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ENVIRONMENTAL IMPACT STUDY FOR THE REHABILITATION AND EXPANSION OF THE CAMBAMBE HYDROELECTRIC POWER PLANT

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Abbreviations

AAR	Regional Coverage Area
AIA	Environmental Impact Assessment
AID	Direct Influence Area
AII	Indirect Influence Area
AH	Hydroelectric Power Plant
ART.	Article
BCR	Roll-Compacted Concrete
CCD	Desertification Fighting Convention
CDB	Biological Diversity Convention
CFI	International Financial Corporation
CRC	Cambambe Rehabilitation Consortium
DEC.	Decree
DME	Waste Material Storage
DST	Sexually Transmissible Diseases
EFB	Concrete Covered Rock Breakwater
EIA	Environmental Impact Study
ELISAL	Luanda's Cleaning and Sanitation Company
ENE	National Electricity Company
EPAL	Luanda's Province Water Company
ETA	Water Treatment Station
ETAR	Effluent Water Treatment Station
GAMEK	Medium Kwanza Management Office
GoA	Govern of Angola
GWh	Gigawatt Hour
HPP I	Electric Central 1
HPP II	Electric Central 2
IIAA	Angola's Agronomical Investigation Institute

LBA	Environment Bases Act
LBRA	Aquatic Biological Resources Act
LGT	General Labor Act
LNEC	National Civil Engineering Laboratory
LOTU	Territorial Management and Urbanism Act
MINAGRI	Ministry of Agriculture
MINAMB	Ministry of the Environment
MW	Megawatt
NA	Water Level
NBSAP	National Strategy and Action Plan for Biodiversity
OIT	International Labor Organization
ONG	Non-Governmental Organization
OP	World Bank's Operational Policy
PGA	Environment Management Program
PMF	Probable Maximum Flow
SADC	Austral Africa Development Community
SEA	State Office for Waters
SIDA	Acquired Immune-Deficiency Syndrome
SONEFE	National Study Society and Overseas Enterprise Financing
TIRFAA	International Treaty on Phytogenical Resources for Nutrition and Agriculture
EU	European Union
UICN	World Union for Conservation
ZCIT	Inter-tropical Convergence Zone
WCD	World Commission for Dams

CHAPTER 1
INTRODUCTION

1. INTRODUCTION

This chapter presents the issues related to the background of the Cambambe Power Plant rehabilitation and extension project, the objectives of the environmental impact study report, as well as the enterprise justification within the local and regional context. It also presents the exact location of the enterprise and defines the study scope.

1.1. BACKGROUND

The first hydroelectric power generation feasibility studies covering the medium Kwanza river section were carried out during the colonial period, when the potential for the generation of 6,510 MW annually was identified, based on the installation of nine (9) hydroelectric power plants.

Between 1950 and 1970, companies from different countries carried out studies with different approach and accuracy strategies. The first studies were conducted by the American company *Hydrotechnic Corporation*, in the year of 1955, using Marshall Plan resources. In this decade, the Angolan government institution responsible for the energy sector, the Kwanza, Bengo and Lucala Study Brigade, extended the original works.

The parameters assessed by these studies were mainly related to the physical characteristics of the medium Kwanza river section hydrographic bay, particularly: the local hydrological regime, including the assessment of the levels available for the implementation of future hydroelectric power plants, the flow and the local climate characteristics.

Such studies were based on a field work that used photogrammetric flights and aero-photogrammetric restitutions, and were referred to the official 1st order network and to the average sea level measured in the Luanda's tide meter. Another item that was considered in this stage was the possibility that the power plants could be built independently of each other and that their implementation projects should take the best advantage from the natural river falls, producing energy with enough power to meet the local demand.

Based on this information and considering the energy and elevation needs, one of the dams foreseen for the medium Kwanza river section was the Cambambe power plant. This dam was built in the 60's and included the building of a concrete arch-shaped dam with double curvature, spillway integrated to the dam structure and the hydraulic generation circuit, composed by a low pressure water inlet, with a maximum height of 30 meters.

The dam design considered two (2) different phases, being the first one built in the early 60's, reaching a height of 68 meters, with a dam crest level of 112.75 meters in the side sections and 102.15 meters in the central section, and free passage for high-water discharge. This first phase was completed in 1962. The second phase, covered by this report, considered the elevation of the dam up to the 132.00-meter level and the insertion of gates into the dam structure for high-water discharge. This second phase (expansion) is the main focus of this EIA, including the rehabilitation phases that have their general project description presented in Chapter 2.

The Cambambe Power Plant (AH), located 11 km from the city of Dondo, entered in operation in 1962 and was designed to be implemented in two phases, which are:

- First, with a total installed power of 260 MW split into four (4) units of 65 MW, to be operated at reduced fall and without flow control by means of upstream lakes (effective power of 180 MW); and

- Secondly, with the enlargement of the generation system, through the construction of one (1) additional powerhouse of the protected type, excavated in the open air and protecting the four (4) generator units with a unitary power of 175 MW, the total installed power will be 700 MW (175 MW x 4).

The sequence of the SONEFE works, the General Medium Kwanza Plan – Previous Study and Definition do 2nd stage (1966) and the respective adjournment (1972). have presented supplementary and more accurate data about the medium Kwanza river section, including information regarding the preliminary inventory.

In the beginning of the 80's, the report *Energy Resources Survey of Angola* identified the energetic potentials of the hydrographic units existing in the Republic of Angola. The highlight of this report, regarding its hydroelectric power generation potential, was the Kwanza river, thus confirming the SONEFE studies. Based on such results, within the context of the restructuring process of the Angolan infrastructures, an option was made to invest in the medium Kwanza hydroelectric potential, with the construction of the Capanda Hydroelectric Power Plant, which started operation in 2004 with an installed power of 520 MW.

In the following year, EngeHidro reassessed the alternatives presented by the SONEFE and Energoprojekt companies, which results are presented in Table 1.1.

Table 1.1: Medium Kwanza River Basin – Comparison between hydroelectric potential studies

Studies	**Energoprojekt**		**EngeHidro**	
	GWh	**MWmed**	**GWh**	**MWmed**
Capanda	1.000	114	1.937	221
Nhangue	1.300	148	2.241	256
Laúca	4.700	537	5.043	576
Caculo Cabaça	7.500	856	8.032	917
Cambambe	4.100	468	4.259	486

Source: Intertechne Consultores S.A., Revision of the Fall Division in the Medium Kwanza River Section

Based on the studies mentioned above and on the growing energy needs in the country, steps were taken to carry out the second Cambambe AH construction phase, which will increase the installed power through the elevation of the lake and the increase of the Kwanza river controlled flow upstream of Cambambe, with emphasis for the Capanda AH, located 134 km upstream of Cambambe.

The following drawings (Figures 1.3 and 1.4) show the arrangement for the implementation of four (4) hydrogenerator groups with a unitary power of 175 MW, resulting in an installed capacity of 700 MW.

Figura 1.3: Pormenor do arranjo geral da implantação da Central II.

Figura 1.4: Pormenor do arranjo geral do circuito de geração, em corte, da Central II.

1.2. JUSTIFICATION

The Republic of Angola undergoes presently a very dynamic phase of its development process, after decades of almost total stagnation as a result of passed civil conflicts. Such economic growth process is now reaching rates of almost 15% a year. However, to ensure the continuation of this phase, which is extremely important for the improvement of the Angolan population living conditions, ensuring the even distribution of the benefits around the whole national territory, it is necessary to renew and expand the country's economic infrastructure, mainly that related to the electric power supply.

The increase in the country's energy demand is already being felt, mainly in the large cities where the supply is subject to frequent interruptions.

According to the annual electric power report issued by the Catholic University of Angola (2007), in the period from 2001 to 2005, due to the economic growth, the electric power demand increased by 36%. The report also points out that there is a contained demand that will quickly grow when the offer shows up. Practically 90% of the companies operating in Angola use their own generators to fulfill their energy needs and to face the unstable supply.

Such situation is building the pressure for the increase of the electricity offer in the country, which growth is still restricted due to the low electric power availability. According to a report issued by the Ministry of Industry (2007), the expansion of the industrial sector depends on the increase of the electric energy offer, and depends also on other improvement plans and the implementation of strategic infrastructure. According to the Ministry of Energy, these other plans also include the alignment of the power tariffs, so they Will be able to compensate the production, transport and distribution costs.

The National Electricity Company (ENE) data, presented in Table 1.2, shows that the country's electricity consumption was muçu higher during the last decade.

Table 1.2: Electric energy consumption in Angola, em GWh per Supply System (1990/2007)

	Electric Power Consumption (GWh)				
Year	**North System**	**Center System**	**South System**	**Isolated Systems**	**Total**
1990	582,20	102,40	60,30	32,90	777,80
1991	696,20	111,50	67,10	29,90	904,70
1992	714,80	127,20	65,30	37,40	944,70
1993	677,80	97,10	62,60	36,30	873,80
1994	756,80	95,70	63,70	20,90	937,10
1995	820,70	101,40	76,30	29,20	1.027,60
1996	808,80	96,50	80,70	60,50	1.046,50
1997	904,80	87,50	76,80	76,10	1.145,20
1998	1.054,30	87,30	97,30	69,30	1.308,20
1999	1.064,80	99,60	83,10	88,40	1.335,90
2000	1.145,80	93,00	89,70	97,50	1.426,00
2001	1.264,30	146,10	125,00	99,00	1.634,40
2002	1.400,80	156,00	120,40	105,10	1.782,30
2003	1.559,10	149,00	131,50	155,40	1.995,00
2004	1.814,17	117,76	131,68	179,81	2.243,42

2005	2.137,32	136,23	160,90	202,74	2.637,19
2006	2.414,35	166,72	159,75	241,99	2.982,81
2007	3.137,43	481,22	162,18	500,17	4.281,00

Source: National Electricity Company (ENE). Program for the Energy Sector Development 2008-2013. The 2007 data is estimated.

The Angolan energy matrix, despite the predominance of the hydroelectric power, as shown in Table 1.3, presents a significant participation of thermoelectric generation. Almost 40% of the energy is supplied thermoelectric plants, which totaled an installed production capacity of 1,010 MW in 2007. Such thermoelectric generation, in addition to increasing the process cost, also brings a high level of pollutant emissions. Together with this situation, there are also distribution problems that allow the consumption of only 81% of this amount, because from a total of 2,231 km of installed lines, only 55,3% is available.

Table 1.3: Angolan Energy Matrix in 2007.

Energy Generation Source	Power			Participation (%)
	Installed	Available		
	MW	MW	%	
Hydraulic	627.2	606.9	96.8	62.1
Thermal	382.4	211.5	55.3	37.9
Total	1,009.6	818.4	81.1	100.0

Source: Catholic University of Angola, Energy of Angola (2007).

The configuration of the present Angolan electric power supply system is organized in the form of four (4) non-interconnected systems, named according to the geographical localization where they are implemented, as shown in Table 1.4 that indicate the provinces serviced by the same, and the respective installed and available powers as well.

Table 1.4: Hydroelectric Energy Supply Systems in 2007.

Systems	Serviced Provinces	AH	Installed (MW)	Power Available (MW)	Participation (%)
North	Luanda, Bengo, South Kwanza, North Kwanza and Malanje	Capanda	520	520	74%
		Cambambe	180	135	
		Mabubas	17,8	0	
Centro	Benguela	Lomaum	35	0	13%
		Biópio	14,4	7,2	
South	Huíla and Namibe	Matala	40,8	27,2	6%

North Lunda (isolated systems)	Cabinda, Huambo, Bié, Zaire, Kuando Kubango, Cunene, Moxico, North Lunda, South Lunda and Uíge	Luachimo	8,4	4,2	7%
Total			**816,4**	**693,6**	**100%**

Source: Catholic University of Angola, Energy of Angola (2007).

From the analysis of the Table 1.4 data we can see that the north system has the largest installed and available power, corresponding to 74% of the country's energy. This situation is justified by the presence in this region of the largest cities of the country, as for example, the capital Luanda, therefore holding the largest demographic density and consequently, being the region with highest economic development.

It is also important to point out that the estimated country's hydroelectric potential exceeds18,000 MW, according to surveys in only six (6) of its 48 basins (Table 1.5). This means that, in addition to the exploration of only 3.86% of the estimated potential, the generation potential of 87.5% of the country's rivers remains unknown.

Table 1.5: Hydroelectric Potential of AHs above 50 MW.

Hydrographic Basin	AH	Potential Power (MW)
Lucala River	7	980
Kwanza River	10	5,730
Longa River	7	1,190
Queve River	8	3,020
Catumbela River	15	1,679
Cunene River	14	2,045
Total	**61**	**14,644**

Source: Catholic University of Angola, Energy of Angola (2007).

Among the 48 hydrographical basins of Angola, the Kwanza river basin holds the largest energy generation capacity; presently, 700 MW are generated in the two hydroelectric plants that feed the north system, the Cambambe Hydroelectric Power Plant (AH) with an installed capacity of 180 MW and the Capanda AH with 520 MW. However, the estimated capacity of the entire basin is of 6,780 MW, with a guaranteed energy of 26.200 GWh. In this scenario, there are studies that make feasible the construction of another seven (7) hydroelectric power plants downstream of the Capanda hydroelectric power plant.

The beginning of operation of the Capanda hydroelectric power plant allowed the duplication of country's generation capacity and will make feasible the construction of new plants downstream of it, and also the possibility of increasing the average energy of the Cambambe Hydroelectric Power Plant, due to the benefits of the Kwanza river flow control by the Capanda AH, in the order of 350 m3/s during the whole year.

With the implementation of this project and based on the simulations carried out, the following results were obtained for Central I (regarding the Cambambe AH elevation):

- Installed Power (MW) .... 260 MW
- Average Energy (MWavg) .... 229 MWavg = 2,006 GWh/year

Simulations for the alternatives of increasing the installed power for Central II (Cambambe expansion with a second power houses) were equally performed, considering different assumptions and provided the benefits of increasing the capacity and the resulting energy are assessed. For the energy sizing study the following basic concepts were used:

- **Average Energy (EM):** is the average value of the monthly generation along the entire flow history.
- **Gross Height (Hb):** is the difference between the upstream water level (in the lake) and the downstream water level (when the Kwanza River returns to its natural bed).
- **Reference Height (HRef):** is the net fall for which the turbine, under full distributor opening, supplies the nominal generator power.

Energy simulations were carried out to determine the energetic result of Central II, with the assessment of the installation alternatives for variable quantities of new generating units, so, with the implantation of Central II a generated energy increase will take place with the best possible cost-benefit ratio.

This way, only the energy that is additional to the energy already generated in Central I will be considered as the Central II energetic benefit. The simulations present the respective results in the following Tables.

Table 1.6: Energetic Simulations on Monthly Basis

AFTER REHABILITATION		POWER ADDITION / ELEVATION		FINAL CONFIGURATION	
Installed Power (MW)	**Average Energy (MWavg)**	**Power Installed (MW)**	**Average Energy (MWavg)**	**Power Installed (MW)**	**Average Energy (MWavg)**
260	229	140	108	400	337
260	229	180	138	440	367
260	229	220	167	480	396
260	229	260	194	520	423
260	229	300	221	560	450
260	229	340	248	600	477
260	229	380	274	640	503
260	229	420	296	680	525
260	229	460	309	720	538
260	229	500	315.5	760	544.5
260	229	520	317	780	546
260	229	540	319	800	548
260	229	580	322.5	840	551.5

260	229	620	325.8	880	554.8

Source: ENGEVIX (2009).

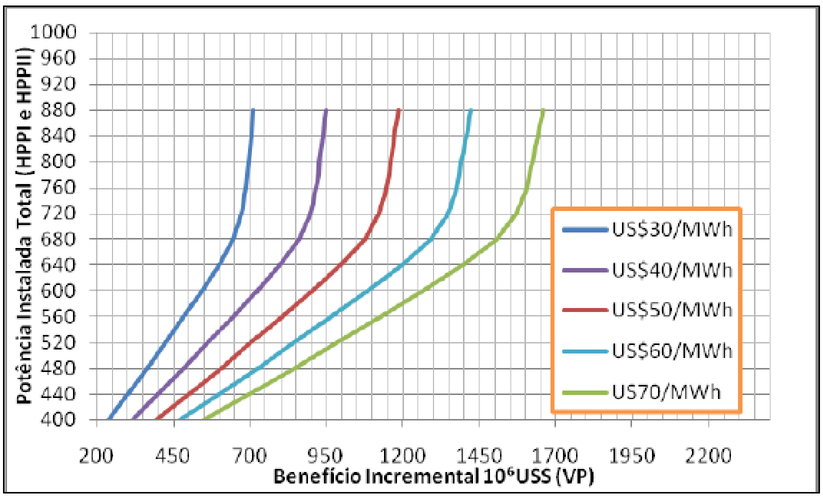
Table 1.7: Other Parameters Regarding the Energetic Simulations Carried Out for Cambambe AH.

Installed Power (MW)	Max. WL Normal (m)	Hydr. Losses (m)	Ref. Flow (m3/s)	Gross Height (m)	Ref. Height (m)	Efficiency T/G	Unavailable (m)	Average Level Downs. (m)
400	130	2.3	405	114	111.7	90%	9.0%	16
440	130	2.3	445	114	111.7	90%	9.0%	16
480	130	2.3	486	114	111.7	90%	9.0%	16
520	130	2.3	526	114	111.7	90%	9.0%	16
560	130	2.3	566	114	111.7	90%	9.0%	16
600	130	2.3	607	114	111.7	90%	9.0%	16
640	130	2.3	648	114	111.7	90%	9.0%	16
680	130	2.3	688	114	111.7	90%	9.0%	16
720	130	2.3	729	114	111.7	90%	9.0%	16
760	130	2.3	770	114	111.7	90%	9.0%	16
800	130	2.3	810	114	111.7	90%	9.0%	16
840	130	2.3	850	114	111.7	90%	9.0%	16
880	130	2.3	891	114	111.7	90%	9.0%	16

Source: ENGEVIX (2009).

Figure 1.1 below shows the incremental benefit at the present value with the installed power increase. The curves show that there is a clear advantage up to approximately 720 MW (260MW+460MW). Above this value, although the benefits are always increasing, they become proportionally lower.

Figure 1.1: Incremental Benefit under Full Installed Power



Source: ENGEVIX (2009).

Legend:

Full Installed Power (HPPI and HPPII)

Incremental Benefit 10^6 USS (VP)

The indicated power of 700 MW for Central II, already foreseen in the phase I construction period in the 60's, added by the existing 260 MW, totaling 960 MW, is coherent with the economical advantage of this analysis.

