# Upstream Nachtigal Hydroelectric Project

SUMMARY OF ENVIRONMENTAL AND SOCIAL STUDIES

**Agence de Lyon**
Le First Part-Dieu
2 avenue Lacassagne
69425 Lyon cedex 03
Tel. : 04 37 65 38 00
Fax : 04 37 65 30 01

**DATE:** 23-MAY-17 **REF:** 8541191

ARTELIA, L'union de Coteba et Sogreah

# CONTENTS

# FIGURES AND TABLES

# 1. INTRODUCTION

## 1.1. PROJECT BACKGROUND

Faced with growing needs for energy, in 2006 the Government of Cameroon developed a long-term Electricity Sector Development Plan by the year 2030 and updated the plan in 2014 till year 2035 (PDES 2035). The plan is a technical, environmental and economic framework for the development of electricity production. According to the ranking of the 54 potential hydroelectric production sites in Cameroon established by the ESDP 2035, the Nachtigal site (dubbed Nachtigal Upstream) is one of the most interesting hydropower sites in the country, in economic and environmental terms. It is therefore listed among the priority facilities in the overall development strategy. The development of this project is one of the main tools that would help address, in a sustainable manner Cameroon's, development needs.

Technical and economic studies conducted in 2005 and 2006 demonstrated that the project is feasible but dependent on building the Lom Pangar upstream regulation dam. It required waiting for the Lom Pangar project to get to an advanced stage before relaunching the Nachtigal Hydroelectric Project in 2011. Five years after the initial ESIA of 2006 and in accordance with Cameroonian regulations, the ESIA was updated in 2011. This later is the baseline ESIA of the project including the preliminary ESMP.

***Fig. 1. The Nachtigal Upstream site***

On 8 November 2013, a joint development agreement (JDA) was signed between a Group of Investors including the Government of Cameroon (GoC), EDF, the International Finance Corporation (IFC) and Rio Tinto Alcan (RTA)* for the development of the project.

**RTA has meanwhile left the project development.*

The project is a response to the energy needs of Cameroon and electric production by the project is for the South interconnected network (RIS) through ENEO, the Cameroonian operator. The objective is that the project development phase ends in 2017. The commissioning of generators will take place between 2021 and 2022.

## 1.2. PURPOSE OF THE DOCUMENT

An environmental compliance certificate was obtained in April 2014 based on the 2011 ESIA baseline. However, the preliminary ESMP attached to the ESIA showed that it was not detailed and accurate enough to the new co-developers and the Ministry in charge of the environment in Cameroon (MINEPDED). It was therefore necessary to provide more details to make it more operational and adapted to new realities of the Project. In this regard, the co-developers have outlined a complementary environmental and social studies

program, some of which are envisioned by the ESIA to complement the latter and develop a detailed ESMP, which has been validated July 2016.

The purpose of this document is to present in an organized manner the summaries of environmental and social studies as a continuation of the 2011 ESIA.

After a presentation of the project (§ 2) and the summary of the 2011 ESIA (§ 3), this document presents, in three sections, complementary studies conducted:

- 4: POST-ESIA ADDITIONAL Baseline studies: METEOROLOGY, AIR QUALITY, NOISE LEVELS AND SEDIMENT TRANSPORT ;
- 5: ADDITIONAL INVENTORIES AND STUDIES on IMPACTS ON THE NATURAL ENVIRONMENT ;
- 6: ADDITIONAL STUDIES ON THE HUMAN ENVIRONMENT

The table below gives the list of complementary studies presented in these sections.

**Tabl. 1 - List of complementary studies conducted to complete the 2011 ESIA**

| Section | Title / Object | Authors | |
|---|---|---|---|
| POST-ESIA ADDITIONAL Baseline studies: METEOROLOGY, AIR QUALITY, **NOISE LEVELS AND SEDIMENT TRANSPORT** | | | |
| 4.1 | Local Meteorology | CARFAD | |
| 4.2 | Air Quality Baseline | CARFAD | |
| 4.3 | Ambient Noise Baseline iN VILLAGES near THE PROJECT | CARFAD | |
| 4.4 | Expertise of hydro sediment impact on the Sanaga river. | ARTELIA | |
| **ADDITIONAL INVENTORIES AND STUDIES on IMPACTS ON THE NATURAL ENVIRONMENT** | | | |
| 5.1 | Update of the fauna and flora | CARFAD | |
| 5.2 | study on the distribution and flowering of Ledermanniella | Dr. Ghogue (IUCN / CARFAD) | |
| 5.3 | Fish population base line study | Dr. Bitja-Nyom (University of Ngaoundere | |
| 5.4 | Minimum environmental flow | ARTELIA | |
| 5.5 | STUDY On the need to clear vegetation in the NACHTIGAL reservoir area prior to reservoir filling | EDF | |
| **ADDITIONAL STUDIES ON THE HUMAN ENVIRONMENT** | | | |
| 6.1 | Economic and social study and management plan for sand-mining sector. | EGIS Cameroun | |
| 6.2 | health study and action plan | CARFAD | |
| 6.3 | Local Capacity and manpower study and action plan. | CARFAD | |
| 6.4 | social influx management plan | EGIS Cameroun | |

# 2. DESCRIPTION OF THE PROJECT

## 2.1. BRIEF HISTORY

The site of the Nachtigal upstream dam was identified in the 1950s, and described more explicitly in 1974 under pre-project studies carried out by EDF-Dafeco on behalf of Electricité du Cameroun (later known as SONEL).

The possibility to equip the site with a high power hydroelectric facility has since been reviewed severally, especially on behalf ALUCAM between 2006 and 2012. These studies identified the main features of the facility (RN ranking, dam axis, main functions, ...) taking into account technological developments since the first studies of the 1970s and Cameroon's growing energy demand.

In 2013, following the change of the Project developers, the co-developers (the Government of Cameroon, EDF, RTA and SFI) decided to launch a detailed pre-project study (PPS) to refine previous studies mentioned above and optimize the design. Without questioning the fundamentals, the PPS carried went far more in depth into certain aspects and revised others. The main changes to the project at the PPS stage concerned:

- the possibility to generate state-of-the-art energy for the RIS, including an increase of the tidal range of the reservoir and an hydropeaking operation of generator units ;
- the establishment of a minimum in-stream flow to preserve certain habitats;
- closing the left bank of the reservoir using a secondary dam to prevent interaction with the embankment of the Transcam2 railway and have ample space in relation to high water level;
- evacuation of floodwaters mainly through free threshold (more robust);
- readjustment and optimization of the main structures (dams, canal, plant, production point) for easier, faster, less expensive construction, better hydraulic operation or easier maintenance. .

Project modifications on the 2011 design can minimize certain impacts or create new ones, and thus require new measures. A downstream and cumulative impact assessment reviews the environmental and social implications of these minor design and operational changes.

## 2.2. KEY PROJECT FEATURES

- The project is developed by four* partners (the State of Cameroon, EDF, IFC and RTA), under a joint development agreement signed on 8 November 2013; **three since the departure of RTA from the project*
- The consortium has exclusive rights to develop the project under an agreement signed with the State of Cameroon on 10 July 2014;
- The project is a national priority to further secure the electrical system of Cameroon;
- The project is to design, build and operate for the duration of the lease a dam and a hydroelectric plant on the Sanaga RiverSanaga River at the Nachtigal Falls upstream (located at 65 kilometers northeast of Yaoundé) and an evacuation line of 50 kms of 225 kV in technical terms up to Nyom2 (north of Yaoundé);
- The total capacity installed stands at 420 MW, with 7 generators with an electric power unit of 60 MW, corresponding to a 980 $m^3/s$ design flow.
- Hydrology is regulated by the upstream Mbakaou and Lom Pangar dams providing an objective turbinable dry season flow of 650 $m^3/s$ and an average annual energy yield of 2.85 TWh at Nyom2;
- The run-of-river dam operates on small land and limited environmental and social impacts;
- The investment is funded under Project finance;

- Construction is expected to start in 2018 and operational commissioning of the 7 turbines will be between 2021 and 2022.

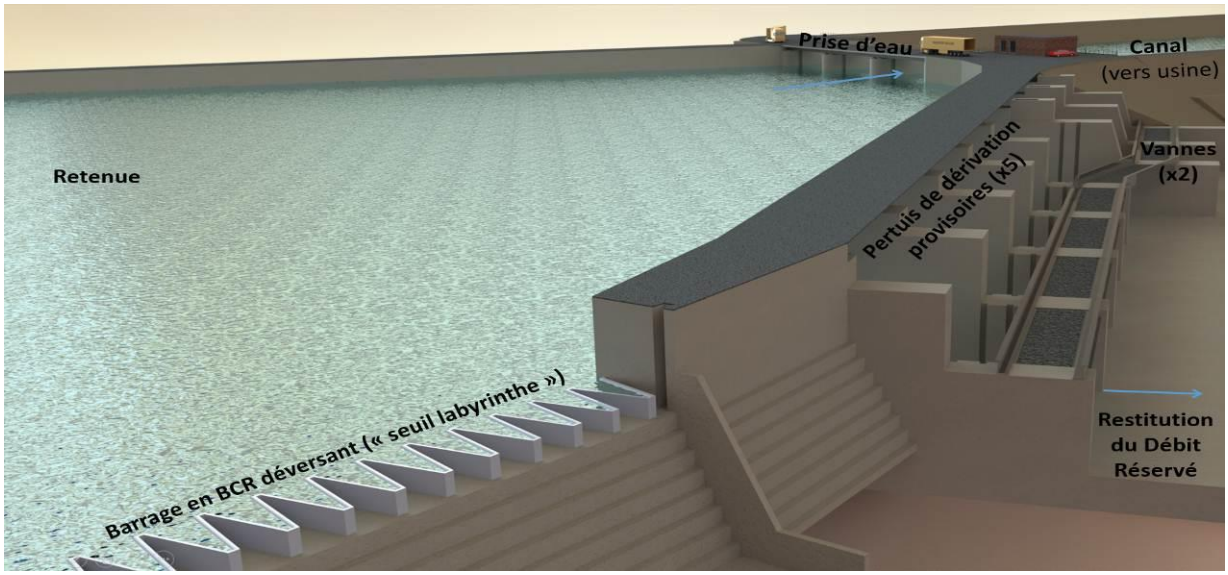



***Fig. 2. View of upstream facilities***

## 2.3. OPERATION METHODS

There are two clearly marked seasons in a hydrological year at Nachtigal: a period of 32 weeks (dry season) during which hydrological intake is regulated at 650 $m^3/s$ by upstream reservoirs (Lom Pangar and Mbakaou) and a period of 20 weeks (wet season) during which the inflow may exceed significantly the design flow of the facility by 980 $m^3/s$. Several operating methods have been retained, as follows.:

- During the wet season, inflow is well above the design flow of the facility, thus a run-of-the-river maximum operation flow has been retained;
- During the dry season, two operational methods will be possible:
  - Run-of-the-river operation, the facility instantaneously turbining all the water inflow at a constant reservoir level;
  - Daily hydropeaking operation helps to provide maximum power to the grid during peak consumption hours by slightly deepening the reservoir, and limiting production during the rest of the day to replenish the hydraulic stock.

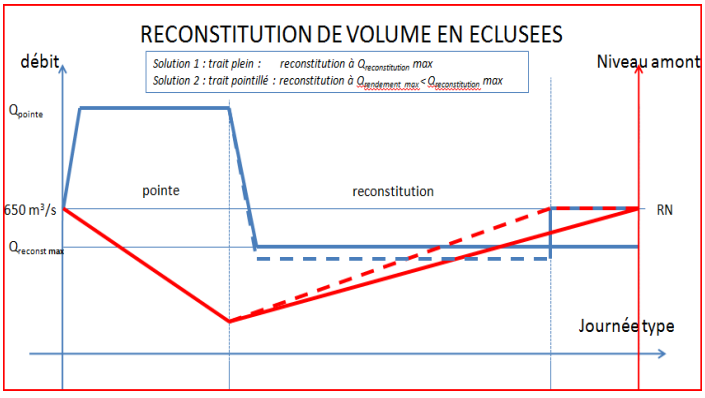



***Fig. 3. Principal of hydropeaking operation***

## 2.4. PROJECT FEATURES AND LAYOUT

The table below provides the technical factsheet of the facility and the figures that follow show the location and the layout of the project

**Tabl. 2 - Technical factsheet of the facility**

| | |
|---|---|
| **General** | |
| Nominal power of the installation | 420 MW (7*60MW) |
| Design flow | 980 $m^3/s$ |
| NR reservoir area | 4.21 $km^2$ |
| NR reservoir volume | 27 800 000 $m^3$ |
| Useful volume between NR and MOL | 6 100 000 $m^3$ |
| **Hydrology** | |
| Target flow (95 % of the time) | 650 $m^3/s$ |
| Exceptional flood (Qi10 000) | 7 500 $m^3/s$ |
| Ten-year flood (Q10) | 4 400 $m^3/s$ |
| **Characteristic levels** | |
| More extreme high waters (MEHW) | 514,7 NGC |
| Highest waters (HW) | 514,5 NGC |
| Normal reservoir (NR) | 513,5 NGC |
| Minimum Operation Level MOL) | 512,0 NGC |
| **Main release dam** | |
| Dam type | Dam weights BCR — Upstream face BCRE |
| Spillway type | Free airy maze threshold on dam ridge with a developed length of 4 710 m |
| Full length of the dam | 1 455 m (of which 1 380 m long pouring) |
| Maximum height on foundation | 13,6 m |
| Ridge elevation pad on the right bank | 516,00 NGC |
| Upstream face | Vertical |
| Downstream face | Staircase;1V/0,5 H |
| Ridge width | 7 m at the ridge 512,1 NGC |
| Maze threshold ridge elevation | 513,60 NGC |
| **Left bank close-up dam Barrage** | |
| Dam type | Dam weight BCR — Upstream face BCRE |
| Total dam length | 553 m |
| Maximum height from foundation | 16 m |
| Upstream face | Vertical |
| Downstream face | Staircase;1V/0,4 H |
| Ridge width | 5 m |
| Ridge | Varying from 516,0 NGC to 518,5 NGC |
| **Temporary by-pass opening** | |
| Type | 5 Conventional vibrated concrete floodways |
| Opening threshold | 501 NGC |
| Floodways | 5 x 17 x 16,2 m |
| Cofferdam construction phase | Metal cofferdams |
| Final closure | Concrete plugs |
| **Gated flood spillway** | |
| Type | 2 gated floodways with vibrated conventional concrete |
| floodways | 2 x17 x 14,2 m |
| Floodways threshold | 503 NGC |
| Floodgate | 2 valves segment 17 x 10,7 m |
| Valves | Installed on valves segment — 2,5 x 14m |
| Floodgate flow under RN | 2 x 980 $m^3/s$ = 1960 $m^3/s$ |
| Floodgate flow under PHE | 2 x 1110 $m^3/s$ = 2220 $m^3/s$ |
| Floodgate flow under CME | 2 x 10 $m^3/s$ |
| Valves flow under RN | 2 x 80 $m^3/s$ |
| Operation cofferdam | Metal cofferdams |
| **Upstream water intake canal** | |
| Type | 3 Conventional vibrated concrete floodways |
| floodways | 3 x17 x 11,2 m |
| Floodway threshold | 506 NGC |
| Operation cofferdam | Metal cofferdams |

| | |
|---|---|
| **Inlet canal** | |
| Length | 3 067 m |
| Width of invert | Varying from 60 m to 20 m |
| Maximum depth | 15 m |
| Internal slopes | 2.1H/1V |
| External slopes | 2.1H/1V — berms all 7 m |
| Waterproofing | Conventional vibrated concrete — 0.2 m |
| **Water inlet by-pass** | |
| Length | 250 m |
| Width of invert | Varying from 20 m to 70.20 m |
| Maximum depth | 21,5 m |
| **Power water inlet** | |
| Type | 7 Conventional vibrated concrete sluices |
| Width of sluices | 5,60 m |
| Height of sluices | Gradual from 15.10m to 5.60 m |
| Head valves | 7 valves winch wagon 5.6m x 5.75m |
| cofferdams | 1 metal cofferdam 7,00m x 5.875 m |
| Wire rack | 63 m x 15, 5 m— slanted at 15° |
| **Penstock pipes** | |
| Type | 7 separate piping |
| Embankment slope | 45° |
| Internal diameter | 5.60 m |
| Length | From 74.5 m to 80.5 m |
| Velocity (at turbined Qmax) | 5.7 m/s |
| **Hydropower plant** | |
| External dimensions: | |
| Height above foundations | 35.75 m at the ridge |
| Width | 46.75 m |
| Length | 142.2 m |
| Turbine (Francis vertical axis) — Water power | 7 x 62 MW |
| Electric power at transformer outputs | 60 MW |
| Rotation speed | 136.4 tr/min |
| Alternator 10,3kV, 50 Hz | 7 x 73 MVA |
| Three-phase power transformer 10,3/225 kV | 8 x 73 MVA, ONAN/ONAF<br>(a spare transformer) |
| Cofferdam | 14 sets of cofferdams 6.7x 6.2 m |
| **Outlet canal** | |
| Length | 800 m |

| Transport post and lines | |
|---|---|
| Liaison Plant – Production post | |
| Type | Aster 228 — 7 x single-beam and single conductor |
| Length | 7 x 800m |
| Production post | |
| Type | 225 KV open to 2 sets of busbar |
| Line 225 kV | |
| Supply point | Connection station of Nyom 2 |
| Type | Aster 570 — double-beam — double conductor |
| Length | 50.3 km |
| Width of the DUP allowance area | 50 m |
| Corner pylon | 10 (+start and finish gantries) |


***Fig. 4. Location of the project***

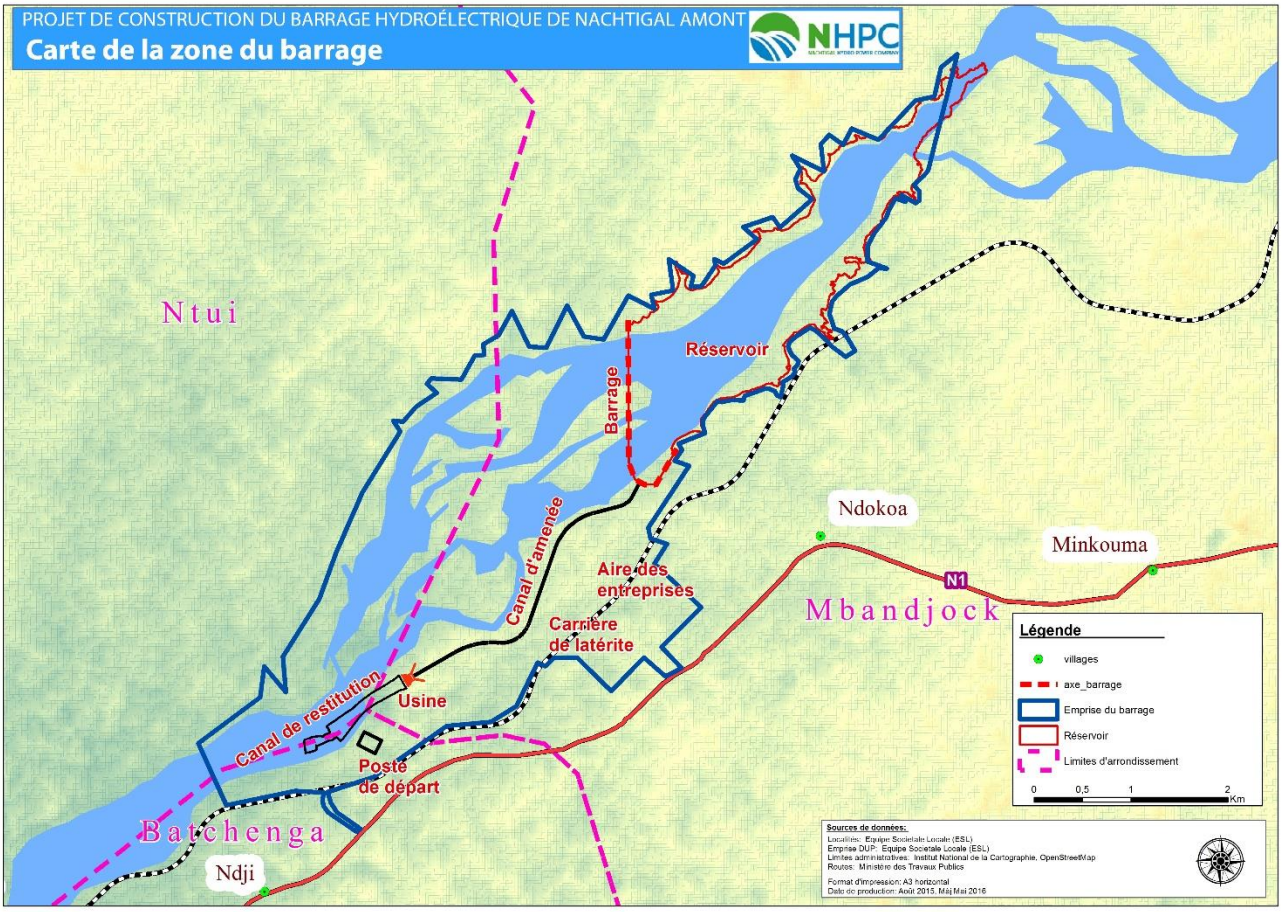



***Fig. 5. Layout of the project***

# 3. 2011 ESIA

The summary below is a synthesis of the 2011 ESIA, including updated information to reflect changes in the project since 2011 (instream flow, hydropeaking operation ...) and knowledge of the area (Census data, biodiversity inventories....).

