | 1.030 | 930 | 850 | 1.500 | 1.500 | 970 |
| Net hydraulic jump | m | 523 | 474 | 412 | 414 | 508 | 169 | 506 | 296 | 499 |
| Upstream watershed area | $km^2$ | 309 | 318 | 518 | 518 | 518 | 623 | 123 | 146 | 229 |
| Mean flow | $m^3/s$ | 11 | 14 | 17 | 17 | 17 | 20 | 5 | 7 | 10 |
| Nominal power | MW | 51,8 | 57,4 | 61,6 | 62,0 | 76,0 | 29,8 | 22,0 | 17,8 | 45,1 |
| water conduits (total) | m | 9.817 | 11.582 | 10.375 | 9.032 | 12.473 | 6.148 | 9.070 | 5.640 | 7.014 |
| Geology | | | | | | | | | | |
| very good | % | 40 | 80 | - | - | - | - | - | - | - |
| good | % | 60 | 20 | 100 | 100 | 98 | 20 | 100 | 100 | 90 |
| fair | % | - | - | - | - | 2 | 80 | - | - | 10 |
| Underground power house | | | | | | | | | | |
| access tunnel | m | 800 | 750 | 500 | 600 | 700 | 350 | 1.300 | 1.300 | 800 |
| turbines | # | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| (v = vertical; h = horizontal) | type | Pelton v | Pelton v | Pelton v | Pelton v | Pelton v | Pelton v | Pelton v | Francis h | Pelton v |
| Main road accesses | | | | | | | | | | |
| improvement of existing roads | km | 5,2 | 5,2 | 5,2 | 5,2 | 5,2 | 8,1 | 4,7 | 4,7 | 4,7 |
| new service roads | km | 8,5 | 12,1 | 4,4 | 5,3 | 5,6 | 2,2 | 10,2 | 3,2 | 5,2 |
| **II Economic and Environmental Considerations** | | | | | | | | | | |
| Works costs | | | | | | | | | | |
| water uptake and water conduits | MUS$ | 2,70 | 9,70 | 2,65 | 2,65 | 2,65 | 2,90 | 1,25 | 1,45 | 1,85 |
| tunnels (load and discharge) | MUS$ | 24,24 | 22,64 | 30,46 | 26,23 | 37,31 | 21,81 | 22,37 | 13,79 | 17,13 |
| load well and construction window | MUS$ | 1,87 | 1,68 | 1,37 | 1,74 | 2,09 | 1,28 | 1,46 | 1,32 | 1,98 |
| underground power house | MUS$ | 4,52 | 4,38 | 4,03 | 4,30 | 4,73 | 2,21 | 5,41 | 4,94 | 4,05 |
| equipment and distributor | MUS$ | 15,78 | 16,37 | 17,64 | 17,79 | 20,72 | 9,85 | 8,78 | 6,91 | 13,45 |
| access roads | MUS$ | 4,44 | 5,88 | 2,80 | 3,16 | 3,28 | 2,50 | 5,02 | 2,22 | 3,02 |
| unforeseen costs (35%) | MUS$ | 18,74 | 21,23 | 20,63 | 19,55 | 24,77 | 14,19 | 15,50 | 10,72 | 14,51 |
| **Total Investment** | MUS$ | **72,29** | **81,88** | **79,58** | **75,42** | **95,55** | **54.74** | **59,79** | **41,35** | **55.99** |
| **Unit Cost (cost index = CI)** | US$/kW | 1 396 | 1 426 | 1.292 | 1.217 | 1.257 | 1.837 | 2.718 | 2.323 | 1.241 |
| length of new roads | km | 8,5 | 12,1 | 4,4 | 5,3 | 5,6 | 2,2 | 1,02 | 3,2 | 5,2 |
| distance to Hermosas National Park | km | 2 | 2 | 7 | 7 | 7 | 12 | 0,5 | 4 | 11 |
| magnitude of environmental impact | max. 100 | 73 | 79 | 61 | 61 | 66 | 33 | 100 | 50 | 43 |
| Uncertainties and risks | | | | | | | | | | |
| topography | | low | low | low | low | low | low | low | low | medium |
| hydrology | | high | high | medium | medium | medium | medium | high | high | medium |
| geology | | low | low | low | low | low | high | low | low | medium |
| impact and environmental feasibility | | medium | medium | low | low | low | low | high | medium | low |
| **III Multiple Criteria Ranking of Alternatives** | | | | | | | | | | |
| According to CI | | 5 | 6 | 4 | 1 | 3 | 7 | 9 | 8 | 2 |
| According to resource utilisation | | 5 | 4 | 3 | 2 | 1 | 7 | 8 | 9 | 6 |
| According to risks and uncertainties | | 5 | 5 | 1 | 1 | 1 | 5 | 9 | 5 | 4 |
| Multiple criteria ranking | | 5 | 5 | 3 | 1 | 2 | 7 | 9 | 8 | 4 |
| **Alternative / Final order of eligibility** | | 1A / V | 1b / VI | [illegible] | 2A2 / II | 2b / I[illegible] | 3 / VII | 1A / IX | 1B / VIII | [illegible] |




Map 3. Location of ARHEP 2B main civil works: tunnels, water diversion and intake, water discharge, construction windows and access roads (adapted from SEDIC, 1999). The construction of the temporary roadway from La Virginia village to Window 1 might require the relocation of 1 or perhaps 2 houses that lay near the alignment for the road (arrows 1. and 2. on the upper left, indicate their approximate location, symbols are much larger than actual existing infrastructure and works). However, the roadway will be narrower (5,0 m) than it was specified in the project design; thus during actual construction the need for relocation might very well be avoided. Relocation of other houses, identified by Sedic, 1999, will not be needed as the temporary roadway between Window 1 and Window 2 will not be built, according to Generadora Unión S. A.

Table 2. Characteristics of ARHEP 2B, selected alternative

| parametre | unit | value |
|---|---|---|
| **Power Plant** | | |
| Underground Powerhouse | | |
| engine house width | m | 14 |
| engine house length | m | 37 |
| height engine house | m | 27 |
| nominal water flow | $m^3/s$ | 18 |
| total hydraulic jump | m | 520 |
| nominal installed power | MW at turbine axis | 79,6 |
| number of units | number | 2 |
| type of units | turbine – generator, vertical axis | |
| type of turbine | Pelton | |
| mean annual energy | GWh/year | 568 |
| valves Ø | m | 1,1 |
| synchronic generator | MVA | 43,33 |
| | kV | 13,8 |
| load bridge | KN | 800 |
| **Transmission** | | |
| transformers | kV | 13,8/115 |
| sub-station | kV | 115 |
| **Diversion Works** | | |
| diversion structure | concrete weir | |
| flood control width | m | 39 |
| flood control height | m | 5 |
| concrete intake channel L | m | 105 |
| settling tank (3 cells) L | m | 86 |
| conduction tunnel L | m | 8.570 |
| discharge tunnel L | m | 2.894 |
| **earth cut and excavation** | | |
| underground excavations | $m^3$ | 195.244 |
| surface works | | |
| new roads (5,6 km) | $m^3$ | 350.875 |
| road improvement (5,2 km) | $m^3$ | 65.773 |
| water uptake | $m^3$ | 50.000 |
| total surface cuts | $m^3$ | 466.648 |
| surface fills | $m^3$ | 102.159 |
| materials to be disposed | $m^3$ | 364.489 |
| capacity of 11 disposal pits | $m^3$ | 1.102.000 |

On the basis of these criteria, the alternative Amoyá 2b was selected for development and it is the one that the rest of this document refers to as Amoya project or ARHEP. Table 2. lists the main features and specifications of the hydroelectric generating component and of the complementary works, mainly the access roads.

## 3 The project region

The extent of the ARHEP region depends on the environmental or geographic components and processes under consideration. Water-related components and processes (hydrology, limnology, aquatic vegetation, aquatic invertebrates and ichthyo-fauna, etc.) are restricted to the Amoya river basin, mainly the portion upstream from the discharge, given the small size of the project and the lack of a reservoir.

Land-related components (soils, vegetation cover and uses, wildlife flora and fauna...), reach areas beyond the watershed to the natural or cultural boundaries of the terrestrial ecosystems, mainly the paramo and high Andean forests, isolated or under protection by the UNP.

Human-related components (population and settlements, infrastructure, cultural, political and economic activities, and so on), transcend the aforementioned boundaries. Chaparral municipal jurisdiction and the neighbouring municipalities (see map 1), roughly conform the project region for the human-related components and processes.

Thus, Chaparral municipal area (2.230 km$^2$), which includes the totality of Amoya River watershed (1.544 km2), and 28% (350 km$^2$) of Paramo de Las Hermosas National Park, and some 85 km$^2$ of unprotected paramo areas to the North and South in the jurisdiction of neighbouring townships (Roncesvalles and Rioblanco), are the ARHEP region of influence, which means the area likely to house the interactions between the project, and the region's environmental and geographic components.

### 3.1 Climate

Based on 1964-1998 data from the meteorological station Granja Demostrativa (1.040 m a.s.l.), a mean annual temperature of 24,3°C and a mean annual rainfall of 1.647 mm is given for the middle Amoya valley, the region of interest of ARHEP. The Amoyá river watershed has a bimodal precipitation regime, with two periods of lower mean rainfall -December to February and June to September- alternating with periods of more abundant rains, April-May and October-November.

Optimal pluvial and thermal conditions in the middle valley of the Amoya river occur ca. the 1.000 to 1.500 m altitudinal belt (fig 1.). These rainfall and temperature optima correspond to the well-developed temperate-belt climate of middle elevations throughout Latin America. It is the coffee-growing area of Amoya (and other inter-Andean valleys), where the ARHEP is located.

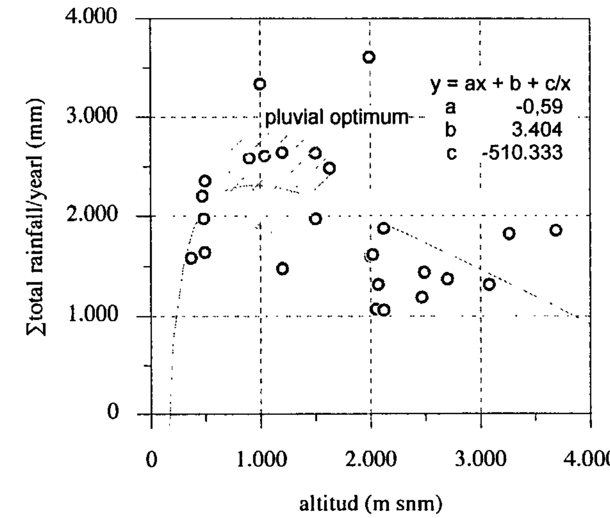



Fig 1. Total annual rainfall as a function of altitude, based on data from 26 stations located on Eastern slope of Central Cordillera in Southern Tolima, utilised for evaluation of hydroelectrical potential of Ambeima and Amoya rivers (Data from Integral, 1998)

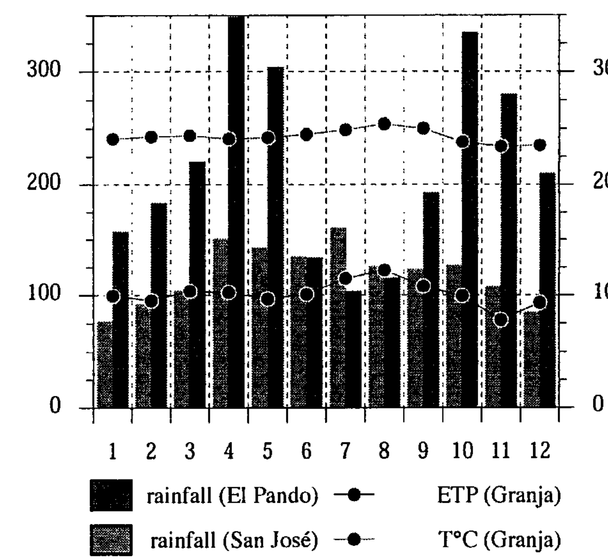
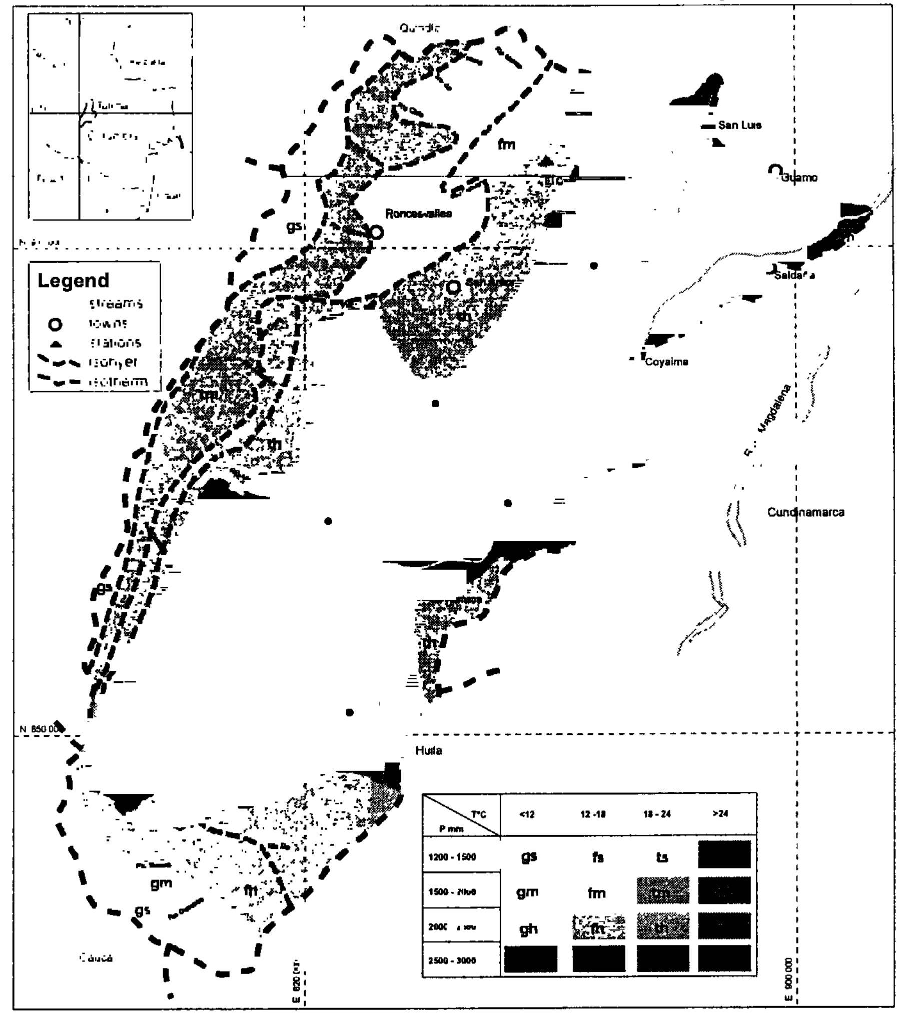



Fig. 2. Climate of Amoya River Middle Valley: Temperature (°C) and EVP (mm) measured at 1.040 m asl. Rainfall, measured at 900 m (El Pando) and at 2.490 m asl (San Jose de las Hermosas) Data from Integral, 1998

A climadiagram (fig. 2.) was drawn with temperatures and evapotranspiration data from La Granja. Rainfall data are shown for two stations at different elevations within the Amoya watershed (El Pando at 900 m a.s.l. and San José at 2.490 m a.s.l.) to underline the diminishing of precipitation and seasonality with elevation.