Therefore, the results obtained with the several simulations, and taking in consideration the initial Cambambe AH elevation project, clearly indicate that:

- The installed capacity in Cambambe's Central I is lower than the existing Kwanza river potential at the enterprise site, which plainly justifies the power plant expansion;

- The alternative analyses for the incremental capacity indicates that there are significant average energy increments for the capacity installed in Central II (second power house), up to the limit of 520 MW;

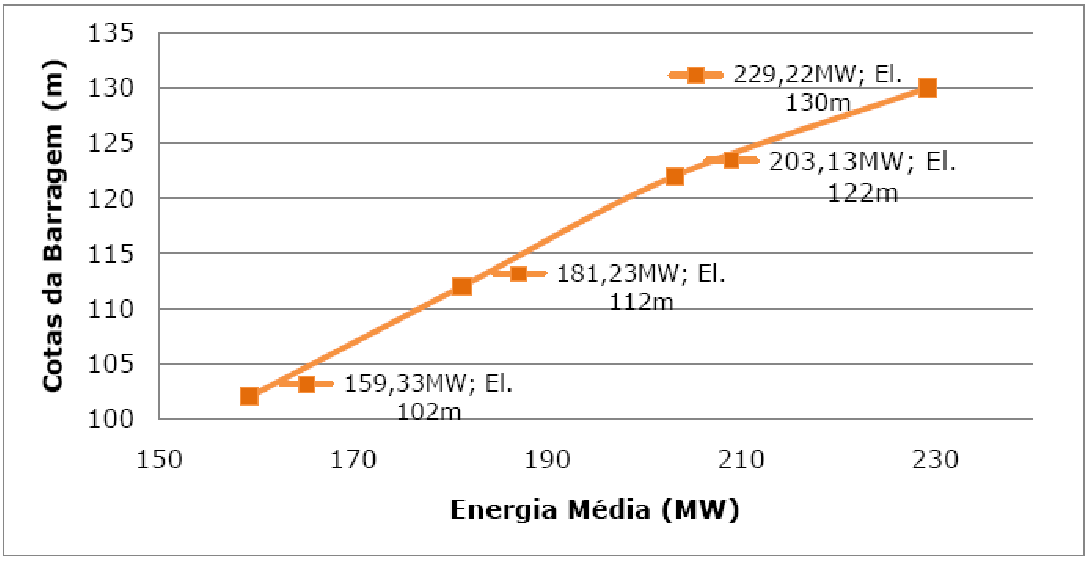
  Beyond this limit, it may be still useful to increase the installed capacity with the purpose of making generation capacity available in the peak regime, which is an important benefit for Angola's North System under the present circumstances, however, without adding any additional average energy.
- The energetic benefit of Cambambe's Central II with capacity of 700 MW results the following:

- Additional installed power (MW).. 700 MW

- Average additional energy (MWavg) 317MWavg =2,776.9,

In energy terms, the increase in the reservoir level produces an increase of the energy generated by the existing central (four machines in Power House I), according to the energy simulations carried out with a series of average monthly flows, as indicated in the following Figure 1.2.

Figure 1.2: Average energy produced by the lake elevation



Source: ENGEVIX (2009).

Legend:
Dam levels (m)
Average energy (MW)

Usually, the main benefits arising from the implementation of this project are the following:

- Assurance of reliability, increase in the service life of the turbines and generators installed in Central 1 and reduction of stops caused by the equipment ‘s mechanical unavailability;
- To increase generation from the current 180 MW to 260 MW, with the height raising works, i.e. to make the installed power of each turbine (65 MW) its effective power.
- To make use of the existing structures and the water surpluses for generation of a second power station, with a capacity of 700 MW total installed power, making the total installed power amount to 960 MW (Power Station I + Power Station II);
- As it is the last hydroelectric power plant in the Kwanza river it will always be benefited by the improvement in flow control after the implementation of the new foreseen projects between Cambambe and Capanda, thus increasing even more the Cambambe AH’s capacity factor;
- hydrological high-water period (humid) is the same as the higher energy demand period in Luanda (from January to June);
- Fewer transmission losses because it is closer the energy consumption center;
- Generation of employment and strengthening of commerce in the regions close to the site.
- Increase in the electric energy supply for the population.

1.3. ENTERPRISE SPONSOR

To carry out the environmental impact study for the mentioned medium Kwanza project in Cambambe, **Odebrecht** hired **Holísticos – Serviços, Estudos e Consultoria, Lda.** – Which, after the land data survey and a consultation of the project’s technical documentation and the associated bibliography, has prepared the present document.

However, it is important to point out that this Environmental Impact Study was prepared for the National Electricity Company (ENE-EP)1, which is the enterprise owner. ENE-EP is a large public interest corporation, with its own legal constitution and autonomy for administrative, financial and patrimonial management. Its target is to consolidate and lead the national electric market and turn the company into one of the most competitive at regional level.

In order to carry out the Cambambe AH’s rehabilitation and expansion works, ENE has organized a public bidding process that was won by a consortium formed by the Brazilian companies Construtora Norberto Odebrecht S.A. (ODEBRECHT), Alstom Brasil Ltda. (ALSTOM), Engevix Engenharia S.A. (ENGEVIX) and by the German company Voith Hydro. These companies hold a long-time experience in the implementation and rehabilitation of small, medium and large hydroelectric enterprises at international level and particularly in the Angolan electric sector.

Within the Cambambe's Rehabilitation Consortium (CRC) that is headed by ODEBRECHT, the above companies will perform the activities briefly described in the following Table.

Table 1.8: Activities of the Consortium Companies.

Company	**Activities**
ODEBRECHT	• implementation and maintenance of the Work Site; • performance of the civil works; • supply and erection of the hydro-mechanic and material handling equipment; • logistic support for the rehabilitation works; • coordination of the execution of the operation and maintenance training; • preparation of the operation and maintenance manuals;

[1] ENE was created by Decree no. 29/98 of September 4 and has established the mission of producing, transporting, distributing and marketing electric power within the international quality standards and

Company	Activities
	• participation in the Commissioning group; • coordination of local activities with the purpose of gathering funds.
ALSTOM	• supply of the equipment and electro-mechanic systems; • participation in the group for Commissioning and performance tests foreseen in the Contract; • supervision of the dismantling and erection of the supplied items.
ENGEVIX	• preparation of the basic design and the execution design for Cambambe AH's rehabilitation; • consolidation of the operation and maintenance manuals for civil works, equipment and auxiliary electro-mechanic systems, among others.
VOITH SIEMENS	• supply of the electro-mechanic equipment and systems for turbine rehabilitation; • dismantling and erection of all self-supplied equipment, among others.

1.4. SCOPE OF THE STUDY

As an answer to the present deficiencies with respect to meeting the energy demand, the rehabilitation and expansion of the Cambambe Dam was proposed. This hydroelectric power plant in the Cambambe is planned to reinforce the national energy system by a value of 80 MW for Power House 1 (also called the Cambambe elevation) and of 520 MW for Power House 2 (also called Cambambe 2), which amounts are still short of meeting the present energy demand.

On one side, the power plant under study consists in a more economic alternative for the increase in the energy offer, featuring higher reliability in the regular supply used to fulfill the country's economic development needs. On the other side, it is important to emphasize that this expansion process of the Cambambe hydroelectric power plant was already foreseen in the initial basic design.

Therefore, due to the project characteristics, its localization and dimensions, some impacts are foreseen, both in the installation phase and in the exploration and production phase. Due to the Environment Bases Act (Act no. 5/98 of June 19) and other applicable legislation, the implementation of such a large project must be preceded by an environmental impact study (EIA) that comprises:

- A non-technical summary of the Study for public consultation purposes and publication of information (including, at least, the objectives, scope, criteria, process summary, characterization of the mean, proposed mitigation measures, conclusions and recommendations);

- The Environmental Impact Study Report that will cover, but not limited to, the following:

o The project description;

- o All technical and project localization alternatives, also comparing them against the alternative of not carrying out the project;
- o Systematic identification and assessment of the environmental impacts generated in the phases of implementation, expansion, rehabilitation and operation of the project's intended activity, including details about specific aspects of the hydrologic resources exploration and the hydroelectric power plant operation;
- o Definition of the limits of the geographical area to be either directly or indirectly affected by the impacts, identified by areas with direct and indirect influence of the project, considering, in all cases, the population of humans and other living beings and the hydrographic basin where it is located.

  - Other elements that, due to their project particularities and characteristics were deemed pertinent, including their importance from the point of view of the economy and development of the medium Kwanza and the surrounding region.

In this context, the following items belong to the scope of this study:

- Identification of the significant environmental questions and effects caused by certain actions inherent to the processes of equipment installation, construction of the hydroelectric power plant and the necessary infrastructure for its support and operation, as well as the deviation of the road and bridge affected by the project;
- Identification of the significant effects on the population, stakeholders and workers affected by the project, caused by the environmental effects foreseen as a result of the project pressures;
- Facilitation and consideration of the contact and information exchange with the public potentially affected, understanding their values as individuals and community with respect to the environment quality;
- Assessment of the concerns expressed by the population regarding the possible effects of the action and determination if and how to proceed with the action;
- Definition of the limits of the desirable depth of the analysis and assessment made in terms of time and resource optimization;
- Determination of the nature of this assessment in terms of analytic methods and consultation process, in order to increase the efficiency of the environmental impact assessment process;
- Organization, focus on and communication of potential impacts and concerns, to support a greater depth in the analysis and in the decision making.

1.5. EIA OBJECTIVES

The fundamental purpose of an Environmental Impact Study consists in the analysis and examination of how the proposed project may result in positive and negative impacts on the quality of the environment and its ecosystems, as well as on the quality of life of the people and the communities subject to these impacts. On the other side, it is expected that a study of this nature should have a prominent role in the minimization, management and ongoing monitoring of the impacts identified in the present document.

The preparation of the present Environmental Impact Study provides support to the environmental legislation in force in Angola, as well as the associated international legislation, particularly the one related with the standards and guidelines of the World Bank, the World Commission on Dams and the International Finance Corporation. This study was conducted with the following objectives:

- Describe the project, inform about the works associated to the construction, expansion, rehabilitation and operation of the Cambambe hydroelectric power plant, as well as the installation of equipment and infrastructure and the analysis of the environmental and social benefits inherent to the implementation of this project;
- Provide information about the alternatives devised to avoid, mitigate or reduce the potential negative environmental impacts in the ecologically sensible areas, comparing the benefits and losses of each different option and presenting the reasons that justify the choosing of the preferred options;
- Identify and describe elements of the community (with emphasis on the communities established near the hydroelectric power plant) and the environment that may be affected by the project and that may cause adverse impacts;
- Propose mitigation measures to reduce pollution, environmental disturbances and other negative impacts occurred during the construction, installation, and the hydroelectric power plant operation phases.

1.6. Localization

The area that is the object of the present work is located in the North System region, and constitutes the largest hydrographic basin of Angola, with enough potential for the installation of new hydroelectric power plants. The Cambambe Hydroelectric Power Plant is located in the territorial limit of the North Kwanza and South Kwanza provinces in the medium section of the Kwanza River (Figure 1.3) at 180 km east of Luanda.

The access to the enterprise site is done by the National Highway EN 230 that starts in Luanda, passes by Viana and reaches the city of Dondo, headquarter of the Cambambe municipality, in the North Kwanza province.

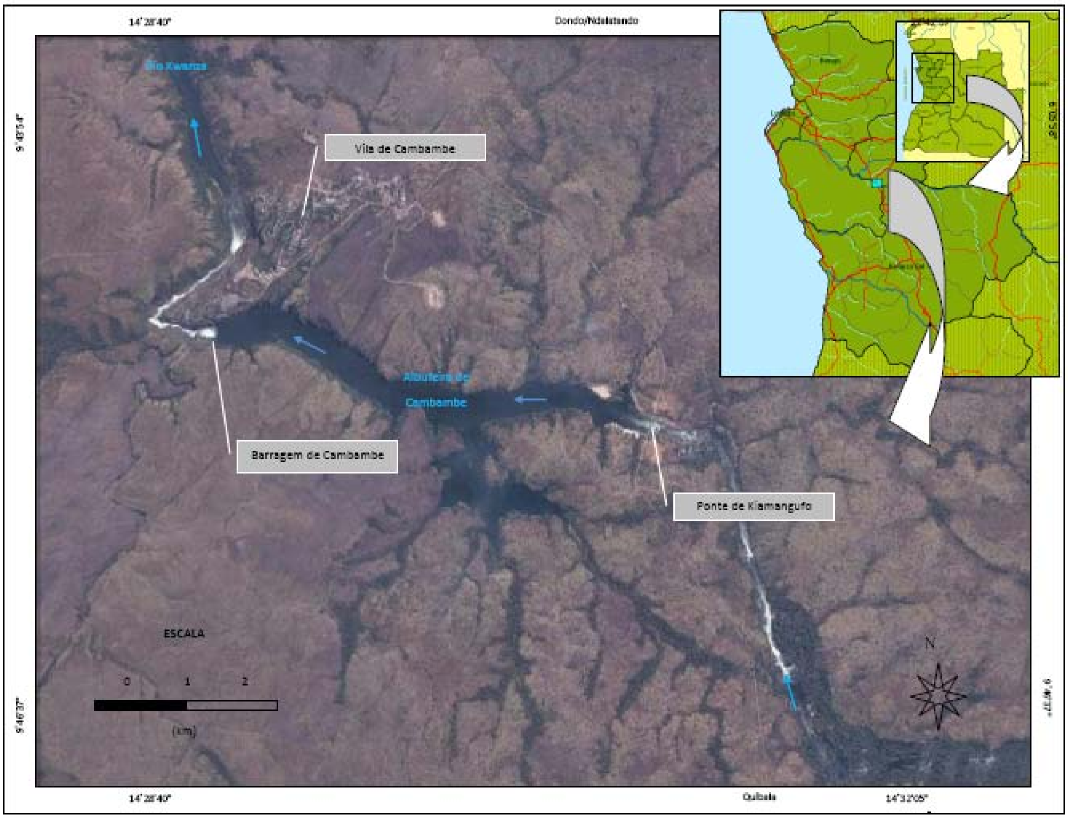


Figure 1.3: Overall view of the Cambambe Hydroelectric Power Plant.

<u>Legend:</u>
VILA DE CAMBAMBE = CAMBAMBE VILLAGE
BARAGEM DE CAMBAMBE = CAMBAMBE DAM
PONTE DE KIAMANGUFO = KIAMANGUFO BRIDGE
ALBUFEIRA DE CAMBAMBE = CAMBAMBE LAKE

1.7 WORK METHODOLOGY

In order to carry out the Environmental Impact Study for the Cambambe Hydroelectric Power Plant expansion and rehabilitation project in the medium Kwanza, a varied methodology was used both for the environmental aspect analysis and the social ones. This methodology included initially the identification of the project's regional coverage (Figure 1.4), indirect influence (Tabela 1.9) and direct influence (Tabela 1.10) areas.

The preparation of this report is the result of surveys carried out in the period from January 2009 to January 2010, technical upgrade in 2012 and has included research methodology and a bibliographic survey, contacts with authorities and field work, as described below:

- The research work and the bibliographic survey include a detailed analysis of the documentation related to the implementation of this dam in the medium Kwanza, with emphasis to the studies, reports and documents of the Capanda and Cambambe hydroelectric enterprises, as well as the development strategy of the energy and water sector;

- Secondary data was also collected and analyzed whenever it was deemed important for the study and indispensable to plan the main data survey and provide the national and regional context that justifies this project. The main information sources include the published reports and data from the Government of Angola portal, academic (Agostinho Neto University and the Catholic University of Angola), as well SONEFE and GAMEK documents;

- Regarding the social part, field visits were conducted to the places affected by the project in the South Kwanza, North Kwanza and Bengo provinces, including direct contacts with the municipal and community administrations, as well as with local and traditional authorities and the population in general. The social and economic base data collection activity intended to and were prepared to focus on aspects related to family units, demographic data and other date about capital amount of the human live, natural, economic, cultural and physical means of the affected communities;

- For the environmental component, exhaustive field surveys were conducted in the area proposed for the project and its surroundings, with emphasis to the main environmental indicators defined for this project and presented in the characterization of the reference situation. Therefore, experts in the most varied areas were employed, who resorted to specific methodologies for each selected indicator. The main indicators were grouped as the physical, biotic, social-economic and cartographic means;

- The contacts with the local (municipal and community administrations) and traditional (sobas, regents and seculos) authorities were conducted during the land data survey process and achieved a coverage of 100% percent, based on the direct contact to gather information and transmit clarifications about the proposed project.

- Within the context of the Carbon Market, a meeting for an exchange of views took place on 2 March 2012, with the Ministry of Energy and Waters and the Environment Ministry, representatives of governmental bodies (Photo 1.1) and traditional authorities (Photo 1.2) of North Kwanza province. All in all, the meeting was to be attended by more than 80 people. The primary objective of this event was to explain to all the authorities and bodies involved the reasons why the enterprise in question comes under the category of clean development, for the purpose of obtaining carbon credits. However, it was also an opportunity to give a brief description of the history of the Cambambe Dam and its principal components, and also of the environmental assessment procedures, in the light of the environmental legislation in force in Angola. The participants had an opportunity to ask questions and hear explanations about the potential benefits of the project, its environmental and social impacts, and mitigation measures proposed in the Environmental Impact Study on Rehabilitation of the Cambambe Dam. Cambambe Environmental Impact Study of the Cambambe Dam. In relation to the Carbon Market,it was explained that the fact that other countries may use the carbon emission quotas that are available to Angola will not compromise the country's development, because the actual emission levels in the country are way below those which would be emitted if Angola were an industrialised country. It was emphasised that the fact that Angola is investing in the production of clean forms of energy contributes to the fact that the country's emission levels continue to be low. Reference was made to a study on the sectors which emit the most carbon in the country, with recommendations on what needed to be done in order to reduce the emissions.

Foto 1.1. Francisco Manuel Diogo, Administrador Municipal Adjunto de Cambambe.

Foto 1.2. Autoridades tradicionais envolvidas no encontro de auscultação.

1.8 PROJECT INFLUENCE AREAS

The main objective of an Environmental Impact Study is to check the effects that the proposed enterprise intends to promote in the places and the region where it will be implemented. Based on detailed knowledge of the local environmental characteristics and of the potential for the generation of enterprise impacts, it is possible to check whether the environment presents adequate conditions for the project implementation.

The definition of the proposed enterprise influence areas is one of the initial stages of an Environmental Impact Study (EIA), because it establishes the geographic limits of the areas that can be submitted to positive or negative changes, whether direct or indirect, making possible the establishment of guidelines for environmental impact assessments.

For the Cambambe Hydroelectric Power Plant project, limits will be established for the influence areas that are susceptible to changes as consequence of the planning, construction, expansion, rehabilitation and operation of the Cambambe Hydroelectric Power Plant, which will consider the physical, biotic and anthropic means.

In order to define the areas of influence of the physical and biotic means, physiographic aspects are considered, as the hydrographic basin contributing to the lake and the biologic component present in the system. For the anthropic mean (social-economic studies) eventual changes in the quality of life of the population living in the directly and indirectly affected areas are considered.

For the anthropic mean, the administrative divisions were considered, as provinces and the directly or indirectly affected municipalities and communities. The present study presents the information available in the databases of the country's official institutions, among other sources considered reliable and significant.

It is worth noting that the environmental impact assessment is specific for each mean, and that the study areas (Areas of Influence) are established based on such specificity. In the case of the area covered by the Cambambe Hydroelectric Power Plant environmental study, the following influence areas were considered for the physical and biotic means:

- Regional Coverge Area (AAR);
- Indirect Influence Area (AII); and
- Direct Influence Area (AID).

1.8.1. REGIONAL COVERGE AREA (AAR)

The Regional Coverge Area (AAR) corresponds to areas that in a general way are potentially subject to indirect impacts from enterprises. For the physical and biotic means, the contribution basin of the medium Kwanza river section was considered, which encompasses a total area of 54,564.71 km² (see Attachment 6, Regional Figure). This selection allows the comprehension of t he processes that act on the structuring of the region's ecologic systems, which are only understood and diagnosed through the analysis of a relatively wide area.

For the anthropic mean, the administrative unit of the Bengo, Luanda, North Kwanza and South Kwanza provinces was considered, taking into account factors that define the possible reach of the enterprise with respect to its reflexes on the encouragement of the economic and energetic development at regional level (see Figure 1.4).