## 3.1. PRE-PROJECT ENVIRONMENTAL AND SOCIAL CONTEXT

### 3.1.1. Sanaga River

The Sanaga River is the largest river in Cameroon. Its origin is the Lom and Djerem confluence, 650 km from the Atlantic Ocean. The Sanaga has a steep slope for a river of this size and with quite exceptional hydroelectric potential. It is the climate of the upstream part of the Sanaga basin, essentially the Adamawa plateau, which determines its discharge at Nachtigal. It rains in this part of Cameroon from April and the real rainy season runs from August to November. Until 2015, the flow of the Sanaga was regulated by the Bamendjin, Mape and Mbakaou dams that store water during the rainy season and release it during the dry season. Between December and May, discharge at Nachtigal is reduced to a minimum of 300 $m^3/s$. The flow later increases to its maximum (of 1000 to more than 3500 $m^3/s$ depending on the year). As of December 2015, the Lom Pangar dam contributes to river regulation (cf. below). Since 2015, Lom Pangar has increased the regulation capacity of the Sanaga.

### 3.1.2. Lom Pangar Dam

The Government of Cameroon has embarked on the construction of the Lom Pangar dam to better regulate the flow of the Sanaga. This dam stores rainy season water and releases it in the dry season. A target minimum flow of 650 $m^3/s$ in the Sanaga River is thus guaranteed even during low flow periods, with only slight modification of flow during high waters. This minimum flow will help ensure the operation of hydropower plants situated downstream on the Sanaga River (Song Loulou, Edea then Nachtigal). The first water releases to support Sanaga flow begun December 2015.

### 3.1.3. Biodiversity

Baseline biodiversity information was obtained for the EIES 2011 and was completed with additional surveys conducted in 2014-2016 (cf. § 5).

#### 3.1.3.1. VEGETATION

The project area is located in the semi-deciduous Guinea-Congolese rainforest. It is a transition zone between forest and savannah. The vegetation in the area of the facilities is chiefly characterized by forest galleries along the river and shrubby savannah maintained as a result of bush fires, one of the main factors determining the regression of forest stands inventoried in the zone. Disruptions caused by logging are visible along the shoreline. The strips of forest found here are cleared for agricultural purposes.

There are no protected areas in the study area. Inventories conducted in the impacted zones (construction areas, flooded zone) revealed a total of 366 plant species, of which 15 are tree species with commercial value and nearly 155 species, not endemic to the study area, are used locally in traditional medicines and other traditional uses (non-timber forest products). No plant species are protected by the Cameroonian legislation. However several species are endangered or critically endangered according to the IUCN.

These species are:

- *Ledermanniella sanagaensis* (aquatic), CR
- *Ledermanniella thalloïdea* (aquatic), EN
- *Marsdenia abyssinica* (riparian/semi-aquatic), CR
- *Hymenodictyon pachyantha* (terrestrial), EN

*Ledermanniella sanagaensis* is endemic to the Nachtigal falls (Project location) and *L. thalloïdea* is endemic to the Sanaga watershed.

Specific studies have been conducted concerning the distribution and ecology of these species, and in particular the Podostemaceae, in the Project zone, cf. §5.2. The distribution was document in 2014 and 2015 prior to the commissioning of Lom Pangar and in 2016 and 2017 after the commissioning of Lom Pangar and the resulting flow regulation.

It is important to note that already as of 2016, few Ledermanniella were found in the Project area as a result of high flows during the dry-season (only two *L. sanagaensis* populations were found and only a few specimens of *L. thalloïdea* were found in 2016 whereas they were both abundant in 2015). No population was found in 2017. However, some were discovered in Mbam river.

3.1.3.2. WILDLIFE

The area is not considered as a major migratory route for birds; no migration corridor has been identified along the future transportation line. However, several protected bird species (Cameroonian wildlife legislation) are present in the project area as well as one species that is endangered (IUCN Red List).

From the list of 34 wildlife and 122 bird species detected in the Project zone, several are protected (Cameroonian wildlife legislation) and/or are listed as endangered or critically endangered by the IUCN, cf. §5.1). . These species are:

| Species | Protection under Cameroonian legislation (Class) | IUCN Red List classification |
|---|---|---|
| **Mammals** | | |
| Giant pangolin | A | VU |
| Commun pangolin | A | VU |
| Hippopotamus | A | VU |
| River hog | B | LC |
| Sitatunga (marshbuck) | B | LC |
| Porcupine | C | LC |
| Cane rat | C | LC |
| Other mammals (not hunted) – 5 species | B | LC |
| Other mammals (not hunted) – 9 species | C | LC |
| **Reptiles** | | |
| Varan (Monitor lizard) | B | NE |
| Naja (cobra snake) | B | NE |

| | | |
|---|---|---|
| Other reptiles (not hunted) – 5 species | C | LC |
| **Birds** (class A or IUCN red list) | | |
| Green Turaco | A | LC |
| Golden Turaco | A | EN |
| Brown cheeked hornbill | A | VU |
| Martial eagle | B | VU |

3.1.3.3. FISHES

A detailed inventory of fish populations in the Project area was conducted in 2014 as a complementary study to the EIA and is presented in detail in §5.3.

The fish inventory revealed that 65 species belonging to 16 families were present, of which 9 are indeterminate or new to science and 24 species endemic to the Sanaga. However, literature review shows that 21 additional species were recorded in the project area, although they have not been inventoried by catches. With the combination of both sources of information, there are up to 86 species (from 18 families) reported in the Project area.

In descending order, specific richness (number of species) per identified family is as follows *Cyprinidae* (17), *Mormyridae* (14), *Clariidae* (6), *Alestidae* (5), *Claroteidae* (5), *Cichlidae* (4), *Mochokidae* (3), *Schilbeidae* (2) and *Mastacembelidae* (2). The other 7 families (*Amphiliidae, Arapaimidae, Bagridae, Channidae, Distichodontidae, Hepsetidae* and *Latidae)* recorded respectively only one species.

In terms of the status of species conservation, most species are classified under the "least concern" (LC) category of IUCN. Four species are currently classified as vulnerable, threatened or near-threatened or endangered (see §5.3).

## 3.1.4. Quality of the environment

3.1.4.1. AIR QUALITY

Air quality is generally good in the study area. The main sources of air pollution identified are impromptu and temporary. They concern mainly bush fires and vehicles plying on earth roads that raise clouds of dust during the dry season. A detailed baseline study of air quality was conducted in 2014 in villages near the construction zone, indicating that the main source of pollution comes from unpaved roads, with elevated fine particle concentrations (PM10) currently observed, cf. §4.2.

3.1.4.2. WATER QUALITY

Water quality of the Sanaga is generally good. Given the large river flows and low local population density, pollution from domestic sources has only local impacts. Even with the addition of food crops, agriculture upstream of the watershed probably has no detectable influence on water quality there.

The main sources of organic pollution in the area come from the two sugar factories, located respectively in Mbandjock and Nkoteng, and the distillery in Mbandjock.

Currently, additional studies on the water quality of the Sanaga in the Project area are underway (since December 2015) to quantify future inputs into the reservoir and water quality risks.

Water supply in the village is obtained either from undeveloped water sources, or directly from backwaters, rivers and other waterways or in shallow wells. These various sources are subject to pollution and / or periodic drying up. Consumption of contaminated water is often a source of disease.

An additional study about water quality is ongoing (since end 2015).

## 3.1.5. Social context

### 3.1.5.1. POPULATION

The population of the area is highly concentrated on both sides of the existing roads and agglomerated around villages. Households are generally fairly large, with 8 to 12 people per household.

Rural exodus is noticeable in some parts of the division and in some villages, such as Nalassi, Ndji and Nachtigal on the left bank, youths are leaving.

Income generated from various activities remains low. Subsistence agriculture and fishing are the main sources of income for villagers followed, to a lesser extent, by the sale of palm products, gathering and hunting. It was also noted in 2011 that there was an increase in incomes from sand mining.

### 3.1.5.2. HEALTH

The nutritional status of the population is generally satisfactory. Cases of malnutrition in children are rare and probably related to poor individual feeding habits. Other cases are often the expression of infectious and parasitic diseases.

Malaria is the most common disease in the study area, representing 47% of reported cases of illness.

Onchocerciasis, or river blindness, is the disease caused by the parasite *Onchocerca volvulus*. It is almost endemic with an infestation rate that sometimes exceeds 60% in some communities, even those located more than 30 km from the Sanaga and the Mbam. Health infrastructures are underdeveloped and where they exist, there is a lack of staff and equipment. Even though the infrastructures are still poorly equipped, an increase in human resources since 2006 has significantly improved the situation.

Between 2006 and 2011, the health care situation improved with the creation of 7 new health facilities, bringing their total from 26 to 33, which led to the creation of 3 new health areas (Ekabita Mendum, Nkolmekok and Ndjoré). The Ngoya health area in the Obala District is one that has witnessed the most significant increase with three new health centers. This increased health coverage has also led to a relative increase in the number of health personnel, but with insufficient technical infrastructures.

### 3.1.5.3. INFRASTRUCTURE

A ferry links the right bank to the left bank of the Sanaga River at Nachtigal village. This connection is important for the trading of goods and transportation of people between villages and is therefore an important trade development tool in the study area, but it is often out-of-service. A project to construct a bridge and renovate the roads connecting to the future bridge (both on the left bank and right bank) is currently planned, with construction to begin before 2020.

The national route 1 (RN1) that has been newly tarred and from which various tracks originate goes through the study area in a generally north-south oriented axis and circulation of timber trucks is intense. The railway that runs through the villages of Ndjore, Ndokoa, Ndji, Olembe-assi, Ndokoa and Mekas passes near future facilities. The railway route partly runs along the future reservoir and within the planned construction area.

#### 3.1.5.4. FISHING

One hundred and thirty fishermen were identified around the Sanaga in 2011 in the Project area, accounting for 193 tons of catch per year. Most of them are also farmers, but they spend most of their time fishing. Fishing is more intensively carried out between November and January (the dry season), during which the fishermen acknowledge that they make almost half of annual income associated with this activity. Fishing remains relatively good during the rainy season, but it is no longer practiced during October floods. The oldest fishermen say there is a decline in catches in recent years.

The fish caught are sold and / or self-consumed by fishermen and their families. Apart from the “Capitaine” and *Mormyrus*, which are more expensive than the other species, the price at the landing depends primarily on the size on the species itself.

#### 3.1.5.5. SAND MINING

Artisanal sand mining is an important income-generating activity and is carried out in several villages, employing hundreds of people locally. Detailed studies have been carried out to quantify sand supplies (cf. §4.4) and to inventory sand-mines and mining employees (cf. Livelihood restoration plan). It can be noted that access to existing sand-mines is already reduced in 2016 and 2017 as a result of high dry-season discharge following the commissioning of Lom Pangar dam.

#### 3.1.5.6. ENERGY

In the project area, villages are mainly connected to the grid, but suffer from frequent electricity quality problems (voltage drop) and continuity (power failure).

35% of the downstream villages are connected to the grid.

#### 3.1.5.7. ACCESS TO LAND

The dominant tenure system in most villages near the future dam area is still the collective ownership of land, with land belonging to the village community. The system is based on customary law or user rights. Thus, each village owns and exploits a more or less demarcated territory, which becomes the land on which it carries out its activities and has some authority over. Ownership of land or ownership attempts creates substantial conflicts. To resolve land disputes, recourse to the village head is a form of securing the land heritage within the village community. Access to land is particularly difficult for women.

Creating a few large farms tends to increase pressure on arable land. In fact, apart from the Mbam-and-Kim, population growth exerts significant pressure on land of all the other divisions of the study area.

#### 3.1.5.8. SACRED SITES

The village of Bidandjengue maintains a sacred site called Ilanga. It is located downstream of the future dam, in the portion that will be deprived of water in the dry season. Other sites were also mentioned.

### 3.1.6. Main developments between 2006 and 2011

Developments and significant changes between 2006 and 2011 are summarized below:

**Road infrastructure:** The tarring of RN1 between 2010 and 2011 has made it possible for villages of the study area at the edge of the river, formerly relatively isolated, to have quick access to Yaoundé under good conditions. This development has transformed the local economy, promoting trade.

**Land pressure:** High population pressure on the outskirts of Yaoundé causes densification of housing and intensification of land registration. This constraint will intensify in the years ahead.

**Agricultural activities:** The main developments observed between 2006 and 2011 are twofold. First densification dedicated to gardening plots on the outskirts of Yaoundé (especially in the Nkolondom area) with a decrease of the duration of fallow. This phenomenon is provoked by population increase in the capital. Furthermore, to the north, particularly north of Ndji and on the right bank to the right of the project, there is a significant increase in cocoa surface areas. This increase is due to increased cocoa prices in recent years, a voluntary government policy and the provision of more competitive varieties. In general, incomes from sales of food products have increased significantly between 2006 and 2011.

**Sand mining:** This activity has grown considerably due to new opportunities created by the national road, the increase in raw material prices and construction activities. It now provides a substantial contribution in cash to hundreds of people in villages located on the shore of the Sanaga River.

**Fishing:** Between 2006 and 2011 there has been relative similarity in terms of number of fishermen, catches and generally, the significance of the economic sector. However, it has been noticed that there is a high renewal of individuals caused by departures or deaths and a growing importance in the proportion of non-native fishermen from Mali and to a lesser extent from Chad.

**Health:** Between 2006 and 2011, the health care situation improved with the creation of 7 new health facilities. This increased health coverage has also led to a relative increase in health personnel, but with technical facilities that is still incomplete.

## 3.2. MAIN ENVIRONMENTAL AND SOCIAL IMPACTS OF THE PROJECT AND CORRECTIVE MEASURES

The impact assessment has systematically assessed the potential impacts of the future project on the biophysical environment and the human environment. Necessary measures were taken to limit or correct these impacts from the project design. Additional monitoring measures are also planned. People whose income may fall during the project will be offered fair compensation. Finally, additional cushioning measures will be taken to reinforce the positive impacts of the project.

### 3.2.1. Impact of the Nachtigal hydroelectric project on the Sanaga River

The hydroelectric dam planned for Nachtigal is a dam designed to channel water at the water intake. Since this is a “run-in-river" facility, the size of the flooded area is small and the impact on flows is low. In fact, during low waters (target flow of 650 $m^3/s$), the entire flow is turbined by the hydroelectric power plant then returned downstream. If the turbines do not work or if the flow is higher than what can be turbined at that time, water passes through the floodgates or over the release dam. During high waters, water flows through floodgates or over the dam.

The principal requirement of the Nachtigal project is regulated flows (by the Lom Pangar dam) The Nachtigal dam itself does not change wet-season river flows downstream of the powerhouse and will only have minor impacts on dry-season flows as a result of moderate hydropeaking.

On the contrary, during low waters, an area located between the dam and the point of return (near the powerhouse) will be partially dried up over a distance of about 3.3 km. This area, made up of islands and branches of rapids, will be dried up from December to July (except for the big left bank branch maintained in water by the in-stream flow). Dam spillover during high waters will replenish this area again.

Hydraulic modeling was conducted to estimate the flow velocities and future water levels at the Nachtigal ferry crossing. This modeling revealed that flow conditions will not change even with hydropeaking. The Nachtigal ferry can continue to navigate in conditions similar to current conditions and safety will not be compromised. Access to the current sand pit in the reservoir site will be flooded and will need to be relocated. (A bridge will be built on the Sanaga at this place, from 2017).

Hydropeaking, untimely stops of turbining as well as the openings and closings of floodgates of the spillway can generate downstream flow variations. Hydraulic calculations show, however, that their amplitude will be limited and negative effects on the operations of the Nachtigal ferry will not be substantial overly.

### 3.2.2. Impact on water quality

One of the risks that can be observed in a dam is that water stagnates and algae grow there. However, water will stay in the Nachtigal dam for an extremely short time, just a few hours. There is therefore no risk to having significant growth of algae.

The waters that will cross the dam will probably be loaded with more organic matter than they are today because of the impact of the Lom Pangar dam, at least in the first years of its operation, and the possible increase in agricultural activities in the water bassin. Discharges from Sosucam and ADIC (African Distilling Company) could instead decrease in the future as part of their compliance with Cameroonian law.

During the first years after dam commissioning, there will be a gradual decomposition of remnants of flooded vegetation and organic matter within the first centimeters of the soil, cf. §5.5. Hydraulic conditions of the dam and speedy renewal of its waters will result in degradation that could temporarily cause a slight lowering of the oxygen content in the water. This water will be quickly re-oxygenated once it returns to the downstream channel thanks to conditions of turbulence observed there. No risk associated with organic methyl mercury is expected because the soils contain very little mercury and the dam will generally not create anoxic conditions necessary to create this type of pollution.