At middle elevations in the Amoya valley precipitation exceeds evapotranspiration most of the year, with the exception of July and August that show slightly higher values of ETP. The differences at higher elevations are not documented for the Amoya valley[5],[6]. The relative humidity (not shown in climadiagram) is similar during first, second and fourth trimesters of the year, with percentages between 73% and 83%. During the third trimester this values drops to 63%-69%.

The regional climate of the south part of the province of Tolima can be observed in map 4.[7]. It is worth noting the great number of climatic conditions that can be found within a relatively small area. Overlaying the altitudinal pattern of temperature and rainfall, there is a South - North negative gradient of precipitation, associated to the widening of the Magdalena river valley.




Map 4. Temperature and rainfall regimes of the Southern part of Tolima province. Note the multiple combinations co-ocurring in the Amoya-Saldaña valleys. This variety of climates has significance in the great biodiversity of the sub-region.

g = gélido/cold | f = frío/cool | t = templado/mild | c = cálido/warm
s = seco/dry | m = mésico/messic | h = húmedo/humid | p = perhúmedo/perhumid

Modified from SEDIC's, 1999 adaptation of IGAC's 1984 Tolima Province monograph.

5 The expected higher rates of evaporation, due to lower atmospheric pressure and adiabatic expansion of air masses, would make the contribution of the paramo biotope all the more important.

6 Meteorological and hydrometric stations in the Amoya valley are few and poorly equipped, lack adequate instruments for some parameters (e. g., wind direction and speed),and the historical records are limited. These deficiencies are particularly critical for the paramo-Andean forest biotopes, that play a fundamental role in the sustainability of the water resources, and in the ARHEP site. It is expected that ARESP will contribute to the solution of these deficiencies.

7 Map and legend were adapted by SEDIC from IGAC's 1984 monograph form the Tolima province.

## 3.2 Hydrology

The Amoya river has its head waters in Paramo de Las Hermosas at an altitude of 4.100 m, 46 km to the Southeast from the projected site of the power plant. It drains to the Saldaña river at an altitude of 327 m. The main hydrological characteristics of the Amoya river and its watershed are synthesised in table 3.

Tab 3. Hydrology of Amoyá River[1]

| parameter | unit | value |
|---|---|---|
| river basin area | $km^2$ | 1544,0 |
| mean multiannual flow at confluence with Saldaña river | $m^3/s$ | 57,0 |
| aititude at hydrographic station El Queso | msnm | 470,0 |
| watershed area at El Queso | $km^2$ | 1145,0 |
| mean multiannual flow at El Queso | $m^3/s$ | 44,6 |
| mínimum multiannual flow at El Queso | $m^3s$ | 16,0 |
| maximum multiannual flow at El Queso | $m^3/s$ | 88,1 |
| watershed area at the intake site La Virginia | $km^2$ | 518,0 |
| altiutude at the intake site | msnm | 1480,0 |
| mean multiannual flow at the intake site | $m^{3/}s$ | 17,2 |
| mean annual rainfall in the watershed | mm | 1624,0 |
| mean annual evapotranspiration in the watershed | mm | 578,0 |
| average yield | $l/s/km^2$ | 33,1 |
| flood with return time = 1.000 years | $m^3/s$ | 800,0 |

[1] After INGETEC 1998, and SEDIC, 1999. Hydrological calculations revised by Restrepo (1998), Saldarriaga (2002) and Deeb, (2003)

The most important tributaries of the Amoyá river are the Davis river, upstream from the water intake and the Ambeima river, downstream from the water discharge. Between these two structures there will be a stretch of reduced flows, determined by the operating conditions of the ARHEP., which will divert to the power plant all flows up to 18,2 $m^3/s$.

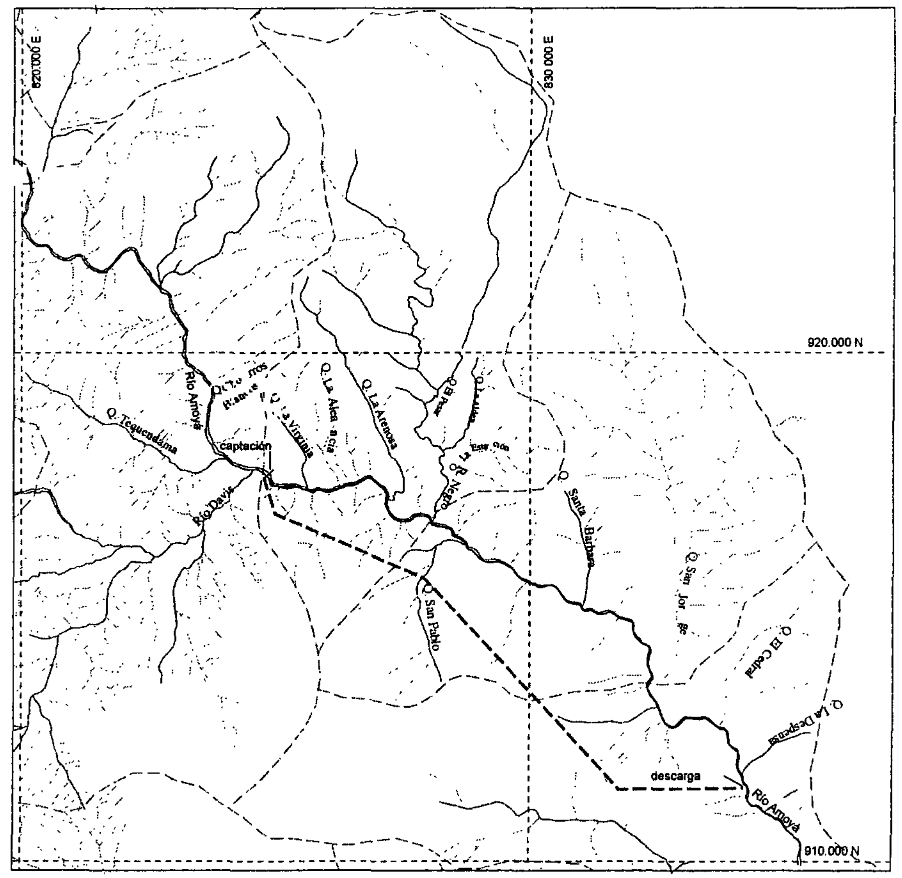
A number of small streams and rivers flow into the Amoya on both margins, along this ca. 13 km long stretch. These are listed in table 4. together with their estimated flows[8], see also map 5.

[8] The mean and minimum flows from table 4. were calculated for each stream with a yield -area equation, similar to the utilised by Hidrotec, 1997 in the evaluation of the hydroelectric potential and later corroborated by other studies. The values differ from those measured by SEDIC during the dry season of 1998 in some cases up to an order of magnitude. The compound value, i. e., the total flow collected within the dry stretch, is 26,6% from SEDIC's value (16,9 $m^3/s$), which would seem too high and would imply almost a doubling of flows in the dry stretch.

Tab 4. Dry stretch watershed

| stream | dry stretch (m) | area* ($km^2$) | | caudal/flow ($m^3/s$) | | |
|---|---|---|---|---|---|---|
| | | individual | accumulated | dry season 1998 | mean | minimum |
| La Virginia | 1.020 | 2,06 | 2,06 | 0,5 | 0,07 | 0,04 |
| La Alcancia | 1.728 | 0,97 | 3,03 | 0,5 | 0,03 | 0,02 |
| La Arenosa | 2.938 | 4,04 | 7,07 | 0,6 | 0,13 | 0,07 |
| Rio Negro | 4.211 | 30,00 | 37,07 | 8 | 1,05 | 0,54 |
| San Pablo | 5.086 | 2,86 | 39,93 | 2 | 0,10 | 0,06 |
| Santa Barbara | 7.863 | 28,98 | 68,91 | 0,5 | 1,01 | 0,53 |
| San Jorge | 10.275 | 6,98 | 75,89 | 1,5 | 0,26 | 0,13 |
| El Cedral | 12.480 | 5,34 | 81,23 | 0,6 | 0,20 | 0,1 |
| La Despensa | 13.630 | 1,60 | 82,83 | 0,7 | 0,06 | 0,03 |

* watershed areas taken from cartography




Map. 5. Streams tributary to Amoya river in the dry stretch. Adapted from SEDIC (1999).

During the dry season of 1998, Sedic (1999) estimated in ca. 17 $m^3/s$, the contribution of 11 streams and 23 smaller tributaries along the dry stretch[9] (tab. 4, map 6.). However, calculations based on rainfall-yield relationships give a more conservative mean value: 4,50 $m^3/s$ for the 128,7 $km^2$ watershed, with an average yield of 34,98 litres/s/$km^2$.

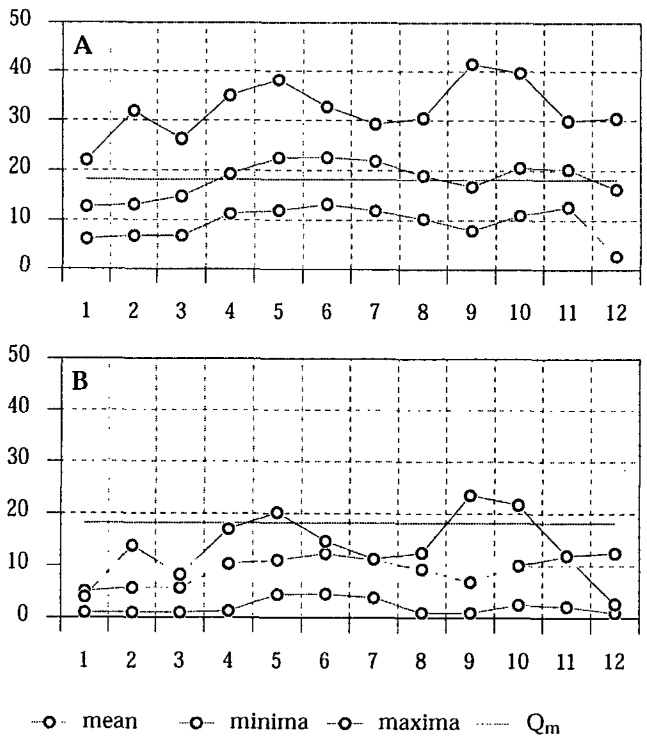



Fig. 3. Amoya River monthly flows at intake structure, today (A) and expected with ARHEP (B). Note that severest droughts are associated with mean river flows. Data from Deeb, 2003

There are no records of the flows of the Amoya river for the project area. The expected values have been extrapolated from El Queso, a station downstream from the project site, at 470 m elevation. The initial calculations by Hidrotec, 1997, have been revised by several authors with a number of methodologies (Ingetec 1998, Restrepo, 1998, Saldarriaga, 2002 and Deeb, 2003). There are no major changes in the pattern of the expected values[10]. The mean monthly flows at La Virginia, the project site, are shown in fig 3A. Fig 3B illustrates the likely changes after the power plant goes into operation.

### 3.2.1 Amoya River water balance

The drought effect could be palliated by the contribution from the tributaries in the dry stretch which would undergo through dry periods at the same time as the main river. However, the effect could be further reduced if a minimum constant flow is allowed to pass through the intake structure, this is the so called *ecological flow* ($Q_e$)[11].

For the calculation of $Q_e$, SEDIC adapted a hydrological approach based on a fixed percentage of average daily flow (ADF) recommended by Tennant (1976) for temperate mountain streams in Montana and Wyoming and widely applied in the 1970's in USA and elsewhere because of its simplicity (Petts and Calow, 1996)[12].

Hidrotec (1997) estimated the Amoya river flows expected at the intake structure by means of a precipitation-yield equation, given the lack of historic flow data for the Amoya river[13]. The minimum flow thus calculated (0,83 $m^3/s$), occurred in January 1992, an ENSO-event period, when the severest droughts are known to occur.

[9] Dry river bed or dry stretch is the denomination given in the Spanish environmental literature to the length of river with flows below average, due to flow diversion. The artificially induced recurrent lower flow regime affects aquatic organisms and in-river ecological processes (production, colonisation, succession...), directly and as a consequence of changes in sediment transport and deposition. It could also affect organisms at water-dependent riparian habitats (biotopes on islands and on alluvial deposits, flood plains), and water consumptive and non consumptive uses and users.

[10] The adjustments have been on the values of mean flow and duration of flow curves, key parametres for the calculations of power and energy.

[11] *Ecological flow* is the term utilised in the Spanish environmental literature (v. gr., González & García, 1995); in English the most common term is *flow for in-river needs* (e. g., Petts & Maddock, 1996). The concept has evolved as a practical matter, but it does rely on solid understanding of the physical, biological and even cultural processes that determine the ecological features of rivers.

[12] Modern approaches better suited for the definition of $Q_e$ take into consideration the dynamic nature of habitat quality. Organisms (aquatic, amphibian and terrestrial) differ in their tolerances to variations in flow and associated physical factors (stream depth, velocity...), habitat quality is then reflected by organism response, usually seen as a demographic phenomenon. These methods, many of which are advocated in the reviews cited (González & García, 1995; Petts & Maddock, 1996; and Brown & King, 2002), demand large quantities of field data and complex statistical analysis, PCA, CA, etc., which are cumbersome to interpret.

[13] Hidrotec's (1997) hydrological calculations have been refined by a number of studies with different methodologies and approaches (Restrepo, 1998; Saldarriaga, 2002; and Deeb, 2003). None of these, however, has addressed the issue of $Q_e$ which remains = 1,0 $m^3/s$.

For this period the mean flow was 7,19 $m^3/s$, the lowest for the analysed series. It was taken by SEDIC as ADF, and scaled according to Tennant's habitat categories (table 5.) in order to determine ecological flows or minimum flows for in-river needs. Thus, SEDIC agrees with the recommendation from the feasibility studies (Hidrotec, 1997 and Integral, 1998)[14] to allow a flow of 1,0 $m^3/s$ to pass through the weir, a value within the lower and the upper limits of Tennant's *fair* habitat category.

Tab. 5. Scale of stream habitat quality based on fractions of ADF*,†

| habitat status | ADF fraction | | | Amoya $Q_e$($m^3/s$) | | |
|---|---|---|---|---|---|---|
| | lower | upper | mean | lower | upper | mean |
| degraded | | 0,1 | 0,05 | 0,0 | 0,7 | 0,4 |
| fair | 0,1 | 0,3 | 0,2 | 0,8 | 2,1 | 1,4 |
| good | 0,3 | 0,6 | 0,45 | 2,2 | 4,3 | 3,2 |
| optimum | 0,8 | 1,0 | 0,9 | 5,8 | 7,2 | 6,5 |

* Amoya ADF = 7,19 $m^3/s$, value adopted by SEDIC, 1999
† After Tennant (1976), cited by SEDIC (1999)

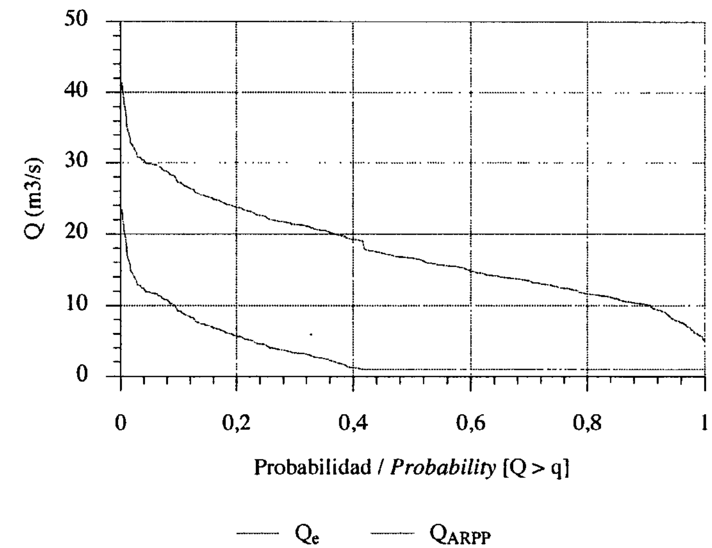



Fig. 4. Monthly flow duration curves in dry stretch ($Q_e$) and available for generation (QARPP). Data from Deeb, 2003.