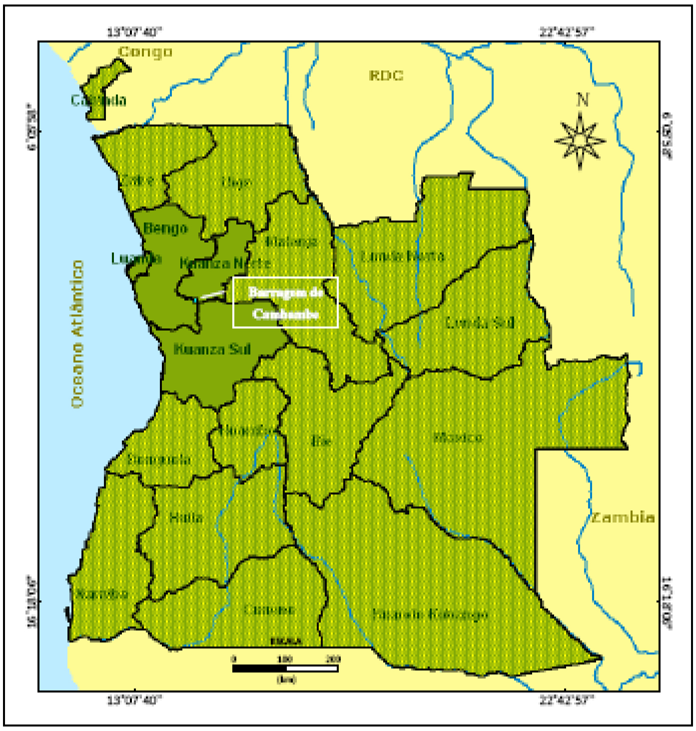


Figure 1.4: Map of the project's Regional Coverge Area

Legend:
Barragem of Cambambe = Cambambe Dam

1.8.2. INDIRECT INFLUENCE AREA (AII)

For the physical and biotic means, the Indirect Influence Area (AII) was defined as the Kwanza river contribution basin. For the anthropic mean, the municipalities whose territories are in some way affected by the enterprise implementation were defined, which are Quiçama, Icolo and Bengo in Bengo, Viana in Luanda, Cambambe in North Kwanza and Libolo in South Kwanza, as shown in Table 1.9 and Figure 1.5. These communities include the small population villages (Uakiluzu and Terra Nova sanzalas and fishermen villages).

Table 1.9: Project's Indirect Influence Area

Province	**Municipality**	**Community**
Bengo	Quiçama	Kixinje and Muxima
	Icolo and Bengo	Calomboloca, Catete and Bom Jesus
North Kwanza	Cambambe	Zenza do Itombe, Dondo and Massangano and the City of Dondo
South Kwanza	Libolo	Munenga
Luanda	Viana	Calulo and Viana

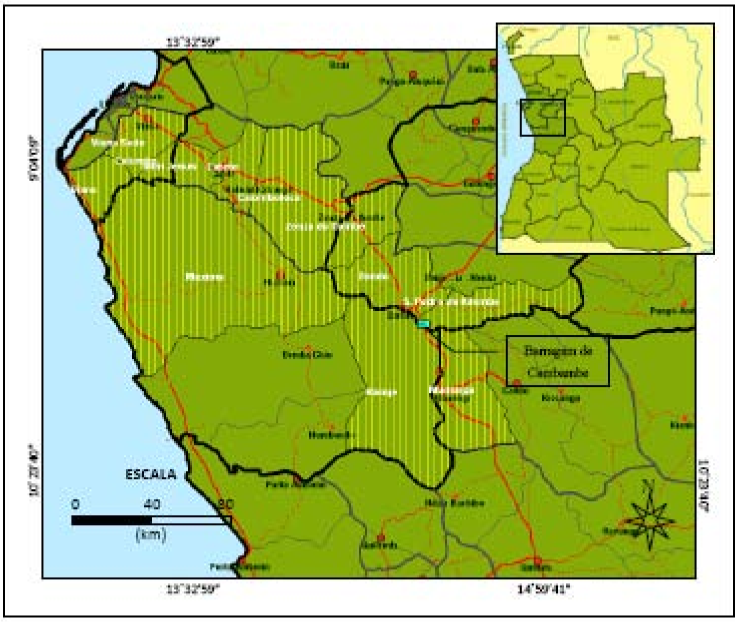


Figure 1.5: Map of the project’s Indirect Influence Area

Legend:
Barragem of Cambambe = Cambambe Dam

1.8.3 DIRECT INFLUENCE AREA (AID)

The Direct Influence Area (AID) corresponds to the areas that will be subject to direct impacts, both positive and negative and for which an adequate monitoring and mitigation measure program will be developed. For the physical and biotic means, the area of the surface flooded by the lake elevation to the 132-m level, including part of the road that connects Dondo to Munenga, the Kiamangufo bridge, and the river beach will be considered. The physical structures to be built and those existing related to the enterprise are also included, which are the work yard, the living quarters, the Cambambe Village’s water capturing system, the reclaimed areas and the surplus material deposit areas added by a five hundred (500)-meter wide peripheral area, defined as a buffer zone (see Attachment 6, Figure 2.15).

For the anthropic mean, the communities described in Table 1.10 were defined, whose territories will be influenced in a direct way by the Cambambe Hydroelectric Power Plant, which are the community of Kixinje in the municipality of Quiçama and the demining camping, the Police Station on the bridge and the river beach located in the community of São Pedro da Quilemba in the municipality of Cambambe (Figure 1.6).

Table 1.10: Project’s Direct Influence Area.

Province	Municipality	Community	Área
Bengo	Quiçama	Kixinje	Margem esquerda da lake
North Kwanza	Cambambe	São Pedro da Quilemba	Demining camping, Police Station, bridge, part of the road, river beach, Cambambe Lake and Cambambe Village

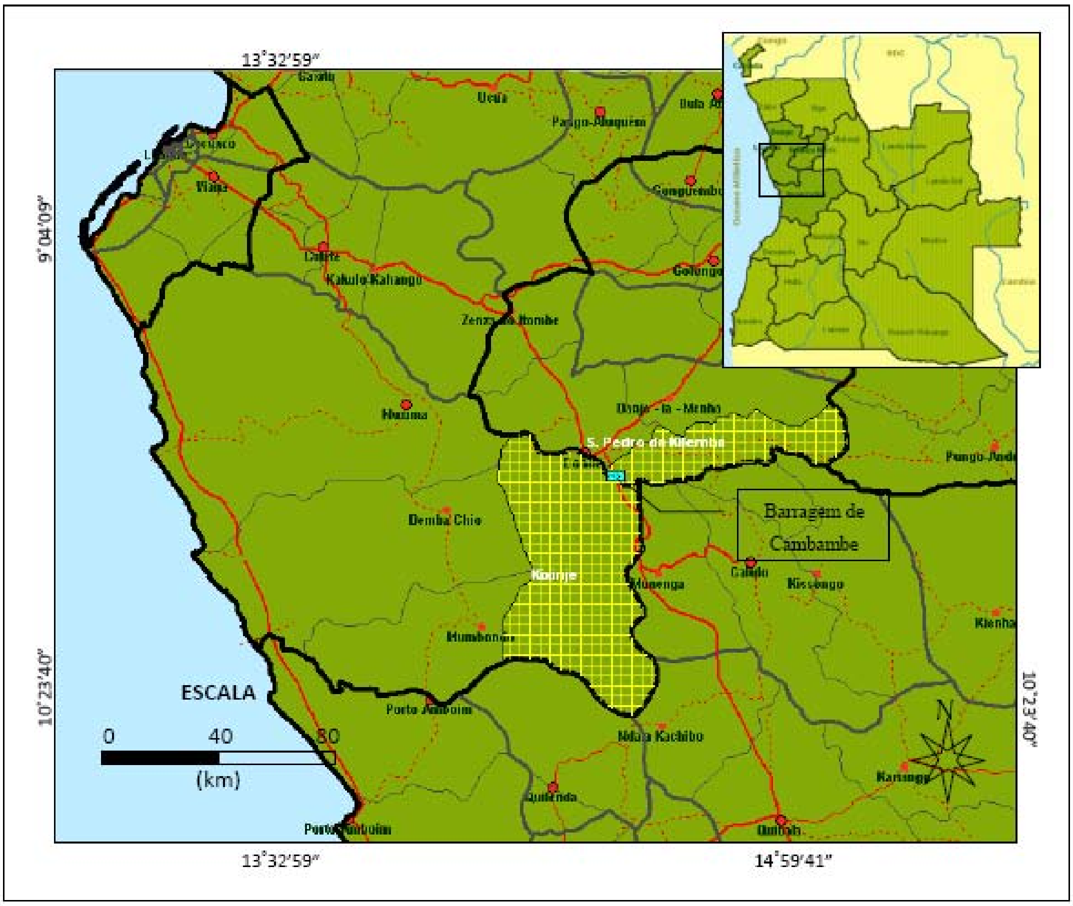


Figure 1.6: Map of the project's direct influence area

Legend:
Cambambe Dam
SCALE

1.9. PUBLIC CONSULTATION PROCESS

The Public Consultation and Disclosure are considered essential functions of the Environmental Impact Assessment, particularly in the case of large projects. Therefore, and for the Cambambe Power Plant rehabilitation and expansion project, a Public Consultation and Disclosure Plan (PCDP) was prepared, in compliance with the International Financing Corporation (IFC) guidelines and based on the national legislation.

The Public Consultation and Disclosure Plan consists of a document prepared and to be used for the definition of the disclosure procedures of the Cambambe Power Plant rehabilitation and expansion project located in the North Kwanza province. The PCDP is an integral part of the Environmental Impact Study preparation process for the mentioned project. The main target of this document is that of guiding this process, including the ways in which the consultation and the disclosure of its results and the project as well, will be organized.

The process must engage the stakeholders that will be directly or indirectly affected by the project's actions and pressure, whether in a negative or a positive way.

The plan defines the way how the public consultation and disclosure for this project will be carried out along the Environmental Impact Assessment process to be conducted either by the Environment Ministry or by possible funding entities.

1.9.1. OBJECTIVES OF THE PCDP

The main objective of the PCDP is to ensure that the public consultation process will be consistent, solid, coordinated and oriented to ensure an effective participation of stakeholders and affected parties, thus allowing the accomplishment of the following

- Ensure that all stakeholders are included in the Consultation and Disclosure Process;
- Ensure that the disclosure of the initial information about the project is adequate and understandable for all stakeholders and affected parties without the need for technical knowledge and for the local population and in the project's neighborhood;
- Ensure that adequate information is disclosed to the people affected by the project and to other stakeholders;
- Ensure that all stakeholders have the opportunity to express their opinions and concerns regarding this project;
- Ensure that all such opinions and concerns will be considered in the decisions regarding the project;
- Ensure that adequate "feedback" is regularly provided to the stakeholders and parties affected by the project; and
- Ensure that an effective communication is maintained during the proposed project's construction and operation phases.

1.9.2. PCDP SCOPE

The preparation and implementation of the PCDP is carried out with the purpose of making it a guiding document, able to identify the expectations of the stakeholders and parties affected by the project. A detailed plan showing the proposed phases and periods for carrying out the consultation is an integral part of this document.

The PCDP identifies the appropriate level of public participation as well as the stages for the final report discussion and the presentation of the project's non-technical summary. The PCDP scope includes the following three stages:

- **Stage 1 – Preliminary Hearing:** This stage includes a preliminary contact with the Ministry of the Environment through the appropriate office for environment impact analysis and assessment. This stage has the purpose of notifying the intention to carry out the EIA and refine the reference terms for carrying it out. It is also used to introduce the Cambambe Rehabilitation Consortium and explain what will be done and how, including the presentation of the enterprise performance schedule with its several phases.

- **Stage 2 – Field Survey:** In this stage the stakeholders and the parties directly and indirectly affected by the project (communities in the flooded zones and its neighborhoods, fishermen and local authorities) are consulted, as well as the local governmental institutions (municipalities and communities). In this stage, an exhausting social and economic data survey is carried out and, at the same time the stakeholders are notified about the focus of the project, and therefore collecting the contributions at local level (see Attachment 1 – List of Contacted Entities and Attachment 2 – List of Fishermen Associations).

- **Stage 3 – Public Consultation:** This stage will be organized by the Ministry of the Environment pursuant the environmental legislation in force and will be used to analyze in detail the main project's negative and positive environmental impacts. In this stage, the measures to mitigate the negative environmental impacts and that bear a high significance will be presented. The public consultation will be conducted in places and in ways in compliance with the Ministry of the Environment, as soon as the study's preliminary assessment process is concluded by the offices in charge of supervising the enterprise activities (energy and water) and the environment.

One important aspect of the Public Consultation and Disclosure Plan is the anticipation of the main stakeholders, which is accomplished, based on the project's localization and nature and on its impacts on the site and on the neighborhood. A Chart is presented below (see Chart 1.1) showing the parties that are considered as stakeholders and affected parties, divided in two categories, which are the primary and the secondary.

Chart 1.1: Stakeholders and parties affected by the project.

Primary Stakeholders

- Project participants (example ENE, the Consortium Parties, Holísticos)
- Community Leaders (Sobas, seculos and regents)
- Municipal and Community Administrators
- Members of the local communities
- Vulnerable groups (youngsters, elders, women, children)
- Present residents / Project site workers with specific knowledge of the site characteristics (dam workers, security personnel)
- Police
- Potential suppliers and contractors
- Local handcraft fishermen associations

Secondary Stakeholders

- The Government of Angola
- The Provincial Government of North Kwanza and Bengo
- The Municipal Administration of Cambambe and Bengo
- The National Civil Protection Committee
- Special interest groups (example: women and children)
- Churches and other religious organizations
- Environmental Protection Associations / International, national and local Community-Based organizations with environmental and social/ development scope
- Higher Education and Scientific Investigation Institutions
- Formation and Employment Centers
- Health Professionals
- Potential suppliers of merchandise, goods and services
- International donators

Each stage is an individual process that is carried out in different periods but according to a schedule during the environmental impact study process preparation. These consultations have different purposes and were based on a series of public consultation methodologies.

CHAPTER 2

PROJECT PRESENTATION

2. PROJECT PRESENTATION

The elevation and the construction of the second Cambambe Hydroelectric Power Plant Central, was always part of the original project conceived during the 50's, but was never executed. However, considering the fast growth of Angola in recent years, which almost immediately causes an increase in the electric power demand, the continuation of these investments is wholly justified.

In the second Cambambe AH stage, the works, supply and erection of the second central generation and transmission systems are foreseen, including the start of operation of the first generation unit 44 months after the beginning of the construction.

Cambambe AH, as it was designed during the 50's, included an arch-shaped concrete dam with double curvature, spillway integrated to the dam structure and a hydraulic generation circuit composed by a low-pressure water inlet with maximum of 30 m, inlet tunnels excavated in rock, underground power house, equipped with four vertical Francis turbines, with rated power of 65 MW, distribution chamber excavated in rock and two discharge tunnels, one for every two generation units.

The dam was devised for two different phases: The first phase was built in the beginning of the 60's, with a height of about 68m, with the dam crest at the 112,75 m level in the side sections and at the 102,15 m level in the central part, with free water passage for high-water discharge. For the second phase, covered by this report, the increase in the dam crest level up to 132.00 m was foreseen, with the insertion of gates inside the dam structure for high-water discharge.

The expansion of the generation system was planned at that time, by means of the construction of two new machine houses, with the same capacity as the previous one, totaling 780 MW of installed power. The location of the new centrals was foreseen at that time as being adjacent to the existing power house.

2.1. JUSTIFICATION OF THE ELEVATION ALTERNATIVES

Angola is experiencing a virtuous growth cycle, based on the country reconstruction, on social inclusion and mainly on the governmental policies intended to reduce the almost total dependency of its economy on oil.

In order to respond to the challenge above, it is indispensable the implementation in the country of a new and diversified production basis and the main supply for this new phase is energy. Therefore, several energy alternatives were analyzed in order to fulfill such demand, and one of them was the continuation of the Cambambe Hydroelectric Power Plant's original basic project.

Therefore, in order to assess the energetic benefits, the technical and safety aspects, as well as the necessary investments to adequate and/or elevate the dam, three (3) elevation scenarios and five (5) structural arrangement alternatives were considered, which are presented below. The present scenario with the water level at 102.15 m was considered, as well as the following lake water levels: levels of 112.00 m, 122.00 m and 130.00 m

2.1.1. PRESENT SCENARIO

The present lake level is maintained at 102.15 m, with the dam crest level remaining at 112.75 m. However, structural reinforcements are needed in the existing structure, as well as the execution of new structures, as described below, to ensure the structure's global stability:

- Reinforcement of the dissipation basin bottom slab, to increase the resistance to erosion;
- Construction of a concrete wall downstream of the dissipation basin (*tailpond dam*) with the purpose of increasing the water buffer height and its energy dissipation capacity as well;
- Construction of concrete side walls on the dam top, in order to limit the overflow zone in the spillway part, to guarantee the stability of the massif lateral structures.

The description above has the purpose of supporting a preliminary estimate, in case the dam overflowing is admitted for both design flows: ten-thousand years and PMF (maximum probable flow), without harming the enterprise stability. But it should be pointed out that, in order to ensure the structure integrity during its whole service life, more accurate studies are necessary, of structural and global stability nature, which were not covered by the present report.

Therefore, and considering the energy supply needs, the present scenario will not be used along this study, because the corresponding incremental energetic benefit is nil.

2.1.2. ELEVATION ALTERNATIVE SCENARIOS

Three alternative scenarios were analyzed, all of them related to the dam elevation to different levels, particularly:

- **Scenario 1:** The lake water level is increased by 10 meters, from the 102 m to the 112.00 m level;
- **Scenario 2:** The lake water level is increased by 20 meters, from the 102 m to the 122.00 m level;
- **Scenario 3:** The lake water level is increased by 30 meters, from the 102 m to the 130.00 m level. In this scenario, it should be pointed out that the bottom discharge will increase its flow capacity by approximately 500 m³/s due to the increase in hydrostatic pressure.

2.1.3. ALTERNATIVE ARRANGEMENTS

In addition to the studies and the basic project developed by the National Society for Overseas Enterprises Study and Financing (SONEFE) and the laboratory trials conducted by the National Civil Engineering Laboratory (LNEC), new arrangement concepts were considered, which resulted in the five (5) alternatives described below and shown in Figure 2.3 below.

The project presented in this section of the report was based on these alternatives.

2.1.3.1. ALTERNATIVE 1 – SONEFE

The concept considered in this alternative is the same adopted in the SONEFE Basic Project. The surplus lake flows are directed to a spillway with flat gates integrated to the dam structure and duly sized to resist to the design floods, in each of the scenarios presented in Chart 2.1.

2.1.3.2. ALTERNATIVE 2 – SAFETY SPILLWAY

The concept used in this alternative is similar to the one used in alternative 1 (SONEFE), but it features a safety item that is the inclusion of a small side spillway on the left bank with capacity for 2.500 m³/s, and has the main purpose of interrupting the spill through the dam and making possible the execution of repair works, mainly in the dissipation basin.

Additionally, due to greater ease in handling the segment gates, the operation rule will give priority to the use of this new spillway in the case of very recurring flows, thus making the operation easier. The spill through the dam flat gates would be used only for infrequently recurring flows.

One important assessment that must be pointed out, is that in the alternatives where the inclusion of the side spillway was considered, the construction costs of such spillway are lower, mainly if the dam level is increased to 130,00 m, because the rock excavation volume will be significantly lower (see Figure 2.1).

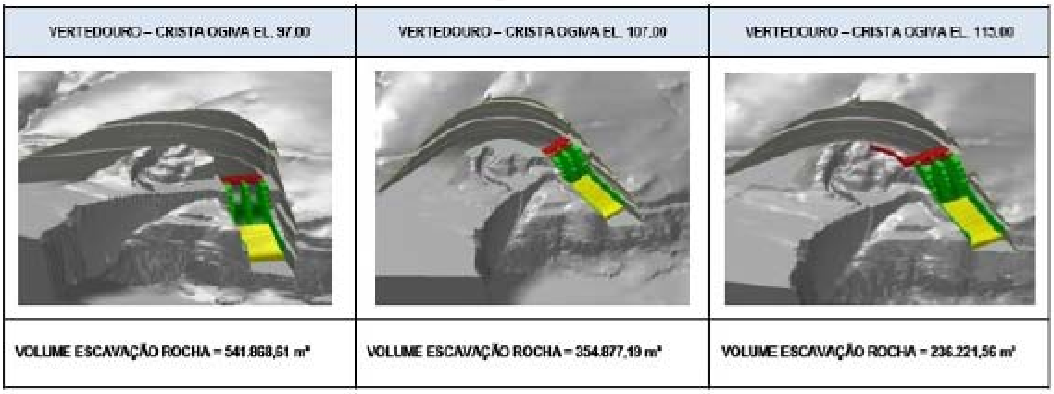


Figure 2.1: Spillway simulations at different levels

<u>Legend:</u>
VERTEDOURO = SPILLWAY
CRISTA OGIVA = OGIVE CREST
VOLUME ESCAVAÇÃO ROCHA = ROCK EXCAVATION VOLUME

2.1.3.3. ALTERNATIVE 3 – LEFT BANK

In this alternative the whole spill is directed to a side spillway located in the left bank, with capacity to handle the design flows: ten-thousand years and PMF (see Figure 2.2).