A program to monitor the water quality of the Sanaga will be developed as a precaution, especially if the water is used for the production of drinking water (cf. downstream drinking water project). It is also proposed that the use of pesticides and fertilizers be strictly controlled in the exclusion zone of the dam site.

### 3.2.3. Impact on fishes

The construction of the Nachtigal dam will have direct impacts on fishes. In fact, movements of some species could be modified because of the obstacle that will be created by the dam and because during the dry season, the downstream part of the reservoir will no longer have water (with the exception of the large branch on the left bank that will still have water from the in-stream flow). These conditions, as well as the creation of water areas with weaker current in the dam, can alter species distribution without accurate prediction. However, the number and size of individual species that thrive in calmer waters could increase.

The situation of fish downstream of the refill will hardly change with little higher flows only in the dry season. When the dam will stop releasing, the section between the dam and the tail race will be watered again. When the dam will cease to release, from November, this section will dry up gradually (except the large branch on the left bank). Only a few deeper ponds will be used as home to small or medium-sized fishes (Cichlids, Mormyrideae, Schilbeideae). Predation by birds will be considerable. During high waters, a fall of a dozen meters at the dam area will produce additional oxygenation of the water which could attract, at the foot of the dam, species indicating an environment rich in dissolved oxygen (*Lates niloticus*, *Barbus* sp., Mormyrideae). A detailed inventory of fish populations in the Project area and the impacts of the project on them was conducted in 2014 as a complementary study to the EIA and is presented in §5.3.

The development of species preferring lentic habitats such as various species of “cat-fish” will be fostered by the creation of the reservoir upstream of the dam, cf. §5.3. Some species, such as Cichlideae and Osteoglossideae (*Heterotis*, locally called "kanga"), will find suitable environments for their development in herbaria of the more stagnant areas, mainly on the right bank.

### 3.2.4. Accessibility to the reservoir and the bypass reach

The reservoir will be available to fishermen, except the area directly above the dam and water intake (on a distance of 500 m from the facilities), because of risks of being carried away by current. Areas where access is prohibited will be materialized in a visible and sustainable manner.

The current area of rapids (the bypass of about 5.5 km), partially dried up between December and July, will be out of bounds because of the risk of sudden release of water over the dam.

### 3.2.5. Land use

#### 3.2.5.1. LANDS USED BY THE DAM AND THE FACILITIES OF THE HYDROPOWER PLANT

The dam will cause the following impacts on the ground:

- Flooding, by the dam, of a surface area of 157 ha of vegetation, including 80 ha of secondary forest, 7 ha of under-forest cocoa farms, 4 ha of other crops and 66 ha of shrubby savannah;
- Loss of 159 ha of land because of the location of the future dam, the in-flow canal, the out-flow canal, the plant and staff quarters (shared loss between the secondary forest and the shrubby savannah);
- Clearing and temporary use of 134 ha of land for site facilities and temporary access (most in the savannah area).

The location of facilities has been planned so as to minimize loss of surface areas, secondary forest areas and farmlands.

Only two houses are concerned within the Hydroelectric facility area.

#### 3.2.5.2. LANDS SITUATED UNDER HIGH TENSION LINES

The route of the power transmission line was determined to minimize impact on homes and on crops. The market gardens of the Obala area and settlements have been avoided. A 50m allowance will be carved out. Large trees on both sides from the corridor of the line that are likely to fall on transmission lines will be felled. This is a minor impact given the small area concerned and the fact that valuable trees have generally already been logged. Only three houses are affected by the transmission line corridor. The line passes over the land of a sawmill in Obala while remaining sufficiently distant from buildings.

### 3.2.6. Impact on forest resources

Given the absence of endemic or protected species, and the small size of the areas concerned, the impact on vegetation is not significant. All sites used temporarily will be reforested at the close of the site

### 3.2.7. Impact on wildlife

The main impact on terrestrial animals and birds will be habitat loss, in a region where the forest is already in decline and human impact has already scared away the most sensitive wildlife. However, the areas concerned are small and wildlife may be distributed around the same ecosystems.

The reservoir could, however, create a more extensive habitat for aquatic birds.

The slow filling of the reservoir will limit wildlife mortality.

An indirect but more serious impact is the risk of increased poaching related to the presence of the workers' camp and the arrival of a spontaneous population on the site, in an area where pressure from hunting is already strong. This risk should be minimized through the following measures:

- Raising awareness of the populations;
- Strengthening control of poaching (forests guards);
- Controlling workers of the camp, providing farm-raised meat at the canteens;
- Control of spontaneous developments outside of the base camp (see further on).

There is also the risk of over-fishing during the construction phase; to reduce this risk, fishing will be forbidden by the workers

The presence of the transmission line can cause collision and electrocution of some birds. The risk of electrocution affects mostly birds that use poles to nest or predators that use poles as an observation post. It should be noted that the design of the line (double dull-double beams) will make it more visible to birds, which reduces collision risks.

### 3.2.8. Impact on local populations

During the construction phase, it is possible that people will try to settle around the work site or its nearby vicinities to look for work, offer their services to employees of the site or try to enjoy other expected benefits of the project. Part of this migrant population will leave the area when the site closes. Specific measures to limit this immigration and the associated consequences will be taken by the contractors, as specified in the ESMP.

### 3.2.9. Impacts on incomes and compensation plan

#### 3.2.9.1. COMPENSATION PLAN

Resettlement and compensation action plans (RCAP) have been developed for the project's impacts on the area of the hydropower plant on the one side and the area of the transmission line on the other side. They are established in accordance with Cameroonian laws and International Finance Corporation Performance Standards (Performance Standard 5). It concerns the loss of use and incomes for cultivated soils, fishery products and houses. Incomes from sand mining are addressed in a livelihoods restoration plan (LRP).

#### 3.2.9.2. POSITIVE IMPACTS ON THE LOCAL ECONOMY

Ultimately, NHPC, the project company, will employ on site about 75 people (including about 50 operators) who will live in Batchenga with their families during the operational phase. The location of the operation quarters of the Executing Authority will help to maximize positive impacts on the local economy. The construction phase should also be an opportunity to increase incomes given that up to 1500 temporary jobs will be created.

#### 3.2.9.3. IMPACTS ON FISHING AND CORRECTIVE MEASURES

The stretch of the Sanaga located between the dam and the refill will be out of bounds for security reasons and fishing will not be possible there. This is a sector with a surface area of about 430 ha.

The portion of the reservoir located within 500 m of the dam and water intake facilities will also be out of bounds for security reasons. The surface area where fishing will be allowed will be limited to about 330 ha between the forbidden area (reserve) and the tail of the reservoir. Fishermen will have to adapt to these new conditions, especially for areas that have become deeper (maximum of six meters of water) which will

develop on the right bank and in the recesses of the two banks and where fishing with traditional nets ("gourahs" of Malians) might not be possible..

Impacts on fishing can be summarized as follows:

- Loss of about 430 ha of fishing grounds downstream;
- Gain of about 130 ha in the reservoir;
- Modifications of species that are present (still difficult to predict);
- Improvement of total productivity (concerning species of more stagnant waters in the reservoir as well as fishing downstream of the refill).

The number of fishermen concerned and how their income will change is difficult to predict accurately. It is basically fishermen operating in the stretch between the refill and the dam whose activities will be affected. This is about a hundred fishermen for whom fishing is not necessarily their mainstay. The activity could instead increase with the creation of the reservoir. The potential of the reservoir is difficult to estimate and will likely be between 18 kg/ha (current river production) and 60 to 80 kg / ha.

The creation of a reservoir of more than 400 ha will also foster the development of species that can get to large sizes such as *Clarias* (Clarotidae) or Capitaine *(Lates niloticus,* Centropomideae)*,* fostering a certain attraction for the development of sport fishing *.* However, this aspect should be reviewed with professional fishermen so that there are no conflicts of interest.

Fishermen's incomes can be improved by taking measures to generally improve working conditions and organization of fishing (including marketing) applicable to all fishermen. Access ramps will be created on the right and left banks of the reservoir to facilitation embarkation.

#### 3.2.9.4. IMPACT ON CROPS AND PLANNED COMPENSATIONS

At the dam site, loss of farmlands concerns 142 ha, including 50 ha of food crop farms and 92 ha of tree plantation, among which 33 ha are cocoa plantations. Compensation mechanisms for these losses are described in the RCAP.

#### 3.2.9.5. IMPACT ON FOREST RESOURCES

Total (dam and power line) loss of secondary forest will include:

- About 80 ha of forest flooded by the reservoir;
- An estimated loss of 140 ha of forest to be cleared on the dam site for permanent and temporary facilities, especially the in-flow canal;
- About 80 ha of forest on the path of power line.

Timber with commercial value consists mainly of softwood, given that high value tropical species in the area have already been logged. Commercial timber volume is about 4000 $m^3$, representing 45-50% of the monthly consumption of sawn wood in Yaoundé. These commercial timbers will be harvested separately from the rest of the deforested areas by MINFOF-approved procedures and companies.

#### 3.2.9.6. IMPACT ON OTHER PLANT RESOURCES

Filling the reservoir and partial clearing will also cause loss of part of the local population’s resources in terms of non-timber forest products (fruits, medicinal plants, etc.). These products are however not endemic and people will have access to identical resources in nearby areas, including areas that will benefit from reforestation and rehabilitation (post-construction) measures as well as dedicated areas that will benefit from targeted planting of non-ligneous forest products.

### 3.2.10. Impact of the transmission line on health

The World Health Organization (WHO) is studying health problems associated with exposure to electromagnetic fields (EMF). Most the research conducted proved contradictory, ambiguous or inconclusive. With current scientific knowledge, all the expertise revealed no evidence of a significant effect on health and on the other hand, agrees that EMFs are not a public health problem.

The following measures will be adopted to reduce risks of electrocution:

- inscription on a signboard at the bottom of each pole indicating the danger of electrocution and anti-climbing harrows
- burying large objects made of conductive materials
- development of a communication plan around this issue to educate the local people about the risk of electrocution (mostly children) for anyone who attempts to climb a pole.

### 3.2.11. Impact on the health of the local population

Impact of the project on health of the local population include:

- changes in the proliferation of vectors of waterborne diseases, related to changes in water flow;
- diseases related to unsafe water supply and poor sewage drainage in case of population growth;
- an increased risk of transmission of diseases because of population growth.

Change of flows could reduce the proliferation of certain vectors of parasites, but encourage others along the Sanaga River.

Health risks related to the project will be greater during the construction phase. Corrective measures affecting this aspect are described in detail in the section devoted to anticipated impacts during the construction phase. These measures should continue to apply after the construction phase. The Project will propose awareness and prevention programs and contribute to the improvement of health infrastructure. Particular attention will be paid to sexually transmitted diseases.

### 3.2.12. Emissions of greenhouse gases avoided

A thermal power plant of the same capacity as the Nachtigal plant would emit about 1.92 million tons of equivalent $CO_2$ greenhouse gases per year (for a producible of 2 850GWh) contributing to global warming. This emission is avoided by the generation of hydropower. Greenhouse gases will on the contrary be emitted during clearing and the decomposition of vegetation at the start of the project and are estimated at about 390 000 tons equivalent $CO_2$.

### 3.2.13. Impact on the landscape

There will be very limited impact on the landscape because people will not be living in the direct vicinity of the site. Rapids will be reduced in the dry season, but similar landscapes exist in the Nachtigal Falls downstream. The reservoir will create a new type of more open landscape, interesting in the sector.

### 3.2.14. Analysis of the risk of dam failure and preparation of an Emergency Plan

The only serious safety risk identified is dam failure. In order to comply with Cameroonian law (Law relating to establishments classified as dangerous, unhealthy and unsuitable) and international guidelines, a study of the consequences of dam failure will be initiated. The recommendations necessary for the development of a Warning Plan to reduce the consequences of such a situation must also be identified.

## 3.3. IMPACTS OF CONSTRUCTION ACTIVITIES OF THE PROJECT AND CORRECTIVE MEASURES

The construction period of the project will generate local jobs and an overall improvement in household incomes. However, a major project with more than 1500 workers can also generate negative impacts on the environment, on people and on workers. These impacts can often be minimized by adopting better environmental, health and safety practices. In the case of the Nachtigal hydroelectric project, the most sensitive impacts for the population may be:

- nuisance related to road transport;
- spontaneous immigration around the site with positive impacts on the economy, but risks to health, safety and the environment.

Special measures will be adopted to control these negative effects. Measures will also be proposed to strengthen economic and social infrastructure at the site. Anticipated impacts and corrective measures implemented are presented here below. Impacts on wildlife during construction (nuisances, poaching and overfishing risk) have already been addressed above.

### 3.3.1. Dust and noise control

The presence of construction equipment and the transportation of equipment and materials from Douala or Yaoundé to the site will be a source of noise, vibration, smoke and dust on the site and on the roads leading to the site.

On site, these impacts will affect primarily workers, since the site is far from settlements. The impacts may be curtailed by the use of equipment and machinery that meet standards and are in good condition. Workers will put on appropriate protective equipment (masks, ear plugs). Dust will be mitigated in the dry season by watering construction sites (given that the main access routes and roads to the site will be tarred).

Off-site, nuisances will be mainly related to road transport. Transportation of equipment to the site can also be done by rail. Road access to the site has been planned such as to avoid transit through nearby towns such as Ndji and Ekombitié.

### 3.3.2. Security on the site and the environs

Risks of accidents are related to construction activities and road transport. The risk of accidents at the construction site will be reduced by adopting health, safety and environment procedures. The risk of road accidents could be minimized by promoting rail transport, prohibiting night transportation, by adopting reasonable speed limits, regularly maintaining vehicles and avoiding dust (which reduces visibility) by watering. The risk of accidents when handling explosives for blasting will be minimized by establishing warning procedures. Access to the site will be strictly controlled during construction.

### 3.3.3. Control of risk of water pollution

Potential sources of water pollution during construction activities and introduced corrective measures are summarized in the table below. Storage and handling of all products that can pollute water will be strictly supervised. Workers will follow an awareness and training program related to water quality. Water quality will be monitored regularly through measures taken in the camp's discharges and in the Sanaga itself.

**Tabl. 3 - Risks of water pollution during construction and responses**

| Source of potential impact | Corrective measures |
|---|---|
| Sewage discharges from the workers camps | • Installation of sanitary equipment and water treatment on the spot |
| Pollution by solid wastes | • Collect waste<br>• Waste management plan |
| Hydrocarbon leaks and other toxic products | • Secured storage platforms with oil separator |
| Discharges from maintenance of machines and other dangerous wastes | • Adapted maintenance area with oil separator<br>• Collect and monitor the destination of used oils, with possible recycling |
| Washing of concrete equipment | • Drainage of waters to sedimentation basin and treatment to compensate for acidity loss before discharge |
| Use of pesticides | • Limited use of approved pesticides and training of workers |

### 3.3.4. Control of works-related erosion and sedimentation

The risks of soil erosion and discharge of sediment into the waters during the earthworks and land clearing will be reduced by imposing a series of measures to companies entrusted with the work.

### 3.3.5. Source of material for the site

Initial estimates of the quantity of material to be excavated and used for the dam indicate that all the excavated rock will be reused for the dam. On the contrary, a shortage of up to 200,000 $m^3$ of loose materials (laterite) is anticipated. These materials can be found on the works site. The areas deforested to allow for laterite mining will be entirely restored to their initial condition.

### 3.3.6. Control of risk of spontaneous population migration around the sites

The spontaneous development of people around the construction sites usually causes major impacts in terms of health, safety and social balance of resident communities.

In order to limit the influx of job seekers around the site while promoting local employment, a coordination plan will be prepared under the authority of the Executing Authority in collaboration with the Cameroonian authorities to organize all envisaged actions.

Furthermore, to limit the uncontrolled development of facilities near the site, the following measures will be taken in agreement with local authorities:

- agree on a plan to limit the settling of migrants who come to buy land in the vicinity hoping to settle there;
- constitute a security brigade to prevent people settlement near the site without the permission of communities

- develop a land management plan of areas bordering the facilities in order to promote sustainable development.

### 3.3.7. Monitoring of the health of workers and the surrounding people during construction

A construction site of a certain size can be a source of risk for both the health of workers and the resident populations. Measures must be taken to limit these risks.

#### 3.3.7.1. HEALTH ON THE SITE

On the site, health of workers will be ensured through health, safety and environment procedures as well as the requirement to provide medical services (prevention, monitoring and treatment) for all employees.

#### 3.3.7.2. HEALTH OF RESIDENT POPULATIONS

During the construction phase, the resident populations will be subjected, because of the risk related to the presence of migrant workers and road transport, to an increased risk of contamination by infectious diseases and sexually transmitted diseases.

These risks can be reduced thanks to spontaneous migration control measures. NHPC will also develop awareness and prevention actions in the project area and also contribute to the improvement of health infrastructure. Other impromptu actions such as waste collection, sewage management or supply of drinking water should also contribute to the improvement of health conditions.

### 3.3.8. Benefits for the local economy during construction

Creating more than 1500 jobs, mostly unskilled, will temporarily increase the income of local people. Local recruitment will be favored. Jobs created and incomes generated will also stimulate an increase in activities of services.

Fishing, sand mining and farming activities will be disrupted during the construction phase. Compensations will be made to those affected and reconversion programs (training, etc) will be developed.

### 3.3.9. Identification and protection of cultural resources

Cultural resources identified in the project area include tombs, sacred sites and sacred trees. No tombs should be affected by the passing of the high-voltage line. The Bidandjengue sacred site will be moved through an adapted rite. All cultural resources (including sacred trees) have not been identified accurately in surveys conducted for the impact assessment, given that local authorities preferred to keep it a secret. A special procedure should therefore be adopted during works to identify sites that could be affected.

## 3.4. SUMMARY OF SHORT AND MEDIUM TERM IMPACTS INCLUDING THOSE OF THE LOM PANGAR DAM AND FUTURE ECONOMIC DEVELOPMENT (CUMULATIVE IMPACTS)

A project such as Nachtigal creates impacts on the natural and human environment. This section aims at evaluating medium and long term impacts which are directly added by Nachtigal to impacts resulting from other development projects (cumulative impacts) as well as which impacts from future development projects induced by Nachtigal can currently be anticipated (induced impacts). The analysis of the project's cumulative impacts is presented in the table below.