For a 2-year return period ($T_r = 2$), minimum flows generated within the dry stretch between intake and discharge would reach 1,5 $m^3/s$, while for the 5-years $T_r$, the generated flow will only be 96 litres/s. The most critical sector will correspond to the first 4 km between water intake and the confluence of the Rio Negro, where only 0,12 $m^3/s$ for the 2 year $T_r$ and 0,08 $m^3/s$ for the 5 year $T_r$ flow into the river. In these regards, it should be noted that depending on the mean flow values at the intake site, three types of conditions could occur (fig. 3A. and 3B):

1. When mean river flow is over 19,0 $m^3/s$. This case would occur on the average 41,9% of the time, according to the flow duration curve (figure 4.), all flows exceeding 18,0 $m^3/s$ ($Q_e$ + excess flow) will run down stream through the river channel. The same high water condition will occur in the tributary streams and rivers in this stretch.

2. When mean river flow is under 2,8 $m^3/s$. This situation will occur with a probability of under 1%[15]. The Amoya power plant could not operate and all flow will run downstream through the river channel. In this case, the very low tributary flows in the dry stretch, would add up to the total flow but will be significantly minor compared to the in-river flow.

3. When mean river flow is over 2,8 $m^3/s$ and under 19,0 $m^3/s$. This is the most likely case (58,1% of the time). The ecological flow of 1 $m^3/s$ will be fundamental for the sustainability of the biotic conditions down to the Quebrada La Virginia confluence. All together, for a 2-year $T^r$, the mean flow at La Despensa would be 2,50 $m^3/s$, and below the discharge would receive between 2,8 and 18,9 $m^3/s$, depending on the mean flow value at the intake.

The fundamental question is whether or not a minimum ecological flow of 1,0 $m^3/s$ –which most likely would occur for extended periods, during ca. 60% of the time– would be sufficient for the sustainability of the uppermost aquatic habitats in the artificial drought stretch. It ought to be pointed out that such

[14] The feasibility study defined $Q_e$ as 1 $m^3/s$, without giving a clear justification of the figure chosen (SEDIC, 1999).

[15] Actually it is not shown in fig. 4, composed with a newer set of data for the ARHEP hydrology, prepared by Deeb, 2003. There are no values under 3,07 $m^3/s$ in the series.

minimum flow would only persist for a very short distance, between the intake and La Virginia brook (1.020 m), or even less if some minor unnamed streams, mainly on the right margin of the river have mean flows as large as those estimated by SEDIC (n° 4.1.2.1, 1999). It has been shown that the lower sector within this stretch, i. e., just up-stream from the discharge of the power plant, would receive up to 3,2 $m^3/s$ restitution flow from the tributaries (tab. 4. and fig. 5.) and up to 4,5 $m^3/s$ if these yields are extrapolated to the whole stretch.

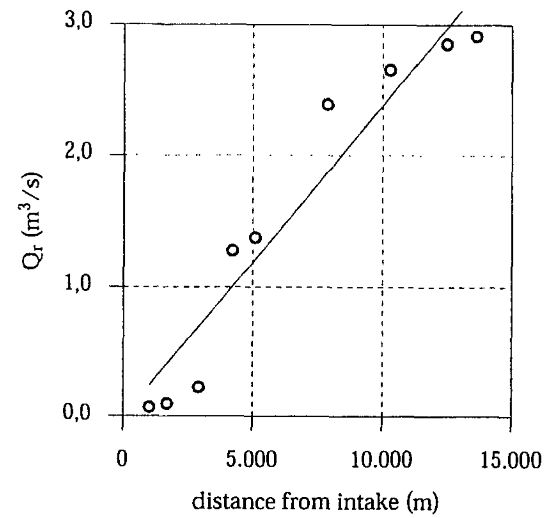



Fig.5.Flow increments in dry stretch. Data from SEDIC (1999)

During the periods of natural severe droughts in the watershed, when the Amoya River at the intake presents flows under 2,8 $m^3/s$ (less than 1% of the time) and the tributaries do not contribute with appreciable flow, the environmental limitations for aquatic biota (periphyton, aquatic invertebrates, and fishes) are likely to be minimal -it is the natural condition- given that the river channel would receive all the flow, because the power plant cannot operate. This event, however, would occur very seldom if ever; the most likely condition is the one derived from mean flows at the intake.

In sum, the conditions of the Amoya river below the intake, once the AEPP goes into operation, are going change notoriously. Prolonged periods with very low flows will be the rule for the dry and transitional seasons; even during the rainy season, the flows will be lower than the historical values. These conditions, however, will rapidly diminish downstream from the intake, as a result of the restitution of water from the large number of tributary streams on both margins of the river. Just before the discharge, some 13 to 14 km below the intake, the Amoya river would have gain on the average from 3,2 to 4,5 $m^3/s$ in addition to the $Q_e$.

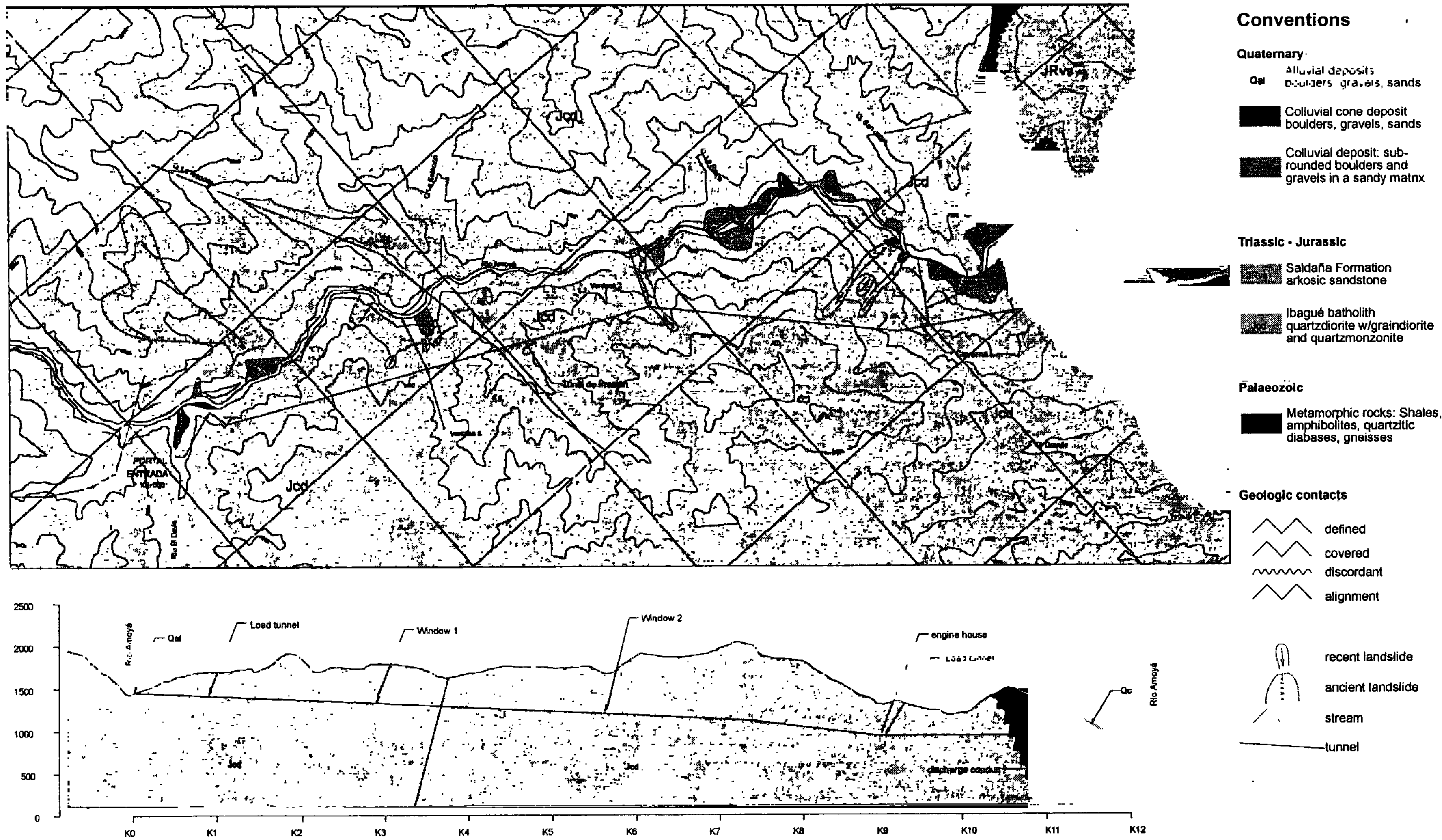
The expected consequences of these hydrological alterations are on the structure and dynamics of the aquatic habitats immediately below the weir and on the main use of the water resource within the dry stretch, namely for dilution of small point or diffused sources of contamination from domestic and agricultural activities.

## 3.3 Geology and geomorphology

Amoya River basin consists mostly of a Jurassic intrusive batholith, together with metamorphic Palaeozoic rocks and Cretaceous to Tertiary sedimentary rocks. Recent alluvial deposits, alluvial cones and colluvial deposits form the Quaternary, particularly in the lower stretches of the Amoya River, below the discharge, which do not exert any influence on the project construction activities, given their superficial location.

Amoya and its main tributary the Ambeima River are delimited by several fault systems which do not cross the ARHEP area but do influence the morphological structure of the different groups of rocks. The contact between batholith and the Palaeozoic rocks through the El Cedral brook and the main structural feature.

Amoya is a colluvial- alluvial valley between a mountainous to hilly relief. The upper and middle basins are characterised by denudation processes (erosion and mass movements). There are a number of scars of localised superficial ancient and present sliding movements, rock falling and bank erosion. See map 6.




Map 6. Geology of the ARHEP area; corresponds also to the dry stretch. Note the preeminence of the Ibague batholith, which structurally and geotechnically offers adequate conditions that minimise the likelihood of conduit derived exfiltration (Villegas, 2003); only the las 900 m of the discharge tunnel will be excavated in the lesser quality palaeozoic metasedimentary rock. The Quaternary deposits are superficial and only have relation to the surface works.

## 3.4 Potential erosion/degradation, stability problems

### 3.4.1 Erosion at the discharge site

In 1998 Ingetec concluded the feasibility studies of Amoya 2b, considered the best alternative for development in the Amoya-Ambeima watersheds. One of the reasons for the choice was precisely the lower level of uncertainty about topographical and geological risks. In 1999 Sedic, designed the adjustments that ARHEP has today. One of the structures modified by Sedic was the discharge and the selection of a more stable location for the water exit structure. The discharge site was chosen so that the water flow from the exit structure would strike directly against the rocky out crop, a very resistant Ibague batholith.

The discharge is formed by two 1,85 m Ø galleries that receive the water from the turbines at EL 945,7 m; a 3,1 km long, free flow, discharge tunnel, with a 0,21% slope that transports the water at a mean speed of 2 m/s; and an exit structure that places the water flow back into the river. This latter is a 9,55 m long canal with 5 scales that span a height of 4,5 m from EL 940 m at the beginning, to EL 935,5 m, to minimise the kinetic energy. A protection key 3,0 m deep, is located at the end of the canc.. The whole exit structure is funded on a rocky up-crop from the Ibague batholith. The floor concrete stabs are fastened to the rock by means of anchor bars placed 1,5 m apart.

The major concern is related to the lower sediment content of the discharge flow rather than to the effect of the water mass, because this is exactly the same that the Amoya has transported before the operation of ARPP; the energy of the discharge would be much smaller at the end of the canal and, in any case, lower than that of much larger natural water masses during storms and high water events. The information needed to make more precise statements about this particular problem is not available.

### 3.4.2 Stability along the pressure conduits

The conduction of water from the intake structure to the subterranean power house and from this to the discharge structure is through two tunnels excavated deep inside the batholith, on the right hand side on the Amoya river. The tunnels surface at the starting and end points (intake structure and discharge), but they are located a depth > 125 m all along, inside the Ibague batholith (see map 6) which is very resistant; the final 1.000 m of the discharge tunnel are excavated in a different type of rock, metasediments of Palaeozoic age mixed with shales and volcanic ashes, the resistance is lower than the Ibagué batholith, but high nonetheless (Villegas, 2003). Thus the stability of the terrain associated to the water conduits is of no concern.

### 3.4.3 Control of sediments, impacts from construction activities

A large number of activities -surface and underground- produce materials that need to be either utilised in the fabrication of concrete mixtures or in fills needed by the project or to be disposed of. Materials from open pit excavations (works at the intake structures, roads and others) and for tunnels (load and discharge tunnels, construction windows 1 and 2, powerhouse access) will be disposed of in special places identified as *depósitos* in the EMP cartography (SEDIC, 1999).

The volumes of materials to be disposed of are presented in detail; here a summary is enough (volumes in $m^3$):

| | |
|---|---|
| volume excavated in underground works | = 195.000 |
| volume excavated in surface works | = 467.000 |
| Σ | = 662.000 (includes 444.000 in rock) |
| minus volume utilised in fills | = 102.000 |
| total volume to be disposed of | = 560.000, which expanded would have a larger volume |

Sedic, 1999 indicates that 11 deposit sites have been studied and designed; they are located along the roads that would be utilised for the construction of the project. The combined available volume in the 11 deposits is 1.100.000 m3. See tab. 6[16].