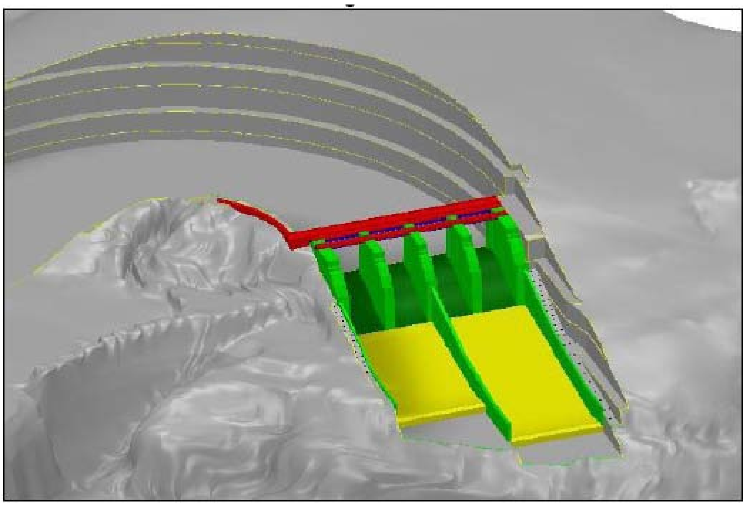


Figure 2.2: Left spillway simulation.

2.1.3.4. ALTERNATIVE 4 – LNEC

The concept adopted in this alternative is the one of limiting the spill through the dam to the flow presented in the studies prepared by LNEC, to attain maximum safety for the dissipation basin integrity, defined as 5,000 m³/s. The surplus flow is discharged through a side spillway.

2.1.3.5. ALTERNATIVE 5 – LIMIT ENERGY (MAXIMUM FLOW X PRESENT ELEVATION)

This concept limits the flow through the dam to the value of the maximum energy already dissipated in the basin, which corresponds to the maximum flow observed times the fall height in the present dam condition (102,00 level). It should be pointed out that this flow varies depending on the elevation scenario. The flow difference is directed to a side spillway.

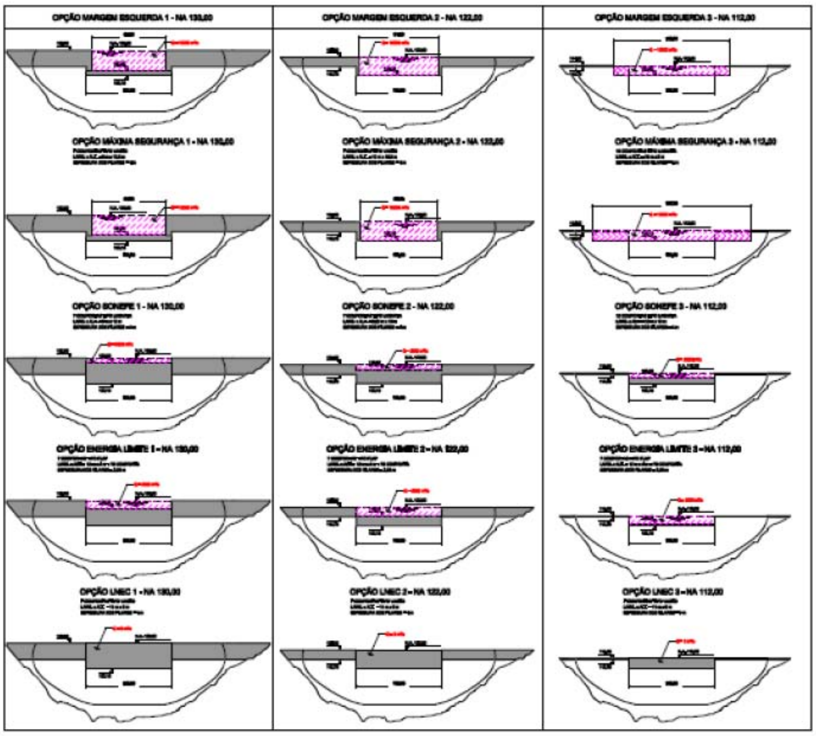


Figure 2.3: Cambambe AH's elevation alternatives.

Legend:
OPÇÃO MARGEM ESQUERDA = LEFT BANK OPTION
OPÇÃO MÁXIMA SEGURANÇA = MAXIMUM SAFETY OPTION
OPÇÃO SONEFE = SONEFE OPTION
OPÇÃO ENERGIA LIMITE = LIMIT ENERGY OPTION
OPÇÃO LNEC = LNEC OPTION

From the combination of the three (3) scenarios with the five (5) arrangement alternatives, the 15 possible options were obtained and are presented in the elevation alternatives matrix (Chart 2.1).

Chart 2.1: Alternative matrix for Cambambe AH's elevation/spillway.

	ALTERNATIVE 1 – SONEFE	**ALTERNATIVE 2 – SAFETY SPILLWAY CRITERIUM**	**ALTERNATIVE 3 – LEFT BANK CRITERIUM**	**ALTERNATIVE 4 – LNEC CRITERIUM**	**ALTERNATIVE 5 – LIMIT ENERGY (MAXIMUM FLOW X PRESENT ELEVATION)**
	USES THE CRITERIUM OF FULL FLOW THROUGH THE DAM	**USES THE SONEFE CRITERIUM, WITH THE INCLUSION OF A SAFETY SPILLWAY ON THE LEFT BANK TO ALLOW EVENTUAL DISSIPATION BASIN REPAIRS AROUND THE WHOLE YEAR**	**USES THE CRITERIUM OF FULL FLOW THROUGH THE LEFT BANK**	**USES THE CRITERIUM OF LIMITING FLOW TO 5.000 M3/S FOR NA = 124 M**	**USES THE CRITERIUM OF MAINTAINING THE ENERGY OF THE ALREADY DISSIPATED MAXIMUM FLOW (2,850 MW)**
Scenario 1 – NA 112	Passage of 13,000 m3/s for NA = 114 m Full flow through the dam Caterpillar-type gate Number of gates = 12 m Gate base level = 102 m Gate width = 12 Gate height = 10 m	10,000 m3/s through the wagon-type dam gate + cofferdam Number of gates = 10 Gate base level = 102 Gate width = 10 Gate height = 9 m	Gates on the dam 13,000 m3/s through the left bank Segment-type gate Numbers of gates = 4 Sill crest = 92 Gate width = 15 Gate height = 20 m * FB gate Pillar thickness = 4.2 m	Passage of 13,000 m3/s for NA = 124 m Gates on the dam 5,000 m3/s through the dam Wagon-type gate Number of gates = 7 Sill crest = 104 Gate width = 11 Gate height = 6 m * FB Gate Pillar thickness = 4 m	Passage of 13,000 m3/s for NA = 114 m Gates on the dam 2,600 m3/s through the dam Flap-type gate Number of gates = 7 Sill crest = 108 Gate width = 12 Gate height = 4 m * FB Gate Pillar thickness = 2.5 m
	Downstream dike level ~ 66m	**Gates on the left side** 3,000 m3/s through the left bank Segment-type gate Number of gates = 2 Sill crest = 97 Gate width = 10.5 Gate height = 15 + FB gate Pillar thickness = 4.0 m	**Without downstream dike**	**Gates on the left side** 8,000 m3/s through the left bank Segment-type gate Number of gates = 3 Sill crest = 92 Gate width = 12.3 Gate height = 20 m + FB gate Pillar thickness = 4.2 m	**Gates on the left side** 10,000 m3/s through the left bank Segment-type gate Number of gates = 3 Sill crest = 91 Gate width = 15 Gate height = 21 m + FB Pillar thickness = 4 m
	Not applicable due to the need to increase the existing span	**Not applicable due to the need to increase the existing span**		**Downstream dike level ~ 62 m**	**Downstream dike level ~ 55 m**

	THROUGH THE DAM	**INCLUSION OF A SAFETY SPILLWAY ON THE LEFT BANK TO ALLOW EVENTUAL DISSIPATION BASIN REPAIRS AROUND THE WHOLE YEAR**	**THROUGH THE LEFT BANK**	**IN 5,000 M3/S ACCORDING TO LNEC STUDIES.** Passage of 13,000 m3/s for NA = 124 m Gates on the dam 5,000 m3/s through the dam Wagon-type gate Number of gates = 7 Sill crest = 114 Gate width = 11 Gate height = 6 m Pillar thickness = 4 m	**THE ALREADY DISSIPATED MAXIMUM FLOW (2,850 MW)** Passage of 13,000 m3/s for NA = 124 m Gates on the dam 2,600 m3/s through the dam Flap-type gate Number of gates = 7 Sill crest = 118 Gate width = 12 Gate height = 4 + FB gate Pillar thickness = 2.5 m
Scenario 2 – NA 122	Passage of 13,000 m3/s to NA = 124 m Full flow through the dam Wagon-type gate Number of gates = 7 Gate base level = 102 Gate width = 9.6 Gate height = 15 m	10,000 m3/s through the dam Wagon-type dam + cofferdam Number of gates = 7 Gate base level = 105 Gate width = 10 Gate height = 10.5 m	**Gates on the left side** 13,000 m3/s through the left bank Segment-type gate Number of gates = 4 Sill crest = 102 Gate width = 15 Gate height = 20 + FB gate Pillar thickness = 4.2 m		**Gates on the left side** 10,200 m3/s through the left bank Segment-type gate Number of gates = 3 Sill crest = 101 Gate width = 15
	Downstream dike level ~ 68m	**Gates on the left side** 3,000 m3/s through the left bank Segment-type gate Number of gates = 2 Sill crest = 107 Gate width = 22.5 Gate height = 15 + FB gate	**Without downstream dike**	**Gates on the left side** 8,000 m3/s through the left bank Segment-type gate Number of gates = 3 Sill crest = 102 Gate width = 12.3 Gate height = 20 + FB	

	ALTERNATIVE 1 – SONEFE	**ALTERNATIVE 2 – SAFETY SPILLWAY CRITERIUM**	**ALTERNATIVE 3 – LEFT BANK CRITERIUM**	**ALTERNATIVE 4 – LNEC CRITERIUM**	**ALTERNATIVE 5 – LIMIT ENERGY (MAXIMUM FLOW X PRESENT ELEVATION)**
Scenario 3 – NA 130	**Uses the Criterion of Full Flow through the Dam** PMF of 13,000 m3/s for NA = 132 m Full flow through the dam Wagon-type gate + cofferdam Number of gates = 7 Gate base level = 108 Gate width = 9 Gate height = 15 m **Downstream dike level** = 70m	Pillar thickness = 4.0 m **Uses the Sonefe Criterion, with the Inclusion of a Safety Spillway on the Left Bank to Allow Eventual Dissipation Basin Repairs around the Whole Year** 10,000 m3/s through the wagon-type dam gate + cofferdam Number of gates = 7 Gate base level = 108 Gate width = 9 Gate height = 10.5 m **Gates on the left side** 3,000 m3/s through the left bank Segment-type gate Number of gates = 2 Sill crest = 115 Gate width = 10.5 Gate height = 15 + FB gate Pillar thickness = 4.0 m	**Uses the Criterion of Full Flow through the Left Bank** **Gates on the left side** 13,000 m3/s through the left bank Segment-type gate Number of gates = 4 Sill crest = 110 Gate width = 15 m Gate height = 20 m + FB gate Pillar thickness = 4.2 m **Without downstream dike**	Gate Pillar thickness = 4.2 m **Downstream dike level** = 64 m **Uses the Criterion of Limiting Flow to 5.000 M3/S According to LNEC Studies** Passage of 13,000 m3/s for NA = 132 **Gates on the dam** 5,000 m3/s through the dam Wagon-type gate Number of gates = 7 Sill crest = 122 Gate width = 11 Gate height = 6 Pillar thickness = 4 m **Gates on the left side** 8.000 m3/s through the left bank Segment-type gate Number of gates = 3 Sill crest = 110 Gate width = 12.3 Gate height = 20 + FB gate Pillar thickness = 4.2 m **Downstream dike level ~ 66 m**	Gate height = 21m + FB gate Pillar thickness = 4.2 m **Downstream dike level** ~ 60 m **Uses the Criterion of Maintaining the Energy of the Already Dissipated Maximum Flow (2,850 MW)** Passage of 13,000 m3/s for NA = 132 Gates on the dam 2,600 m3/s through the dam Flap-type gate Number of gates = 7 Sill crest = 126 Gate width = 12 Gate height = 4 m + FB gate Pillar thickness = 2.5 m **Gates on the left side** 10,400 m3/s through the left bank Segment-type gate Number of gates = 3 Sill crest = 109 Gate width = 15 Gate height = 21 m + FB gate Pillar thickness = 4 m **Downstream dike level = 65 m**

	ALTERNATIVE 1 – SONEFE	ALTERNATIVE 2 – SAFETY SPILLWAY CRITERIUM	ALTERNATIVE 3 – LEFT BANK CRITERIUM	ALTERNATIVE 4 – LNEC CRITERIUM	ALTERNATIVE 5 – LIMIT ENERGY (MAXIMUM FLOW X PRESENT ELEVATION)
Favorable aspects	Smaller amounts involved in the services	Value closer to the value originally foreseen by SOFENE for the spillway through the dam. Maximum reduction of the lateral spillway costs The use of a lateral spillway creates conditions that allow repairs in the basin all the year around. Limits operation with partial opening of the segment gates, which are more recommended than the flat ones in this case.	Maximum safety in terms of dam stability due to the complete elimination of the spillway from the dam structure. Easy gate operation and higher reliability. Eliminates the risk of dissipation basin erosion Reduces to a minimum the dependence on the hydrologic regime and on eventual water level lowering in the reservoir. The building of a downstream dike is not necessary.	Reduces the left bank spillway and consequently the costs involved in its implementation. Keeps the flow through the dam within the maximum limit specified as safe by LNEC.	Reduces the risk of dissipation basin erosion by limiting the flow through the dam to the maximum energy margin observed. Uses flap gates with dimensions within the normally used standard.

	ALTERNATIVE 1 – SONEFE	**ALTERNATIVE 2 – SAFETY SPILLWAY CRITERIUM**	**ALTERNATIVE 3 – LEFT BANK CRITERIUM**	**ALTERNATIVE 4 – LNEC CRITERIUM**	**ALTERNATIVE 5 – LIMIT ENERGY (MAXIMUM FLOW X PRESENT ELEVATION)**
Unfavorable aspects	SONEFE had forecast a flow of 9,000 m3/s. The present value of 13,000 m3/s requires higher and heavier in gates and, therefore, the structural aspects of this solution must be checked. The caterpillar gates must be replaced by large wagon gates, seldom used, which present higher pressure losses due to the lateral grooves. According to trials carried out by LNEC, the basin is not safe for flows above 5,000 m3/s. It is necessary to consider the behavior of the sediments carried by the sand trap located in the space between the control wall and the dam. Protection walls must be built to protect the existing accesses to the drainage gallery on the right side of the dam. Medium complexity planning and execution, with some dependence on the hydrologic regime and on eventual water level lowering in the reservoir. Operation with partial opening is not recommended due to excessive vibration.	It is necessary to consider the behavior of the sediments carried by the sand trap located in the space between the control wall and the dam. Protection walls must be built to protect the existing accesses to the drainage gallery on the right side of the dam. Medium complexity planning and execution, with some dependence on the hydrologic regime and on eventual water level lowering in the reservoir.	Large excavation volumes and higher costs for the implementation of a new spillway.	It is necessary to consider the behavior of the sediments carried by the sand trap located in the space between the control wall and the dam. Protection walls must be built to protect the existing accesses to the drainage gallery on the right side of the dam. Medium complexity planning and execution, with some dependence on the hydrologic regime and on eventual water level lowering in the reservoir.	Large excavation volume and high costs due to the new spillway dimensions.

Note: Criteria used for all alternatives:

1) The use of the bottom discharger the sand trap was not considered;

2) A check with the PMF flow = 13.000 m^3/s was considered for a over-elevation of 2 m, matching the dam crest;

3) In no alternative and with the spillway in the dam, the spillway crest elevation is lower than the 102-m level, which is the spillway crest level.

2.2. ECONOMIC-ENERGETIC ASSESSMENT OF THE ELEVATION

As previously mentioned, the possibility of increasing the installed power was already foreseen in the original project, by means of the elevation of the lake by 30 meters, and also due to the increase in the controlled Kwanza river flow, through the implementation of new reservoirs downstream of Cambambe AH, as Capanda, already in operation.

Some definitions and concepts adopted in the present study are shown below, which must be well understood to allow the interpretation of the results obtained. The Cambambe AH has its downstream flow presently controlled by the Capanda Dam reservoir, around 134 km downstream.

With the implementation of other lakes in the section between the Capanda and Cambambe dams, this control capacity will be increased. For the determination of the energetic benefit resulting from the motorization alternatives of the second Cambambe central and the dam foreseen for Laúca, the control effects downstream of Capanda were considered, including the control capacity of the Cambambe Lake itself, which has the purpose of operating in peak regime in the most critical hydrologic periods.

As described in Chapter 1, in the energy sizing study, the following basic concepts were used:

- **Average Energy (EM):** is the average monthly generation value along the entire flow history;
- **Gross fall (Hb):** is the difference between the upstream water level (in the lake) and the downstream water level (after return to the Kwanza river natural bed);
- **Reference fall (HRef):** is the net fall for which the turbine, with the full opening of its distributor, produces the generator's rated power.

Simulations were carried out to determine the second central energetic result, with the assessment of the alternatives for the installation of variable quantities of new generation units, so, with the implementation of the second central, there will be an increase in the generated energy with the best cost/benefit ratio possible. The main data used was:

- Number of Generation Units: 4 (only the existing Central) and 7 (existing Central + new Central);
- Turbine type: Francis;
- Normal maximum downstream water level: between 102.00 m and 130.00 m;
- Operation under power: monthly simulations considering Cambambe's run-of-river operation (without using the Cambambe Lake for control purposes);
- Normal downstream water level: 16.00 to 17.40 m;
- Gross fall: 89.60 to 114.00 m;
- Maximum estimated hydraulic head loss: 2.3 m;

- Average efficiency of the Turbine-Generator unit: 91.0%;
- Global availability: 91% (average index adopted in similar hydroelectric power plants in the Brazilian system);
- Historic series of monthly average flows: January 1945 through December 1974.

In order to assess the net benefit resulting from the elevation, the present annual energy values were calculated based on a tariff of US$ 70/MWh, discounting the dam implementation costs for several levels, the results of this assessment are shown in Table 2.1 below.