**Tabl. 4 - Cumulative effects of the Nachtigal project**

| Sectors concerned | Short term impacts (5 years) | Medium term impacts (10 years) |
|---|---|---|
| Hydrology of the Sanaga | No impact resulting from Nachtigal during the construction period | • Limited impact downstream (low to moderate gradient) resulting from hydropeaking during the dry season in Nachtigal.<br>• Major impact resulting from Lom Pangar water discharges to regulate flows. Nachtigal does not change the impact of Lom Pangar. |
| Hydrodynamics of the Sanaga | No significant impact resulting from Nachtigal during the construction period | • Decreased intake of sediments downstream of Nachtigal and in the estuary |
| Water quality of the Sanaga | One-time and very limited risk of discharge of hazardous materials (primarily hydrocarbons) during construction | • No additional impact from Nachtigal, given the small size of the reservoir and its rapid renewal<br>• High impact of Lom Pangar that drowns 540 km $^2$ of uncleared forest and savannah before impoundment; risk of organic load of the water. |
| Fish fauna | The Nachtigal dam will hamper migration at the end of its construction, but it is quantitatively difficult to assess because of lack of knowledge of migratory phenomena specific to the species concerned. | • The construction of other dams (currently planned) on the Sanaga River could have cumulative impacts on fish distribution and migration. A watershed-level study is needed to address these issues.<br>• The poor quality of water released by Lom Pangar can alter the overall distribution of species in the basin, migrant individuals either downstream (towards Nachtigal) or to the tributaries to escape deoxygenated waters<br>• The reservoir of Nachtigal provides a stable volume suitable for the development of species of calm waters, which can compensate for partial drying up of 3.3 km branch during the dry season downstream of the dam. In addition, water downstream the Nachtigal dam will be reoxygenated |
| Artisanal fishing | The construction period could lead to fishing pressure in the area of the Sanaga that is higher than normal due to the higher demand from hired manpower. However, the Project intends to take restoration management measures to minimize this impact. | • The reservoir may attract more fishermen than production can bear (estimated at 18 fishermen).<br>• Furthermore, fishing may decline in the entire Sanaga because of alterations of water due to Lom Pangar. |
| Forestry | Limited risk during construction if measures of the Environmental and Social Management Plan are properly implemented. | • Regional development induced by Nachtigal can accelerate pressure on secondary forest. It is observed that the forest may disappear to give way to agricultural development. |
| Biodiversity | Limited risk during construction if measures of the Environmental and Social Management Plan are properly implemented: hunting and poaching prohibited for workers, meat supply to limit pressure on bushmeat; the result will depend on the ability to control the spontaneous population in the area. | • Socio-economic development of nearby agglomerations started during construction could be perpetuated, engendering increased demographic pressure on the biodiversity of the region. |
| Urban development | Limited impact around construction sites if recruitment is made mainly among the local population as recommended by the impact assessment and if measures for the management of spontaneous migration are implemented. | • Probably limited, the Nachtigal project does not generate activities on the site. The village of the operator will have only a few dozen operators |

| Sectors concerned | Short term impacts (5 years) | Medium term impacts (10 years) |
|---|---|---|
| Social and economic development | The concentration of salaried workers will accelerate local socio-economic development during construction through the development of petty services (trade, market gardening, etc.). | • Training and awareness programs on hygiene, health and environmental management provided to workers during construction should help local people to improve on all these aspects in the future. The possibility of transferring the controlled release put in place during construction could serve as blueprint and accelerator to better environmental management in the region. |
| Industry | The industrial and transport sectors in Cameroon will be stimulated during the construction of Nachtigal and Lom Pangar. | • In the medium and long term, the industrial sector of Cameroon and its GDP will directly benefit from increased energy supply. |
| Land pressure and social influxes | Land pressure and social influxes will increase around Batchenga, due to Nachtigal project, road and drinking water projects. | • In the medium and long term, Nachtigal's impact is limited. |

In a nutshell, it is possible to state that:

- The project will result in negative cumulative impacts on land pressure and social influxes in the project area, but which will be short-term. These impacts are a direct result of concomittant construction projects (water pumping station, bridge and road construction to Ntui) in the same area as the Nachtigal dam. Coordination among these different projects is necessary to limit and monitor these cumulative impacts.
- Induced positive acceleration of local development during construction coupled with the proposed Local Development Plan will result in positive fallouts that will be perpetuated over the long-term.
- At a national level, the Nachtigal project is highly dependent on the Lom Pangar project.
- At the level of the Sanaga Basin, the Nachtigal Project will have limited impacts, since most of the hydrological changes that will be observed will be related to Lom Pangar.

# 4. POST-ESIA ADDITIONAL BASELINE STUDIES: METEOROLOGY, AIR QUALITY, NOISE LEVELS AND SEDIMENT TRANSPORT

## 4.1. LOCAL METEOROLOGY

A complete weather station has been installed in Batchenga at NHPC headquarters. Meteorological data thus collected will be very useful for proper interpretation of information on the initial state of the site environment.

This station has been operating since May 2014 to measure the following parameters at regular time intervals :

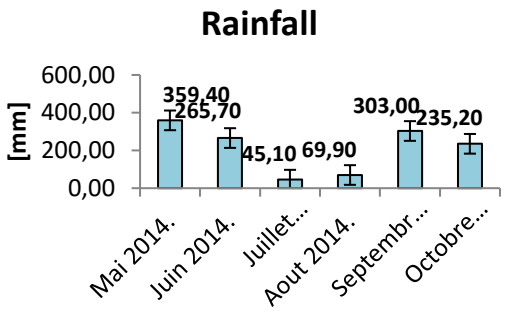
- Relative pressure [hPa]
- Temperature [°C]
- Humidity [%]
- Dew point [°C]
- Wind-chill [°C]
- Wind speed [km/h]
- Wind direction
- Rainfall [mm]

The study area has four seasons, namely:

- a long dry season (November to February);
- a short rainy season (March to June);
- a short dry season (June to August);
- a long rainy season (August to November).

The following statistics are for the period from May to October 2014 and therefore cover three out of four seasons.

The study showed that rainfall observed in May and June were higher than in September and October 2014 and that the supposed period of short rainy season (March to June) may have been wetter than the long rainy season (August to November), at least in 2014. The monthly average temperatures range between 25 and 27.5 °C in Batchenga and relative humidity between 62 and 80%. The wind speed was between 0 and 8 km/h, and the predominant wind directions are west-south-west and west.



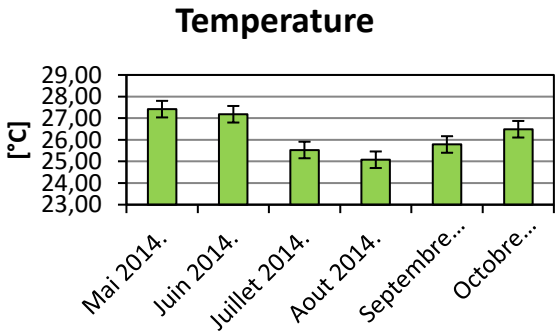



*Fig. 6. Rainfall and temperature data in Batchenga, May to October 2014*

## 4.2. AIR QUALITY BASELINE

A study on air quality was conducted to update the evaluation of the initial state of affected areas around the site of the Nachtigal hydroelectric project. The objective is to make an inventory (current air quality) in places that could be affected by the works and construction activities (dam, plant, living quarters, etc.), including releases from machinery and trucks, increased road traffic, dust suspension (crushing, road traffic on unpaved roads, equipment storage, etc.).

The methodology consisted into carrying out one-time measurements (day and night) of ambient air quality at 4 points in three villages located close to areas of future works, future developments (Operation Quarters of the Executing Authority in Batchenga, Companies Area, Construction Site) and roads, either in Batchenga, Ndji or Ndokoa/Ekombitié.

Measuring ambient air gas was carried out using a gas analyzer (Handheld Gas Monitor S500, KANOMAX, USA) and particles ("dust") were measured using a dust analyzer (Dust Sentry KANOMAX, USA). The gas and particles measured were sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), carbon monoxide (CO), ozone ($O_3$), volatile organic compounds (VOCs), dust suspensions lower than 10 microns (PM10) and dust suspensions lower than 2.5 microns (PM2.5). These gases and particles are part of the list of monitored air pollutants found in Article 4 of Decree No. 2011/2582/PM to lay down rules for atmospheric protection. The current air quality measured in the villages mentioned above was determined by comparing the results with national and international standards.

The results show that concentrations are generally below the limits prescribed by Cameroonian standards, WHO and USEPA, indicating that the project area is an unpolluted site. The air quality values indicate low concentrations of gaseous pollutants reflecting a lack of pollution from stationary sources (industry, urbanization, fuel operating unit, etc.); major cumulative effects are thus to be excluded. The main air pollution sources include unpaved roads, local traffic (on National Road No. 1) and domestic activities such as the use of firewood, slash and burn agriculture and bush fires.

The presence of PM10 airborne dust in high concentrations is due to the proximity of unpaved roads, so during the execution of the project, appropriate measures have to be taken to fight against dusts on these roads, mostly in the dry season and close to residential areas. Frequent rainfall in the area is a natural way of regulating this air pollution. Nevertheless, it is noteworthy that this study was conducted at the beginning of the wet season and relatively high PM10 concentrations were however encountered.

Thus, fine particles reduction measures must be implemented to limit the impact of the construction site on surrounding air quality.

## 4.3. AMBIENT NOISE BASELINE IN VILLAGES NEAR THE PROJECT AREA

The objective of monitoring ambient noise is to make an inventory of noise levels encountered in the villages that would be affected by construction works. This study was conducted in accordance with the laws governing environmental impact assessments in Cameroon, including Decree No. 2011/2583 / PM of 23 August 2011 on noise and smells regulation.

More specifically, the methodology used consisted of one-time measurements in dB(A) (day and night) of noise levels experienced at 4 points in three villages located close to the work areas, facilities (MOA living quarters, entrepreneurs and construction sites) and roads.

- Government High School Batchenga, concerned by the Operation Quarters of the Executing Authority
- Ndji Village concerned by the Work Site/DUP
- Ndokoa/Ekombitié Village concerned by the Area of Companies and the Work site

The extended area of the project is located in a quiet rural area. Background noises are dominated by the sounds of nature and motorcycles and cars. Houses are generally over 100 meters from very quiet roads and/or railway lines, and are not frequently over flown by planes.

The ambient noise levels are generally low and varied between 30 and 32.5 dB(A) depending on the station and the measuring period. The results clearly show that noise level is not influenced by wind since there is no wind or low wind (+/- 5 km/h) and as such sound levels are generally below 33 dB (A) .

- At Station 1, near Government High School Batchenga, the noise level varied between 30.6 and 31.3 dB(A) in the morning and 31.3 and 32.5 dB(A) in the evening
- At the second station (Ndji), noise varied between 30.6 and 31.6 dB(A) during the day and between 31.1 and 31.4 dB(A) in the evening.
- At the third station (Ndokoa/Ekombitié), the ranges were 30,8 to 31,1 dBA and from 31.1 to 31.4 dB(A) in the morning and evening respectively.
- Finally, at the fourth station (Ndokoa/Ekombitié), noise varied between 30.6 and 31.1 dBA in the evening

The results obtained show a general trend toward increased noise in the evening and peak recordings between 6:00 to 7:00. This is justified by the fact that early in the morning, people move to where they work and during that time the roads are used more frequently by motorcycles; on the contrary in the evening, they return to their homes and engage in noisy activities.

This study reveals that noise levels observed currently on the hydropower project site and from all stations remain well below the WHO and the World Bank Group limit values .

## 4.4. EXPERTISE OF HYDRO-SEDIMENT IMPACT ON THE SANAGA RIVER

### 4.4.1. Objectives and questions asked

The sediment problem was identified by impact assessments as a potentially major component of the project:

- In terms of economic activity: sand of the Sanaga River represents the main source of sand supply in Yaoundé (for construction activities); extraction activities generate significant revenues for municipalities where the quarries are located,
- In social terms: extractions are done mainly traditionally (using canoes and buckets). Thus, the sector employs many people from villages living closest to the river, but also from various regions of Cameroon, sometimes neighboring countries.
- In terms of hydropower exploitation, wear down of generators, filling of the reservoir.

The construction of the Nachtigal dam will impact sediment transport, however:

- In what context will this impact be felt? Volumes of sand currently at stake (volumes carted and volumes mined) are poorly known. The current impact of mining on the morphology of the river is not known
- How to perpetuate economic and social activities?
- The Lom Pangar dam, partly flooded in September 2015 and situated about 300 km upstream of the site earmarked for the Nachtigal dam, will averagely also have a middle term impact on sediment transport. What will be the residual contribution of the Nachtigal dam with regard to changing sediment produced?

These issues have prompted the developers to commission ARTELIA to carry out a study specifically on sediment (in 2014) also envisioned by the 2011 ESIA as a preliminary measure for the project.

### 4.4.2. Methodology

Observations, calculations and expert opinion were used in this study, as documented by:

- An on-the-site mission with various investigative activities such as:
  - Sample surveys and observations of sand *in situ;*
  - Observations of 4 geological segments made on the left bank near the dam site;
  - Identification and positioning of sand mining sites;
  - Geo-referenced photographic documentation;
  - Semi-directive interviews including quantitative elements with sand pits actors (i) divers and / or canoe-rowers and/or loaders and / or sand mine managers and (ii) municipalities on the following aspects: (i) Site and mining method (ii) Types of sands mined, (iii) Volumes mined according to the season, (iv) Evolution of mines over the years, (v) Sand stock in the river, and (vi) Socio-economic aspects of the activity;
- A literature compilation with (i) geological, soil and orographic maps developed by IRD, monographs published by IRD and (iii) a set of old photographs and old sandbanks identification;
- Interviews with other experts on the ground such as Gaston Liénou (IRD sedimentology researcher) and Benoît Messanga geologist and manager of Monatele quarry and Laurent Leveque expert geologist at EDF;
- Modeling using CAVALCADE (internal Artelia modeling software on sediment transportation) very graphically representing 300 km of the Lom Pangar - Nachtigal river reach in order to estimate the time before the impact of developments;
- Hydro-sedimentary modeling located in the reserve under TELEMAC 2D to estimate the "trapping" and "migration" of sediment in the future Nachtigal reservoir;
- Building a GIS with geo-localized information obtained from literature review and field mission.

All of these investigations have helped establish:

- An initial assessment of sand mining and storage
- A better understanding of sediment transportation;
- A better understanding and quantification of hydro-sedimentary impacts of the project;
- Recommendations of management measures.

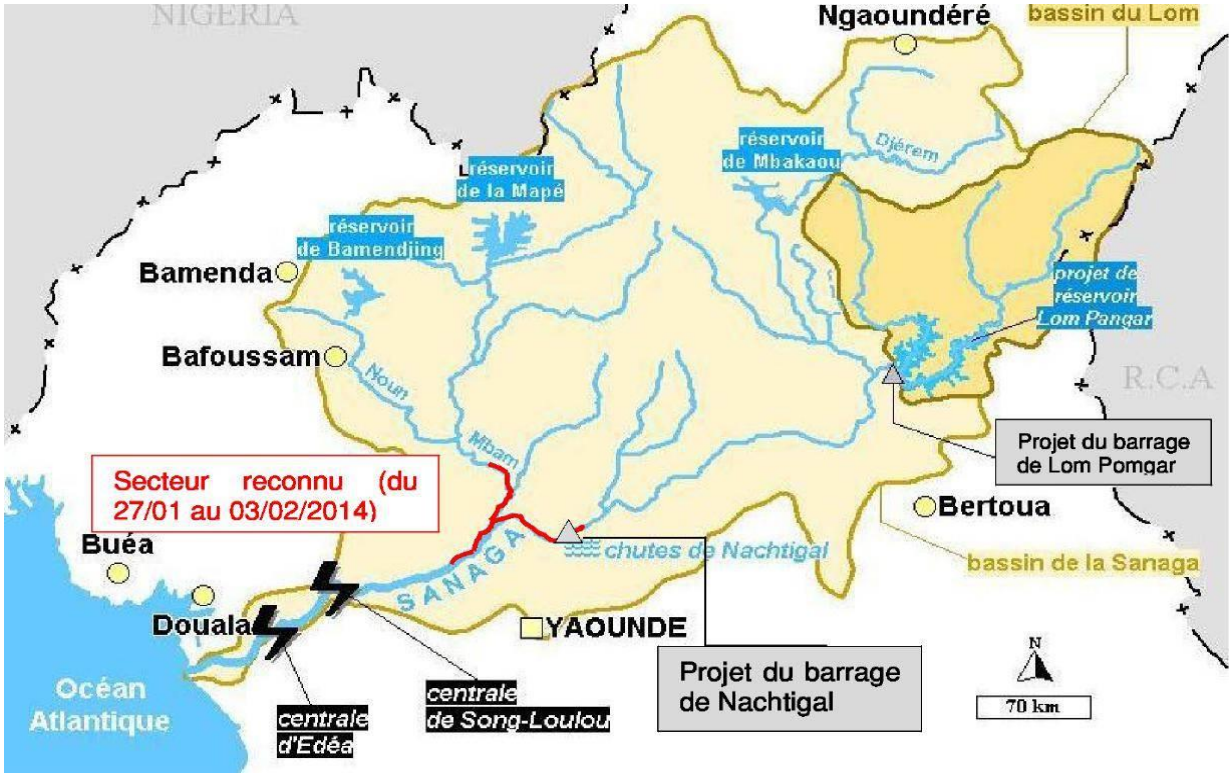



***Fig. 7. Recognized sector (27/01 to 03/02/2014)***

## 4.4.3. Assessment of current sedimentary diagnosis and trend of resource depletion

### 4.4.3.1. MINING IN 2013 AND EVOLUTION

An analysis of these interviews and cross-checking them helped estimate the volumes extracted in 2013 for various stretches. The volumes extracted in 2013 on these stretches of the Sanaga and Mbam were estimated at 950,000 $m^3$/year.