Tab. 6. Area and volume of land fills

| depósito/land fill | área/area (m2) | volumen/volume (m3) |
|---|---|---|
| Los Iguaes | 27.000 | 270.000 |
| Los Naranjos | 9.700 | 115.000 |
| Descarga | 5.600 | 150.000 |
| El Cedral | 20.000 | 130.000 |
| Puente Negro | 5.000 | 43.000 |
| Vega Chiquita | 2.400 | 8.000 |
| Puente Rojo | 5.000 | 37.000 |
| Rivera 1 | 750 | 35.000 |
| Rivera 2 | 5.000 | 45.000 |
| Captación | 2.800 | 17.000 |
| Iguaes 2 (reserve) | – | 250.000 |
| Σ | 83.250 | 1.100.000 |

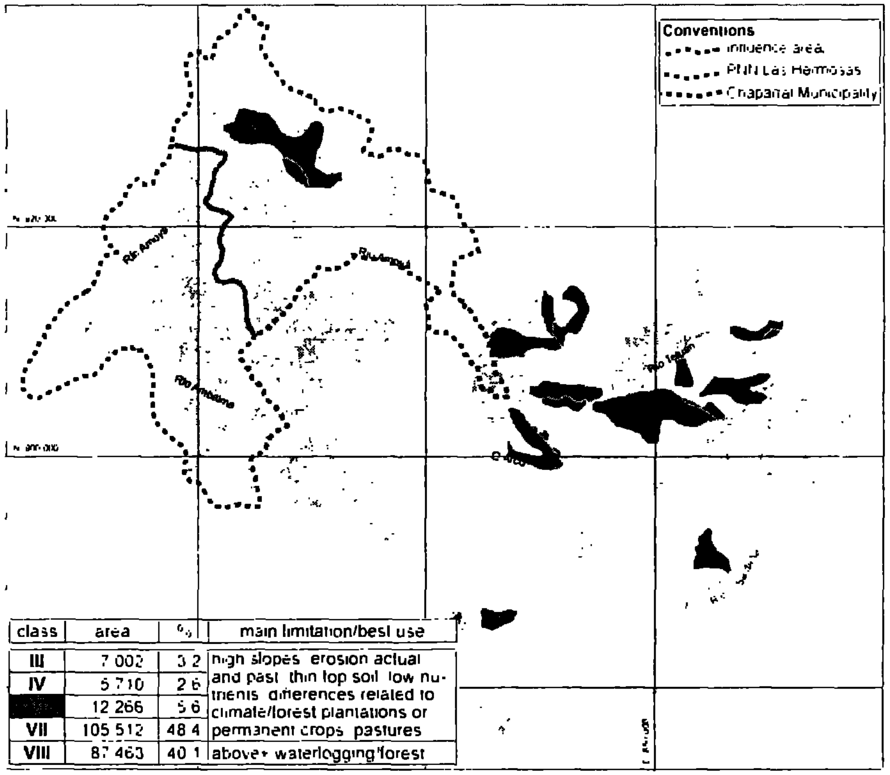
The works designed for the conformation of the deposits take into consideration the natural slopes, the resting slope of the materials, the maximum filling heights, berms at different levels, as well as drainages, supporting walls, and other specific works to guarantee -within the best current geotechnical knowledge- the stability and structural behaviour of the deposits.

According to Sedic, 444.000 m3 of excavation are good quality rock that could be selected, classified, stored to be donated or sold to be utilised in concrete or asphalt mixtures for common interest works. Indeed, Generadora Union has made statements in this regards. What this means is that the volume available in the deposits could be a bit larger.

[16] Villegas, 2003 gives slightly different figures for the volumes to be excavated, total and in rock, and takes into consideration an expansion factor of 1,4 for rock material and of 1,1 for common material. These figures make the volume available in the 11 deposits more tightly adjusted to the needs.

## 3.5 Soils, soil uses and other natural resources

In the upper and middle Amoya River valley, soils constitute a poor resource. Even though they are rich in volcanic ashes, which helps to retain nutrients and water, they have evolved on a steep-sloped relief, are not well developed, are well drained and fairly eroded. In general they are not adequate for agriculture. Forestry is the recommended use and, to certain extent, cattle raising in the upper, lower-sloped sectors[17]. Map 7 shows the general distribution of soil classes in Chaparral and in the Amoya River basin[18].




| class | area | % | main limitation/best use |
|---|---|---|---|
| III | 7 002 | 3 2 | high slopes erosion actual and past thin top soil low nutrients differences related to climate/forest plantations or permanent crops pastures |
| IV | 5 710 | 2 6 | |
| | 12 266 | 5 6 | |
| VII | 105 512 | 48 4 | |
| VIII | 87 463 | 40 1 | above+ waterlogging/forest |

Map 7. Soil types in the Chaparral Municipality which includes the Amoya watershed. Areas of classes measured in cartography. Modified from SEDIC, 1999. Paramo, Andean forest areas (class VIII) are of no use whatsoever for agriculture, besides limitations common to other soil classes, climate and water-logging constitute additional restrictions.

17 The recommendation of *cattle grazing* is in a production system for intensive stable-sheltered herds or with strict rotation of pastures; not for extensive low productivity browsing, itinerant free range-roaming herds such as the ones commonly found throughout the high elevations areas in the three cordilleras in Colombia.

18 Soil classes as defined by the Soil Conservation Service of the USA; it takes into account risks and limitations: erosion, hydromorphism, root environment and climate. Classes ranking is from I, best to VIII, worst.

Land use in Amoya valley adequately reflects these limitations. Most of the rural properties are very small and fragmented (25,4 to 30,1 ha, rural property average size for the whole municipality of Chaparral). Forests are located in the upper steepest, inaccessible areas, within the Las Hermosas National Park and in the very steep sloped terrain of the Las Hermosas canyon. The middle valley, where the project will be located, corresponds to the pluvial-thermal optimum (best conditions of rainfall and temperature) but soils are poorest and erosion problems, due to excessive use and higher rainfall, reduced even more the quality of the resource.

Pastures, alone, or in combination with young secondary vegetation is the main use of the soil in the upper watershed, while multiple species subsistence farming with coffee as cash crop, occupy most of the land at middle elevations. The lower part of the middle valley is occupied by coffee and cacao plantations. See map 8.

## 3.6 Water quality

In the zone of direct influence of the Project were carried out physicochemical and bacteriological analyses along the course of the Amoyá River, and along some of its main tributaries: River Davis and River Negro, and the brooks La Virginia, San Jorge, El Cedral and La Despensa.

The parameters considered for the evaluation of the water resource included the levels of dissolved oxygen (DO) in the currents, indicators of contaminant charges DQO y $DBO_5$, pH, indicators of Nitrogen and Phosphorous concentrations, turbidity, suspended solids, oils and greases. Related to the water's microbiological quality, concentrations of coliforms (total and faecal) were measured, which indicate contamination by domestic, agricultural and livestock discharges.

### 3.6.1 Current status

The quality of the water of the Amoya river and its affluents in the area to be influenced by the ARHEP is high in general terms. Waters are cool, well oxygenated, with small electrolyte concentrations, low tensions of phosphorus and of nitrogen, and low concentrations of suspended and dissolved solids (tab. 7.). Benthic invertebrate communities were diverse and taxa with narrow ecological tolerances were abundant. Fish diversity and abundance was low but the sampling effort was also low. Other than subsistence farming and extensive cattle raising, there are no other activities (mining, industrial processes…) that can alter water quality to an appreciable degree.

Tab. 7. Average conditions of Amoya river and tributaries during the 1999 dry season. After SEDIC, 1999

| parametro/ parametre | Amoya river (n = 4) | | | tributaries (n = 6) | | |
|---|---|---|---|---|---|---|
| | range | mean | s | range | mean | s |
| elevation (m) | 930-1500 | 1.211 | 281 | 955-1700 | 1.276 | 329 |
| pH | 7-8 | 7,5 | 0,6 | 8-9 | 8,1 | 0,4 |
| apparent colour (UPC) | 25-26 | 25,3 | 0,5 | 5-40 | 23,3 | 12,5 |
| true colour (UPC) | 20-25 | 21,3 | 2,5 | 0-30 | 15,5 | 11,6 |
| air temperature (°C) | 20-25 | 22,1 | 1,9 | 20-23 | 21,4 | 1,4 |
| water temperature (°C) | 15-20 | 17,5 | 2,3 | 15-21 | 18,2 | 2,8 |
| dissolved oxygen (mg/l) | 8-9 | 8,4 | 0,2 | 8-9 | 8,2 | 0,3 |
| $O_2$ saturation (%) | 99-100 | 99,8 | 0,5 | 100-100 | 100,0 | 0,0 |
| BOD (mg/l) | 0-7 | 2,7 | 3,1 | 1-2 | 1,7 | 0,4 |
| COD (mg/l) | 10-62 | 28,3 | 23,4 | 11-25 | 19,9 | 5,9 |
| turbidity (NTU) | 3-7 | 5,9 | 1,8 | 1-14 | 7,7 | 4,7 |
| conductivity (µS/cm) | 109-146 | 134,0 | 17,0 | 56-450 | 228,8 | 136,6 |
| total solids (mg/l) | 108-132 | 118,8 | 12,6 | 50-268 | 166,5 | 75,4 |
| suspended solids (mg/l) | 1-15 | 6,5 | 6,2 | 5-14 | 9,2 | 4,1 |
| total nitrogen (mg/l) | 0-0 | 0,15 | 0,06 | 0-0 | 0,22 | 0,10 |
| total phosphorus (mg/l) | 0-0 | 0,13 | 0,05 | 0-1 | 0,25 | 0,18 |
| oils (mg/l) | 1-2 | 1,55 | 0,66 | 1-4 | 2,18 | 1,33 |

Population is small and mainly dispersed towards the high basins and living in nucleated settlements in the coffee growing area at lower elevations. The limited sampling programme carried out by Sedic in 1999 manifested though, localised foci of pollution associated to discharges of raw sewage to the streams and discharges of coffee-bean shell digesters in the lower stretch, below the Rio Negro. The latter activity is a seasonal, post harvest affair; it consumes large quantities of water which is returned with a high BOD to the streams, loaded with secondary compounds (saponines, organic acids...), Uribe & Laverde (1972); and Bedoya & Salazar (1985).

### 3.6.2 Trends and expected changes with ARHEP

Coffee plantations are not expanding in Colombia; on the contrary, the coffee-culture has been contracting throughout the Central Cordillera since the mid 90's, due to a constellation of reasons. Thus, it seems that the main contributing activity to water quality deterioration in Amoya middle valley will remain constant or even at lower intensities for the near future. Population, on the other hand, could increase, attracted by the employment opportunities and general climate of betterment in the area or associated to the apparent resurgence of the poppy culture in Southern Tolima (González & Briceño, 2002)19. The social programme –complementary of the hydroelectric generation facility and currently on the design stage– has contemplated these scenarios and has provisions to minimise their impact (Generadora Union, 2002).

Water quality is not likely to suffer any major, permanent or prolonged changes, from the construction or operation of the ARPP. If there were changes, these would occur in the dry stretch or below the discharge. The possible alterations would be associated with: increased load of contaminants and reduction of flow to dilute current loads.

Newer load is really limited to inert sediments derived from excavations and top soil removal during the construction phase. Sedic (1999) designed a programme to minimise the accidental dumping of sediments and other inert materials to streams and to handle properly all types of liquid and solid wastes. There is an ample programme for utilisation of excavated materials and a number of deposits along the existing road network whose combined capacity well exceed the expected volume to be excavated. Thus, the statement about negligible contributions of pollutants from construction activities holds true.

The reduced flows in the lower Amoya channel, below the weir, could imply a recurrent deterioration of water quality in the proximal areas to the weir, where the drought effect will be greatest. The available data about loads (pollutants, concentrations, location, seasonality, and so on) and dilution flows (from Amoyá after ARPP goes into operation plus flow from tributaries) are not sufficient to generate a mitigation solution. However, the framework for a mitigation strategy can be outlined, based on the concept that current pollution loads to the Amoya system ought to be reduced and that it is feasible in the short term to do so. This strategy would require the following components:

1. implementation of the water quality monitoring and of the environmental education and awareness programmes, formulated by Sedic as part of the ARHEP-EMP (1999)
2. investments of the social component of ARESP in health and sanitation, giving priority to the critical coffee growing areas, and in agreement with the results of the monitoring programme
3. integration of technical, financial and institutional support from Cortolima, the Provincial Government of Tolima and the Municipal Government of Chaparral as well as local NGO's, in the implementation of the sanitation and pollution control programme.

[19] Population increases do not mean only larger loads from domestic sewage; they imply besides, expansion of clear cutting activities and therefore sediment production and deposit, an effect already taking place in the area, e. g., quebradas San Pablo and San Francisco, Sedic, 1999

## 3.7 Terrestrial flora and fauna status in ARHEP area, effects of project activities

### 3.7.1 Vegetation

The area of direct influence of the ARHEP is dominated by pastures and small crop plots that have driven a major change in land use, and the corresponding degradation, fragmentation and destruction of the natural forested areas. Within these strongly altered areas, some secondary forest remnants are still conserved, mainly due to the adverse topographic conditions (steep slopes), often they are located next to streams and rivers.

Some of the commonest tree species in these remnant forests are Yarumos (*Cecropia* sp.), Lecheros (*Brosimum* sp.), Balsos (*Ochroma* sp.), Cámbulos (*Erythrina* sp), Laurel (**Lauraceae**), Dulumoco (*Saurauia* sp.), Carboncillo (**Leguminosae**), Candelo (**Annonaceae**), Pedrohernández (*Toxicodendron* sp.), Pringamosa (Urera sp.) y Zurrumbo (Trema sp.).Note that these are all early secondary growth vegetation, fast growers, heliophyllous species.

Grasses whether native or improved varieties, with may species of herbs are the largest plant cover type. The dominant crop is coffee grown under shadow, principally under fast growing Cámbulos (*Erythrina* sp.), Guamos (*Inga* sp.) and Balsos (*Ochroma* sp.), as well as plantain, fruit trees, and some timber species.

### 3.7.2 Fauna

The fauna found at the area of influence of ARHEP is basically that associated to disturbed bitopes -cultivated areas and pastures- and to human inhabited rural districts. The small patches of forests, mainly along the banks of streams and rivers, are too small and isolated from one another to house viable populations of more exigent species such as mountain tapir (*Tapirus pinchaque*), spectacled bear (*Tremarctus ornatus*), deers (*Mazama americana, Odoicoileus virginianus*) and other large vertebrates known to occur elsewhere in the better conserved areas of the watershed, up stream from the ARHEP area and in other high elevation areas, e.g., upper Ambeima and upper Davis rivers.

During the field work the following fauna species were identified: 3 amphibian species (Anura order)belonging to 3 families; 9 reptile species, in which Saurian individuals were the most abundant; 69 bird species, belonging to 29 families and 12 orders; and 13 mammal species, in which Carnivora and Rodentia were the most diverse orders, comprising 4 and 3 species respectively.