Table 2.1: Net benefit of Centrals 1 and 2 in the final configuration

Water level	Power Available Total	Average Energy	Costs with the Elevation (C)	Incremental Benefits HPP I + II (B)	(B - C)	(B / C) (*)
(m)	(MW)	(MW)	US$ 10^6	US$ 10^6	US$ 10^6	US$ 10^6
102	700	421	0	0	0	0
112	725	466	196	227	31	1.16
122	750	510	212	452	240	2.13
130	780	546	233	635	402	2.73

***Notes:** 1) Incremental benefits obtained at present value, considering a period of 50 years and a return rate of 12% a.y. 2) Costs based on the assessment for Alternative 3, PMF, Basic value for the 102 level = USD 55 E6, (HPP I – Electric Central 1; HPP II – Electric Central 2)

Based on the dada shown above, with the inclusion of the new Central, the Cambambe Hydroelectric Power Plant will produce an average energy of 2,776.9 GWh a year, which, added to the existing Central, will generate the total average energy of 4,783 GWh a year,

Table 2.2. below presents an estimate of the annual revenue considering a tariff of US$ 70 per MWH that should be obtained after the modernization of Central 1, the execution of the elevation and the construction of Central 2.

Table 2.2: Estimated annual revenue at US$ 70.

Central	Annual Energy Production (MWH)	Tariff (US$)	Total Revenue
Cambambe 1	1,962,000	70.00	137,340,000
Cambambe 2	2,821,000	70.00	197,810,000
Total	**4,783,000**		**334,810,000**

In this case, it can be observed that the total annual revenue is in the order of US$ 300 million dollars a year. Considering a service life of more than 30 years, the total nominal values reach US$ 9 billion.

Considering that a significant part of the energy presently produced in Angola is originated from Thermal Power Plants, it is important to calculate which would be the cost savings due to the replacement of the more expensive thermal energy by the renewable hydraulic energy. For this analysis, a tariff of US$ 100.00 was considered for thermal generation (Table 2.3).

Table 2.3: Estimated annual revenue at US$ 100.

Central	Annual Energy Production (MWH)	Tariff (US$)	Total Revenue
Cambambe 1	1,962,000	100.00	196,200,000
Cambambe 2	2,821,000	100.00	282,100,000
Total	**4,783,000**		**478,300,000**

In this situation, the cost savings reach values close to US$ 500 million, with the total nominal value for the 30 year-service life exceeding US$ 14 billion. Therefore, in terms of the elevation scenario and based on the analyses conducted, it can be noted that the energetic benefit, for any of the configurations adopted in this study, either with only the existing generation units or considering the insertion of the second Central, presents a clear advantage towards the dam elevation up to the 132.00-m level, with the normal of operation water level set at 130.00 m.

Additionally, and as an indirect benefit for the elevation up to the 130,00-m level, the bottom discharge tunnel flow will increase, thus allowing a reduction in the flows split between the lateral spillway and the dam, as well as lower excavation volumes in the cases where the construction of a complementary spillway structure in the left bank is foreseen.

The use of the dam at the 112.0-m level together with Central 1 (existing) presents no advantage at all because the costs to implement the elevation exceed the energetic benefits, although it is possible in this case to avoid the relocation of the highway bridge over the reservoir. However, the benefit resulting from the construction of the new power house is small when compared to the advantages arising from choosing a higher level reservoir.

There is a clear advantage in the choice of the 130.00-m level as the maximum lake level, because there are many gains. This conclusion becomes evident when the tariff chosen to carry out the analysis (US$70.00/MWh) is applied.

The alternatives known as Left Bank, LNEC and Limit Energy have yielded very close values and, economically, can be considered similar. The SONEFE alternative is the one that shows a higher economic advantage, although with high risk.

In the case of damages due to dissipation basin erosion during high-water periods, the necessary recovery presents many difficulties, including the possibility of regressive erosion in the dam base that may cause, in extreme cases, the rupture of this structure.

The safest alternative under the technical point of view is represented by the left bank spillway alternative, because high waters will be discharged at a longer distance from the dam. For alternatives considering gates built into the dam (Limit Energy, LNEC, SONEFE and Safety Spillway) the work area available on the top of the dam will be very limited. This aspect, added to the need for carrying out the services with the reservoir in operation and possible high-water events during the construction period, will lead to execution problems that are difficult to evaluate.

The alternative known as Safe is a SONEFE variant that reduces the risk problems, because, in the case of damages in the dissipation basin, the lateral spillway would be able to handle the most frequent high-water events, thus keeping the basin free for repairs. It appears favorable in economic terms. However, even if only the alternative with flat gate spillways appears to be the most economic, the technical recommendation favors the lateral spillway alternative – Alternative 2, because:

- it is a modern trend found in similar projects built in the last years, where multiple spill devices were provided;
- it allows greater operational flexibility, only requiring the use of flat gates under the flow conditions found in extreme high-water events; better preservation of the basin and, consequently, of the dam structure by avoiding the discharge of the most frequent high-water events;
- allows inspection and eventual repairs in the basin at any time, even during high-water events.

To summarise the position, the chosen alternative has the following technical specifications:

- A concrete dam with a double-curvature arch, raised to the final level of 132 m;
- A downward-sloping spillway composed of a structure with two (2) segment-type sluices, 19.50 m wide by 15.00 m high;
- A generation system composed of a water intake, four (4) water conveyance tunnels, with a circular section 7.70 m in diameter, a power house for four (4) Francis-type vertical machines, totalling 700 MW installed power and an escape channel 40 m long to return the waters to the river;
- A reservoir with an approximate area of 6.08 km2 and a volume of 96.19 Hm3 at its normal maximum water level;
- For maintenance of the sluices, coffer dam gates are provided, with a span? of 19.50 m, a ground sill of 115.0 m and a height of 15.00 m.

2.3. OVERALL ENTERPRISE DESCRIPTION

This section is contains a general description of the project, particularly of the already existing structures, based on the initial basic project, and a brief assessment of the present condition of these structures. It also a description of the present reservoir and of the future structures to be built within the scope of the Cambambe Power Plant rehabilitation and expansion phase.

2.3.1. EXISTING STRUCTURES

Are described in the Cambambe AH project that was developed in 1950 and had the temporary deviation works started in 1958. The studies of the enterprise overall plan were concluded in December of the same year. According to this plan, the enterprise would consist of a concrete arch with double curvature, having its crest at the 132.00-meter level, and a built-in spillway.

Two bottom discharge channels and an underground power house designed for the installation of four (4) power generation units were foreseen, each of the later with a 65 MW capacity.

The enterprise was designed to be built in phases, according to the consumption evolution, with provisions for the easy installation of future generation units and the gradual generated power upgrading.

In the first phase, the dam was built only up to the 112.75-m level, around 20 m below the definitive level of 132,0 m, with the spillway remaining at 102.15 m and operating without gates, in the free layer mode.

At this time, two 65 MW units were installed, having the exploration started in November 1963 at a reduced fall allowing the generation of only 45 MW per unit, because the reservoir retention level remained around 28 m below the initially foreseen water level.

The two final 65 MW generation units were installed in 1973, and the available installed power has risen to 260 MW (4 x 65 MW), from which only 180 MW (4 x 45 MW) were generated for the reasons mentioned above.

Presently, after almost 50 years from the beginning of operation, the following structures are installed (see Figure 2.4):

- Dam and spillway, as defined in the initial plan, including all equipment necessary for the Cambambe AH operation;
- Power House (Cambambe I) presently generating 180 MW (with an installed power of 260 MW) including the Central 1 water intake (to be rehabilitated) and all the power generation equipment;
- Substation for power transformation and feeding of power lines;
- General workshop to provide support to the Cambambe AH operation;
- Offices to house the Cambambe AH operation personnel;
- Work yard/warehouse for the storage of spare materials; and
- Cambambe Village (where the Cambambe AH workers and ex-workers live).

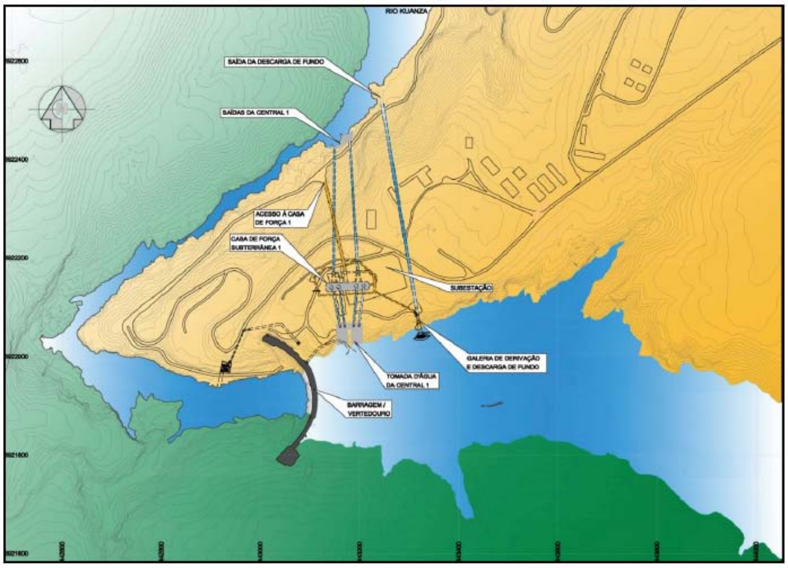


Figure 2.4: Overall plan of the existing Cambambe AH structures

Legend:
SAÍDA DA DESCARGA DE FUNDO = BOTTOM DISCHARGE OUTLET
SAÍDAS DA CENTRAL 1 = CENTRAL 1 OUTLETS
ACESSO À CASA DE FORÇA 1 = ACCESS ROAD TO POWER HOUSE 1
CASA DE FORÇA SUBTERRÂNEA = UNDERGROUND POWER HOUSE
SUBESTAÇÃO = SUBSTATION
GALERIA DE DERIVAÇÃO E DESCARGA DE FUNDO = DEVIATION GALLERY AND BOTTOM DISCHARGE
TOMADA D'ÁGUA DA CENTRAL 1 = CENTRAL 1 WATER INTAKE
BARRAGEM / VERTEDOURO = DAM / SPILLWAY

2.3.1.1. OVERALL RESERVOIR DESCRIPTION

The Cambambe Power Plant is located in the medium Kwanza region, around 11 km from the city of Dondo, and its reservoir has the characteristics shown in Table 2.4.

It is important to point out that the Cambambe reservoir has presently a very small storage capacity, and the dam has being operating practically in the run-of-river mode. The discharge of high-waters is being presently done over the dam crest, at the 102.15-m level. It is also important to note that the maximum recorded flow was of 3,740 m³/s in April 1969.

Table 2.4: Main characteristics of the present and future Cambambe AH reservoir.

Description	**Current AH at Cambambe**	**AH at Cambambe after Raising**
Sub-basin area	6,547 km^2	6,547 km^2

Drainage area	116,357 km^2	116,357 km^2
Reservoir basin	1.3 km^2	6.08 km^2
Distances	Approximately 180 km from the Atlantic coast and 134 km from Capanda AH	Approximately 180 km from the Atlantic coast and 134 km from Capanda AH
Altitude	47 m	47 m
Position of the axis of the dam	Latitude: 9^o 45' 07.00" S Longitude: 14^o 28' 51.25" E	Latitude: 9^o 45' 07.00" S Longitude: 14^o 28' 51.25" E
Maximum operational level	112.75 m in the jambs 102.15 m in the central part	130.00 m
Maximum level in all	112.75 m	132.00 m
Estimated useful volume	28.7 x 10^6 m^3	50 x 10^6 m^3
Installed power	260 MW	960 MW
Minimum observed flow rate, September 1950:	39 m^3sec	N/A
Maximum observed flow rate, September 1950:	3,829 m^3 /sec	N/A
Full flow rate in ten thousands	9,000 m^3/sec	9,000 m^3/sec
Probable maximum flow rate – PMF (estimated)	11,000 m^3/sec	11,000 m^3/sec
Ecological flow rate	500 m^3/sec	500 m^3/sec
Discharges	Derivation, water level (NA) on the 102.00 m slope: 450 m^3/sec Sand remover: 90 m^3/sec	Derivation, water level (NA) on the 130.00 m slope: 800 m^3/sec Sand remover: 110 m^3/sec

		Estimated solid flow: 1.5 x 10^6 tonnes/year

When the dam has been raised, the reservoir, at the normal maximum water level at a height of 130 m, will have an area of about 6.08 km^2, with a useful volume of approximately 96.19 Hm^3. The reservoir is capable of operating from the minimum operational level of 102 m, considering the dam without elevation, up to the maximum normal level of 130 m, in the maximum elevation condition.

2.3.1.2. CONDITION OF THE EXISTING STRUCTURES

Considering that in this phase of the works it is difficult to separate the overall condition of the structures from their safety conditions, due to the fact that both things are closely connected, it makes sense to assess them together, in the same way the particular observations were done. Therefore, this item is carried out as a whole, without separation and particularization.

To start with, we will consider the existing dam and its very close interaction with the population that lives and thrives in the dam's central core area, particularly the Cambambe Village, including all resulting advantages and inconveniences.

However, in order to analyze this question it is necessary to define the movement area, particularly the " dam core" zone where most of the dam construction works will take place, as the intake tunnel, the machinery house, the electric central, the control room, the deviation channel, and all the existing structures used in the dam construction/exploration, in their present and future conditions.

Generally, all this structure is already aged, although most of it does not have a structural nature and do not present any danger for the Cambambe AH operation. It is equally visible the presence of material (scrap, old parts and idle equipment) resulting from the Cambambe AH construction and operation process, which, despite the negative visual aspect of the landscape, it does not interfere with the Cambambe AH safety and operation.

However, except for the existing general workshops, the fuel and lubricant storage area also presents a degraded aspect that will require particular attention from the construction owner, with the objective of implementing environmental and safety controls, in addition to those already implemented.

There are absolutely general parameters that must be observed to ensure the safety of the installations and workers, with emphasis to scrap removal. It is important that the structures belonging to the old general workshops are submitted to a restoration and rehabilitation process and that all the waste material is removed and stored in an appropriate location.

As previously mentioned, there is a permanent common territorial use of the population in all areas of the existing dam and the new areas as well, to be expanded, renewed and rehabilitated, this means that the boundaries between "dam" and "population" is not clear and this aspect must be improved.

When all identification rules are in place and strictly observed, the zones and areas where the consortium will carry out its activities must also be subject to layout rules, including the construction's auxiliary areas. These structures include living quarters, camping, lodging areas, social areas, and all the others that are specific of the construction, as work yards, workshops, warehouses, the several work fronts, yards for machinery, materials, equipment, groceries, etc. This means everything that belongs specifically to the works and also everything that is supplementary and auxiliary to the works.

Another example is the access to the right bank walkways that are equipped with stairs that need safety improvements. Another aspect is related to the tunnel that provides access to the machinery house and also the several tunnels, galleries and accesses inside the massif where the dam is built, which need illumination-level improvement, repairs in some connections that are precarious and makeshift, and some water pipes that show leaks.

In a project of this size, it is convenient the placing of a large graphic informative placard showing the overall localization plan for the entire enterprise, which shall be later complemented with partial placards showing each particular area with respect to its specific function. Presently there is insufficient visual identifying information for users, visitors, or companies providing the several necessary services and that are moving around for the first time. This entire situation must be improved, including the improvement of the illumination, both at identification level and at the level needed in the actual work areas.

This kind of enterprise usually have activities that are carried out 24/24 hours, without interruption, so a perfect circulation must be ensured in all as areas at any time.

Such large enterprises are normally guided by a general work schedule that is later split into specific partial schedules separated per activity and work fronts, and they necessarily undergo a period that is usually called "Mobilization and Establishment of the Work Yard". According to the observations conducted, this phase is still in progress because of the present works in the power houses that are taking advantage of the best construction and occupational safety techniques, including the use of the adequate personal and collective protection equipment applicable to each process stage.

From the local observation and the documentation it can be established that the location of the quarry explorations necessary for the works were already identified, which were already used in the past for the construction of the first dam. As this place is located in the right bank and very close to the river, the water drainage problems must be carefully approached to avoid the risk of making the exploration unfeasible in rainy weather, or if any other problem should arise in the exploration banks in such season.

The heavy traffic of building machines and equipment for this activity requires the definition of proper paths for machines and the transport means for stones and the resulting materials, including indication signaling and night illumination.

2.3.2. STRUCTURES TO BE BUILT – EXPANSION

In addition to the crest elevation from 112.75 to 132 meters, the main installations to be built include a new power house in the open air with four (4) 175 MW generator units

(Cambambe II) totaling 700 MW of installed power, a new spillway located in the dam left bank (see Figure 2.5) and a new bridge that will replace the existing bridge that will be submerged (see Photo 2.1).

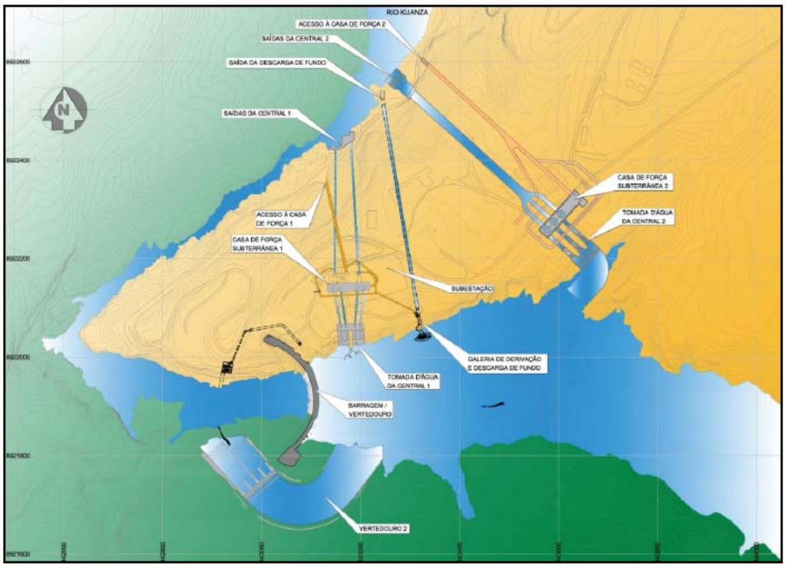


Figure 2.5: General plan of the existing structures and of those to be built at Cambambe AH.

Legend:
RIO KUANZA = KWANZA RIVER
ACESSO À CASA DE FORÇA 2 = ACCESS ROAD TO POWER HOUSE 2
SAÍDAS DA CENTRAL 2 = CENTRAL 2 OUTLETS
SAÍDA DA DESCARGA DE FUNDO = BOTTOM DISCHARGE OUTLET
SAÍDAS DA CENTRAL 1 = CENTRAL 1 OUTLETS
ACESSO À CASA DE FORÇA 1 = ACCESS ROAD TO POWER HOUSE 1
CASA DE FORÇA SUBTERRÂNEA 1 = UNDERGROUND POWER HOUSE 1
CASA DE FORÇA SUBTERRÂNEA 2 = UNDERGROUND POWER HOUSE 2
SUBESTAÇÃO = SUBSTATION
GALERIA DE DERIVAÇÃO E DESCARGA DE FUNDO = DEVIATION GALLERY AND BOTTOM DISCHARGE
TOMADA D’ÁGUA DA CENTRAL 1 = CENTRAL 1 WATER INTAKE
TOMADA D’ÁGUA DA CENTRAL 2 = CENTRAL 2 WATER INTAKE
BARRAGEM / VERTEDOURO = DAM / SPILLWAY

Still as a result of the new proposed Cambambe AH lake normal operation level, with the elevation from the present 102-m level to the 130-m level, it will be necessary to relocate a section of approximately 6 km of road from Dondo to Huambo, including a 100-metre bridge (see Figures 2.6 and 2.7).