**Tabl. 5 - Estimated volumes of sand mined in 2013**

| Municipality | Stretch | Estimate of volumes mined in 2013 ($m^3$/year) |
|---|---|---|
| Mbandjock, Batchenga and Saa | The Sanaga from Ekombitie to Pont de l'Enfance<br>Pk 5 to 45[1] | 260 000 |
| Ebebda | The Sanaga from upstream of Ebebda to the confluence with the Mbam<br>Pk 45 to 70 | 300 000 |
| Bokito | The Sanaga from the confluence with the Mbam jto the rapids between Ebebda and upstream of Monatele.<br>Pk 70 to 77 The Mbam | 170 000 |

[1] Pk (Kilometre Point) 0 is positioned on the path of the future Nachtigal dam

| | | |
|---|---|---|
| Monatele | The Sanaga at Monatele Pk 77 to 90 | 220 000 |
| Total | | 950 000 |

These volumes are fast growing in recent years, but the evolution is not the same on the various sites and for various periods. Based on data and assumptions, an evolution curve of volumes mined is presented here of which only the increase should be considered. Recent proliferation of quarries shows that this activity is still expected to grow. However, the growth of this activity may be limited by the volume of sand that can be mined from the Sanaga and the Mbam. In fact several clues suggest that there is a gradual depletion of sand stock in the river bed that varies depending on the stretches:

- In the Nachtigal and Ndji rapids area, there seems to be a balance presently between what comes from upstream and what is mined
- At Ebebda, however, depletion is clearly felt: miners say it is more difficult to find sand as the years go by.
- On the Monatélé stretch (downstream of the Mbam - Sanaga confluence), this depletion is less felt. In fact, the huge contributions of the Mbam, the current capacity of quarries, the more recent opening of quarries and the morphology of the river on this stretch, can limit signs of possible depletion.
- On the Mbam further upstream, this depletion problem has not occurred since mining is marginal

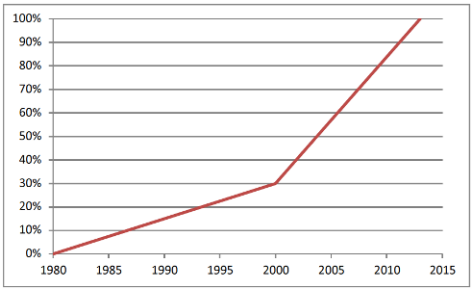
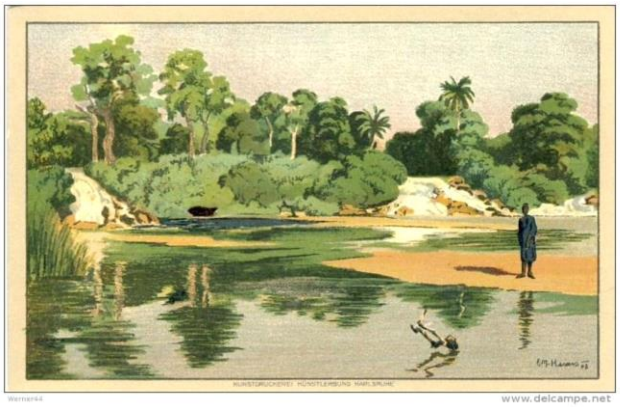
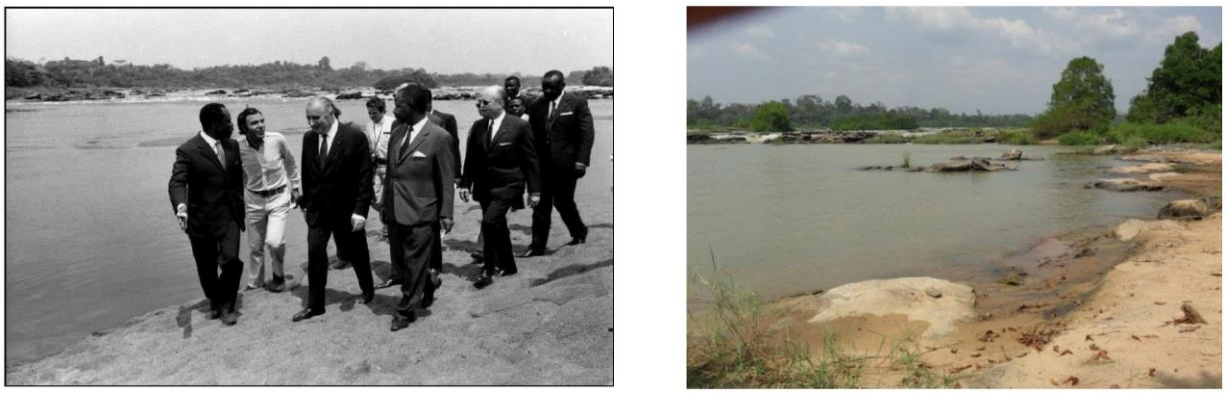



***Fig. 8. Overall increase in volumes mined from 1980 to 2013***

The study helped establish assumptions and observations about the current stock and the initial stock that the series of illustration below aptly document.




Left: Drawing of the Nachtigal Falls : many sand banks are visible
Right: Same stretch photographed during our mission : no sand bank visible during low waters.



Left: Visit of Pompidou at Batchenga in 1971. This photograph at Pk 8 shows a sand bank behind the delegation.
Right: Photograph of the same stretch taken during our mission. No sand bank visible during low waters

***Fig. 9. Illustrations of stocks evolution***

To conclude, the findings and assumptions on stock of sand in the river bed of the Sanaga and the Mbam for the various stretches are as follows:

**Tabl. 6 - Findings and assumptions on stock of sand**

| | **Sanaga** | **Sanaga** | **Mbam + Sanaga** | **Sanaga** |
|---|---|---|---|---|
| | Upstream of Ebebda | Ebebda upstream of the Mbam confluence | Mbam + Sanaga from the confluence to the Ebebda-Monatele rapids | Monatele |
| Findings | No more stock in the river bed at the end of the mining season. Stock renewed almost every rainy season. Stock at the end of the rainy season only at the bottom of falls and branches | Drastic decrease in stock, huge initial stock: deposits in the river bed<br>Disappearance of sand banks that existed in the 1980s | Important contributions of the Mbam<br>Little stock | Diminishing stock<br>Huge initial stock: deposits on the river bed<br>Disappearance of sand banks that existed in the 1980s |
| Assumptions | Initial small stock but visible on old documents. Currently, contribution consumed each year<br>There is no deposit in unmined areas | Balanced stretch in the 80s before mining. Current slope probably close to the balanced slope<br>Mining well above contribution<br>Initial stock completely consumed | Initial low stock<br>Presently contribution consumed every year<br>There are no deposits in unmined areas | *Short stretch balanced in the* 90s before mining Current slope probably close to the balance slope<br>Stock halving but remaining stock |

4.4.3.2. SEDIMENT CONTRIBUTIONS

The Engelung and Hansen formula (well suited to transport sands) was used for the calculation of natural sediment contributions. It helps to calculate on a balanced stretch the average annual volume transported in this case comparable to the transportation capacity.

On the other unbalanced stretches the calculated transportation capacity is much higher than the actual transportation and is thus not representative of what is actually transported: the actual transportation is in fact limited by the volume of sand coming from upstream; they are transit areas, the sand is not deposited.

Parameters used and the natural sediment flow estimated for the various stretches are as follows:

**Tabl. 7 - Parameters and natural sediment flow**

| Stretch | D50 (mm) | Slope balance (‰) | Minor river bed width (m) | Natural sediment flow ($m^3$ /year) |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Sanaga to Nachtigal | 0.75 | 0.105 | 570 | 630 000 |
| Sanaga upstream of the confluence with the Mbam | 0.65 | 0.105 | 700 | 630 000 |
| Mbam | 0.9 | 0.12 | 450 | 340 000 |
| Sanaga downstream of the confluence with the Mbam | 0.75 | 0.1 | 865 | 970 000 |

Naturally, that is to say, before massive sand mining in the minor riverbed, it can be estimated that the Sanaga transported approximately 600 to 700 000 $m^3$ of sand per year, the Mbam 300 to 400 000 $m^3$ of sand per year. Downstream of the confluence, the transportation capacity is estimated at 900 to 1 100 000 $m^3$/year.

**Note:** *It is important to note that these estimates depend on more or less mastered assumptions and thus these estimates are orders of magnitude.*

#### 4.4.3.3. ASSESSMENT OF SEDIMENT TRANSPORT

Two assessments were made to highlight mining and natural flow of sand: the first for 2013 that corresponds to the maximum extraction and the second for the last 33 years (1980-2013), 1980 being the start of mining.

**Tabl. 8 - Assessment of sediment transport in 2013**

| | **Volume for 2013** | | | | ***Natural volume*** |
|---|---|---|---|---|---|
| River | Sanaga | Sanaga | Mbam +Sanaga | Sanaga | *Sanaga* |
| Stretch | Upstream of Ebebda | Ebebda upstream of the Mbam confluence | Mbam +Sanaga* | Monatele | Monatele |
| Pk | 5 to 45 | 45 to 70 | 70 to 77 | 77 to 90 | 77 to 90 |
| Volume entering the Sanaga (thousands of $m^3$/year) | 630 | 370 | 70 | 240 | *630* |
| *Volume* entering the Mbam (thousands of $m^3$/year) | - | - | 340 | - | *340* |
| Volume mined in 2013 (thousands of $m^3$/year) | 260 | 300 | 170 | 220 | *0* |
| Diminishing stock (thousands of $m^3$/year) | 0 | 0 | 0 | 50 | *0* |
| Volume taken out of the stretch (thousands of $m^3$/year) | 370 | 70 | 240 | 70 | *970* |

**Tabl. 1 - Assessment of sediment transport for 33 years since 1980**

| | **Volume for 33 years** | | | | |
|---|---|---|---|---|---|
| River | Sanaga | Sanaga | Mbam +Sanaga | Sanaga | **Sanaga** |
| Stretch | Upstream of Ebebda | Ebebda upstream of the Mbam confluence | Mbam +Sanaga* | Monatele | **Overall** |
| Pk | 5à45 | 45 à 70 | 70 à 77 | 77 à 90 | **5 to 90** |
| Volume entering the Sanaga (thousands of $m^3$/year) | 630 | 560 | 520 | 820 | **630** |
| Total volume entering the Sanaga in 33 years (thousands of $m^3$/year) | 20800 | 18500 | 17100 | 27000 | **20800** |
| *Volume* entering the Mbam (thousands of $m^3$/year) | | | 340 | | **340** |

| | | | | | |
|---|---|---|---|---|---|
| **Total volume** entering the Mbam in 33 years (thousands of $m^3$) | **-** | **-** | 11200 | **-** | **11200** |
| Volume mined in 33 years (thousands of $m^3$) | 3300 | 3800 | 2200 | 1500 | **10800** |
| Diminishing stock (thousands of $m^3$) | 1000 | 2500 | 900 | 500 | **4800** |
| Total volume taken out of the stretch (thousands of $m^3$) | 18500 | 17100 | 27000 | 26000 | **26000** |
| Average volume taken out of the stretch (thousand of $m^3$/year) | 560 | 520 | 820 | 790 | **790** |

(*) Mbam +Sanaga from the confluence to the Ebebda Monatele Rapids

The assessment of mining-contribution made for 2013 gives a view of the impact of current mining on sediment continuity:

- Out of the 970 000 $m^3$/year of sand entering the study area (630 000 $m^3$/year by the Sanaga and 340 000 $m^3$/year by the Mbam), only 70 000 $m^3$/year went out, being less than 10%;
- Mining done now correspond to approximately natural contributions;
- On the right of the confluence, the Mbam currently brings in most of the sand corresponding to 340 000 $m^3$/year as compared to 70 000 $m^3$/year for the Sanaga.

**Note:** *All these results are orders of magnitude, due to the high uncertainty of the underlying assumptions. However, cross-checking of information helps to validate the major trends obtained. The uncertainties on the sediment contributions of the Mbam are stronger because of little available data. It is possible that annual contributions are higher than the volumes indicated above.*

To conclude, actual natural sediment transport was estimated as:

- 600 000 $m^3$/year for the Sanaga upstream of the confluence with the Mbam;
- 350 000 $m^3$/year for the Mbam upstream of the confluence.

Current mining can be estimated as:

- 560 000 $m^3$/year in the Sanaga upstream of the confluence,
- 170 000 $m^3$/year in the Mbam upstream or on the right of the confluence,
- 220 000 $m^3$/year in the Sanaga at Monatélé (downtream of the Sanaga/Mbam confluence).
- Being 950 000 $m^3$/year overall.

To conclude, sand depletion seems to be accelerating with:

- The initial stock of the entire area was estimated at about 5 000 000 $m^3$, but it seems there is a very small quantity left, may be less than 10% ;
- Volumes mined (situation in 2013) are comparable to contribution volumes, about 1 000 000 $m^3$/year.
- Volumes mined are expected to increase (increased demand, development of the road network, the coming of suction mining on a number of sites resulting in deeper extraction).

### 4.4.4. Hydro-sediment impacts

#### 4.4.4.1. IMPACTS OF THE PROJECT ON RISK OF SILTATION OF THE RIVER BED

The risk of current excess mining is a destabilization of this stretch. In fact, in recent years, the sand volumes mined correspond to the natural influx, in the stretch of our study. Analyses showed that virtually no sand volume is emerging from the stretch of the study.

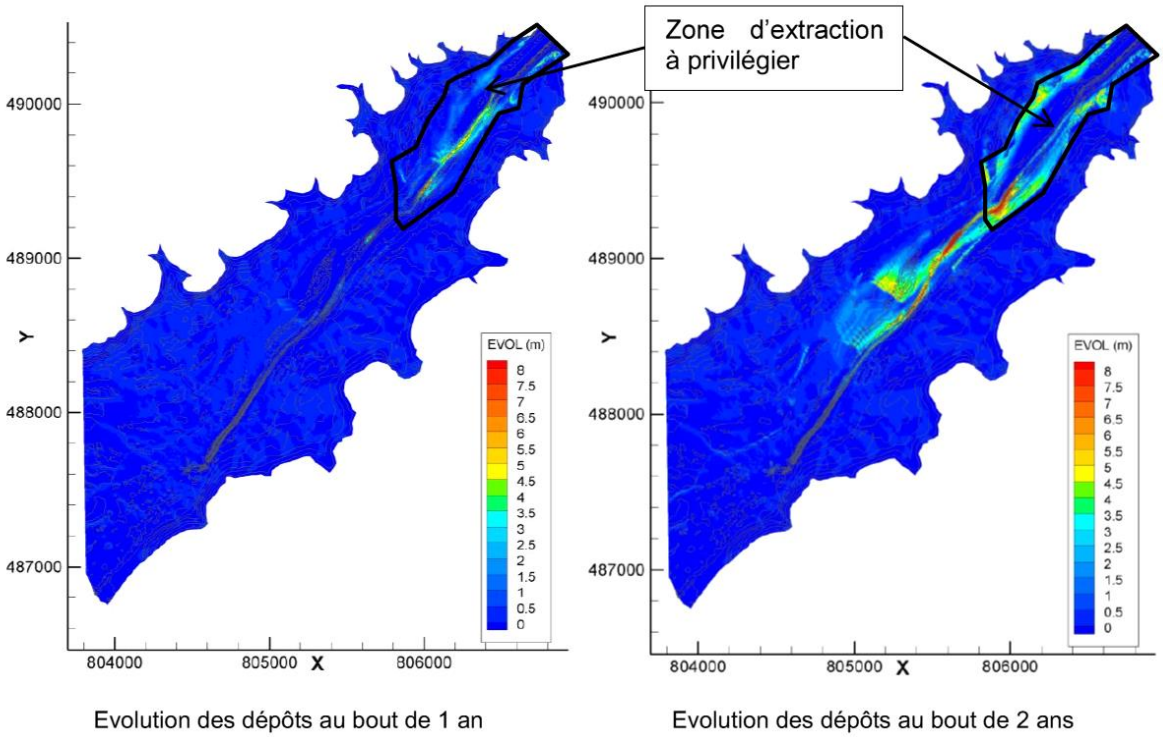
Given that the volume of sand currently coming out of the stretch of the study is a priori almost zero because of extractions, the construction of the Nachtigal dam should not over impact this trend and modify this risk.

#### 4.4.4.2. IMPACTS OF THE PROJECT ON SAND MINING ACTIVITIES

The findings of the digital model 2D TELEMAC of the reservoir made by ARTELIA alongside this study show that sand will be trapped at the tail of the reservoir and will take about twenty years to reach the dam (if there is no special extraction from the tail of the reservoir). During this interval, the fraction of sand passing through the dam will be very low despite the opening of valves during the rainy season.

It is therefore possible to consider an almost complete blockage of sand in the reservoir to the scale of the time of viability of mining sites. The consequences of this blockade are not the same depending on the stretches:

- Upstream of the dam: this mainly concerns the Ekombitié quarry which will then be situated in the reservoir. The current site itself will be flooded but a displacement of 1 to 2 km toward upstream would be easy. Contributions will increase with the building of the reservoir.
- Immediate downstream of the dam: It is unlikely that available stock be large in the by-pass stretch, since in this area stocks are currently very limited. Small annual contributions of this area will no longer be exploitable pretty quickly after the start of the project.
- Downstream of the dam: Batchenga Municipality. All these quarries will witness a rapid drop of their contribution since the current stock of sand is almost zero in terms of volumes mined.
- Ebebda upstream of the Mbam confluence. Presently has the largest mining sites, estimated at 300 000 $m^3$/year. All of these quarries will witness a fast drop in their contributions since the stock, large in the 1990s, is almost zero today in terms of volumes mined. In 2013, it seems that the sand miners collected everything from upstream contributions
- Mbam (sites 17 to 19, 25 and 26): these mining sites are situated on the Mbam and will as such not be affected by the construction of the dam.
- Monatélé (sites 20 to 22): today the sites mine mostly sand from the Mbam since at the confluence of the current contributions of the Sanaga are limited as compared to the contributions of the Mbam (70 000 to 340 000 $m^3$/year). The building of the dam will block the contributions of the Sanaga but will not fundamentally change contributions at the level of Monatélé. However, stocks still available at Monatélé are low and will certainly be exhausted at the same period as the start of dam operations. Thus a feeling of no-zero impact for operators of quarries (which may be attributed to the construction of the Nachtigal dam without any justification for this).
- Downstream of Monatélé until Edea: there are probably far fewer quarries because Yaoundé is far off. The building of the dam will block the contributions of the Sanaga but will not fundamentally change contributions downstream of Monatélé that will already be greatly reduced by current extractions.




TELEMAC 2D Modeling

***Fig. 10. Prefered mining area at the mouth of the reservoir, Ekombitié sand mine***

To conclude, total contributions of the Mbam and the Sanaga at the study site, being in the order of magnitude of the contributions, if a constant mining volume is maintained, it will be necessary to extract all the sand that enters the tail of the reservoir. This solution raises many social and economic issues:

- These adjustments assume that the personnel working in quarries are mobile. This seems to be the case for some of them (who come from other provinces), but the owners of the deposits and heads of quarries are from each municipality.
- In addition, municipalities that are currently collecting fees (3000 CFAF/truck) should be involved in the process because some municipalities will no longer have quarries on their territory.
- So, sand concentration conditions in the tail of the reservoir and the extraction depths may prompt mechanization of extraction. Though this modernization can help maintain the volumes extracted, it will result in decline of available jobs and the loss of income for many workers.

#### 4.4.4.3. IMPACT OF UPSTREAM DAMS (LOM PANGAR AND MBAKAOU) ON SEDIMENT TRANSIT ON THE RIGHT OF NACHTIGAL

The building of various control dams at the heads of the Sanaga and Mbam watersheds could eventually have an impact on the natural flow of sand in the study area. In fact, upstream reservoirs have very large volumes, of 1 800 to 6 000 million cubic meters; causing a complete blockage of sand from upstream.

The building of the Mbakaou reservoir in 1968 and Lom Pangar in 2015 will result in a decrease in the surface of the sand contributor basin (BV drained by reservoirs = 20 200 + 19 700 = 39 900 $km^{2)}$, corresponding to 50 % of the watershed from the Sanaga to Nachtigal (76 400 $km^{2}$). Sand contributions should therefore ultimately be reduced approximately by half.

Using the CAVALCADE model, we sought to evaluate how long it will take for the blockage of sediment to be felt at Nachtigal after operating Lom Pangar. The time will depend mostly on assumptions such as sand thickness and the initial stock. The following findings were obtained.