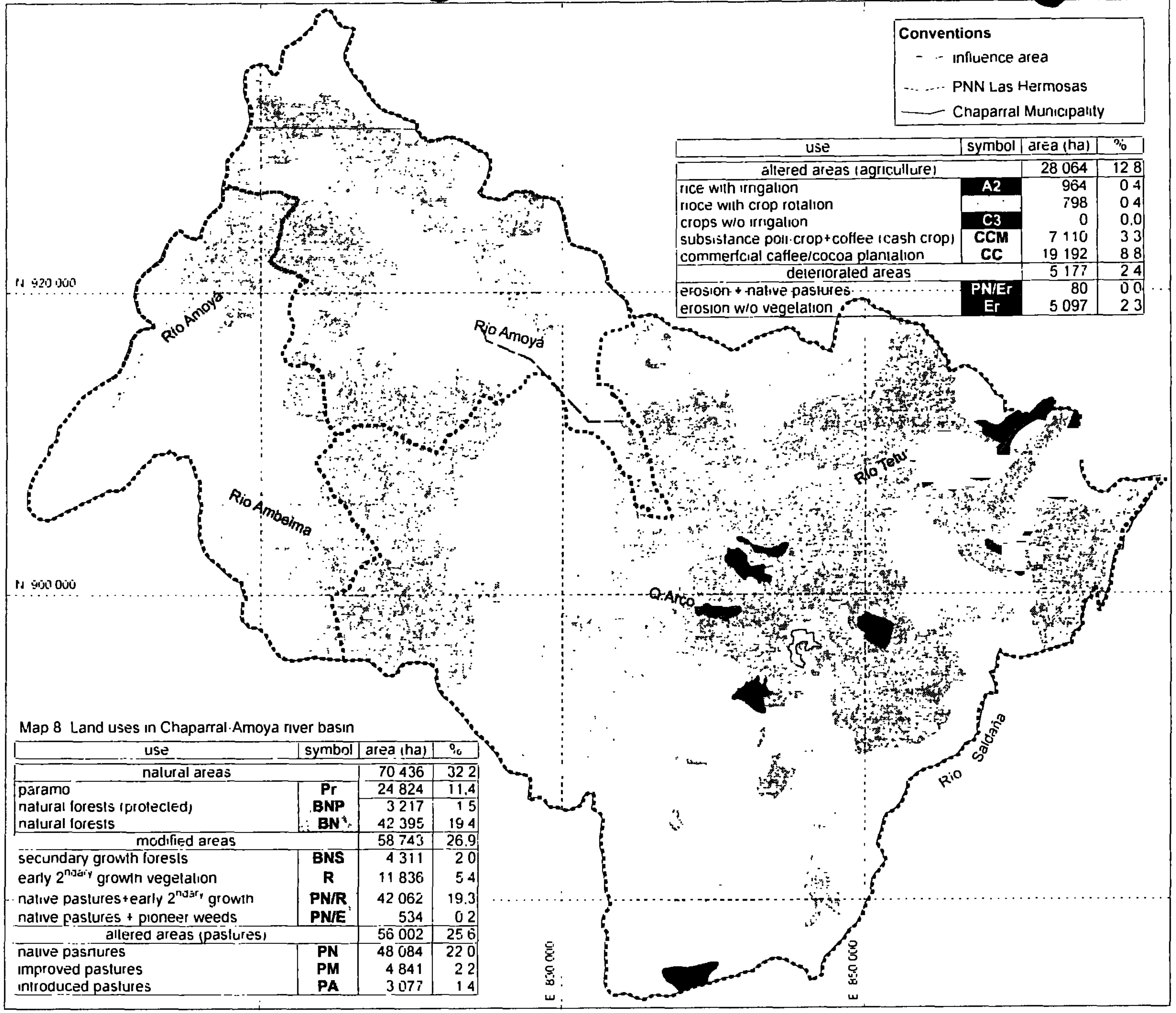
In the streams and rivers sampled within the Amoyá River Watershed, 11 orders of aquatic macroinvertebrates were registered, most of them belonging to genera or species considered as good water quality bioindicators.

Two complementary approaches are used to outline the status of flora and fauna within the Amoya basin. On the one hand, the status of the habitats is analysed with the help of the land uses cartography, done by Municipio de Chaparral in 1998 for the Territorial Ordering Plan (POT) and presented by Sedic, 1999 (map 8.). The status of organisms is mostly inferred from the conservation literature, as few studies deal specifically with the Amoyá valley.

### 3.7.3 Status of habitats

The different units identified in map 8. (Municipio de Chaparral, 1998 and Sedic, 1999) were organised into 4 conservation categories (see map 8 legend): *natural, modified, altered* and *deteriorated*, according to a scheme first formulated by WWF and IUCN in the 1980's and adapted and complemented by Neotropicos (1996)[20]. Three large altitudinal belts with differences in use and conservation status can be recognised in Chaparral: natural areas in the upper reaches, grazing-traditional coffee subsistence agriculture and modern coffee plantations at mid elevations and mechanised agriculture in the low lands. For the ARHEP, only the first two have significance, Chaparral urban area lays outside the Amoya river basin, the road that leads to the project area enters the Amoya valley some 5 km west from the city.

[20] The distinction amongst biotopes is related more to the dynamics of ecological processes in them (speed of colonisation and succession -response processes to natural or induced perturbations; reversibility of natural or induced disturbances; and need of human support to bring about changes) than to their structure. In natural biotopes, species colonisation and primary and secondary succession can proceed without human support or interference. In intervened biotopes, colonisation and succession are accelerated or slowed down by man, induced perturbations are reversible. In altered biotopes, colonisation and succession should be induced and managed; reversibility of induced perturbations is slow (ca. 1 human generation). In deteriorated biotopes, colonisation and succession should be induced and managed, induced perturbations are of extremely slow reversibility (several humans generations), Neotropicos, 1996.




| use | symbol | area (ha) | % |
|---|---|---|---|
| altered areas (agriculture) | | 28 064 | 12 8 |
| rice with irrigation | A2 | 964 | 0 4 |
| rioce with crop rotation | | 798 | 0 4 |
| crops w/o irrigation | C3 | 0 | 0.0 |
| subsistance poli-crop+coffee (cash crop) | CCM | 7 110 | 3 3 |
| commercial caffee/cocoa plantation | CC | 19 192 | 8 8 |
| deteriorated areas | | 5 177 | 2 4 |
| erosion + native pastures | PN/Er | 80 | 0 0 |
| erosion w/o vegetation | Er | 5 097 | 2 3 |

Map 8 Land uses in Chaparral-Amoya river basin

| use | symbol | area (ha) | % |
|---|---|---|---|
| natural areas | | 70 436 | 32 2 |
| paramo | Pr | 24 824 | 11.4 |
| natural forests (protected) | BNP | 3 217 | 1 5 |
| natural forests | BN | 42 395 | 19 4 |
| modified areas | | 58 743 | 26.9 |
| secundary growth forests | BNS | 4 311 | 2 0 |
| early 2$^{ndary}$ growth vegetation | R | 11 836 | 5 4 |
| native pastures+early 2$^{ndary}$ growth | PN/R | 42 062 | 19.3 |
| native pastures + pioneer weeds | PN/E | 534 | 0 2 |
| altered areas (pastures) | | 56 002 | 25 6 |
| native pasnures | PN | 48 084 | 22 0 |
| improved pastures | PM | 4 841 | 2 2 |
| introduced pastures | PA | 3 077 | 1 4 |

### 3.7.3.1 *Paramos and Andean forests (natural areas)*

Natural areas are restricted to the paramos and Andean forests, lower productivity biotopes of the upper reaches of the Ambeima and Amoya watersheds, limited by the acidic soils, often water-logged and the complex topography. Natural areas occupy ca. 1/3 of the land surface; practically there are no natural areas below the 2.300 m elevation[21]. Natural areas include 26% the PNN Las Hermosas, some 35 $km^2$ of paramos and ca. 350 $km^2$ of Andean forests which lay outside of the protected area, mostly in upper Ambeima's and Davis's watersheds[22].

The high degree of isolation, the inaccessibility and the lower productivity for traditional agriculture, have permitted the persistence of large tracts of land in a natural or quasi-natural condition, although there have occurred a number of human activities for prolonged periods (at least since the mid XIX century according to SEDIC, 1999), characterised by the extensive utilisation of land, the use of fire and biocides to manage succession: potatoes cultivation, which requires besides lime enrichment of soil; extensive grazing of ovine and bovine cattle, which compacts soil, induces erosion, displaces native herbivores and favours the establishment of ruderal herbs, and more recently, poppy cultivation, not very different from other cultigens in regards to its ecological consequences.

The latter, conforms a complex cycle of increase and decrease in which the international price of alkaloids and the enforcement of illicit crop control policies are just two factors. According to González & Briceño, 2002, there is a recent resurgence of the poppy culture in southern Tolima, including Chaparral and the Amoyá valley. If this new cycle resembles the former one, around the 1990's, two factors would induce changes in the composition vector of Amoya's landscape: forest replacement and immigration.

### *3.7.3.2 Paramo ecosystem and water economy of Amoya watershed*

Paramo ecosystem is a climacic, neotropical, high elevation, mostly herbaceous biotope, with a relatively high degree of endemism (large ratio of endemic to cosmopolitan species) of vascular plants as well as mosses, lichens and liverworts, very fragile and subjected to very slow natural succesional processes which exacerbate its fragility.

[21] A number of small to medium size, dispersed, fragments of tropical forests in natural status are located in the third altitudinal belt, below the ARHEP area of influence. The combine area of 18 fragments in the map is only 25 $km^2$ (mean fragment area = 1,4; standard deviation = 1,2 $km^2$).

[22] The degree of fragmentation cannot be determined from the available land use cartography (1:200.000 scale)

High altitude thin air, low atmospheric pressure, high solar radiation and evaporation, derive in very low metabolic processes in plants and animals: Slow productivity and growth rates in plants, slow rates of decomposition of organic matter and low bacterial and micro-organism activities, slow activities by animals and may other unique properties, and in the evolution of adaptations to deal with these eco-physiological restrictions.

Amongst these, the mechanisms to reduce evapotranspiration and to conserve water, play a very important role in the capacity of paramo vegetation and soils to regulate water flows. In the case of the Amoya River watershed, two factors add to this condition. On the one hand, the large number of high mountain lakes (over 300 according to UPN), within the paramo area in Las Hermosas National Park, and its relatively humid climate, as compared to other paramo ecosystems in Colombia and elsewhere in the Andean regions.

As was indicated earlier, optimal pluvial and thermal conditions occur at a lower elevation, around the 1.000 to 1.500 m belt, the altitude of the ARHEP and the traditional coffee-growing area throughout the American tropics, including the Amoya watershed. However, the paramo contribution to the water economy of the Amoya watershed –and of ARHEP– is derived mainly from the reservoir effect of the paramo vegetation and soils, rather than from a higher precipitation in the upper reaches of the watershed.

Thus, ARHEP benefits greatly from the conservation of paramo ecosystem, while it does not generate directly any threats to its persistence. The fears that the ARHEP would induce immigration and give access to the paramo areas, are not well founded, given at least three main reasons: One, the paramo areas, whether inside the National Park, or outside it, are quite far ecologically and physically from the project area. Two, ARHEP will require very modest development of new roads -only 5 km- which will be abandoned and the right of way restored to the present conditions, once the project is finished. And three, it ought to be pointed out the Amoya river paramo areas, as well as other sensitive biotopes in the upper basin, have suffered -even since before the creation of the National Park- severe alterations from settlements, cattle raising and agriculture, including the more recent extensive poppy cultivation. This constellation of factors underlines even more the need to carry out a project such as the ARESP -and ARHEP- in order to generate the financial and human resources needed to restore and conserve the paramo ecosystem.

### *3.7.3.3 Sub-Andean forests (extensive grazing-modified and subsistence agriculture-altered areas)*

In this belt lays the area most likely to be influenced by the ARHEP. A large proportion of the Andean-forest-biotope (205 $km^2$) and the upper reaches of the sub-Andean forest biotope (114 km$^2$) are mostly dedicated to extensive cattle grazing. Pastures are indeed the most important use of land in the Amoya river watershed, almost 100.000 ha (45,1% of the watershed area) are pastures, single or combined with young secondary vegetation (*enmalezados* or *rastrojos* in the map's legend). The upper third of the length of the Amoya river, within dry stretch –below the weir and upstream from the discharge– is mostly dedicated to pastures, near the river channel and with natural forests in the upper reaches from both margins.

The lower two thirds of the dry stretch are the coffee growing area equally divided into an upper part, mostly subsistence agriculture which combines coffee, a cash crop, with a large number of annual as well as perennial crops for self consumption, and the lower part with modern coffee plantations. Land use in the coffee growing area is intensive, which reflects the land-tenure structure[23].

In the upper and middle Amoya River valley, soils constitute a poor resource. They have evolved on a steep-sloped relief, are not well developed, are well drained and fairly eroded. In general they are not adequate for agriculture. Forestry is the recommended use and to certain extent, cattle raising in the upper, lower-slope sectors.

Land use in Amoya valley adequately reflects these limitations. Forests are located in the upper steepest, inaccessible areas, within the Las Hermosas National Park and in the very steep-sloped terrain of the Las Hermosas canyon. The middle valley, where the project will be located, corresponds to the pluvial-thermal optimum (best conditions of rainfall and temperature) but soils are poorest and erosion problems, due to excessive use and higher rainfall, reduced even more the quality of the soil resource. Pastures, alone, or in combination with young secondary vegetation is the main use of the soil in the upper watershed, while multiple species subsistence farming occupy most of the land in the middle elevations.

### 3.7.4 Status of organisms

The composition of the fauna and flora of the Amoya valley is little known. Paramo organisms have been better studied than other biotopes, but there are no specific studies of Las Hermosas National Park and neighbouring paramos. The Andean and sub-Andean forests of the Amoya valley have not been studied at all. SEDIC (1999), sampled the areas likely to be occupied by the ARHEP works and nearby rests of natural habitat; the lists of species thus generated for the area of influence of the project were cross-checked with the endangered species lists (red lists) published in the Internet by Institute Alexander von Humboldt[24], which do not discriminate the regions where a particular taxon has a given status. These lists were re-checked with the recently published red book series (Universidad Nacional de Colombia & Ministerio del Medio Ambiente, 2002) for some of the major taxa –mammals, aves, reptilia, fishes, phanerogamous plants (partial), briophytes– and fail to produce any new results. The synthesis of Sedics reports are presented in tab. 8.

Tab. 8. Synthesis of observations on species richness in Amoya middle valley 900-1600 m a.s.l. (SEDIC, 1999)

| taxon/category | families | species | in red list |
|---|---|---|---|
| mammalia | 10 | 13 | |
| aves | 29 | 67 | |
| reptilia | 5 | 9 | |
| amphibia | 3 | 3 | |
| pisces | 5 | 6 | 1 |
| woody plants | 42 | 76 | 1 |
| herbaceous plants | 25 | 43 | |

The rather scanty assemblages of flora and fauna from this table do not reflect the biodiversity of the Amoya region, but the inaccessibility of the natural habitat relicts within the middle valley, better illustrated with the oblique aerial photographs, taken during the dry season of 2003 (photos 1 to 6), and the limited low sampling effort carried out by Sedic, for all taxa in general, but particularly for amphibians and reptiles which are known to be much more diverse in these biotopes.

SEDIC's sampling was not restricted to natural habitats which are very fragmented and dispersed (see photographs 1 to 6), therefore the lists for mammals and aves include many insectivorous and omnivorous species normally found around human settlements (e. g.: Didelphis *marsupialis, Dasyprocta punctata, Sciurus granatensis* amongst mammals and *Thraupis episcopus, Turdus* spp, *Tyrannus melancolicus, Coragyps atratus, Crotophaga ani*, amongst the bird species).

23 The average size of the land holdings in Chaparral is 25,4 to 30,1 ha (IGAC, 1996), depending if PNN Las Hermosas is considered as a single state property or not. In any case, the mean land holding area in Amoya middle valley must be much smaller, because this figure includes the large land holdings (> 100 ha) with mechanised agriculture of the low valley.

24 Instituto de Investigacion de los Recursos Biológicos Alexander von Humboldt, a research organisation dependent from the Ministry of the Environment of Colombia. http://www.humboldt.org.co

1. Las Hermosas Canyon. Note steep slopes, forests rests on upper reaches

2. San José de las Hermosas, small settlement above the weir

3. Pasture management with fire in middle valley

4. Mossaic of uses and successional areas of different age

5. Erosion signs and intense use of land at rio Davis confluence

6. Palm break, typical of secondary succession in Andean forests

photos by Generadora Unión S. A.

### 3.7.5 Expected effects of the ARHEP and mitigation

Project's works and activities will be localised in reduced sectors within areas heavily altered by agricultural land use, scattered and nucleated rural settlements and a large network of secondary roads and mule and foot paths, among other factors. Peasant economies in the Amoya valley[25] traditionally are not used to reinvest in the natural environment to compensate for the accelerated transformation of resources; consumption is carried out without restitution (or rates of consumption are larger than rates of restitution and than natural restoration rates), the cycle crop/pasture - abandonment - recuperation - cultivation/pasture renewal is too short to allow for an effective accumulation of resources. The severity of this effect increases with elevation, the higher up the mountain the slower the natural rates of succession and the more damaging that human activities are.