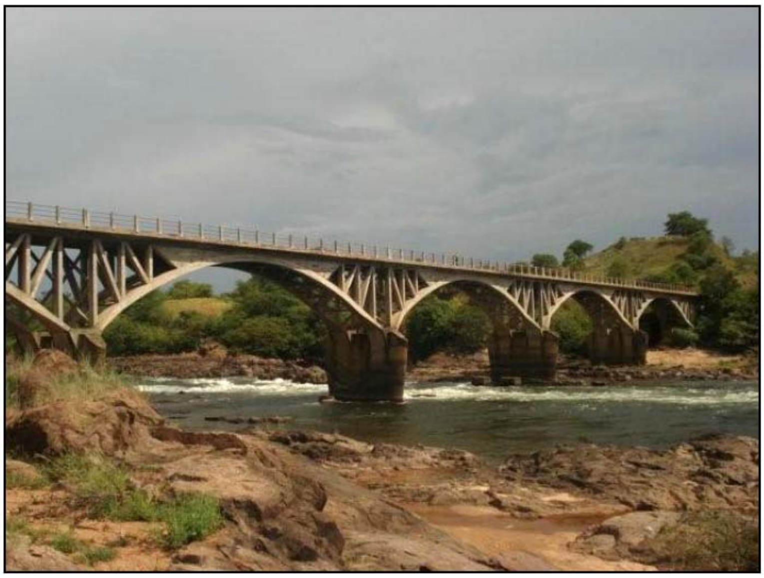
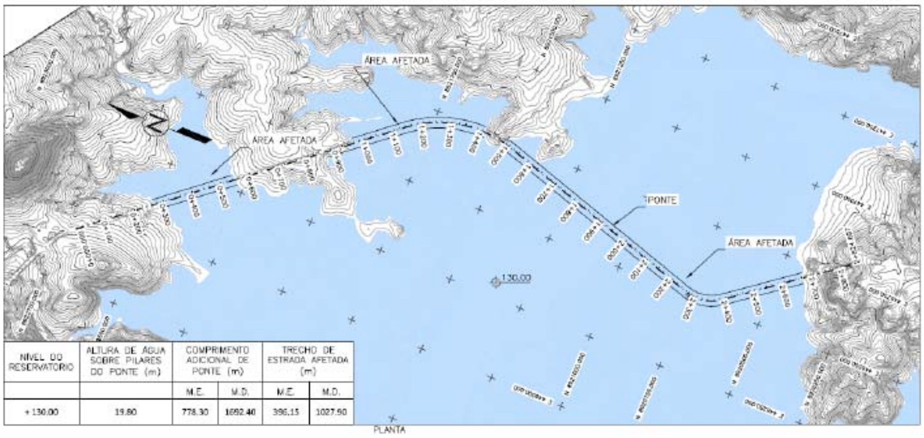


Photo 2.1: Existing bridge upstream of Cambambe AH.



NÍVEL DO RESERVATÓRIO	ALTURA DE ÁGUA SOBRE PILARES DO PONTE (m)	COMPRIMENTO ADICIONAL DE PONTE (m)		TRECHO DE ESTRADA AFETADA (m)	
		M.E.	M.D.	M.E.	M.D.
+ 130.00	19.80	778.30	1692.40	396.15	1027.90

Figure 2.6: Lake at the 130-m level and a sketch of the affected area.

Legend:
NÍVEL DO RESERVATÓRIO = RESERVOIR LEVEL
ALTURA DE ÁGUA SOBRE PILARES DO PONTE = WATER LEVEL ABOVE THE BRIDGE PILLARS
COMPRIMENTO ADICIONAL DA PONTE = ADDITIONAL BRIDGE LENGTH
TRECHO DE ESTRADA AFETADA = AFFECTED ROAD SECTION

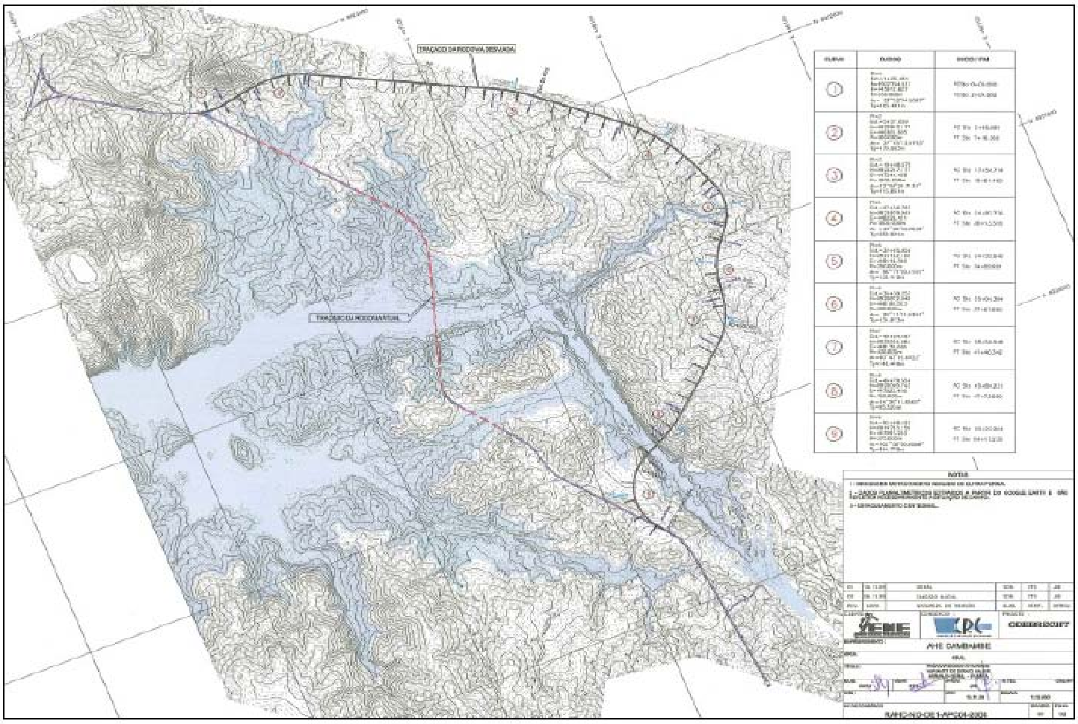


Figure 2.7: Proposed route for the new road and bridge.

Legend:
TRAÇADO DA RODOVIA ATUAL = PRESENT ROAD ROUTE
TRAÇADO DA RODOVIA DESVIADA = DEVIATED ROAD ROUTE

The new hydraulic generation circuit of the new Power Station will be composed of a Water Intake, four Water Delivery Tunnels, excavated out of the rock, with a circular section of 7.70 m and an approximate length of 510 m per tunnel, a Power House of the sheltered type, excavated in the open air, protecting the four (4) generator units and their respective equipment and auxiliary systems, followed by a 40.00 m long drainage channel, to return the waters to the river. The characteristics of the proposed spillway as well as the Cambambe storage-elevation ratio are presented in Tables 2.5 and 2.6 below.

Table 2.5: Characteristics of Cambambe AH and of the new spillway

Type of Spillway	2 (two) 15 m x 19.5 m sluice gate segments

Length of Crest of Ground Sill	115 m
Maximum Storage Level	130 m
Maximum Storage Capacity	101.78 million m^3
Spillway Discharge Ratio	Q = 4,500 m^3/sec

Table 2.6: Cambambe AH Storage-Level ratio.

Storage (millions of m3)	**Level (masl)**	**Storage (millions of m3)**	**Level (masl)**
0.18	55	10.87	95
0.62	60	14.05	100
1.31	65	19.18	105
2.25	70	27.56	110
3.45	75	39.70	115
4.90	80	55.92	120
6.61	85	76.32	125
8.58	90	101.78	130

The Cambambe Power Plant, with the inclusion of this new Power House (Cambambe II), will generate an average power of 2,776.9 GWh a year, which, added to the existing Central, will generate a total average power of 4,783 GWh a year. These new structures will allow an increase in the electric power supply and the integration of the Cambambe AH into the Angola Electric Power Transmission System through a 400 kV Substation located close to the new Generation Central to which the Angola Transmission System will be connected by one (1) 400 kV Transmission Line in the new ZEE Luanda Substation to be built. The new Cambambe Substation will also be connected to the existing Substation through a small 220 KV interconnection line.

In order to allow this interconnection, as well as the connection to the other public network systems, other works out of the present scope were defined, and will be split into nine subsystems, as shown in Figure 2.8.

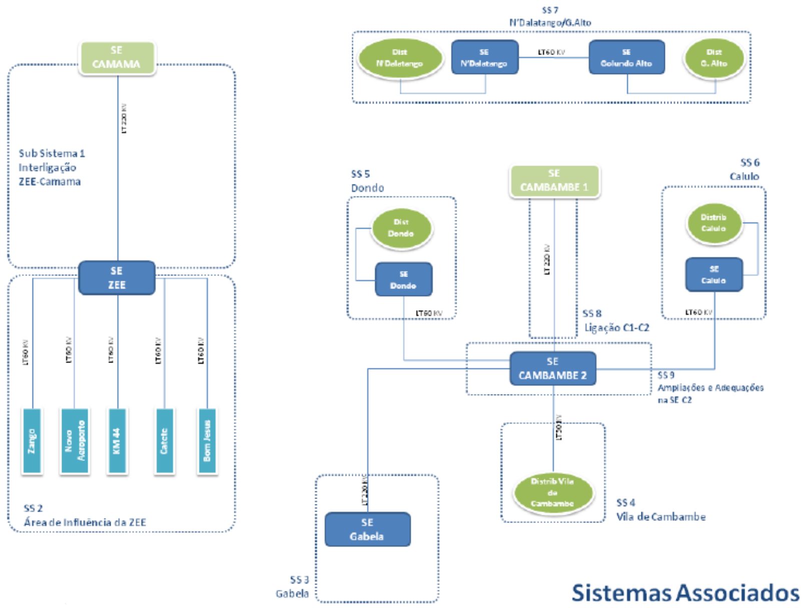


Figure 2.8: Systems associated to the Cambambe AH.

Legend:
Associated systems
Sub-system 1
Interconnection to ZEE Camama
Connection C1-C2
Expansions and Adjustments in SE C2

2.3.2.1. SUPPORT INFRASTRUCTURE

This section defines the criteria to be applied in the implementation of the support infrastructures for the Cambambe Rehabilitation Consortium (CRC), as well as the structures to be built, including offices, lodging facilities, administrative office, workshops and the industrial yard. It also describes the premises established for the operation and maintenance of these facilities, establishing the attributions/facilities to be made available by the ENE, with respect to the Consortium infrastructure.

Offices
The office installations comprise three main modules located close to the ENE Control Building, which are:

- **Central Office:** Is the project's central office with 667 m2 of built area. There is also an adjacent office presently used to house the rooms and offices Consortium members ALSTOM, VOITH, ENGEVIX, ODEBRECHT, DAR and ELECNOR, with a built area of 163 m2.
- **Administrative Support Office:** This office has a total area of 140.36 m^2, comprising six rooms and one meeting room used for personnel training and lectures.

- **Medical Station:** Has a total built area of 147 m^2. It counts with a covered waiting area, reception, emergency room, observation room, consultation room, laboratory, drugstore and a covered ambulance parking area.

Lodging facilities

The purpose of the lodging facilities built on the work site is to house expatriated human resources and also national human resources coming from other provinces, both for activities belonging to the rehabilitation scope and those belonging to the elevation works. Three kinds of lodging were considered, which are: Type A for the management, Type B and Containers for the other indirect administrative staff and Type C for the direct staff. The total housing capacity is for 1,540 people at present.

- **Type A**: This includes the accommodation for managers/directors and visitors. It has a total built area of 209.47 m2, with 7 individual apartments with private bathrooms, a living area and a service area.

- **Type B**: This includes the accommodation for indirect personnel. The plan is to have 13 individual modules, with capacity for 299 people. The total area of modules B1 to B13 is 693.92 m2.

- **Type C**: This includes 15 housing modules with a capacity for 1,050 people, namely the personnel directly mobilised in order to carry out the work. Each module is from 199.68 (C8 to C15) to 223.20 [m2] (C1 to C7). The total area of modules C1 to C15 is 422.88 m2.

- **Lodging in containers:** The lodging containers are located close to the entertainment area and the canteen, and consist of 10 20-feet industrial containers equipped with private bathroom. Circulation among the containers is ensured through the implementation of a central corridor. Additionally, there is a central integration social area built with prefab wooden structure, with a total area of 349.17 m^2.

- **Hotels and a guest house**: There are two hotels, called Hotel Catita and Hotel Suiça, with capacity for 96 people and a guest house called Pousada Verde with capacity for 44 people.

Complementary facilities

- **Leisure Area:** This includes a gymn, a tennis court, a climbing wall, football pitches, a swimming pool, a cinema/theatre, games rooms, a television room, telephone kiosks, an internet access room, a library and a “jango” [Angolan for a place in which to meet and eat together]. It will include a total built area of 675 m2, made of concrete block masonry..

- **Canteen and Industrial Kitchen:** For the elevation works it was necessary to implement an industrial kitchen and a high-capacity canteen, adequate to the number of workers. The industrial kitchen has a built area of 280 m^2 and capacity to prepare up to 4,000 meals a day. The canteen has built area of 300 m^2. It is important to point out that in the case of rehabilitation the solution of rehabilitating an ENE area located close to the Village Club was adopted, to be used as industrial kitchen and canteen.

- **Laundry:** The laundry facilities have a total area of 69.44 m^2.
- **Multisport courts:** Located in the central portion of the lodging area, comprises two multisport courts and a tennis court, duly protected by wire fences and with illumination to allow night use. The total built area is of 1,728 m^2.

Workshops and Industrial Centers

These workshops consist of intermediate yard where mold and reinforcement centrals were installed, mechanical, electrical and industrial workshop, several offices, concrete laboratory and gas station. They also include a lower yard, downstream of the Central Discharge Tunnels, where the Concrete Central, Crusher, Ice Central, Water Reservoir and Warehouse are located. The workshops are equipped with a water/oil separator and a sedimentation tank used to collect the water used to wash the concrete truck spouts.

The infrastructure mentioned above is presented in Table 2.7, and some of it is already built and occupied by the workers employed in the present Cambambe AH phase.

Table 2.7: Foreseen structures.

FACILITES	AREA m2	CAPACITY People
OFFICES		
Partner Offices Alstom, Engevix, Voith, Odebrecht, DAR and Elecnor	163	-
Central Office	667	-
Administrative Support Office	140	-
Medical Station	147	-
Lodging Engineers/Technicians		
Lodging A	209	7
Lodging B1	212	20
Lodging B2	212	16
Lodging B3	212	16
Lodging B4	212	16
Lodging B5	212	16
Lodging in containers (movable)	349	17
Lodging C1	381	96
Lodging C2	381	96
Lodging C3	381	96
Lodging C4	381	96
COMPLEMENTARY FACILITIES		
Canteen and Kitchen	580	500
Entertainment Area and Gym	675	20
Laundry	69	-
Sport Courts	1.728	-
Telecommunication	-	-

FACILITES	AREA m2	CAPACITY People
System		
WORKSHOPS AND INDUSTRIAL CENTERS		
CRC Warehouse	800	17
Civil Production Office	120	15
Mechanical Workshop	260	13
Electric / Hydraulic Workshop	150	5
Field Office (Earth and Rock)	119	10
Reinforcement Central	310	-
Carpentry Central	400	-
Field Tool shop	316	-
Tire repair / Lubrication	350	-
Fuel Station	120	-
Industrial Area (Elecnor)	413	-

The work yard facilities (see Figure 2.9 for lodging and Figure 2.10 for workshops), buildings, yards, utility networks, including streets and urbanization, will be built according to the execution projects and specifications, both prepared by the Consortium.

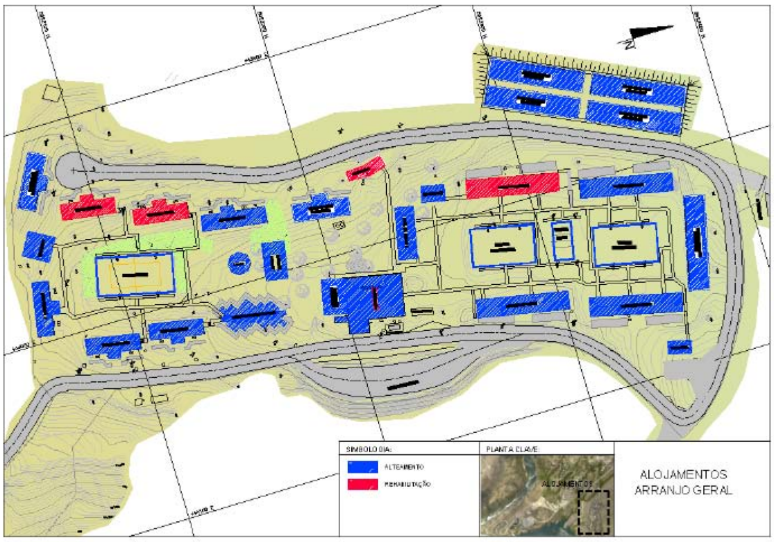


Figure 2.9: General lodging arrangement.

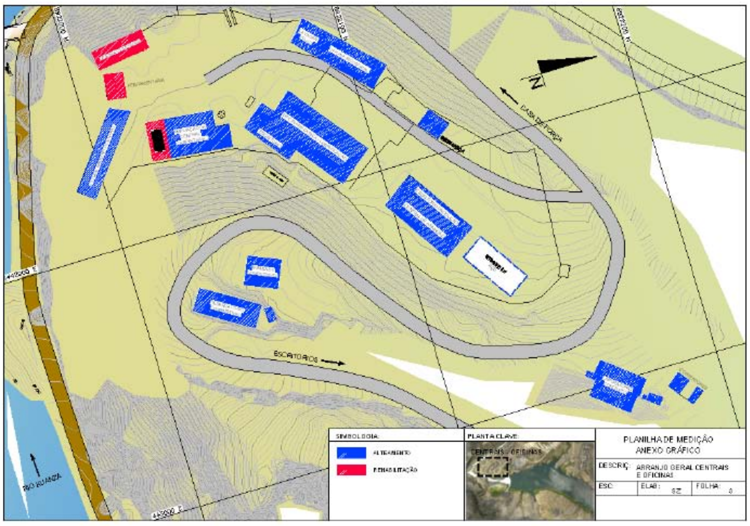


Figure 2.10: General workshop arrangement.

These constructions will have the main purpose of ensuring the appropriate development of all the project activities, the common well being, the harmonic relationship and a permanence period with acceptable tranquility and comfort levels for all the people directly involved in the construction works.

The camping will be composed by temporary housing (as containers and/or prefab houses), which will follow the same style of the housings built in the previous phase.

The construction and facilities of the Consortium's work yard will have satisfactory capacity to match the foreseen service volumes and schedule. In order to install the work yard, build the internal roads, locate the surplus material deposit (DME) and the storage for the excavation materials, the environmental protection provisions must be observed and the appropriate areas for this purpose must be released.

The work yard facilities and buildings planned to meet the infrastructure needs of the Cambambe AH rehabilitation and expansion project will include the following:

- Land preparation, including land leveling, excavation, demolition, landfill, draining, street building, fencing and any other service necessary for the work yard implementation;
- Design and construction of foundations and bases, including the supply of all the material necessary to install the equipment and to erect such equipment;
- All the necessary buildings to house offices, warehouses, workshops, deposits, and all the equipment and accessories necessary for the operation;
- Systems for drinking and industrial water adduction, treatment and distribution;
- Systems for sanitary sewage and effluents, including sewage treatment station;

- System for light and power distribution from a point defined by ENE, from a distance lower than 30 m, including the network and illumination in the night work areas;
- Service roads for access to the work fronts, including service access;
- Installation of a pumping system for draining and maintenance of the cofferdam areas, fire prevention and fighting system, external and internal communication system, and local communication in the work activities;
- Compressed air system;
- Pumping system for draining in the work site; and
- Communication system.

The following auxiliary facilities will be necessary for the execution of the works, particularly the structures listed in Table 2.8.

Table 2.8: Auxiliary facilities foreseen.