**Tabl. 2 - Time before noticeable decrease of contributions at Nachtigal**

| Average sand thickness (m) | Initial sand stock (millions of $m^3$) | Time before noticeable decrease of contributions at Nachtigal (years) | Average speed of movement of corresponding sands (km/year) |
|---|---|---|---|
| 1 | 90 | 200 | 2 |
| 0.5 | 45 | 100 | 4 |
| 0.25 | 22.5 | 55 | 9 |
| 0.1 | 9 | 25 | 22 |

It appears that the time before a noticeable decrease in sand contributions of the Sanaga at Nachtigal corresponds roughly to the initial sand stock in the river reach, divided by the annual transport capacity (650 000 $m^3$/year) - residual contributions.

It seems that for contributions to be halved, due to the building of upstream reservoirs, it would certainly take 50 to 100 years to happen at Nachtigal, for an initial stock estimated at 20 to 40 million cubic meters. It seems that the impact of existing upstream reservoirs is not yet felt significantly up to the Nachtigal site and certainly it is the construction of Lom Pangar that will have the highest long-term impact on the sediment assessment.

### 4.4.5. Recommendations

The first recommendation of the report is to consider moving some of the sandpits immediately downstream of the project in the Ekombitié area at the tail of the reservoir. If regaining pre-project extracted volumes remains technically realistic, reducing socio-economic impacts is much more problematic.

The second recommendation is to put in place a hydro-sediment follow-up with the aim of separating the specific impact of the Nachtigal dam on the sediment assessment vis-à-vis the impact of other elements (extraction, other reservoirs) and making reliable the specific observations made during expertise to specify quantitative and temporal estimates.

# 5. ADDITIONAL INVENTORIES AND STUDIES ON IMPACTS ON THE NATURAL ENVIRONMENT

## 5.1. UPDATE OF THE FAUNA AND FLORA BASELINE

This section contains a set of technical papers written by Dr. Achoundong, expert botanist, Dr. Kitio, ethnobotanist and Dr. Ghogue, expert aqua-botanist for the flora part (component 1) and Mr. Bouba and Dr. Ndjidda for the fauna wildlife part (component 2), all consultants at the Centre Africain de Recherches Forestières et de Développement (CARFAD), an environmental consulting firm based in Yaoundé, Cameroon.

This study complements the inventories carried out for the Environmental and Social Impact Assessment (2006 and 2011) and is part of the recommendations of the ESIA as a prerequisite to the execution of the project. It should be noted that at a meeting of the 2011 ESIA restitution workshop, the ESIA team was made to understand that there is *Podostomaceae* endemic in the area of the falls and which had not been described in the inventories of the ESIA. That is why this plant has been the subject of special attention in this investigation.

The work site and influence areas of the hydroelectric project (including islands in the Sanaga) were inventoried in full for flora and fauna except when the landscape did not allow for a complete inventory. The areas of the future by-pass stretch and of the reservoir were surveyed for aquatic flora. A study on the uses of plants (ethnobotany) was also carried out.

The inventories have revealed the presence of some species with conservation or protection status (national) that deserve special attention, of which there are :

- Podostomaceae *(Ledermanniella* sanagaensis, *Ledermanniella thalloïdea*), aquatic plants present in the reservoir, the by-pass stretch or downstream of the reservoir with a high rate of endemism. These species are classified as "CR" (critically endangered) or “EN” (endangered) by the IUCN.
- The bird Bannerman's Turaco *(Tauraco bannermani)* found in the future dam site. This species is endemic to Cameroon and is classified as "CR" (critically endangered) by IUCN. It is also on the list of full protection "Class A" of Cameroonian law.
- Other Class "A" species inventoried in the study area include, for example, the green turaco *(Tauraco persa)* and the giant pangolin *(Manis* gigantea).

Particularly for species protected under Cameroonian law (Class "A"), a file authorizing movement will be required (submitted with the Ministry of Forestry and Wildlife (MINFOF). A specific management plan will also be necessary for species on the IUCN red list.

### *Camerooonian regulatation*

According to Section 78 of Law No. 94/01 of 20 January to lay down forestry, wildlife and fisheries regulations, animal species living on the national territory are distributed in three protection classes A, B and C in accordance with Order No. 0565/A/MINEF/DFAP/SDF/SRC “to list animals of classes A, B and C”:

- Class A species are fully protected and may in no case be killed. Their capture or keeping is subject to obtaining an authorization issued by the administration in charge of wildlife.
- Class B species are protected, they may only be hunted, captured or killed after obtaining a hunting permit
- Class C species are partially protected. Their capture and killing is regulated following conditions determined by Order of the Minister in charge of wildlife.

### 5.1.1. Fauna

#### 5.1.1.1. METHODS

For terrestrial fauna, the approach was to look through the forest paths opened to carry out flora inventory and count all animals observed, as well as note down indication of presence on an inventory plot. The name of the species, the number of individuals seen, the indication of presence (droppings, footprints, sound, feces, nests, remains of meals, damages, soiled and shelter hole) and the quantity per indication are recorded on a counting form.

For avian fauna, the experts walked through the trails, village and forest tracks and making observations, by listening to cries and making calls to identify species.

The various species encountered daily were recorded in order to determine an abundance index for each species per day. There were 4 categories:

- C for common, meaning commonly and invariably encountered;
- F for fairly common, meaning habitually encountered;
- S for often, meaning irregularly encountered;
- R for rare, meaning rarely encountered.

Semi-structured surveys with hunters, bar tenders, bush meat sellers and local traditional authorities of the project area and markets were used to complete the inventory data.

The fauna study was conducted in close cooperation with the flora inventory team so that fauna data could eventually be linked with different vegetation features.

#### 5.1.1.2. RESULTS

**Terrestrial fauna**

A total of 34 of the most common species were identified during the inventories (most of these species are hunted). The common cane rat is the species encountered most in all project sites with an Abundance Kilometer Index (IKA) of 6.4.

The main species encountered and of which the abundance kilometer index is greater than 1 are:

- artiodactyls (sitatunga, wild boar and Peters duiker):
- lagomorphs (hares);
- rodents (common cane rat, porcupine, brush-tailed porcupine and Gambian rat)

During these inventories, the presence of the common pangolin *(Phataginus tricuspis) and the giant pangolin (Manis gigantea),* fully protected Class A species according to Cameroonian law, was noted. However their abundance is low in the project area (IK 0.04 and 0.08, respectively).

**Avian fauna**

During the inventory period, 122 bird species were identified on the sites of the living quarters, the plant, the dam, workers' camp, laterite quarry, the inflow canal and the DUP zone between the plant and the dam.

There are three bird species that are fully protected by Cameroonian regulations (Class A): Green Turaco (LC, IUCN), golden Turaco (EN, IUCN) and the brown cheeks hornbill (VU, IUCN). The martial eagle, although classified "VU" by IUCN is class "B" under Cameroonian law.

Among the endemic species found in Cameroon, there is a species, namely the golden turaco, which was identified during the inventories on the banks of the Sanaga in the future dam site.

**Protected species “Class A”**

Some species encountered are fully protected by Cameroonian law under "Class A", namely the green turaco *(Tauraco persa),* the golden turaco (*Tauraco bannermani*), and the common pangolin and giant pangolin (*Manis gigantea*).

#### 5.1.1.3. CONCLUSION AND RECOMMENDATIONS

Since the riparian forest to the right of the reservoir will be flooded, the community of birds living there will have to move either upstream or downstream of the Sanaga RiverSanaga River where they will find the same type of habitat. Noise that will be produced by heavy machinery during construction of the dam will scare away most birds; such an impact will have but a temporary effect if it is not excluded that a new interesting habitat is offered by the reservoir.

Since there are very few large fauna species, execution of the project will only have minor impacts, which can be considerably mitigated by implementing proposed recommendations.

The following measures are recommended to minimize the project's impacts on fauna:

- It will be desirable to strengthen awareness of various stakeholders including workers and drivers on regulations related to fauna in the project area.
- Minimize habitat destruction by restricting clearing to the barest minimum of the needs of the site;
- Facilitate the escape of animals in forested areas that will be flooded by slowly filling the reservoir;
- Restore soils and habitats after works.

### 5.1.2. Flora

#### 5.1.2.1. METHODS

**Terrestrial flora**

After reviewing available maps, a GIS expert drew a network of forest paths to help explore all the vegetation of the site and to identify the maximum number of species present. Complete inventories were carried out on sites of less than 35 ha; only samplings were done for other sites,

On the ground, a team of pathfinders marked out and opened the paths mapped out by the GIS expert and a team went through the paths taking note of all plants encountered. For each woody stem higher than 10 cm in diameter encountered, the botanist expert takes down the name of the species and estimates the diameter. For herbaceous species, note is taken of their presence. Unidentified species on the ground are collected and photographed, to be identified with the National Herbarium.

**Aquatic flora**

Inventories were conducted from upstream to downstream of the future dam, on a stretch of about 7.5 km on the river for a slope of 50 m (Alt.514 m - Alt 464 m.). The main objective of the work was to identify and collect Podostemaceae on this stretch; four sampling points were selected based on their relatively high turbulence (suitable habitat for Podostemaceae) and their accessibility. All harvested plants were pressed and dried in an oven at low heat. Identification of specimens was done at the National Herbarium, using both other specimens from the herbarium and existing flora especially the Flora of Cameroon and Flora of West Tropical Africa series.

**Ethnobotany**

To collect ethnobotanical data, surveys were conducted on a sample of the population of the study site. The goal was to collect precise information on the uses that people make of local plants. The population sample surveyed is made up of people who are familiar with the plants' names and use. Those who best meet these criteria are recruited from among those who have a particular interest in plants; it is the case with traditional practitioners, sawyers, hunters, craftsmen and the elderly.

5.1.2.2. RESULTS

**Terrestrial flora**

A total of 531 plant species, including 259 tree species and 272 shrub or herbaceous species were identified. Data on their ecology show that they are light species that very actively colonize the various open microhabitats of the semi-deciduous forest: gallery forest, secondary forest, cropland, bushes, edges of watercourses, savannah regrowth, selvages.

In all surveyed sites, *Trilepisium madagascariense* (light tree species) appears to be the most abundant tree. The other ten strongly represented trees in the sites are: *Celtis africana, Ricinodendron heudelotii Sterculia rhinopetatala, Pterygotha macrocarpa, Milicia excelsa, Ceiba pentandra, Lannea welwitschii, Pseudospondias microcarpa, Celtis mildbraedii.*

Many timber species are present. They are: *Triplochiton scleroxylon (Ayous) Terminalia superba (Frake) Milicia excelsa (Iroko) Pycnanthus angolense (Ilomba), Sterculia rhinopetala (Lotofa), Lophira alata (Azobé), Afzelia afriacna (Doussié Apa), Sterculia oblonga (Koto), Erythrophleum suaveolens (Tali), Mansonia altissima (Bete), Nesogordonia papaverifera (Kotibe), Alstonia boonei (Emien) Canarium schweinfurthii (Aiélé), Entandrophragma cylindricum (Sapeli) Entandrophragma utile (Sipo), Nauclea diderrichii (Bilinga), Pterocarpus soyauxii, Piptadeniastrum africanum.*

**Aquatic flora**

One of the objectives of this study was to confirm the presence in the area of two Podostemaceas: *Ledermanniella thalloidea,* endangered (EN), and *Ledermanniella sanagaensis,* critically endangered (CR). Only *Ledermanniella sanagaensis* was harvested during these inventories. More detailed surveys and during low water would perhaps also help harvest *Ledermaniella thalloidea* that was not encountered during these surveys. The high turbulence of the Sanaga waters does not facilitate the installation of other freshwater plants. Presently, only seven strictly aquatic plants are identified. They are:

- *Dicraeanthus africanus*;
- *Ledermanniella sanagaensis*;
- *Ledermanniella thalloidea* ;
- *Letestuella tisserantii* ;
- *Pistia stratiotes* ;
- *Tristicha trifaria*;
- *Cyperus alopecuroides* ;

Some optional hydrophytes (species usually associated but not necessarily with aquatic environments) are reported:

- *Ludwigia decurrens ;*
- *Marsdenia abyssinica ;*
- *Echinochloa pyramidalis.*

These plants are usually present on the banks of the riverbed.

**Ethnobotany findings**

Ethnobotanical surveys show that in the study area, 155 plant species are used by man. The main categories of use selected here are:

- Medicinal plants (143);
- Food plants (64) ;
- Medico-magical plants (33).

**Conservation status**

The conservation status of all identified species has been established. In all, two species of the site are critically endangered, two endangered, eleven vulnerable, four near threatened (NT); the rest are of minor concern.

Critically Endangered (CR) species include:

- *Ledermanniella sanagaensis (Podostemaceae) – aquatic;*
- *Marsdenia abyssinica (Asclepiadaceae) – facultative aquatic (banks).*

Endangered (EN) species include:

- *Ledermaniella thalloidea (Podostemaceae) - aquatic;*
- *Hymenodictyon pachyantha (Rubiaceae) - terrestrial.*

Vulnerable (VU) species include:

- *Cyperus alopecuroides (Cyperaceae) – aquatic;*
- *Vernonia guineensis (Asteraceae) – terrestrial;*
- *Pterorhachis zenkeri (Méliaceae) – terrestrial;*
- *Afzelia africana (Caesalpiniaceae) – terrestrial;*
- *Entandrophragma cylindricum (Méliaceae) – terrestrial;*
- *Entadrophragma utile (Meliaceae) – terrestrial;*
- *Lophira alata (Ochnaceae) – terrestrial;*
- *Mansonia altissima(Sterculiaceae) – terrestrial;*
- *Nauclea diderrichii (Rubiaceae) – terrestrial;*
- *Nesogordonia papaverifera (Sterculiaceae) – terrestrial;*
- *Macaranga praxii (Euphorbiaceae) – terrestrial.*

Nearly threatened (NT) species include:

- *Polyscias fulva (Apiaceae) – terrestrial;*
- *Pararistolochia goldieana (Aristolochiaceae) – terrestrial;*
- *Macaranga saccifera (Euphorbiaceae) – terrestrial;*
- *Diospyros crassiflora (Ebenaceae) – terrestrial.*

### 5.1.2.3. CONCLUSION AND RECOMMENDATIONS

Generally, all the vegetation affected here also exists elsewhere in other nearby localities in Cameroon either in gallery forests lining the banks of the Sanaga or those of its tributaries. The majority of species encountered has a wide ecological spectrum and thus has the ability to live in other types of forest. Therefore, this study as those of 2006 and 2011 concluded that there is no protected area in the

study area and that except for Podostemaceae, no species with special protection status has been identified during field investigations. Only Podostemaceae could be of major concern because of their high rate of endemism that makes them fragile.

Works planned in the area will result in the destruction of large mass of vegetation. Earthworks will cause habitat disturbances (vegetative cover loss, fauna habitat loss, erosion risk,). This will in all cases involve minor impacts that can be effectively mitigated through the implementation of proposed recommendations.

Except for Podostemaceae, plants impacted here have no special international conservation status and/or also exist elsewhere in similar habitats in Cameroon. *Marsdenia abyssinica*, though of limited distribution in Cameroon is widely distributed in Africa. In the study area, *Marsdenia abyssinica* was encountered only at the downstream station of the future reservoir (2.9 km downstream of the reservoir). Consequently, it is considered that the destruction of Podostemanceae would be the only major potential impact.

It should also be noted that the lentic waters created by the dam will create a more favorable environment for the proliferation of certain aquatic species. Particularly *Pistia stratiotes* and *Echinochloa pyramidalis*, currently very poorly represented in the less turbulent branches of the Sanaga waters, could develop in the reservoir area.

To mitigate these impacts the following effective measures are envisaged:

**Terrestrial flora**

- Location of preferred infrastructure in savannahs or fallows, avoiding as much as possible mature forests;
- Recovering timber;
- Restoration of sites after works;
- Promotion of cropping of wild fruits;
- Massive collection of botanical specimens for the National Herbarium.

**Aquatic flora**

- Undertake an in situ conservation by creating in the area of the site a Podostemaceae sanctuary;
- Undertake ex situ conservation;
- Conduct more in-depth surveys to search for other potentially present Podostemaceea, or also search for the same species elsewhere in Sanaga River or other rivers of Cameroon

**Ethnobotany**

For ethnobotany, it is recommended to train people on the importance of medicinal plants and better management of Non-Timber Forest Products (NTFPs). This training aims to remedy the shortcomings identified with the help of people namely:

- scarcity and unavailability of certain plants,
- popularization of the benefits of medicinal plants,
- preservation of NTFPs in all development activities.

## 5.2. STUDY ON THE DISTRIBUTION AND FLOWERING OF LEDERMANNIELLA

The additional Flora study of 2014 (see section 5.1.2 above) confirmed the presence of *Ledermanniella sanagaensis*, species of Podostemaceae endemic to the site and Critically Endangered (CR) according to IUCN Red List, which was not the case of the other species of the same family, *Ledermaniella thalloïdea* classified as Endangered (EN), still according to the IUCN Red

List. Another plant, *Marsdenia abyssinica* (Asclepiadaceae) was also harvested and evaluated later as Critically Endangered nationally. It therefore became necessary to work for their preservation, and prior to any conservation action is knowledge of the specificities of the target species.

The overall objective of this study is to understand the ecology and flowering *of Ledermanniella sanagaensis* and *Ledermanniella thalloidea*. This overall objective can be divided into three specific objectives: mapping the local distribution of species in the project area; study of flowering of *Ledermanniella* and study of the re-immersion after flowering in four stations.

### 5.2.1. Methodology

Five field missions were carried out:

- Mission 1: botanical inventory and geo-referencing of populations (18 to 25 March 2015);
- Mission 2 and 3: study on the flowering of *Ledermanniella* and habitat conditions (31 March 2015 to 4 April 2015, then 13 to 16 April 2015);
- Missions 4 and 5: monitor the re-immersing *of Ledermanniella* and study local habitat conditions during this phase (19 to 22 May 2015 and 17 to 20 June 2015).

During the first mission, all populations of target aquatic plants were mapped on the study linear; the four study stations (distributed from upstream of the reservoir to downstream of the future by-pass stretch) were identified. These stations were monitored during subsequent missions. During missions 2 and 3, observations were made on the four sites selected during the geo-referencing mission. The following measurements were taken: the distance from the shore, geo-location of each group of feet, the number of feet over an area of 60 $cm^2$, an estimate of the population size, the presence or absence of floral organs, the number of flowers. The following habitat conditions were noted: flow features, water height, its speed and the type of substrate binding of *Ledermanniella*.

During each of the four missions, a water sample was collected at each site and for three days, meaning 12 samples per mission and a total of 48 water samples on all four missions. These samples were sent to the laboratory of the University of Dschang for further physical and chemical analyzes.

### 5.2.2. Findings

All species of major conservation interest on the site were found. They are:

- *Ledermanniella sanagaensis (Podostemaceae), CR ;*
- *Ledermaniella thalloidea (Podostemaceae), EN ;*
- *Marsdenia abyssinica (Asclepiadaceae), CR (national).*

It should be noted that these three species do not represent a comprehensive list of aquatic plants on the site, or even that of *Podostemaceae*, but these are the ones that have been retained because of their endemic nature or conservation status.