[25] This statement is true of most peasant economies throughout Latin America. Nomadic, itinerant cultures that practice field rotation (slash-burn-cultivation harvest-abandonment) are the closest –in results, not in concepts– to a re-investment driven peasant economy.

Construction activities –road improvement and temporary service roads construction, excavation windows for tunnels, dam and sedimentation structures, borrow pits, camps, shops and other temporary facilities, etc.– will extend for over two years and will be distributed, during this period, over a very large area, ca. 3.000 ha, inscribed within 22 rural districts (*veredas*) that together have an area of 427 km$^2$, plus 355 km$^2$ from PNN Las Hermosas, within Chaparral jurisdiction. However, the area effectively affected by the works will be much smaller than all those figures. The EIS estimated (Sedic, 1999) in 128 ha the total area needed for the project, a rather modest figure. The damage that this can cause in the area is equally modest.

Nonetheless, in order to bring about changes in the social attitude towards natural resources and conservation in the Amoya region, it is most convenient that the ARHEP sets a good example. There are a number of ways in which the project could generate some positive changes:

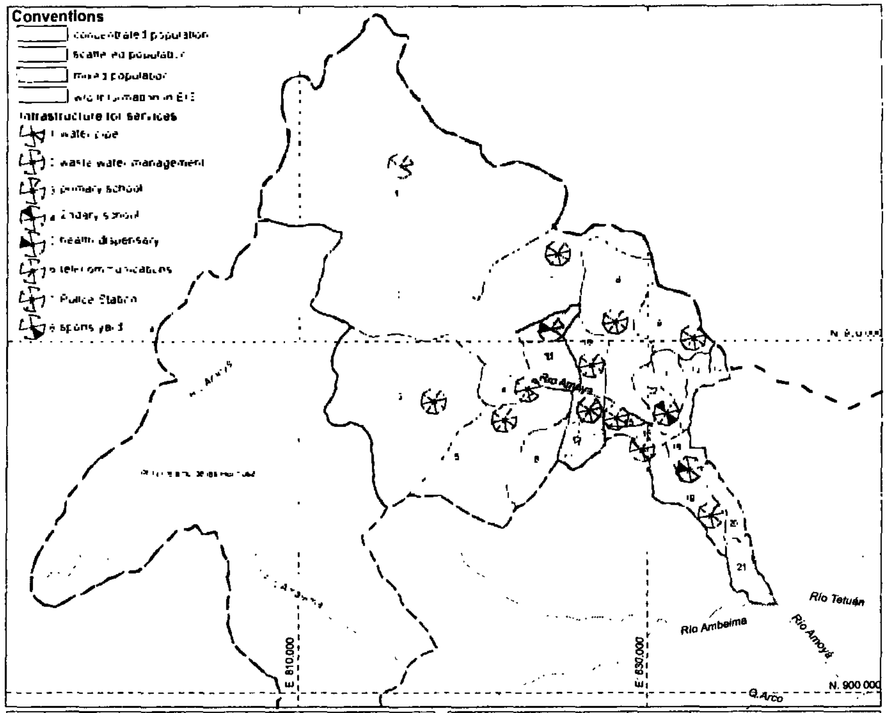
1. Restoration of areas temporarily occupied by the project (e. g., land fills and abandon roads, borrow pits, road sides) with fast growing, woody species, native to the Amoya valley.
2. Sponsoring of the conformation of school tree-nurseries, arboreta y herboreta, seed banks and other similar activities to produce material for restoration purposes
3. To stimulate the creation of school-based ecological groups to engage in a program of observations and documentation of natural phenomena relevant to the restoration processes, such as: phenologgy (plant leafing and leaf fall, blooming, fruiting and associated animal behaviour, e. g. pollination, fruit/seed dispersal, predation...), parent-tree identification
4. To advocate and promote the realisation of small restoration experiments in school grounds, which are not related to the ARHEP restoration activities, in order to reinforce the general importance of re-investment in the natural environment.
5. To catalyse the participation and engagement of city and provincial government institutions, CORTOLIMA and local NGO's in supporting the school system initiatives in restoration and conservation

## 3.8 Population, social, economic and cultural aspects

Although the data are scanty, several aspects of the population reflect the low quality of the resources and its inadequate use. On the one hand, in spite of its old age (at least over 200 years), settlements continue to be dispersed, they have not evolved into consolidated villages or a rural nucleated pattern common in newer colonisation areas in Colombia and elsewhere. Only San José de Las Hermosas in the upper cordillera has evolved along this line. Second, there is a consistent pattern of emigration and return immigration, associated to the up and downs in the supply of rural employment opportunities in the region. This was documented for the land distribution social processes during the La Violencia early periods, around the 1950's (Molano, 1994); and also during the boom of the poppy plantations, about 10 to 15 years ago.

The ARHEP will have a strong influence on the districts (*veredas*) shown in map 9. They cover an area of 427,5 $km^2$ and house some 1.050 families (5.761 inhabitants). Densities vary widely, upper areas being much less populated than the coffee-growing lower zone; settlement patterns range from concentrated to disperse. The housing is poor, houses are built mainly with bahareque (mud and cane walls) and wood, with roofs made of clay and zinc tiles.

*Health and sanitation.* Medical assistance, is inadequate, there are only two health promoters present in the zone of direct influence of the ARHEP, which is not enough to cover all the necessities of the districts. This clearly reflects the crisis faced by the hospital of the municipality. As for aqueduct services, it is frequent that houses take the water directly from close sources, pumping the water through hoses; just in the case of La Virginia there is a tank to keep the water free of sand. Population's health is being affected because just in some cases the water is boiled for human consumption. There is a lack of a sewer system in the area of direct influence of the ARHEP. The management of excreta and garbage is very primitive, very few haoses have septic tanks.




| ID | *vereda*/district | area ($km^2$) | population F* | I* | I/$km^2$ |
|---|---|---|---|---|---|
| 1 | San José | 124,9 | 72 | 381 | 3,0 |
| 2 | Tequendama | 58 6 | | | |
| 3 | Aurora A | 57 8 | | | |
| 4 | El Escobal | 5 4 | 100 | 529 | 98 7 |
| 5 | Janeiro | 31,1 | | | |
| 6 | Aurora B | 8,7 | 100 | 600 | 68,6 |
| 7 | El Cairo | 27,0 | 47 | 249 | 9,2 |
| 8 | Argentina | 27,6 | 100 | 600 | 21,7 |
| 9 | San Jorge Alto | 12,7 | 54 | 228 | 18,0 |
| 10 | Rionegro | 7,0 | 80 | 400 | 57,2 |
| 11 | Virginia | 11,3 | 40 | 250 | 22,1 |
| 12 | San Roque | 4,2 | 22 | 120 | 28,7 |

| ID | *vereda*/district | area ($km^2$) | population F* | I* | I/$km^2$ |
|---|---|---|---|---|---|
| 13 | San Jorge | 4,0 | 36 | 180 | 45,1 |
| 14 | Porvenir | 2,0 | 30 | 130 | 63,9 |
| 15 | La Honda | 2,2 | | | |
| 16 | Los Sauces | 3,6 | 55 | 275 | 75,3 |
| 17 | San Pablo | 8,6 | 70 | 490 | 56,7 |
| 18 | Vega Chiquita | 4,0 | 20 | 70 | 17,4 |
| 19 | El Moral | 10,1 | 100 | 400 | 39,4 |
| 20 | Angostura | 4,7 | 23 | 100 | 21,2 |
| 21 | La Salina | 5,9 | 11 | 60 | 10,1 |
| 22 | Sta Bárbara | 5,9 | 90 | 700 | 117,8 |
| | ∑ | 427,5 | 1.050 | 5.761 | 43,0 |

* F = # of families I = # inhabitants

Map 9. Patters of population settlement and basic infrastructure in middle Amoya river valley. The table below the map lists areas and settlers in the rural districts (*veredas*). Unpublished data from 1st semester 2003 surveys, kindly facilitated by Carlos Castaño Uribe to Generadora Unión S. A., to be quoted in the present report. Figures in red are inferred; grey boxes are without data.

*Education.* Facilities and service is inadequate; most districts have a primary school. In the Santa Bárbara district there functions a secondary school that is also attended by youngsters from nearby districts.

*Economy.* Land is mainly dedicated to agricultural activities. Main crops are coffee, plantain, cassava, beans, corn, tomato, peas, and fruit trees among others. The second most important economic activity is cattle and pigs raising. Almost ten years ago, the ARHEP area was affected by the poppy boom. Together with its cultivation, strong social, economic, and politic changes occurred. At present, poppy cultivation has been importantly diminished, and PLANTE projects are being developed. In the rural area some municipal, regional and national institutions are present, however, their performance and the implementation of projects in the zone is still very poor.

### 3.8.1 Archaeological findings potential

The potential for archaeological findings in the ARHEP region is high, given that the area was inhabited by the Pijao ethnic group, which has the reputation of being the strongest aboriginal tribe in the territory of what now is Colombia. The Pijao people offered resistance to the Spanish conquerors until late in the XVIII century, according to the sources cited by Sedic (1999), and their stronghold territory included the Amoya valley and the Las Hermosas paramo and Andean forests, indeed it reached from the Cauca to the Magdalena rivers valleys.

The area however has not been researched. For this reason Sedic carried out a preliminary survey that included ethnic-historic sources, testimonial evidence from the local inhabitants -some of whom are themselves interested in archaeological rests[26], and had actively searched the area– and extensive field work with local guides. The survey identified 24 sites, associated to small natural or artificial terraces, some of them in proximity of the Amoya river or tributary. Besides yielding material evidence in some of these sites (ceramic fragments, stone-carved waterers, basket weavings, rest of bones and other traces of human habitation), the survey concluded that the area is indeed of great historic and cultural interest.

Particular works of the ARHEP are restricted to small areas, but there are a large number of works sites scattered over a large area: borrow pits, permanent or temporary deposits, road improvement works, temporary roads, excavation windows, etc., which claim for the design of a strategy to properly deal with the likelihood of accidentally uncovering archaeological rests. Sedic strategy included three archaeological components in the EMP and an archaeological monitoring programme. The strategy is well conceived and it is based on first hand knowledge of the area and of the type of situations likely to be encountered.

Archaeological prospecting (plan C-11). It is conceived as a preventive measure to reduce the potential loss of knowledge about the history and culture and to help to construct local and regional identity. It should follow guidelines established by Instituto Colombiano de Antropología (ICAN, is the national governmental organisation responsible of the archaeological heritage) and specific requirements of environmental license. A detailed survey of the works sites with local guides and appropriate equipment is proposed; it should be developed before the construction phase. The prospecting will gave a three month duration and should define the scope of the archaeological rescue (C-12) One of the objectives of a extensive pre-construction prospecting is to reduce the costs of interruptions in the work plan in the case of eventual findings.

Archaeological rescue (C-12). Its scope, duration, costs, depend on the results of the C-11 plan (prospecting). It is also conceived as a preventive measure and has the same overall objectives of C-11. Specifically it is designed for the recuperation of material evidence and for the thorough documentation of the sites, the objects and other vestigial evidence that might be uncovered, and for the adequate handling of objects, artefacts and material evidence, according to the guidelines for field and laboratory work established by ICAN. The plan includes the preparation of a detailed report which should also be approved by ICAN. The archaeological rescue should be carried out before any of the construction activities.

Dissemination of archaeological information (C-13). It is conceived as a compensation measure, oriented towards the dissemination to the local population (Amoya valley, Chaparral and South Tolima) and to the academic and scientific communities at large, the results of the different components of the archaeological research carried out by ARHEP and to send a seed of pride in the rich history of Chaparral and the Amoya valley. The plan is to be carried out during the operation phase of ARESP.

Archaeological monitoring (D-5). It is a preventive measure designed to minimise the risk of accidental or intentional destruction or misappropriation of archaeological evidence. It should be carried out during the construction phase, according to the norms and requirements established by ICAN. It is responsibility of ARHEP owner but it covers duties particular to all construction contractors and their personnel. The plan includes detailed protocols for all interested parties.

[26] Alas this interest is for the purpose of finding gold ornaments and other valuable items for which there is an illegal market with international ramifications.

# 4 Environmental evaluation

## 4.1 Scope of the evaluation

The following paragraphs synthesise the EIS of the Amoyá River Hydroelectric Project. This takes the diagnoses of the main regional and local elements of the physical, biotic and socio-cultural environment described in the precedent chapters, and contrasts them with the diverse activities and actions that involve the execution of the project The purpose is to identify, describe and evaluate the impacts generated by the latter and to delineate the appropriate measures to prevent, correct, mitigate and compensate those impacts. These last elements conformed the Environmental Management Plan.

## 4.2 Works and basic construction actions

The ARHEP will generate 80 MW in two turbine-generator units that will operate as run-of-river, using a water flow of 18 $m^3/s$.

The project comprises the following works: access roads, intake works (intake dam, adduction conduits and settling tanks), water conduction and appurtenant ancillary works (pressure channel, pressure tunnel and construction window), tunnel and discharge works, powerhouse and appurtenant works, base camps, machinery repair shops; quarries hydraulic concrete plants (see tab 9.).

Tab. 9. Summary of works, indicators

| works item | unit | quantity |
|---|---|---|
| accesstunnel to power house | m | 700 |
| Σwater conduits | m | 12.473 |
| new roads | km | 5,6 |
| road improvement | km | 5,2 |
| underground excavation | $m^3$ | 195.244 |
| surface excavation | $m^3$ | 466.648 |
| materials to be disposed | $m^3$ | 364.489 |

The works will be completed by the following activities and actions during the construction stage: machinery and equipment operation, construction and implementation of base camps, repair shops and fuel deposits; accesses opening, removal of plant cover and humus (top soil) layer, formation of banks and landslides, improvement of existing roads and construction of projected roads, stabilisation of river banks, bridges building, establishment of areas for spare materials, exploitation of sources of materials (quarries and borrow pits), construction of works for bank treatment and establishment, demarcation and sign-posting (temporal and definitive), construction of intake and discharge works, access gates to underground works, construction of underground civil works in two stages, subterranean excavations, electromechanical assemblies and equipment proves.

### 4.3 Selected method for the environmental evaluation

Once the physic, biotic and socio-cultural primary features were recognised at local and regional levels, a ranking of environmental management areas was carried out, with the purpose to analyse the environmental restrictions, as well as locate and delimit exclusive and restricted areas based on the geomorphologic, hydrologic, climatic, biotic and social vulnerability of ecosystems.

Three categories of environmental management were established, as follows: exclusion areas, areas susceptible of intervention with restrictions, and areas susceptible of intervention without restrictions. For each of these categories, specific environmental management measures were established.

Once the zoning of environmental management areas was defined, an environmental evaluation of the area of direct influence of ARHEP was performed, under to different scenarios: without and with the project.

The environmental evaluation without project pretends to evaluate the actual environmental state based on the information and descriptions presented in the baseline. With that purpose, the environment was divided in first, second and third order components. The first order components are qualified from a zero (0) reference level –that corresponds to an undisturbed state– to a three (3) reference level –that corresponds to a very disturbed state. From these data, the current state of the components of second and third grade is established, based on their intervention percentage.