Structure	Area (m2)
Camping	2.500
Warehouses	12.000
Central workshop	37.500
Operational workshops	15.000
Electromechanical shed	5.000
Fuel pump	5.000
Concrete central	10.000
Crushing central	90.000
Surplus material deposit	177.000

2.3.2.2. QUARRY AND SURPLUS MATERIAL DEPOSIT AREAS

The quarry to be used for this work will be located on the right-hand margin of the dam, as shown in the figure below.

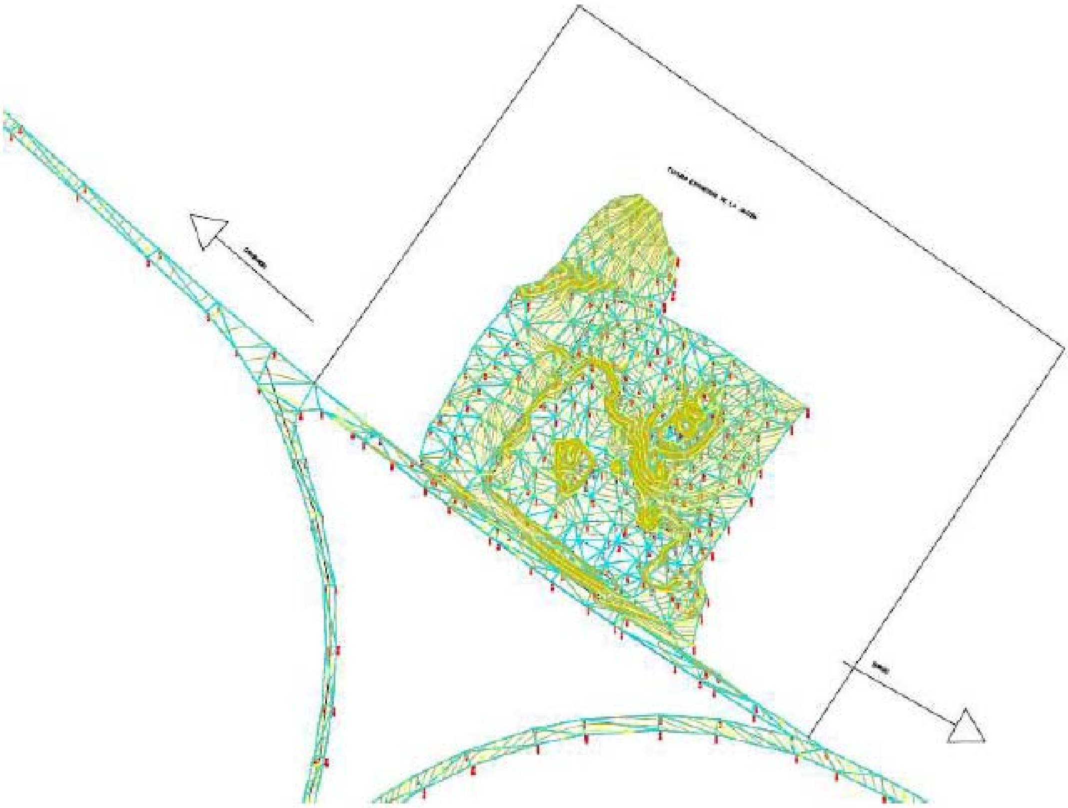


Photo 2.2: Detail of the place of the deposit on the right-hand margin of the dam.

The material removal volume estimate is of around 150,000 m³. The volume of foreseen underground excavation is of 280,000 m³ and of open air rock excavation is of approximately 450,000 m³. The necessary concrete volumes foreseen are of 82,000 m³ for the new central, 59,000 m³ for the dam, 45,000 m³ for eventual dam reinforcement and 60,000 m³ for the spillway. The concrete additives to be used are mainly composed by plasticizers, retarders and air incorporators. The consumption of 300,000 kg of cement is foreseen.

The waste material must be discarded into surplus material deposits (see Figures 2.11 for Phase 1 and 2.12 for Phase 2) that will be established in appropriate places. These deposits must be stable and present uniform and regular slopes.The surplus material deposit areas must be built according to the site preparation and draining criteria.

Deposit of excess material must be laid in continuous layers with maximum thickness of 1.0 m, so it will later be compacted by the action of the traffic of the transport and spreading equipment. In order to provide adequate draining, the surplus material deposit surfaces must present a minimum down slope of 2%.

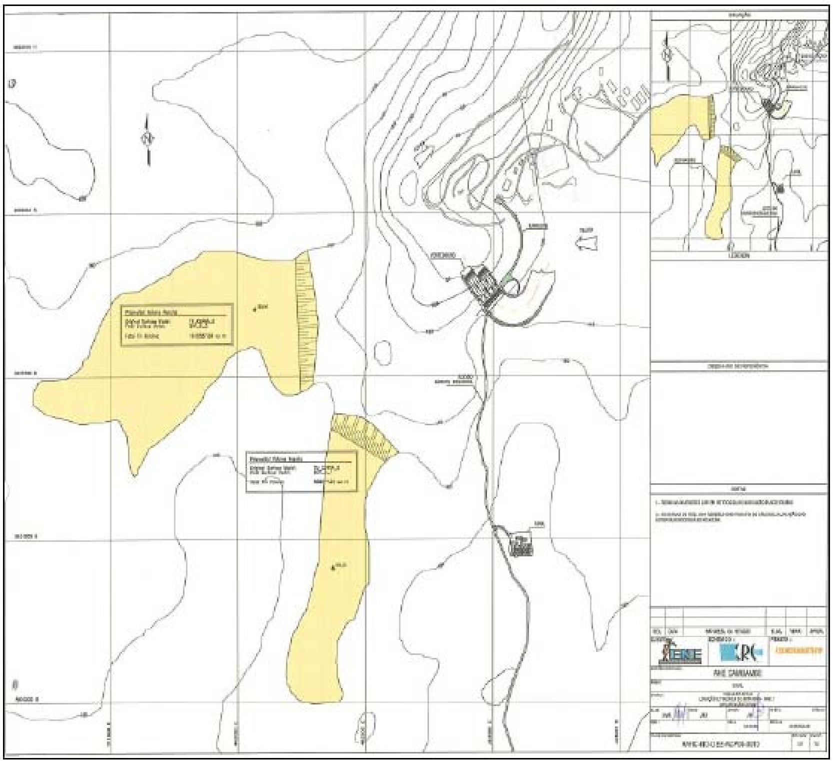


Figure 2.11: Surplus material deposit areas for Phase 1.

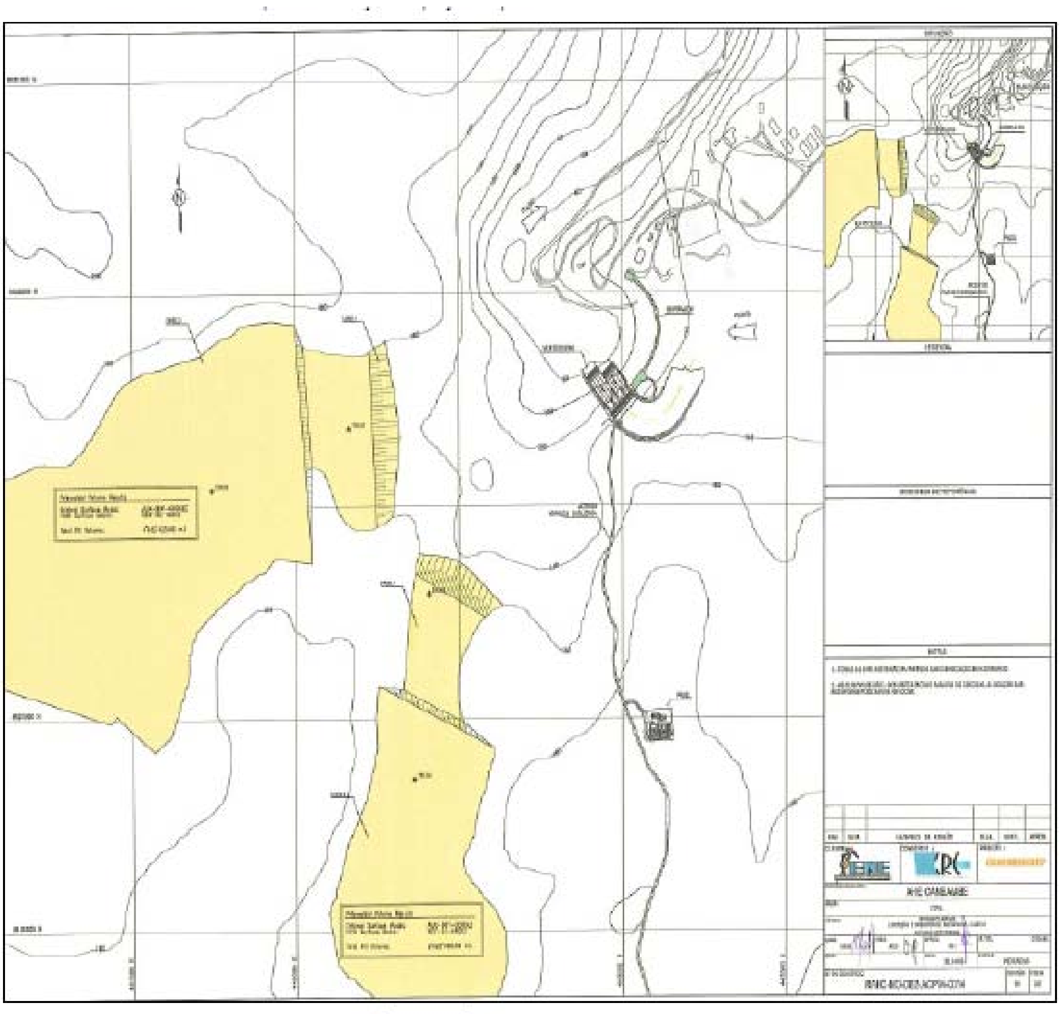


Figure 2.12: Surplus material deposit areas for Phase 2.

Figure 2.13 below presents a map of the localization of the main areas required for this project. These areas include a quarry and a crushing central (see Photo 2.3), concrete central, storage area, surplus material deposit areas (waste) and the new Cambambe Village. The size of each area is the following:

- Quarry: 80,000 m^3
- Crushing central: 4,458 m^2
- Concrete central: 2,260 m^2
- Storage area on the left bank: 5,929 m^2
- Storage area on the right bank: 5,625 m^2
- Surplus material deposit areas: 546,000 m^2

The inert material necessary for the production of the aggregates to be used in the concrete and in the access roads on both river banks will be obtained from the exploration of the old quarry existing in the site, which was used during the first phase of the dam construction.

The place that will lodge the workers to be recruited for the dam operation will be established in an 8.4-hectare area northwest of the main entrance (Figure 2.15). It will be composed of houses and entertainment areas.

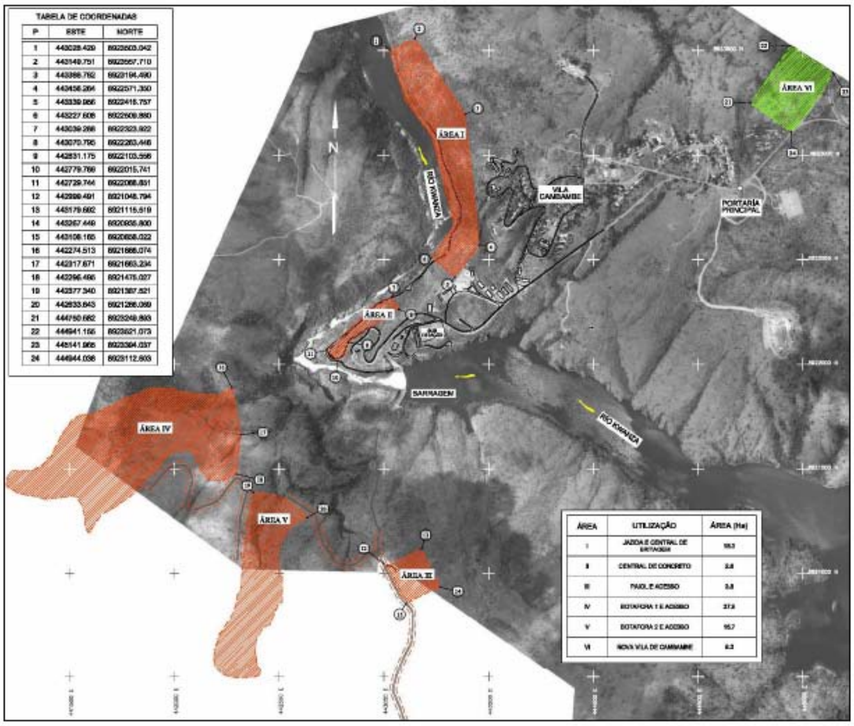


Figure 2.13: General arrangement of the required areas.

Legend:
TABELA DE COORDENADAS = COORDINATE TABLE
ESTE = EAST
NORTE = NORTH
ÁREA = AREA

RIO KWANZA = KWANZA RIVER
VILA CAMBAMBE = CAMBAMBE VILLAGE
BARRAGEM = DAM
PORTARIA PRINCIPAL = MAIN GATE
UTILIZAÇÃO = USE
JAZIDA E CENTRAL DE BRITAGEM = QUARRY AND CRUSHING CENTER
PAIOL E ACESSO = STORAGE AND ACCESS
BOTAFORA = WASTE DISCARD AREA
NOVA VILA DE CAMBAMBE = NEW CAMBAMBE VILLAGE

Photo 2.3: Detail of the future crushing central.

2.4. CONSTRUCTION PHASE

The AH construction phase will be described below with more detail, including the following activities:

- **Rehabilitation (civil and electromechanical works):** This activity includes the phases of mobilization, storage and work yards and the manufacturing of the equipment, the generation units and the Power House modernization. This conclusion of this activity is foreseen for December 2011.

- **Elevation:** This activity will include in a first phase the mobilization of special equipment and in a second phase the execution of the elevation work. For the elevation work that will be concluded in August 2012, simultaneous actions will be carried out to elevate the right and left dam sides.

- **Lateral Spillway Construction:** This activity includes cleaning and shrub cutting actions, rock excavation and the construction of structures, walls and the bridge over the spillway. This activity should be concluded until October 2012.

- **Construction of the New Bridge and the Upstream Road:** This activity includes a new road route with approximately 6 km and a bridge 100-meter long.

2.4.1. RIVER CONTROL

This section deals with the general procedures to be used in the execution of the necessary river control services and works during the new Cambambe Power Plant Central construction period, as well as the rehabilitation works, comprising services and works that include, but are not limited to, the following activities:

- Common excavation for the construction of the penstock intake and discharge channels and the discharge tunnel, and the execution of the open-air rock excavation foreseen for these channels, built under the protection of the natural septa remaining from the rock excavation or the auxiliary cofferdams [2] in the intake and discharge channels of the said tunnels;
- Underground rock excavation of the Power House tunnels and vault;
- Construction, maintenance and removal of the auxiliary cofferdams and septa; and

[2] Landfills, temporary or definitive, necessary for the dry execution of excavations and other structures built with the purpose of retaining waters of any origin.

- Initial draining and control of the water existing in the area between the main cofferdams and in other construction areas, of any origin.

The water level lowering will be carried out in a way that keeps the foundations sufficiently dry to allow the execution of the works. The drained water will be discharged away from the cofferdam or the excavation limits, so as to prevent reflux or erosion in the several work fronts. The channels, trenches and wells built inside the foundation area of the permanent concrete structures will be filled with concrete of the same quality of the one used in the permanent works, and their surfaces will be treated in the same way as the foundations.

2.4.2. DEFORESTING, STUMP REMOTION AND SCRAPING

This section deals with the procedures and guidelines to be observed in carrying out the deforesting, excavation and foundation preparation services for the construction works of the generation, substation, trench, storage yard, surplus material deposit and reclaimed area structures.

The deforesting, stump remotion and scraping services will consist of the remotion of the vegetation material originated from trees and shrubs, so the resulting surface will be completely free of debris.

In this case, deforesting is understood as the cutting and remotion of all trees, shrubs, grasses and similar vegetation existing in the area, and stump removal is understood as the removal of stumps and roots to the proposed identified places. Scraping is understood as the remotion of all the vegetation in a thickness of 20 cm to be later used in the recovery of degraded areas.

In no case, branches, trunks, roots and other debris originated from deforesting, stump removal and scraping operations will be launched in rivers, springs or ravines.

The areas to be deforested and have stumps removed will be those foreseen in the programmed excavation project or those used as access, landfill, surplus material deposit, material storage and reclaimed areas. The limits of these areas will extend up to 10.0 m away from the marks that identify excavations, landfill borders, surplus material deposits and stockpiles.

When necessary, trenches, drains or channels will be built around the excavation limits to collect superficial waters and conduct them away from the excavation areas. All excavated surfaces remaining permanently exposed must present stable slopes and uniform final finishing.

2.4.3. COMMON EXCAVATION

For this project, excavations above and below the water level are foreseen. The first activity includes the remotion of colluvial, residual and saprolitic soils, saprolites, turfs, alluviums and boulders with volume lower than 1.0 m³ or loose rock pieces, as well as any material that can be removed with the help of the blade of a CAT D-8 tractor or equivalent type.

The second activity includes all common material (several kinds of soil, colluvial and alluvial deposits) located in the river banks or bed, below the water level, which will be removed by appropriate methods and equipment, such as: suction dredges, "drag-lines", retro-excavators, etc.

2.4.4. Underground Rock Excavation

The underground rock excavation will be carried out specifically for the construction of three penstocks, the underground power house vault, the discharge tunnel and the drain tunnel system.

The underground excavation will be controlled by instruments, so the design assumptions may be checked and the efficiency of the foreseen support systems may be confirmed. The instruments to be supplied, installed and monitored during the construction will consist of convergence meters installed according to the work fronts progress, where indicated and where deemed necessary.

For the excavation of the discharge tunnel and the power house vaults, jumbo-type equipment will be employed, however, the use of manual or caterpillar-mounted drilling machines may eventually be approved in restricted areas, installed on pantographic platforms. The section lowering will allow the excavation to be carried out by caterpillar-mounted drilling machines of the ROC-601 or similar type, with the boom adapted to the perforation of the bores located in the excavation limits.

The section widening in the horizontal sections will be excavated by mechanized equipment mounted over a movable platform (Jumbo type). The drain galleries will be excavated by smaller equipment, either mechanized or manual, with the necessary characteristics to operate in restricted space locations.

The portal of the Tunnel Trail will be dug carefully in order to avoiddamage to adjacent rock. Generally speaking, the tunnel shall beexcavated in two phases, being the work, initially, concentrated in the corresponding section the vault and subsequently in sectioncorresponding to recess.

2.4.5. USE OF EXPLOSIVES

The explosives to be used will be stored in duly prepared places, specifically the explosive warehouse, in adequate containers and in compliance with the country's legislation. 300,000 kg of detonation gel and 500,000 kg of explosive cartridges will be used.

2.4.6. RIVER DEVIATION

The construction methodology used to carry out the permanent works related to the dam elevation and the new lateral spillway has taken into account the detailed analysis of the historic Kwanza river flows along humid and dry periods.

The humid period occurs between the months of January and June, while the dry period occurs between the months of July and December. Therefore, the following flows were adopted as the maximum design flow, which correspond to the maximum flow for a return period (tr) of 25 years:

- For the humid period: 3,800 m^3/s;
- For the dry period: 750 m^3/s (which is the present capacity of the Bottom Deviation Discharge).

The river deviation will be carried out during the dry period by means of the bottom discharge system located upstream of the dam on the right bank, with the purpose of lowering the reservoir level and releasing the present dam's central spillway crest and allowing the central span elevation.

The central span elevation will be carried out only during the dry period, when it is possible to carry out the river deviation due to the recurring flows. During the humid period, the Kwanza river will flow normally through the dam's central span, because the flows are higher than the bottom discharge system capacity. Therefore, during this period, only the dam side portions can be elevated.