A total of 47 data points of presence was noted during the mission. *L. sanagaensis* is the dominant *Podostemaceae* and is distributed on both sides of the future dam. *L. thalloïdea* was not detected before the 5$^{th}$ campaign, but its distribution and representativeness (covered area) would be similar to those of *L. sanagaensis*.

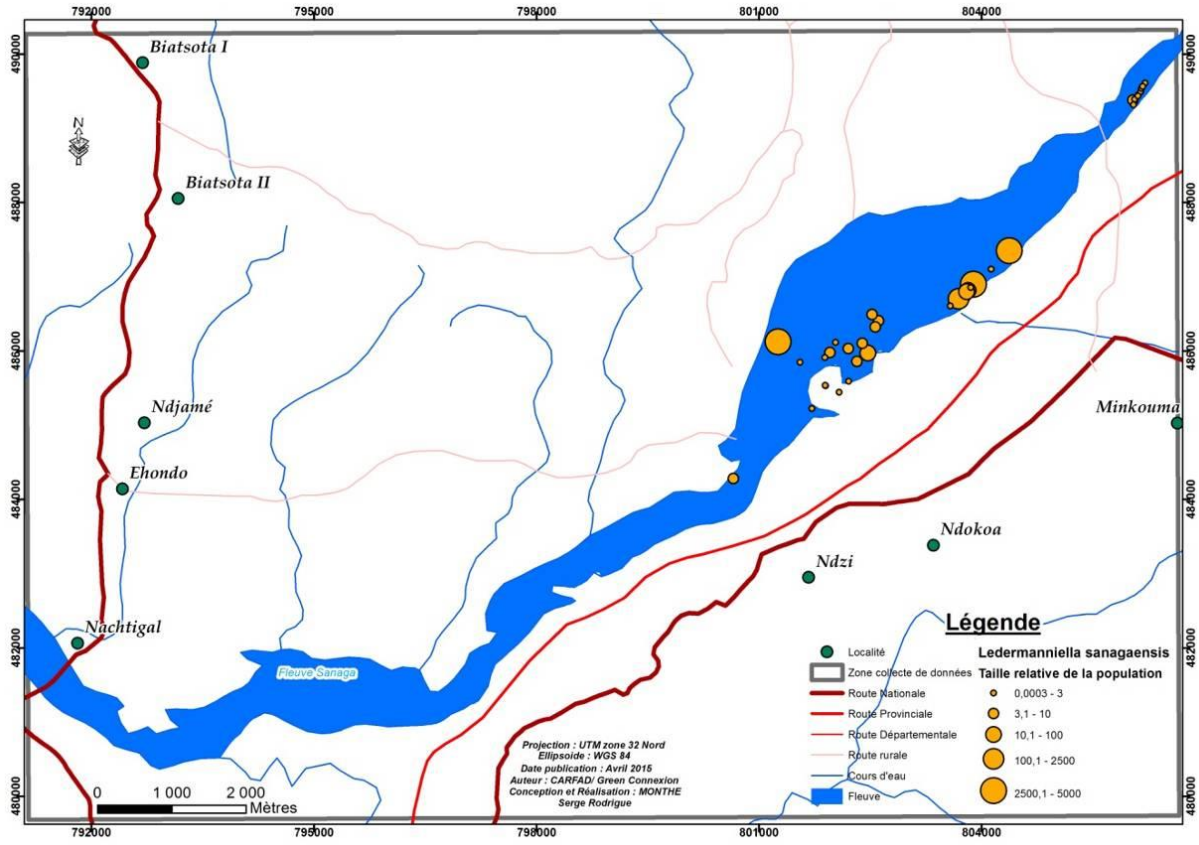



***Fig. 11. Distribution of L. sanagaensis noted during the first campaign. The circles are proportionate to the size of the surveyed populations.***

On an area of 60 cm$^2$, the number of individuals *of Ledermanniella sanagaensis* varies between 100 and 150. Also, where it is present, the density of this species varies between 16 000 and 25 000 individuals per square meter. Once discovered, *Ledermanniella thalloidea* showed a similar density. The size of the individuals of the above species varies between 0.4 and 0.5 cm long.

*Ledermanniella sanagaensis* and *L. thalloidea* once mature bear many flower buds (between 80 and 450 for an area of 60 cm$^2$). Until 19 June, the last day of the field mission, the rocks at the site were still not completely covered by water on stations 1 and 2

The host rock of *Podostemaceae* generally in the site is gneiss and their size rarely exceeds 5 m$^2$. During the observation periods (low flows), water height measured in places occupied by *Ledermanniella* varied between 6 and 51 cm and the speed varied between 0.13 and 2 m/s.

Water quality was generally good in all the stations. These are freshwater with very low or zero salinity, of which the pH is almost neutral. Conductivity is very low.

### 5.2.3. Discussion

*Ledermanniella sanagaensis* is the hydrophyte best represented on the site, followed by *Ledermanniella thalloidea*. Present knowledge shows that their distribution does not extend downstream to the Nachtigal ferry. In 2015, the largest population of these two species was found in the area covered by the future reservoir of the dam. *Marsdenia abyssinica* on its part is found rooted here and there in the crevices of the rocks along the entire length of the dam area.

*Ledermanniella sanagaensis* and *L. thalloidea* are small plants. Here, they grow attached to the gneiss or dead wood lying across the current. They live in crowded populations of several thousand individuals per square meter. The distance from the borderline of the water course does not influence their distribution but they always grow in fast-flowing waters. They prefer the surface of rocks close to the bottom of water. When matured, they develop many buds. When the water level drops, which brings them closer to the surface or simply exposes them, they can open a lot of flowers per day, and each flower that blooms can averagely last a day. The results show that before wilting, flowering of *Ledermanniella* is active during the early water recession phases. Several flowers open during the same day and the open flowers last on average 1 day. It should be noted that the study period was particularly dry (average flow observed in June 2015 was 50% of monthly inter-year average), which disrupted the observations of re-immersion of *Ledermanniella*.

### 5.2.4. Recommendation of actions to manage *Ledermanniella*

It should be stated in advance when the Lom Pangar reservoir starts operating from the 2016 dry season, with the associated increase in dry season flows, there would be significant impact on the possibilities of flowering *Ledermanniella*. Only two L. Sanagaensis populations were found in 2016 as a result of high flows during the dry-season, and 0 in 2017.

- Fine-tune the distribution map of target species. Survey and research target species in nearby tributaries to the Sanaga (known distribution of *L. sanagaensis* and *L. thalloï*dea). This research is expected to last a minimum of one year on selected sites in order to cover the annual cycle of each species. *L. sanagensis* has been noted on the Mbam.
- In-situ conservation. It will entail conserving species on the spot. Technically, this would help to locally maintain or reproduce current ecological conditions in one way or another.
- Translocation. This is the ultimate remedial measure. Given that there is no guarantee that any operation to move biodiversity shall succeed, it is important to maximize the chances of success before any such initiative. For this reason, it is important to undertake many preliminary studies of the physicochemical conditions of the host environment and methods of pollination and dissemination of the species concerned. Comparative studies of the physicochemical features of Sanaga River and surrounding water courses are underway and their findings are expected. Several methods of translocation should also be tried: harvesting the seeds, gathering individuals with ripe fruits, the translocation of shaped stones where individuals are rooted.

All these measures require regular monitoring of populations (in-situ and transplanted).

## 5.3. FISH POPULATIONS BASELINE STUDY

### 5.3.1. Purpose and objective

A study was carried out in 2014, led by Dr. Bitja-Nyom, ichthyologist and researcher at the University of Ngaoundere (Cameroon) to improve knowledge (qualitative and quantitative) on fish populations of the Sanaga in the Nachtigal Upstream Hydroelectric Project area and thus consolidate the initial state. During the 2011 and 2006 ESIA, fish inventories were made based on a socio-economic study on fishery that helped to identify 25 species on the ground caught by fishermen. In its ESMP, the 2011 ESIA recommended a deepening of ichtyological inventories as a prerequisite to executing the project.

The study had several objectives:

- Make a list of fish species present in the project area (upstream and downstream of the future dam axis);
- Determine the seasonal dynamics of the presence and abundance of species and detect possible migration (longitudinal or lateral);
- Specify biological and ecological characteristics and conservation status of species present;

- Locate potential spawning grounds of species present;
- Decide on the need (and if possible the value) of in-stream flow for fish species and a fishway.

### 5.3.2. Materials and Methods

In order to meet these objectives, several methods have been implemented over a period of 10 months (from January to October 2014):

- 21 stations were fished, including 12 on the Sanaga and 9 on tributaries with semi-quantitative monthly catches (fishing using variable net mesh) to 12 stations on the main axis of the Sanaga and one-time catches for some tributaries;
- Literature review on the distribution of fish species in the middle Sanaga (data analysis of museums, bibliographies, etc.);
- Literature review and field study to define some biological and ecological characteristics. This literature review was supplemented by field measurements whenever possible;
- Identification and characterization of proven spawning grounds of some species in the Project area.

### 5.3.3. Findings

Fish biodiversity

The fish inventory revealed that 65 species belonging to 16 families were present, of which 9 are indeterminate or new to science and 24 species endemic to the Sanaga. However, literature review shows that 21 additional species were recorded in the project area, although they have not been inventoried by catches. With the combination of both sources of information, there are up to 86 species (from 18 families) reported in the Project area.

In descending order, specific richness (number of species) per identified family is as follows *Cyprinidae* (17), *Mormyridae* (14), *Clariidae* (6), *Alestidae* (5), *Claroteidae* (5), *Cichlidae* (4), *Mochokidae* (3), *Schilbeidae* (2) and *Mastacembelidae* (2). The other 7 families (*Amphiliidae, Arapaimidae, Bagridae, Channidae, Distichodontidae, Hepsetidae* and *Latidae)* recorded respectively only one species.

Abundance and species occurrences

A total of 10,167 individuals (all species) were sampled, representing a total fresh biomass of 610 kg obtained in the total sampling area between January and October.

Analysis of the quantities of fish caught per unit effort (CPUE) showed that in general, from January to October, the catch gradually reduces in quantity and quality (i.e. the dry season is the most productive season in terms of CPUE). Fishing in the river is more profitable between January and February; it remains at an intermediary level between March and June and then slows down between July and October, when the flood level of the Sanaga peaks; profitability of fishing is rather reversed in the tributaries, peaking during the period of high waters around October. This finding suggests that there are movements of populations from the Sanaga to the tributaries during high waters.

Specific richness of various stations

All river stations (except for left-bank stations at Njoré and Mbandjock with degraded waters) have species richness (26 to 40 species per station) higher than tributary stations (11 to 23 species per station).

Habitats of fish species

The various fish resting, feeding and spawning habitats in the Sanaga River and its tributaries around the site were characterized for their temperature, pH, conductivity, suspended solids, total dissolved solids and

dissolved oxygen; their features were approached through an assessment of current velocities, depth and profile of the various stations.

Catches of species per feature have been linked with the literature review of the ecological characteristics of species. The findings show that:

- The distribution of species between the features of white and/or rapid water and those living in relatively calm waters is almost equivalent (46.3 and 53.7% of species, respectively);
- 41.4% are benthic species while 58.6% are pelagic species (though they occasionally exploit the benthos);
- The majority of species (64.1%) mainly spawn during the flood season, almost a third (28.2%) spawns all year round (many lay eggs) and only 7.7% seem to prefer the dry season to lay their eggs.

Status of species conservation

In terms of the status of species conservation, most species are classified under the "least concern" (LC) category of IUCN. Four species are currently classified as vulnerable, threatened or near-threatened or endangered (see Table 3). A focus on these four species is presented here-below.

**Tabl. 3 - Identified fish species and conservation status (according to IUCN)**

| Species (family); IUCN status | Occurrence: Number of stations (%) | Total abundance (Number of individuals) | Occurrence status and zoning in the study area | Known distribution (literature) |
|---|---|---|---|---|
| *Chrysichthys longidorsalis* (Claroteidae); VU | 10 (48%) | 75 | Quite frequent; Exclusively present in the river and absent in tributaries, sympatric with other *Chrysichthys* species that are not endemic | Endemic to the Sanaga |
| *Labeobarbus mbami* (Cyprinidae); EN | 7 (33%) | 13 | Accessory; Known mainly uncontaminated river stations downstream of Mbandjock, on either side of the axis of the future dam; also found in the tributary station Nia. The project area is the natural limit of fluvial dispersion. | Mbam. Dispersion limit situated around the Nachtigal falls. |
| *Sanagia velifera* (Cyprinidae); NT | 8 (38%) | 45 | Accessory; Present in the majority of Nachtigal river stations sampled at Mbandjock, absent in tributaries. | Sanaga and Nyong watersheds in Cameroon. |
| *Marcusenius sanagaensis* (Mormyridae): VU | 7 (33%) | 25 | Accessory; River stations and degraded or undegraded tributaries | Endemic to the Sanaga (Nanga Eboko, Nachtigal, Mbam and its tributaries). |

### 5.3.4. Impact of the project on fish populations

The Project will provoke some environmental changes in the reservoir and in the bypass portion that may locally modify the fish populations. However, as opposed to African large dams, specific features of the future reservoir (small area 4.2 km$^2$, shallow depth: 11 m maximum on the right of the dam, with a very short water stay time: about 12 hours and the risk of anoxia at very low depth) classify it under the category of dams that have minimal impact on fish populations.

Analysis of conservation has shown that most species should be classified under the category Least Concern (LC) of IUCN and those already classified as endangered are not threatened with extinction by the PHNA.

The main foreseeable changes in the future reservoir will concern among others reducing the speed of water flow which will become relatively calm thereby fostering lentophilic species, increasing the depth that will foster certain benthic species but especially those that are benthopelagic capable of feeding on the surface and in the deep, moving into marginal spawning areas for species that lay on open substrate in shallow water such as *Tilapia* and *Hemichromis,* disappearing or silting of spawning grounds for rheophilic species such *Labeo spp* that will stay mostly in the periphery.

### 5.3.5. Fishway

The report concludes that the development of a multiple species fishway (or another similar structure) at Nachtigal is not justified by currently available ecological data.

In fact, many arguments do not confirm the usefulness of such arrangement:

- The existence of the same species and the same biotopes upstream and downstream of the Project;
- The similarity between upstream and downstream habitats;
- The presence of numerous tributaries on either side of the dam;
- Historical data showing the absence of significant longitudinal migration;
- Findings showing the importance of lateral migration;
- Spillway allowing for an ecologic continuity during high flow season,
- Natural waterfalls in the Sanaga are already insurmountable obstacles for many species

Catch and carry operation will be realized, in order to allow a genetic mixing of fish population.

### 5.3.6. Instream flow

Provision for an instream flow at the foot of the dam will probably maintain fish species activity on the left bank of the bypass stretch. This bypass river bank should provide suitable conditions for the development of the majority of known species such as *Tilapia, Hemichromis, Sarotherodon, Lates, Heterobranchus, Schilbe, Synodontis,* etc.

The left bank has specific richness (and high CPUE), contrary to the right bank which, though characterized by high photosynthetic activity, takes the form of a wide shallow flood area and where the lowest fishing yield is observed. These findings confirm the need to concentrate the instream flow on the left bank.

The value of this flow cannot be determined based on current ecological knowledge for fish species. Nevertheless, it is essential to set up a fish monitoring system to validate the value that will be adopted.

## 5.4. MINIMUM ENVIRONMENTAL FLOW

This note has been written to assist in determining an appropriate minimum flow for the Project.

### 5.4.1. Methodology

Environmental flows can be described as "the quality, quantity and regime of flow necessary to maintain the components, functions, processes and resilience of aquatic ecosystems that provide goods and services for people."

Environmental flow is a management concept. To determine it, scientists generally use four types of methods:

- Hydrological method based on historical records of flows. With this method, environmental flow (or if applicable the instream flow) is determined by applying a rule in relation to the module or in relation to flows characterized by low waters (for example 1/20$^{th}$ of the inter-annual module).
- The hydraulic method is based on the relationship between hydraulic parameters, and the morphology of the water course and the minimum flow value (i.e. the wetted surface). These methods are easily applied in morphologies with little or no modified single channel but they are irrelevant in the case of heavily modified or multiple channel water courses
- The microhabitats method is based on the relationship between aquatic organisms and hydraulic conditions. It couples a hydraulic model of the stretch to the knowledge of the ecological requirements of organisms for their physical habitat (speed, water depth and bottom type) in order to estimate the habitat surfaces at varying flows. This method requires extensive knowledge of the various development stages of the target species. It also requires a hydraulic model that does not work today in a torrential system, falls and waterfalls and in the case of multiple channels.
- The 'holistic' method includes all other methods including societal aspects, combining their advantages, but also disadvantages. It needs to reach a consensus between the various uses, industrial and environmental requirements. Interest is limited if there are no or limited data on the ecology of species. It is a conceptual method that is rarely applied.

## 5.4.2. Results

### 5.4.2.1. INSTREAM FLOW TARGETS

In addition to the biodiversity aspects, existing uses of the bypass stretch was also considered, namely (i) fisheries, (ii) search plants for medical, commercial or food purposes, and (iii) the use of drinking or toilet water. Assuming that these uses are (i) currently very limited, (ii) will no longer be possible after the project given the presence of the inflow channel, and that (iii) security constraints will lead to prohibiting access to this area, water uses are not criteria to consider in estimating instream flows.

For biodiversity, the following points were considered:

- Habitats present on the site are mainly natural, farmlands being classified as modified.
- Only one critical habitat was listed in inventories as defined in (ii) (PS6 16. § 2): The Nachtigal site represents "areas of great importance for endemic species and/or with limited distribution" for *Ledermaniella sanagensis*, endemic aquatic plant of rocks of the site.
- As demonstrated by the experts who conducted the inventory, the site does not correspond to the criteria of (i) (§ 16. PS6) for critically endangered (CR) and/or endangered (EN) species nor to criteria of (ii) critical habitats for other endemic species:
    - The study on fish biodiversity, conducted by Dr. Bita-Nyom concludes as follows on endemic or EN species identified:
        - Labeobarbus Mbami EN: survival downstream of the project site is neither conditioned by instream flow in the future bypass stretch which is currently already hardly used by this species nor a fishway,
        - Chrysichthys longidorsalis VU endemic to the Sanaga: Present exclusively in the river and absent in tributaries, it will certainly proliferate in the future reservoir as is already the case in the reservoir of the Mape dam within the Mbam/Noun tributary system.
        - Marcusenius sanagaensis (VU): ubiquitous species, capable of living even in relatively degraded environments like Mekono and Mengolo. It is present downstream far from NDJATA in the future bypass stretch and upstream far (from Njoré to Mbandjock to) from the path of the future dam. Moreover, its presence was reported in the Rivers Mbam and Noun far from our study area.

- The value of this flow cannot be determined based on current ecological knowledge on these fish species;
- The findings show the need to concentrate the instream flow on the left bank.

In conclusion, it is preferable to target *Ledermaniella* spp. as a species that can be termed target for the restitution of the instream flow. In all cases, fish species will benefit from the minimum flow without jeopardizing the biodiversity of the area.