The environmental evaluation with project pretends to establish the environmental features after the implementation of the activities related to the construction and operation of the Amoyá River Hydroelectric Project, based on the current state of the environment. This evaluation consists of the following steps: desegregation of the components of the ARHEP, establishment of the Project-Environment interaction through a two-entries matrix, with the activities and operations in its vertical axis and the susceptible environmental elements in the horizontal axis; identification of impacts using diagrams action-effect-impact; classification of identified impacts according to their most rele-

[25] This statement is true of most peasant economies throughout Latin America. Nomadic, itinerant cultures that practice field rotation (slash-burn-cultivation harvest-abandonment) are the closest –in results, not in concepts– to a re-investment driven peasant economy.

vant environmental features; organisation of the impacts into a hierarchy, and as a final point, description and characterisation of the most relevant impacts.

### 4.4 Hierarchical organisation and quantification of the significant environmental impacts

The qualitative evaluation and hierarchical organisation of recognised impacts are based on the *Scheme of evaluation and hierarchical organisation of environmental impacts*[27], that describes features such as sign (adverse, favourable), temporal dimension (temporary or permanent), reversibility, recoverability, and magnitude.

[27] Adapted by the Forest Engineer Nicolás Roa A., from Guide Nº 2 , Ministry of Publ;ic Works, Spain, cited by SEDIC, 1999.

By their combination it is possible to establish the hierarchical organisation of each impact into a 0 to 5 scale. Additionally, an appropriate environmental measure for future applications is recommended. The results for the ARHEP are presented in tab. 9., simplified from SEDIC, 1999. Note that all the effects are adverse, therefore the sign column was eliminated[28],[29].

[28] Given the multi-causality multi-effect conditions of most environmental relations between a given project and a region, summaries of effects are often misleading as a given phenomenon is twice or more times accounted. In the case of the Amoya EIS, this situation is present; see for instance, *displacement* and *reduction* of terrestrial fauna, two effects with somewhat different qualifications. Other examples of multiple effect accounting are marked with gray boxes in table 10.

[29] The scales adopted by SEDIC to qualify the different attributes of a given consequence are relative; there are no standards to compare with. All it means is changes in relation to today's conditions.

Tab. 10. Ranking of adverse environmental impacts identified by SEDIC, 1999

| impact | temporality | reversibility | recoverability | magnitude | ranking | environmental management |
|---|---|---|---|---|---|---|
| land use changes | permanent | irreversible | irrecoverable | critical | 5 | compensation |
| landscape deterioration | permanent | irreversible | irrecoverable | critical | 5 | compensation |
| sloped terrain instability | temporal | irreversible | recoverable | severe | 3 | corrective |
| river dynamics and diminished flow | permanent | irreversible | irrecoverable | critical | 5 | compensation |
| water quality reduction | permanent | irreversible | recoverable | severe | 3 | corrective |
| air quality reduction | temporal | reversible | recoverable | moderate | 1 | mitigation |
| alteration of aquatic communities | permanent | irreversible | irrecoverable | critical | 5 | compensation |
| displacement of terrestrial fauna | permanent | irreversible | irrecoverable | critical | 5 | compensation |
| vegetation loss | permanent | irreversible | irrecoverable | critical | 5 | compensation |
| fragmentation of aquatic ecosystems | permanent | irreversible | irrecoverable | severe | 4 | compensation or corrective |
| terrestrial and aquatic habitats loss | permanent | irreversible | irrecoverable | severe | 4 | corrective |
| reduction of terrestrial fauna | permanent | irreversible | irrecoverable | severe | 4 | compensation or corrective |
| damage to infrastructure | temporal | irreversible | recoverable | severe | 3 | corrective |
| generation of hopes and expectations | Temporal | reversible | recoverable | moderate | 1 | mitigation |
| cultural and social clashes/friction | Temporal | reversible | recoverable | compatible | 0 | prevention |
| life quality alteration | permanent | irreversible | irrecoverable | critical | 5 | compensation |
| adoption of new technologies and materials | permanent | irreversible | irrecoverable | critical | 5 | compensation |
| appearance/increase sexually transmitted diseases | temporal | irreversible | recoverable | severe | 3 | corrective |
| temporary/permanent physical disabilities | permanent | irreversible | irrecoverable | critical | 5 | compensation |
| unsatisfied demand of services (health, others) | temporal | reversible | recoverable | moderate | 1 | mitigation |
| housing relocation | permanent | irreversible | irrecoverable | severe | 4 | compensation or corrective |
| political conflict generation | temporal | reversible | recoverable | moderate | 1 | mitigation |
| sacking+commerce of archaeological pieces | temporal | irreversible | irrecoverable | severe | 4 | compensation or corrective |
| damage+destruction of archaeological evidence | permanent | irreversible | irrecoverable | critical | 5 | compensation |

# 5 Environmental management measures

The Environmental Management Plan is the essential tool to prevent, correct, mitigate and compensate the predicted impacts caused by the activities and actions of the project. Its main objective is to promote the compatibility among Project, environment and community.

The environmental management measures are presented as index cards containing the following structure: general considerations, objectives, impacts to be controlled, description of activities, mechanisms and strategies of participation, spatial scope, instruments and indicators for monitoring, schedule of execution, people in charge, resources and projected budget.

Programs of monitoring were designed to verify the achievement of the proposed environmental management measures. These programs are applicable during the stages of construction and operation of the Project.

On the other hand, a Contingency Plan was designed for the treatment of risks derived from natural, human and operational hazards on physic, biotic, and socio-cultural elements of the environment.

Below, table 11., are listed the programmes that conform the environmental management plan recommended for the Amoyá River Hydroelectric Project: They are presented, following SEDIC's reports, organised by environmental component. The synthesis considers first the impacts and situations that ought to be managed, the type of measure and the appropriate program.

Table 12 details the costs of the EMP, underlines the responsibilities (contractor, project owner, engineering designer, etc.) and presents a simplified time plan of implementation of the EMP expenditures. This latter table includes some costs not detailed in the EMP prepared by SEDIC, 1999 and is based on a similar document prepared by Generadora Unión S. A. on June, 2003.

Tab. 11. Synthesis of Environmental management plan

| Impacts to be managed | type of measurement | ID | programme or measurement | cost at 10.2002 US$ |
|---|---|---|---|---|
| **Management of the physical environment** | | | | |
| generation of instability in sloped terrain and landscape alteration; loss and contamination of top soil, water quality alterration + effects on aquatic organisms; loss of vegetation cover and alteration of plant communities; fauna displacement<br>accidents by traffic of heavy machinery/vehicles | preventive | A-1 | Setting, operation and departure from temporary facilities | |
| lowering of water quality (sediments, biodegradeble and toxic material in streams) from camps, shops and other temporary facilities | preventive | A-2 | Management and treatment of sewage and other effluents | 16.506 |
| soil and stream contamination by inadequate disposal of solid wastes from different origins (camps, shops, etc.) | preventive | A-3 | Integral management of solid waste | 31.395 |
| damage of existing infrastructure, Chaparral Municipality water supply pipe | preventive | A-4 | Management of aqueduct infrastructure | |
| alterration of soils: erosión, waterlogging, compaction, loss, contamination and others | mitigative | A-5 | Protection, management and conservation of soils | [illegible] |
| alteration of fluvial and stream dynamics, changes in channel morphology, slope instability, loss of vegetation cover, load of inert materials to streams (sediments)<br>changes in land use and private land holding alteration; landsepape transformation<br>noise and uncorfortable nuisances | mitigative | A-6 | Explotation of materials' sources (quarries, borrow pits, etc.) | [illegible] |
| particle emission; sediment production; loss of vegetation cover<br>soil compaction, erosion slope instability and mass movement<br>alteration of / effects on: infrastructure, private land, land uses and landscape | mitigative | A-7 | Final disposal of excavation materials | [illegible] |
| emission of particles and gases; noise and visibility reduction<br>landscape alteration or damage to crops by dust settling on vegetation | mitigative | A-8 | Management of tailings and emissions to the atmosphere. | 53.337 |
| mass movements, rock and debris falling, erosion, degradation of river banks, and effects on infrastructure and natural drainage network ; landscpe alteration | mitigative | A-9 | Conservation and restoration of terrain stability | [illegible] |
| debris accumulation and affects on soils,vegetation cover, land use and landscape | compensatory | A-10 | Revegetation of altered areas (land fills, abandon roadways, camp+shop sites | 85.711 |

Tab. 11. Synthesis of Environmental management plan (continuation)

| Impacts to be managed | type of measurement | ID | programme or measurement | cost at 10.2002 US$ |
|---|---|---|---|---|
| **Management of the biological environment** | | | | |
| natural habitats reduction and fragmentation, fauna displacement<br>increase of hunting/poaching of species with commercial value | preventive | B-1 | Workshops on preservation of ecosystems | 24.489 |
| erosion, top soil loss; landscape alteration | preventive | B-2 | Removal ofvegetation cover | 8.121 |
| clear cut and over-extraction of valuable timber from forests remnants<br>reduction of forested areas, habitat destruction and degradation, fragmentation ansd isolation of animal populations | compensatory | B-3 | Conservation of forested areas | 13.058 |
| deterioration of Amoya's tributaries, lowering of water quality in dry stretch<br>recurrent lowering of flow in dry stretch and consequences on aquatic organisms | compensatory | B-4 | Conservation of watersheds | 19.591 |
| **Social management plan** | | | | |
| generation of hopes and expectations, cultural and social clashes/friction and life quality alteration; sacking+commerceplus damage+destruction of archaeological yields | preventive | C-1 | Environmental and cultural sensibilisation of population | 8.405 |
| changes in land uses and land property, alteration of land tenure structure, generation of hopes and expectations, social and political conflicts, changes in individual and group movility, increase of living costs | preventive | C-2 | Negotiation of the acquisition of terrains | [illegible] |
| lowering of life quality of affected families, increment of social tensions, migration increase | preventive | C-3 | Relocation of affected houses | [illegible] |
| generation of hopes and expectations, cultural and social clashes friction<br>population increase | preventive | C-4 | Contract of new personnel | [illegible] |
| lowering of quality of sorroundings, landscape deterioration, social and political frictions | preventive | C-5 | Environmental education to personnel | [illegible] |
| socioal and cultural clashes, lowering of living and human environment qualities; damage of archaeological heritage | preventive | C-6 | Environmental education to the community | 8.405 |
| increase of accidents and temporary and permanent lessions; increase of diseases EDA and IRA | preventive | C-7 | Industrial security. | [illegible] |
| lowering of living quality and human health, social tensions | preventive | C-8 | Control of sexually transmitted diseases | [illegible] |
| high morbility and mortality rates; social and political clashes<br>unsatisfied demand for public services and public health programs | preventive | C-9 | Basic health services. | [illegible] |
| deterioration of community's health; social and polítical tensions | compensatory | C-10 | Multipurpose Community Unit and Office of Community Services. | 86.642 |
| damage and destruction of archaeological heritage<br>loss of knowledge and history; building oflocal and regional identity | preventive | C-11 | Archaeological prospecting | 11.179 |
| damage and destruction of archaeological heritage<br>loss of knowledge and history; building oflocal and regional identity | preventive | C-12 | Archaeological rescue | 48.978 |
| lack of knowledge about local history | compensatory | C-13 | Dissemination of archaeological information | 2.204 |
| **Monitoring plan** | | | | |
| mass movements, rock and debris falling, erosion, bank degradation, damage of infrastructure and risks; increase of maintenance costs; financial losses due to changes in time plan | preventive | D-1 | Geothecnic monitoring of stability | - |
| lowering of water quality of Amoya and tributaries<br>recurrent diminished flows in dry stretch, effects on aquatic organisms | preventive | D-2 | Monitoring of water quality | 38.497 |
| work time loss; emission of particles and gases, noise; landscape degradiation for settling of dust on vegetation | preventive | D-3 | Monitoring of air quality | 53.288 |
| social and political tensions; Inmigration; hopes and expectations | preventive | D-4 | Monitoring of social actions | 24.489 |
| damage and destruction of archaeological heritage<br>lack of knowledge about local history | preventive | D-5 | Archaeological monitoring | 24.489 |

Tab. 12. Environmental Management Plan and Community Programmes

| | component | US$ at October, 2002 | comments | P | | | construction | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1 | | | 4 | | | 7 | | | 10 | | | 13 | | | 16 | | | 19 | | | 22 | | | 25 | | | 28 | | | |
| Compromisses | | 5.330.001 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Owner's responsibility | | 397.531 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Contractor responsibility | | 4.932.470 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Management of the physical environment | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A-1 | Setting, operation and departure from temporary facilities | | included in contractors direct costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | |
| A-2 | Management and treatment of sewage | 16.506 | contractors costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | |
| A-3 | Integral management of solid waste | 31.395 | contractors costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | |
| A-4 | Management of aqueduct infrastructure | | contractors costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | |
| A-5 | Protection, management and conservation of soils | | contractors costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | |
| A-6 | Explotation of materials' sources | | contractors costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | | | |
| A-7 | Final disposal of excavation materials | | included in general construction costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | |
| A-8 | Management of tailings and emissions to the atmosphere | 53.337 | contractors costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | |
| A-9 | Conservation and restoration of the geotechnic stability | | contractors costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | |
| A-10 | Replanting in areas where spare materials will be placed | 85.711 | contractors costs | | | | | | | | | | | | | | | | | | | | | | | | | | | | • | • | • | • | • | • | |
| | Management of the biotic environment | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| B-1 | Workshops on preservation of ecosystems | 24.489 | project owner costs (estimated by GU) | • | • | • | | | | | • | • | • | | | | • | • | • | | | | • | • | • | | | | | • | • | • | • | | | | |
| B-2 | Removal of plant material | 8.121 | contractors costs | | | | | | | | | | • | • | • | • | • | • | • | | | | | | | | | | | | | | | | | | |
| B-3 | Conservation of forested strips | 13.058 | contractors costs | | | | | | | | | | | | | | | | | | | • | • | • | | | | | | | | | | | | | |
| B-4 | Conservation of watersheds | 19.591 | project owner costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | |
| Protecting reforestation programme (20 ha) | | 39.182 | project owner costs (estimated by GU) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Social management plan | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| C-1 | Sensitising of the population | 8.405 | project owner costs | • | • | • | • | • | • | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| C-2 | Negotiation of the acquisition of terrains | | included in general construction costs | | | | • | • | • | • | • | • | • | • | • | • | | | | | | | | | | | | | | | | | | | | | |
| C-3 | Relocation of houses (if needed) | | included in general construction costs | | | | • | • | • | • | • | • | • | • | • | • | | | | | | | | | | | | | | | | | | | | | |
| C-4 | Contracting and induction of new personnel | | contractors costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | |
| C-5 | Environmental education programme for personnel | | contractors costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | |
| C-6 | Environmental education programme for the community | 8.405 | contractors costs | | | | • | • | • | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| C-7 | Industrial security | | contractors costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | |
| C-8 | Control of sexually transmitted diseases | | contractor's + owner's + MCU's costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | |
| C-9 | Basic health services | | contractor's + owner's + MCU's costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | |
| C-10 | Multifunctional Community Unit and OAC | 86.642 | project owner costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | |
| C-11 | Archaeological prospecting | 11.179 | project owner costs | • | • | • | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| C-12 | Archaeological rescue | 48.978 | project owner costs (estimated by GU) | | | | • | • | • | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| C-13 | Divulgation of archaeological information | 2.204 | project owner costs | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Monitoring plan | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| D-1 | Geothecnic monitoring of stability | | contractor's+owner's+engineering designer's costs | | | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | •••••• |
| D-2 | Monitoring of water quality | 38.497 | contractoed's +project owner's costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | •••••• |
| D-3 | Monitoring of air quality | 53.288 | contractoed's +project owner's costs | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | •••••• |
| D-4 | Monitoring of social actions | 24.489 | project owner costs (estimated by GU) | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | •••••• |
| D-5 | Archaeological monitoring | 24.489 | project owner costs (estimated by GU) | | | | • | • | • | • | • | • | • | • | • | • | • | • | • | | | | | | | | | | | | | | | | | | |

Tab. 12. Environmental Management Plan and Community Programmes (continuation)

| component | US$ at October, 2002 | comments | P* | construction 1 | 4 | 7 | 10 | 13 | 16 | 19 | 22 | 25 | 28 | O* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Environmental supervision | | included in general supervision costs | | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | |
| Environmental auditing | 41.631 | project owner costs | | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | |
| Contingency plan | | contractors costs | | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | ••• | •••••• |
| Environmental follow up | 1.988 | project owner costs | | | | | | | | | | | | |
| Forest utilisation taxes | 485 | project owner costs | | | | | | | | | | | | |
| Environmental Licence publication | 147 | project owner costs | | | | | | | | | | | | |
| Water concession | 2.521 | project owner costs | | | | | | | | | | | | |
| Used water effluent permit | 1.681 | project owner costs | | | | | | | | | | | | |
| Multipurpose Communal Unit (operation and programmes) | 668.000 | project owner costs | | | | | | | | | | | | |
| Reforestation and basic sanitation | 844.000 | project owner costs | | | | | | | | | | | | |
| Other works | 532.000 | project owner costs | | | | | | | | | | | | |
| Total | 2.665.000 | | | | | | | | | | | | | |

P = pre-construction phase O = operation phase

Operation time-plan is for a typical year

## 6. Conclusions

The construction and operation of ARHEP does not present any major threat to the natural and cultural conditions found at the present time at the middle valley, where the majority of the activities will take place and where the population likely to interact with the project lives.

The works are mostly concentrated in underground excavation of the tunnels for the conduction of water and the cavern needed for the power plant. The rock where most of the excavation will take place belongs to the Ibague batholith, which offers high security of stability and negligible risks of ex-filtrations.

Access roadways needed are short: 10,8 km, ca. 50% of which will be improvement of existing roads and the rest, temporary service roads, to be built along the Amoya left bank; once there is no longer a need for them, they will be abandon and the fallow terrain allowed to eventually integrate to the natural landscape. The temporary access roadway from La Virginia to Window 1, might require the displacement of 1, or at the most, 2 houses that lay near the alignment of the roadway; however, during actual construction the need to displace these houses could be avoided, especially considering the ephemeral nature of the infrastructure being built. Nevertheless, if houses need relocation the project will (i) built new houses with similar or larger areas; within the same land plot if possible (ii) provide the new houses with basic services (water, sanitation, electricity); and, (iii) support families relocation.

Other surface works are associated to the exploitation of quarries and borrow pits for materials needed for the concrete mixtures, and the back filling of permanent deposits for the materials left over from the surface and underground excavations. There are 11 deposits, distributed along the permanent roads in order to minimise transportation costs and roadway traffic, they have a combined capacity of 1,2 million $m^3$, somewhat larger than the expected volume of excess materials, taking material expansion into consideration. The environmental management plan includes detailed treatment of the deposits once their capacity is reached and the reclamation of the area with top soil saved from surface works elsewhere and planting of native woody, fast growing species to accelerate restoration.

An ample survey to identify likely areas of archaeological yields was conducted an a comprehensive plan for prospecting and rescue of eventual findings, was drawn up, in agreement with the guidelines and requirements from the Colombian Institute of Anthropology, the authority in matters related to the preservation of the cultural heritage.

The implementation of the different programmes of the EMP is fully integrated to the development of the social and conservation elements of ARESP, including a very solid component of community participation. Programmes and activities go beyond what is strictly needed to attend the limited alterations expected from the construction and operation of ARPP.

The main aspect in regards to the environmental effects is related to the modification of the natural regime of the Amoya river in a short stretch below the weir, as a consequence of the operation of the project. The diminished flows are likely to have effects on the aquatic habitats and organisms of the short stretch, and on the current mis-utilisation of the river as a sink for domestic and coffee-agriculture-related contamination loads. It ought to be pointed out that neither of the loads is large nor are they expected to grow in the near future. This condition reduces the importance of the potential effect of the reduced flows.

The project design contemplates a permanent flow of 1 $m^3/s$ that would pass through the weir to be maintained as *minimum flow for in-river needs* or *ecological flow*. The installed capacity and mean energy of the ARPP are not affected by this $Q_e$.

The potential effects (to habitats and organisms and for dilution of contamination loads) are both susceptible of minimisation and it is recommended that the ARHEP includes mitigation and control measurements –such as the ones here outlined– as components of the social and conservation plan of the ARESP.

ARHEP on the other hand, depends to a large –and unknown degree– on the conservation of paramo and Andean forest habitats of the upper watershed. Most of the area is under protected status in the Las Hermosas National Park; this however does not guarantee the persistence of the conditions that make paramo soils and vegetation a live water reservoir. Indeed, cultivation, free ranging cattle grazing, fire management of pasture lands, poaching, illegal appropriation of lands, and more recently, poppy cultivation, are amongst the main threats for the sustainability of the paramo.

These conditions, together with the fragility and limited resilience of both biotopes, particularly of paramos, claim for the implementation of long term, wide reaching, conservation programmes, and the integration of efforts with the MoE, CORTOLIMA, Chaparral and neighbouring municipalities and with the local population and their organisations.

ARHEP has the possibilities of generating resources that can be applied to the conservation of the paramo and Andean forest biotopes and to the formation of the human resources with the knowledge and sensitivity needed to carry out that singular challenge.

## Bibliography and documentation


Adams, Jonathan M. & H. Faure. 1995. Global atlas of paleovegetation since the last glacial maximum. South & Central America including Mexico and the Caribbean. 18-21,000 years ago (Last Glacial Maximum, or LGM). Quaternary Environments Network (QEN). http://www.soton.ac.uk/~tjms/samerica.html

Becking, M L. 1990. Un estudio comparativo preliminar sobre la retención de agua por la vegetación y el suelo, en un área con clima relativamente seco (Neusa) y otra con clima relativamente húmedo (Chuza), Cundimarca, Colombia. Ecoandes Project Report, Universiteit Van Amsterdam. p 3-17.

Bedoya Montoya, Héctor Jairo; José Néstor Salazar Arias. 1985. Los lodos de la digestión anaeróbica de los frutos de la pulpa del cafeto como abono para los almácigos. CENICAFE 36(4):112-124. Chinchiná, Caldas

Brehm, J. & M.P.D. Meijering. 1982. Fließgewässerkunde. Quelle & Meyer/ Heilderberg. 311 pp.

Brown, Cate & Jackie King. 2002. Environmental flows requirements and assessment. Chapter 5., pp.110-134 in Rafik Hirji, Phyllis Johnson, Paul Maro, Tabeth Matiza Chiuta (eds.) Defining and mainstreaming environmental sustainability in water resources management in Southern Africa. SADC, IUCN, SARDC, IBRD, SIDA.

CVC. 2000. Planacción 2000-2003. http://www.cvc.gov.co/frames/texto/planesprog/planaccion.htm

Deeb, Alejandro. 2003. Servicios Ambientales del Río Amoyá. Revisión de Análisis Hidrológicos y de Generación Eléctrica. Informe inédito al WB. Marzo de 2003.

Flórez, Franz Kaston. 2003. JIMBA KUSH DEL TOLIMA. Programa participativo de conservación de danta en comunidades paeces del Tolima. Informe sin publicar. Ibagué.

González Arias, José Jairo, Luis Hernando Briceño. 2002. Escenario amapolero en el sur del Tolima. http://www.mamacoca.org/feb2002/

González del Tánago del Río, Martha y Diego García de Jalón. 1995. Restauración de ríos y riberas. Escuela Técnica Superior de Ingenieros de Montes. U.P.M. Madrid

Groombridge, Brian & Martin Jenkins. 1998. Freshwater Biodiversity: a preliminary global assessment. WCMC Biodiversity Series No. 8 World Conservation Monitoring Centre WCMC - World Conservation Press. WCMC, UNEP. http://www.unep-wcmc.org/information_services/publications/freshwater/

Hidrotec Ltda. 1997. Estudio del potencial hidroeléctrico de los ríos Amoyá y Ambeima. Inédito.

Hofstede, Robert. 1995. Effects of burning and grazing on a Colombian páramo ecosystem. Ph D Dissertation. Hugo de Vries- Laboratorium Univesity of Amsterdam. Amsterdam, Netherlands

Hofstede, Robert. 1997. La importancia hídrica del páramo y aspectos de su manejo CDPP_2: Contribución. http://www.condesan.org/infoandina/Foros/cdpp/cdpp31.htm

Hofstede, Robert. 2002. Los páramos Andinos; su diversidad, sus habitantes, sus problemas y sus perspectivas. Un breve diagnóstico regional del estado de conservación de los páramos. http://www.paramo.org/regional.PDF

IGAC. 1996. Diccionario Geográfico de Colombia. Versión en CD ROM. Bogotá.

Ingetec, S.A.1998. Aprovechamientos hidroeléctricos de los ríos Amoyá y Ambeima. Documento UNION AA/001. (Julio,1998)

Instituto Mi Río & Universidad de Antioquia. 1997. Aspecto social, ecológico y ambiental del río Medellín. Instituto Mi Río, informe final, inédito. Medellín.

Instituto Mi Río & Universidad de Antioquia. 2001. Segunda evaluación biológica del río Medellín. Instituto Mi Río, Colombia Limpia Ltda., Colnet Ltda., informe final, inédito. Medellín.

Lizcano, D. J., V. Pizarro, J. Cavelier and J. Carmona. 2002. Geographic distribution and population size of the mountain tapir (Tapirus pinchaque) in Colombia. Journal of Biogeography, 29, 7-15

Mejía Villegas S. A. 1998. Estudio de Conexión de la Central Hidroeléctrica Amoyá 2B 78MW en el Departamento del Tolima. Documento 8-320-9600-001

Mojica, J. I., C. Castellanos, S. Usma y R. Álvarez. 2002. Libro rojo de peces dulceacuícolas de Colombia. La serie Libros Rojos de Especies Amenazadas de Colombia. Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Ministerio del Medio Ambiente. Bogotá, Colombia

Molano, Alfredo. 1994. Trochas y fusiles.Universidad Nacional de Colombia/Instituto de estudios olíticos y Relaciones Internacionales. El Áncora Editores.

Moreno Beltrán, Luis Francisco. 1989. Colonización del perifiton en tres embalses del oriente antioqueño. M. Sc. Thesis: Universidad de Antioquia, Facultad de Ciencias Exactas y Naturales, Departamento de Biología.

Navas, Carlos A. 2002. Herpetological diversity along Andean elevational gradients: links with physiological ecology and evolutionary physiology. Comparative Biochemistry and Physiology - Part A: Molecular & Integrative Physiology Volume 133, Issue 3 , November 2002 , Pages 469-485

Olson, David M., Eric Dinerstein, Jonathan Adams, Robin Abell, Rodolfo Werner, Patrick Hurley. 1998. The global 200: a representation approach to conserving the earth's distinctive ecoregions. http://www.worldwildlife.org/news/pubs/g200pdf.pdf

Peterson, Christopher G.1987. Influences of flow regime on development and desiccation response of lotic diatom communities. Ecology 68 (4): 946-954.

Petts, G. E., & I. Maddock. 1996. Flow allocation for in-river needs. pp. 60-78 in: Geoffrey Petts and Peter Calow. River Restoration. Blackwell Science, Oxford, England.

Rangel Ch., J. Orlando (Editor). 2000. La región de vida paramuna de Colombia. Colombia diversidad biotica. Universidad Nacional de Colombia (Bogota).

Restrepo, Pedro Juan. 1998. Revisión de los cálculos hidrológicos y energéticos de los ríos Amoyá y Ambeima. Documento inédito para Generadora Unión S. A.

Roldán, Luis Fernando & Lenis S Gustavo Adolfo. 1986. Inventario íctico del Cañón del río Claro y de sus principales afluentes. Universidad de Antioquia. Facultad de Ciencias Exactas y Naturales.

Saldarriaga T., Carlos. 2002. Proyecto Amoyá,. Hidrología mensual y diaria. Simulación Energética. Curvas de duración de caudales. Informe n° 3. Documento inédito para Generadora Unión S. A., Medellín (diciembre de 2003)

Salomons, Johannes Barwold. 1986. Paeoecology of volcanic soils in the Colombian Central Cordillera (Parque Nacional Natural Los Nevados). Dissertationes Botanicae Band 95. J Cramer. Berlin.

Sedic S. A. 1999. Proyecto Hidroeléctrico del Río Amoyá. Estudio de Impacto Ambiental. Generadora Unión S. A. Medellín.

Shwarzbold, A. 1990. Métodos ecológicos aplicados al estudio del perifiton. Acta Limnol. Brasil. Vol III. 545-592

Silva Carreño & Asociados S. A. Octubre de 1994. Actualización estudios preliminares pasos de la cordillera central paralela Ibagué – Armenia y corredor Melgar – Buga . Oficio a Ministerio de Transporte.

Sturm, Helmut; Orlando Rangel Ch. 1985. Ecologia de los paramos andinos: una vision preliminar integrada Universidad Nacional de Colombia (Bogota)

Tennant, D. L. In-nstream flow requirements for fish, wildlife, recreation and related environmental resources. Fisheries 1(4): 6-10

UNDP. 2000. Colombia: Conservation of Montane Forest and Paramo in the Colombian Massif, Phase I. Project Brief. UNDP.

UPN. 1999. Proyecto Conservación de la Biodiversidad de Importancia Global en los Ecosistemas de Páramo y de Bosque Alto Andino del Macizo Colombiano y Nudo de los Pastos. (ETAPA DE FORMULACION). Ministerio del M edio Ambiente. PNUD - GEF. http://personales.com/colombia/popayan/MINAMBIENTE/index.htm

Uribe, Alfonso; Bercelio Laverde. 1972. Distribución anual de la cosecha de café. AVANCES TECNICOS CENICAFE. N°16.

van der Hammen, Thomas. 1992. Historia, ecología y vegetación. Corporación Araracuara. Bogotá.

Vargas Rios, Orlando. 1997. Un modelo de sucesión-regeneración de los páramos después de quemas. Caldasia. 19:331-345

Vargas Tisnés, Isabel Cristina. 1989. Inventario preliminar de la ictiofauna de la hoya hidrográfica del Quindío. Corporación Autónoma Regional del Quindío. División de recursos Naturales. Sección Aguas. Inédito.

Vari, R.P. & S.H. Weitzman, 1990. A review of the phylogenetic biogeography of the freshwater fishes of South America. In Peters, G. and R. Hutterer (eds.): Vertebrate in The tropics, Museum Alexander Koenig, Bonn, pp.381-393

Villegas Gutiérrez, Fabio. 2003. Informe sobre los riesgos durante construcción. "Proyecto de Servicios Ambientales del Rio Amoya". Hidroger S. A. Inédito, mayo, 2003.

Welcomme, Robin L (comp.). 1988. International introductions of inland aquatic species. FAO Fis Tech. Pap. (294):318 p. http://www.fao.org/docrep/x5628e/x5628e0e.htm