Little is known about the ecology of the target species. These Podostomaceae species prefer shallow running waters, and in particular, falls. Efflorescence of these annual plants occurs during low waters when flowers become emerged. It therefore needs a seasonal flow reduction in to complete its reproductive cycle.

The study on flowering conducted in 2015 identified that the densities of *L. sanagaensis* vary from 16 000 to 25 000 individuals per $m^2$ in the project area and the plants seem to prefer to cling to rocks like gneiss close to the bottom of the river. During the observation periods (low flows), the water height measured in places occupied by *Ledermanniella* varied between 6 and 51 cm and the speed varied between 0.13 and 2 m/s.

These characteristics of the habitat of *Ledermanniella* were taken into account in choosing biological flow values.

#### 5.4.2.2. HYDROLOGY

The historical minimum daily average flow of the series was recorded in April 1989 (15 $m^3/s$). The inter-annual module is 946 $m^3/s$. The values of low waters flows for a 10 year return period are about 20 $m^3/s$. The mean annual flow with a 10-year return period is 35 $m^3/s$. It should be noted that current minimum mean annual flow values are much higher now because of water releases from Mbakaou made since 1989 (the mean annual flow with a 5-year return period is 246 $m^3/s$).

The commonly used benchmarks give a broad range of the instream flow (from 7 $m^3/s$ for 30% of (DEFINE QCN 10 years) to 47 $m^3/s$ for $1/20^{th}$ of the mean annual flow), the mean of the range being at 27 $m^3/s$ which is close to the $1/40^{th}$ of the mean annual flow.

#### 5.4.2.3. MORPHOLOGY

From a physical point of view, the ordinary riverbed of the Sanaga has a width of about 250 to 500 m. It increases to nearly 1,700 m wide in the project area by splitting into many channels separated by rocky islets. It includes several islands. These islands divide the river into four main arms: the large left bank arm; the small central arm, the large arm on the right bank and the small arms on the right bank. The flows are multidirectional during high waters in relation to the many prongs and natural thresholds. The large arm on the left bank is currently the preferred channel during low waters.

### 5.4.3. Recommendations

With regard to international best practices and standards, the acceptability and the presence of a protected species CR *(L. sanagaensis),* it is recommended to release an instream flow in the bypass stretch.

However, in this context of little ecological knowledge on the target species (although additional studies are underway), we are not currently able to apply the holistic or micro-habitat methods. Only statistical methods related to hydrology may therefore apply.

The wetted river bed of the Sanaga in the TCC area is about 1,700 m wide and 4 has arms. The current minimum monthly flow during the dry season is about 200 $m^3/s$ (without Lom Pangar but with releases from Mbakaou). This value will rise to 650 m3/s with releases from Lom Pangar. Without releases from Mbakaou,

the average daily discharges between 1973 and 2012 regularly reach 80 $m^3/s$ with a historical minimum of 15 $m^3/s$.

Analysis of the characteristics of low waters flows (from 25 $m^3/s$ to 47 $m^3/s$) and the fact that this flow will be concentrated in a single channel (left bank), leads to the proposal to adopt 25 $m^3/s$ (slightly higher than the 40th of the mean annual flow) as the minimum value for the instream flow. The actual value of the instream flow may therefore be situated between 25 and 47 $m^3/s$.

Current ecological knowledge leads to the proposal (i) to channel the flow primarily to the big left arm of the Sanaga where *Ledermaniella sanagensis* was identified, (ii) to retain 25 $m^3/s$ as the minimum threshold for the instream flow and (iii) to adapt it (within the limit of the preset range) if the concentration of the instream flow on the left bank proves to be insufficient for the survival of the plant.

It is also proposed that additional studies and observations should be continued with a rigorous scientific protocol to improve knowledge on the ecology of this plant and identify any necessary adaptations or modulations.

## 5.5. STUDY ON THE NEED TO CLEAR VEGETATION IN THE NACHTIGAL RESERVOIR AREA PRIOR TO RESERVOIR FILLING

### 5.5.1. Objective

This note aims to identify the advantages and disadvantages of a total or partial withdrawal of ground vegetation on the Nachtigal site, focusing mainly on water quality and greenhouse gases (GHG) and to a lesser extent on some societal aspects.

### 5.5.2. Results

The volume of the reservoir will be 27.8 $Mm^3$. The residence time in the reservoir is short: about 12 hours and the maximum depth will be 11 m at the dam. The terrestrial area flooded by the reservoir is small: 220 ha (including 112 ha of forest on the right bank and islets, 108 hectares of shrubby savannah on the left bank). The secondary forest is characterized by a well-developed undergrowth of cocoa crops; they are habitats that have already been heavily modified with a low occurrence of commercial trees.

The water quality of the Sanaga is generally good despite the impacts of discharges from a sugar factory and a distillery upstream of the future reservoir (Mbandjock) since there is a strong dilution due to low flows of water courses draining these discharges (~1 to 2 $m^3/s$) compared to the low waters flow of the Sanaga (200-650 $m^3/s$ without and with Lom Pangar, respectively). Concentrations of dissolved oxygen are good (between 5 and 8 mg/l) and the waters are very low in minerals. The levels of dissolved organic carbon and 5-day biological oxygen demand can be high (up to 36 and 18 mg/l respectively), resulting from organic matter inputs; these concentrations vary with time. Nitrate levels are low but phosphate contents can be significant (can be > 0.5 mg/l).

Future water quality in the project area will be conditioned by releases of the Lom Pangar reservoir. The most significant oxygen deficits, largely due to decomposition of organic material embedded in the Lom Pangar reservoir, generally observed in the first years after impoundment will be greatly reduced prior to the Nachtigal Dam impoundment in 2020. Downstream of the Lom Pangar dam, it is likely that it remains deteriorated compared to the current situation and that the levels of nutrients and organic matter will remain elevated. Nevertheless, the waters will reoxygenate thanks to numerous rapids along the course of the Sanaga and organic matter released by Lom Pangar will be degraded or taken up (by organisms) prior to arriving at Nachtigal (over 250 km downstream of Lom Pangar). It is therefore likely that incoming oxygen concentrations at Nachtigal will remain identical to those currently observed.

In the tropics, biomass removal is often seen as the solution to the problem of impaired water quality following reservoir impoundment. It has in fact been observed that the quality of water depends on the type

and amount of vegetation submerged. However, lessons from the flooding of the Nam Leuk in Laos and Petit Saut in French Guiana show that complete deforestation is not sufficient to improve water quality since much of the biomass is actually in the soil. Experience from tropical environments show that the only effective solution to preventing the alteration of water quality would be to remove all vegetation but also to destroy soil biomass.

At Nachtigal, modeling the impacts of flooding on water quality shows that the consequences of terrestrial vegetation degradation in the reservoir will result in a small and very temporary drop in the oxygenation of water in the Nachtigal reservoir, which does not justify conditioning vegetation management scenarios on that criterion. In fact, the first day of the flooding, oxygen consumption due to the decomposition of the terrestrial above-ground biomass for 12 hours represents slightly less than 14% of the initial quantity (i.e. <1 mg / l). This figure drops very fast to about 10% after one month, 5% after 4.5 months and less than 3% (approximately 0.18 mg/l) after one year. These decreases in oxygen concentrations are within the natural range of variability observed on the site (i.e. 5 to 8 mg / l).

In terms of greenhouse gas emissions by the reservoir, two scenarios can be compared - with or without removal of the above-ground vegetation (which represents 38,600 tC in the flooded zone). The gain obtained from above-ground vegetation removal in terms of $CO_2$eq is **76 853 $tCO_2eq$** (= amount which would be emitted from the reservoir without above-ground vegetation removal). On the other hand if the extracted wood is burned then the gain becomes negative: GHG emissions would be about **94 100 $tCO_2$**eq. Compared to biomass flows (and/or carbon) entering the reservoir on an annual basis (estimated at about **150 000 tC/year**) and their degradation in the reservoir, the effects of the degradation of flooded organic matter on water quality (consumption of $O_2$ or concentration of dissolved elements) and the production of greenhouse gases will be negligible.

Considering impacts on aquatic biodiversity, it can be considered that fish diversity and productivity in the future flooded forest will be higher than in the middle of open water, which corresponds to the original water course of the river. The flooded forest creates suitable habitats for invertebrates, zooplankton and plankton and creates hiding places for fish.

Flooding the reservoir will likely induce partial loss of the terrestrial biodiversity currently on the riverine islands, including micro-fauna with relatively low displacement capabilities. The terrestrial mega-fauna is usually able to flee the flooded area provided it is not trapped and if there is comparable habitats close by. A slow filling of the reservoir will allow the majority of individual fauna to flee, but will not guarantee zero mortality. Deforestation often causes direct mortality of some fauna. Conversely, the tall trees found in the reservoir after flooding flooded can serve as habitat for some of the avian fauna.

To conclude, water quality and GHG issues do not justify that the future Nachtigal reservoir be deforested. Other aspects (fishing, navigation, landscape) may require partial deforestation for use of certain portions of the reservoir by local people. This partial deforestation would facilitate measures proposed to enhance the reservoir (fishing, navigation ...).

### 5.5.3. Recommendations

A multi-criteria analysis (MCA) was conducted to provide a decision-making support tool, based on 11 criteria. Four scenarios were considered for vegetation management: (i) total clearance with burning, (ii) total clearing without burning, (iii) partial clearing (right bank forest for example) or (iv) no action. There are also other intermediate scenarios (clearing of access corridors on both banks ...) that have not been evaluated since the objective was to show in broad terms, the advantages and disadvantages of the main alternatives.

The MCA results show that total removal (with or without burning) is an unfavorable choice with little interest for the Project. Conversely, the difference between the scenarios of a partial removal and maintaining the vegetation is low. The choice between these two scenarios could be motivated by other considerations (societal aspects, access to the reservoir, wish of stakeholders, etc.). Partial removal of the vegetation would facilitate access to the reservoir for fishing and have a lower impact on landscape

aspects. Conversely, it seems fish productivity is relatively limited given the exploitable fish stock (estimated at 18 fishermen according to the 2011 ESIA).

From an environmental perspective, deforestation, even partial, is not justified for this project. However, taking into consideration societal aspects, interim solutions could be encouraged. It is therefore recommended to use this analysis to initiate discussions with stakeholders to find the best solution.

# 6. ADDITIONAL STUDIES ON THE HUMAN ENVIRONMENT

## 6.1. HEALTH STUDY AND ACTION PLAN

The main objective of this action plan, produced by the CARFAD Consultant, is to propose a set of avoidance, mitigation and cushioning measures in response to the health impacts of the Project. It completes and specifies the diagnosis and health measures identified in the 2011 impact assessment.

A thorough analysis of the health situation of the project area was carried out. Morbidity for each health district of the project area was notably established. All water points and latrines in the area have been identified and analyzed, including the point of view to be taken for rehabilitation of each of them. All health centers and hospitals in the area were listed and analyzed: characteristics of technical platform, needs, lacks as compared to the minimum and complementary package of activities, staffing state and needs. Furthermore, an analysis of health actions developed on other projects in Cameroon (Lom Pangar, Alucam aluminum factory) is proposed.

It appears that the major vector-borne diseases in the area are malaria, schistosomiasis (spread by snails), onchocerciasis (transmitted by black flies, small insects whose larvae develop in the rapid waters of the Sanaga) and various diseases (gastric disorders, etc.). Malaria is the primary cause of morbidity by disease. Numerous other waterborne diseases are present, such as typhoid fever or amebiasis. STIs such as HIV/AIDS are also an important cause of morbidity in the area.

There are few functional drinking water points and virtually no waste treatment facilities. The lack of quality drinking water points, latrines and hygiene are important causes of morbidity in the area. The proliferation of parasitic diseases and other epidemics is partly linked to the quality of drinking water. The availability of health care facilities is relatively low. Moreover, of the 22 health facilities visited, only 2 had sufficient technical platforms. The equipment is often obsolete. Staffing shortages are also very important, both in terms of numbers as well as in terms of initial and ongoing training, the latter being non-existent.

The impacts of the project on health are modest compared to other hydroelectric projects. These impacts have been taken into account and will be avoided or mitigated. Furthermore, additional measures will be implemented in order to achieve a positive impact on health in the area. The main impacts identified are:

- Pollution from waste water and sewage and discharges;
- Possible slight increase in malaria because of the reservoir and possible slight decrease in onchocerciasis due to the destruction of breeding sites of the black fly;
- Possible increase in epidemics and pressure on existing health facilities due to the presence and concentration of workers and others attracted by the opportunities of the work site;
- Possible increase in STI contaminations, particularly HIV/AIDS for the same reasons;
- Possible increase in accidents (increased vehicular traffic);
- Loss of access to non-timber forest resources, including medicinal plants.

In order to address these impacts, a health action plan is proposed. Measures related to the impacts of the project will be extracted and included in the ESMP. Enhancement measures are included in the local development plan. As concerns the health part, specific health requirements have been included in the tendering files of contractors. They are included in their contracts and are mandatory.

The main measures proposed are as follows:

**With regard to the construction of facilities:**

- Setting up of adapted equipment and health teams on the constructionsites;

- Taking preventive measures, prophylaxis and communication/health training in construction sites for both STIs and for other diseases or epidemics and hygiene;
- Development of a partnership with local institutions, such as the Obala hospital for emergency treatment;
- Establishment of staff health monitoring and treatment.

**As concerns support to neighboring structures and villages**:

- Actions to strengthen and upgrade health facilities, drinking water points and sanitation in the area;
- Capacity building actions for staff in health facilities; awareness campaigns and health education to the villagers;
- Prophylaxis/prevention actions in villages;

## 6.2. STUDY AND ACTION PLAN ON LOCAL CAPACITIES AND MANPOWER

The study on local capacity and manpower aims to maximize the fallouts of the Project in terms of manpower and mobilization of local companies during the construction and operational phases. It is part of a voluntary social responsibility of the Project. This is to meet the high expectations of stakeholders in terms of employment, training and business opportunities. The study aims firstly, to propose measures to maximize the positive impact of the site by mobilizing people and local businesses in providing goods and services; secondly, to propose Project enhancement measures related to local economic development, particularly in terms of support to farmers and rural development.

The study was carried out by a CARFAD expert Consultant. It summarizes the opportunities and needs of the project in terms of manpower and provision of goods and services: about 1500 workers, of which more than half will be unskilled workers; provision of food and basic necessities; needs in terms of provision of services (catering, hairdressing, clothing, transportation, maintenance and repair of motorcycles and vehicles, etc.).

Then this study offers a detailed inventory of existing capacities and potentials in the 23 villages in the project area: government, local authorities and professional associations; large and small companies; financial institutions, investment structures, training centers, producer organizations, state of manpower. It is observed that the area has many economic structures and organizations, and abundant relatively skilled and unskilled manpower (e.g., 708 skilled technicians and workers). However, there is a genuine shortage of materials at the training centers.

Based on this inventory of project needs and potentials of the area, an action plan has been proposed. Actions to be implemented by the project are included in the ESMP. They may include:

- Linking the restaurant service and minimarket of living quarters with local producers of basic agricultural products;
- Establishment of partnerships for building training centers, carrying out training, capacity building;
- Local employment on the site, organization of visits and internships for apprentices, etc. ;
- Training for persons affected by the project on managing the amount of their compensation, and workers on banking;
- Arrangements concerning the establishment of money transfer agencies and the scheduling the payment of workers.

## 6.3. SOCIAL INFLUX MANAGEMENT PLAN

The construction of the facility will mobilize about 800 workers on average for almost 5 years, and about 1,500 workers during peak. It is possible that people seek to settle in the vicinity of facilities in search of new opportunities. This can be the source of social conflicts and problems if the phenomenon is not anticipated or properly managed.

The Social Influx Management Plan aims precisely to avoid, minimize and manage these risks.
To this end, it is:

- Identify potential sources and destinations of influxes and related impacts;
- Define measures to prevent or minimize uncontrolled influx;
- Define the terms of employment and in particular the decentralization of recruitment centers;
- Propose conditions for establishing an effective and continuous cooperation with authorities and local communities concerned to help them cope with migration;
- Identify pressures on local infrastructure and social services provoked by influx and propose solutions to upgrade them accordingly;

A literature review and a field survey were conducted by an expert consultant of Egis Cameroon. It highlights certain shortcomings or deficits of education, water and accommodation facilities near the area of the site. It identifies key stakeholders in the management of social flow, current migration trends, legislation and the lessons learnt from similar experiences (Chad-Cameroon pipeline; Lom Pangar). At Lom Pangar for example, a maximum of about 500 migrants was recorded, but their presence was also because of other projects. Having been informed of the terms of recruitment, job seekers rather quickly returned to their home towns or registered for possible employment opportunities. The influx observed in Batchenga and around during the construction phase of the Chad - Cameroon pipeline in 2001-2003 stood at 17.8% as compared to the resident population: 604 migrants, added to 3389 inhabitants.

The study shows that the main area of attraction for migration is between the villages of Batchenga and Minkouma, including the villages of Ndji, Ndokoa and Emana Batchenga. The existence of many and functional communications infrastructure facilitate migration. Divisional and district headquarters are also places of attraction for opportunistic migrants: Ntui, Mbandjock and Obala.

Three scenarios for migration to the Project Area during the construction phase can be considered as complying with the IFC guidelines :

- **Ideal scenario** (low migration risk): site workforce x 0.3, or about 450 people at peak

It is assumed that all proposed measures for prevention and management of flows are effectively taken, and they are closely followed/observed by the sub-contracting companies of the project and by the population.

- **Intermediary scenario** (average migration risk): site workforce x 1, about 1500 people at peak
  It is assumed that inflow prevention and management measures are in place, but there are problems in terms of practical application.
- **Unfavorable scenario** (high migration risk): site workforce x 3, about 4500 people at peak.

In this scenario, prevention and management measures are not applied or effective.

From there, the main anticipated potential impacts are:

- spontaneous creation of settlements at the entrance of project sites that can promote the spread of epidemics;
- modification of the male/female ratio in the project area due to the presence of a large number of majority male workers;
- increased prostitution and STIs;
- increased insecurity related to tensions between the resident population and immigrants;
- intensification of pressure on land, competitive exploitation of natural resources and conflicts between immigrants and the local population;

- increased pressure on community infrastructures;
- inflation of food and rent prices.

An action plan is proposed to prevent, mitigate and manage these impacts. Actions that will be implemented by the project will be included in the ESMP. They may include:

- The establishment of a partnership with the National Employment Fund (NEF) to maximize and decentralize local recruitment and inform the population about its conditions;
- Upgrade water points, schools and nearby health posts/centers;
- Helping municipalities to delineate areas of authorized and unauthorized constructions;
- Helping local businesses in areas of hygiene;
- Interact with local authorities to ensure control over spontaneous settlements;
- Establish liaison committees with villagers; strengthen existing village vigilante committees and/or create new ones;
- Measures to limit epidemics and HIV/AIDS (see health action plan);
- Establish access control measures to sites and facilities of the Project;
- Establish and enforce a code of conduct for workers of the site and living quarters.