The river deviation as described above is an important part of the dam construction planning, which will be made once the present gate mechanical operation system is rehabilitated, including the tunnel cleaning and the gate recovery foreseen in the rehabilitation scope.

2.4.7. NEW ROAD AND BRIDGE

The road deviation will only be made when the construction of the new bridge and road are ready, to avoid circulation problems in the National Highway 230. The route foresees a road approximately 6 km long and an 100-meter long bridge. The bridge and road construction process will take 18 months. An Environmental Impact Study will be done, regarding construction of this new stretch, which will be completed in 2012.

2.4.8. REHABILITATION

The rehabilitation phase in this project includes the entire generation units repair and modernization, including the turbines and the respective generators, intake and restitution hydraulic circuit parts, as well as all the other equipment electric, mechanic, auxiliary equipment, hydromechanic, belonging to the central and its attached structures, water intake, balance shaft, bottom discharge and sand trap.

Additionally, the overhead cranes, the handling and elevation equipment for the several gates and the gates themselves must be included.

The works also include the modernization and expansion of the 220 kV Substations, their auxiliary equipment and the Command Building (involving a large part of the panels and the supervision and control systems).

2.5. PHASE OF THE INSTALLATIONS OPERATION AND MAINTENANCE

In this section, the aspects related to the enterprise operation and maintenance are described, including the work yard.

2.5.1. WORK YARD

The Consortium will provide for its work yard facilities, furniture, equipment, tools and everything else that is necessary for the efficient performance of the works. It is the Consortium's responsibility and duty to carry out all the services and charges inherent to the site's work yard operation and maintenance. This includes the following:

- Internal roads and paths, surveillance, industrial safety and hygiene services, buildings, industrial facilities, water, illumination and sewage networks, communication and service systems, devices and installations for performing the works, supplies, transport, storage and everything else that is necessary, thus providing an infrastructure capable of supporting the performance of the works.
- The Consortium will take all the necessary care to avoid damages to the civil works. Therefore, it will either provide the necessary protections or take any other measure to allow the traffic of vehicles and equipment, handling of tools and the installation of materials and equipment without damaging the existing civil works.
    - The work site will be maintained with the work fronts permanently free of waste material, with the materials stored in an organized way, as to avoid harming the services in progress.
    - The service networks will undergo regular adequate maintenance. The surplus material deposits can only be implemented in authorized areas, in compliance with the Environmental Legislation in force.
    - The Consortium will keep in the site's work yard under its responsibility, an adequate full time surveillance, compatible with the contracted services.
    - The traffic of vehicles inside the Work Yard will be limited to areas periodically established, according to the evolution of the services.

- All Consortium vehicles, including those of its outsourced companies, will bear a clear indication, including the Consortium name, on a card of a model to be approved by ENE, adhered to the windshield.
- The general personnel transport will be carried out in compliance with the Occupational Safety standards.
- Visitors will be required to bear badges with the word "VISITANTE" written on them, which will be delivered and returned at the main entrance.
- All the Consortium personnel, including that of the outsourced companies, must use the appropriate Personal Protection Equipment (EPI), according to the risk exposure.
- The temporary work yard facilities will be of the Consortium property and, at the end of the works, will be removed from the respective areas, which must be left clean and unencumbered, including the demolition of the building foundations, as well as debris and waste material.

2.5.2. FUEL STORAGE

Regarding fuel storage, according to the standards in force in the country (Decree no. 56/08 of April 21 about the Storage of Petroleum Products and Decree no. 57/08 of April 22 about Fuel Transport), diesel oil will be stored only in appropriate elevated tanks, with around 1,200,000 liters, which will be installed on the right bank (see Figure 2.14). A secondary containment barrier must be built as a safety item against the risk of leaks. The fuel facilities will be equipped with decantation basins that will be used to stop any possible leak, thus making the later fuel collection easier.

All these facilities were conceived considering the fuel demand in the elevation works. The total built area including yards and accesses is of approximately 850 m^2. The foreseen fuel consumption for Cambambe I is shown in Table 2.9 below.

Table 2.9: Fuel Consumption.

Description	**Consumption (lts)**	
	Monthly	**Daily**
Peak	130,000	5,000
Average	100,000	3,000

The fuel transport to the work site will always be done by Sonangol or companies authorized by it and accredited for the job, and will always be done by appropriate vehicles. Inside the site, fuel transport will be done by appropriate vehicles following the safety standards established for this operation. Fire-fighting equipment will always be available and in operating conditions.

2.5.3. WATER SUPPLY

The water capture for human consumption will be done from the existing system. However, a drinking water treatment station (ETA) will be built to supply the project needs. The repair of the Cambambe Village elevated reservoir (see Figure 2.15) will be carried out. The estimated drinking water consumption is of 150 l/day per person, so during the peak work season there may be a maximum consumption in the order of 375,000 l/day.

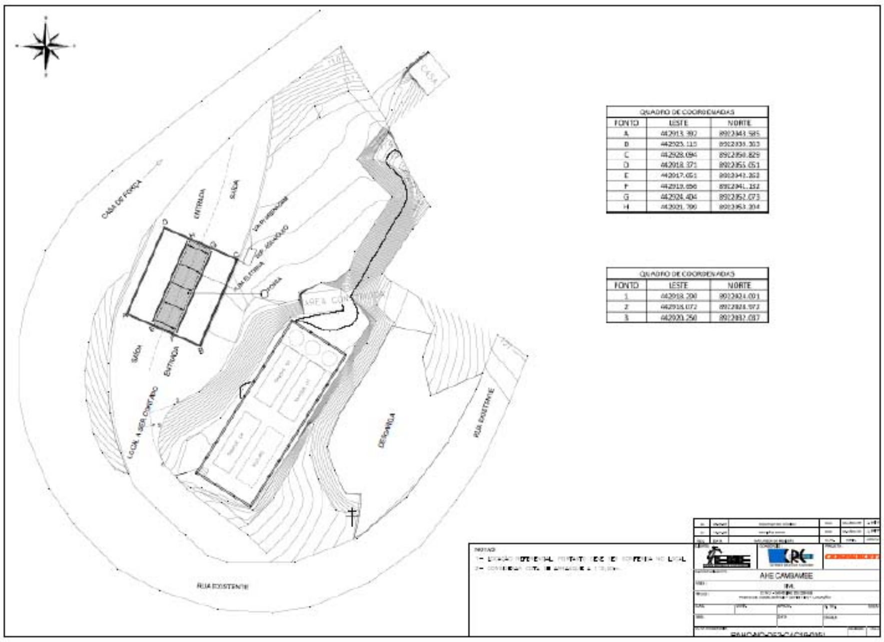


Figure 2.14: Fuel station localization and arrangement.

Legend:
QUADRO DE COORDENADAS = COORDINATE TABLE
PONTO = POINT
LESTE = EAST
OESTE = WEST
CASA DE FORÇA = POWER HOUSE
ENTRADA = ENTRANCE
SAÍDA = EXIT
LOCAL A SER CORTADO = PLACE TO BE CUT
VAI P/ DRENAGEM = TO THE DRAIN
DEP. ÁGUA/ÓLEO = WATER/OIL DEPOSIT
ALIM. ELÉTRICA = POWER SOURCE
FOSSA = WELL
DESCARGA = DISCHARGE
RUA EXISTENTE = EXISTING STREET

Figure 2.15: Localization of the capture point, ETA and Elevated Reservoir.

Legend:
RIO KWANZA = KWANZA RIVER
CENTRAL DE BRITAGEM = CRUSHING CENTRAL
CENTRAL DE CONCRETO = CONCRETE CENTRAL
RESERVATÓRIO ELEVADO = ELEVATED RESERVOIR
VILA CAMBAMBE = CAMBAMBE VILLAGE
TÚNEL CASA DE FORÇA = POWER HOUSE TUNNEL
CASA DE FORÇA = POWER HOUSE
ESCRITÓRIO CENTRAL = CENTRAL OFFICE
OFICINAS INDUSTRIAIS = INDUSTRIAL WORKSHOPS
SUBESTAÇÃO ENE = ENE SUBSTATION
DESCARGA DE FUNDO = BOTTOM DISCHARGE
ALOJAMENTOS = LODGING
TOMADA DE ÁGUA = WATER INTAKE
CAPTAÇÃO = CAPTURE
ELEV. = LEVEL
BARRAGEM = DAM
VERTEDOURO = SPILLWAY

2.6. WORKERS

The estimated number of workers and the time of permanence in the work yard is of 1,500 workers during 24 months for the dam repowering and elevation, and 1,200 workers during 44 months to work in the new central (see Table 2.10).

Table 2.10: Number of workers for the project.

Project Phase	Duration	Number of Workers
Elevation and Rehabilitation	24 months	1,500
Cambambe II Construction	48 months	1,200
Total		**2.700**

The workers will be lodged in three specific areas in the Cambambe AH, which are the old Cambambe Village and in the newly built work yard. The largest part will be composed by local workers and in some specific cases specialized foreign labor will be used. Specialized labor will be used particularly in work coordination activities and equipment erection and testing.

To avoid work accidents and increase in car traffic and fuel consumption, the largest part of the technical personnel will be transported from their lodging to work and vice-versa by an internal collective transport system following specific times.

2.7. ENVIRONMENTAL PROVISIONS

This section deals with the services to be provided and the cares to be taken by the Consortium to adjust the activities regarding the performance of the works to the environmental conservation needs, in order to cause the least possible changes in the natural means. Such provisions are in compliance with the international and the country's legislation in force and specifically with those mentioned in Chapter 3. Standards, procedures and mitigation measures for the impacts identified in this project are presented in chapters 5 and 6 of the Environmental Impact Study.

2.7.1. GUIDELINES FOR DEGRADATION CONTROL IN THE AREAS AFFECTED BY THE WORKS

The activities will be developed in an organized and simultaneous manner and are composed by preventive and corrective actions that will be programmed with the purpose of minimizing the environmental degradation processes. Such actions will include the following:

- Preventive actions that will be launched since the beginning of the works and maintained along the entire duration of the same, intended to contribute for the maintenance of an acceptable environmental quality level and to minimize further actions for the recovery of the affected areas;
- Corrective or environmental recomposition actions that will be carried out immediately after the conclusion of the services in each work front, intended to the physical biotic

recovery of the areas and the later reintegration to the local landscape, leaving them ready to be used again.

The selection of the reclaimed areas and the deposit and surplus material deposit areas, will be, at the same time, in compliance with the project requirements and the environmental conservation needs.

Therefore, based on a certain volume of material to be explored or discarded, the area to be worked will be clearly limited so the cutting and landfill works may be conveniently planned to avoid landscape deformation and draining problems in the nearby areas, silt build-up and pollution, and the execution of unnecessary deforesting.

In order to plan the cuts and the exploration of reclaimed areas, the execution of cuts in slopes and in reclaimed areas will be adjusted to the extraction of the necessary volume of material and the maintenance of the landscape appearance within the area. Therefore, the cuts will be carried out so the slope and the extension of the resulting banks will not fulfill only stability requirements.

In order to plan landfills for surplus material deposits and other deposits, the slope, the extension of the banks and the width of the berms will be defined to comply with perfect stability and support for the deposited materials.

In order to plan storage areas, the discarding of material close to the river bank will be reduced to a minimum in the region downstream from the discharge channel, to reduce the risk of the formation of barriers.

For warehouses that need to be located in the region downstream from the discharge channel, adequate protection will be provided for the banks exposed to the flow, to minimize the risk of material being dragged to the river bed, during high-water situations.

2.7.2. EROSION AND SOIL DEGRADATION CONTROL

During the entire work execution period, vehicle traffic in the several work fronts will be controlled and restricted to the people involved with the services, to avoid erosion and soil degradation. Therefore, the nearby areas will be protected against the compacting of the soil caused by the unnecessary traffic of vehicles and heavy equipment.

Both the work yard surfaces and the slopes of surplus material deposits, landfills and bank cuts will be protected by a superficial draining system. Therefore, drains, trenches, semi-circular channels, dikes and berms may be used to adequately collect and drain superficial waters of any origin, thus avoiding the evolution of erosion processes (furrows, ravines, soil collapsing and slides) and guaranteeing soil stability.

This temporary draining system will be maintained during the entire construction period, until the implementation of the definitive draining and erosion control systems.

Regarding roads and service accesses, an efficient superficial draining system will be foreseen.

2.7.3. GUIDELINES FOR THE RECOMPOSITION OF THE WORK AREAS

As the services are concluded in the several work fronts and phases, stabilization and/or recomposition interventions will be carried out in the affected areas, following the guidelines established in the monitoring plans and taking advantage of the available infrastructure (labor, equipment, tools and vehicles). The process of recomposing the work areas comprises basically the following phases:

- cleaning of work areas;
- land recomposition;
- vegetation recomposition.

2.7.3.1. CLEANING OF WORK AREAS

Before starting the recovery services in the affected areas, a thorough cleaning operation will be carried out with the remotion of all traces of the construction or exploration in such areas.

All work residues and debris will also be removed (concrete, metallic scrap, wood scrap, bags and packages, etc.), as well as the remaining parts of temporary structures and installations, surplus or useless material, etc. In such operation, all the work yard areas inside the work perimeter and, particularly, the work areas used before the contractor mobilization will be included.

2.7.3.2. LAND REPAIR

The purpose of the land repair is the final recomposition through the resizing of the cut banks and landfills and the rearrangement of the draining lines, always seeking to adapt the land appearance in the affected areas to the surrounding landscape.

2.7.3.3. VEGETATION RECOMPOSITION

The revegetation of the recomposed land and of the areas affected by the works will have the following basic targets: soil protection against the development of erosive processes, the establishment of a new biotic balance and landscape recomposition.

2.7.4. SURFACE DRAINING CONTROL

The Consortium will protect the material storage areas and prevent the increase in turbidity with the building of dikes and the implementation of a canal or pipeline (provisory draining) up to a sedimentation basin. Therefore, it will be possible to divert the superficial draining waters originated from reclaimed areas, surplus material deposits and other places where land leveling services are in progress, up to the sedimentation basins.

Regarding the crossing of streams or the direct transposition of machines and construction equipment, the silt build-up and turbidity increase problems will be avoided in the same way.

2.7.5. MANAGEMENT OF INDUSTRIAL OILY EFFLUENTS

In the areas where oil and grease are handled and machines and vehicles are washed, industrial water collection systems will be built, and will be composed by canals and/or pipelines and water/oil separation tanks, of the same type previously mentioned. The tank will be sized to keep a low draining velocity, thus allowing the formation of an oil film in the surface. The collected oil can be reused and the treated water originated from industrial effluents will be reused to spray the internal roads.

The waters originated from the processing of landfill materials and the washing of aggregates, due to the large quantity of solids in suspension, cannot be directly launched to the river, but must be collected with the help of canals or pipelines sized for a minimum velocity of 0.8 m/s and forwarded to the sedimentation basin, which is sized for a minimum retention time of four (4) hours.

Then, the decanted inert material will be discarded on the landfill and the treated waters may be reused for several purposes, as for example the washing of concrete mixers.

2.7.6. MANAGEMENT OF DOMESTIC EFFLUENTS

The served waters and the sewage generated in the campings and lodgings will be adequately treated according to the enterprise owner best practices and the World Health Organization (OMS) recommendations. Detailed information about the domestic effluent treatment processes can be found in the previous item.

The effluent treatment system includes the treatment of two types of effluents, which are the effluents of sanitary origin and the effluents of industrial origin.

Regarding the sanitary effluents, the main production sources with potential to pollute hydrologic resources are offices, lodgings, kitchens and canteens. Measures were implemented to control such effluents, seeking to minimize these impacts by means of sewage treatment using the septic tank system followed by anaerobic filter and final disposal.

The sanitary effluent treatment system is composed by three septic tanks (two septic tanks in the lodging area and one septic tank to meet the office demands). The septic tank set with anaerobic filter conceived for the offices has a treatment capacity of 20,000 l/day, in the lodgings the septic tank set will have a treatment capacity of 40,000 l/day, and the set formed by septic one tank with anaerobic filter will have capacity for 75,000 l/day. The sewage will undergo a chlorination process after passing through the filters. New septic tank sets with anaerobic filters will be later installed to meet the demand increase of a new lodging area. Such treatment capacity expansion will reach around 130,000 to 150,000 l/day. After the treatment, the effluent will be disposed on a natural discharge canal upstream of the dam, with the care of being launched at a safe distance from the ETA water capture point.

Regarding the industrial effluents originated from oil and grease handling areas and the washing of machines, equipment and vehicles, water/oil separation tanks were installed. After the separation, the oil is poured and stored in appropriate containers until the definition of the adequate final environmental destination.

The oil-free water can be launched into the river, provided it meets the recommended quality standards. The monitoring consisting of physical-chemical analysis will be periodically conducted.

As waters originated from landfill material processing and from the washing of aggregates (concrete mixers), due to the large quantity of solids in suspension, are collected and forwarded to the sedimentation basin. The decanted solids, which shall be free of oil, grease, solvents or other elements that can classify them as hazardous, can be disposed in surplus material deposits.

The clarified water resulting from the decanting treatment will be reused to spray the internal roads and stabilize the dust. Should there be water cooling equipment the water must be cooled before being sent to the equalization basin, so it will suit the appropriate standards.

Samples of residual waters will be periodically collected in the primary reception sources and in the reception body, in previously established points and will be later sent to the laboratory for physical-chemical analysis, to allow the monitoring of the implemented treatment systems.

2.7.7. ATMOSPHERIC POLLUTION CONTROL

Among the activities developed for the implementation of the works, some may generate atmospheric pollution, mainly due to the emission of dust originated from the movement of vehicles and machinery, excavation, handling of surplus material, crushing and other constructions, as well as the emission of gases originated from the operation of machines and equipment.

Therefore, some measures that will be implemented following pollution control guidelines are described below:

- Enclosure of activities and transport equipment and systems;
- Particulate material capturing systems as cyclones, cloth filters, washers, etc;
- Material humidifying when undergoing processes and/or storage, by spraying and tank-trucks;
- Paving and spraying on internal traffic paths;
- Periodic equipment maintenance;
- Storage of dusty raw-material in places protected from the action of the wind, such as bays, silos, etc;
- Planting of a vegetation curtain around the dust generation areas.

2.7.8 CONTROL AND MANAGEMENT OF SOLID RESIDUES

The industrial and domestic garbage will undergo a selective collection and the recyclable material will be sent for recycling.

Presently, the solid residues are deposited in the deposit sector used by ENE. The hospital residues will be sent to an incineration chamber to be provided. A residue management strategy will be prepared and will include the following guidelines:

- **Normal Residues (domestic organic):** These residues are deposited in the deposit sector used by ENE. This residue sector will be adapted and transformed into a controlled landfill that will provide better reception and storage for normal residues. Normal residues include paper, plastic and waste from the canteen.

- **Hazardous Residues:** Will be disposed on a temporary storage to wait for their final disposal. The storage area fulfills the necessary requirements for the storage of hazardous residues.

- **Vegetation Residues:** With the purpose of reducing the quantity of vegetation residues, the waste wood and the remaining vegetation residues are being donated to the population, who will use this material to produce charcoal.

- **Metal Residues (Scrap):** The Metal Scrap residues are packed and stored in an appropriate place until their final destination is identified.

Regarding the residues originated from the construction activities, the Consortium decided that it will collect it periodically and will transport and deposit it in an area already used by ENE.

Garbage containers with a clear indication of their purpose must be distributed in convenient places, where they will be periodically emptied. When installed in open air, they will have holes in the bottom and be provided with lids, to avoid rainwater build-up.

The residues will be collected and disposed daily, including the necessary handling under the orientation of the environmental protection agencies and in compliance with the occupational health and worker safety legislation.

2.8. DAM DEACTIVATION PHASE

The best alternative for the deactivation of a dam is the integration of the lake and the associated structures to the local occupation. There are plenty of possible alternatives that can be implemented with the objective of providing quality of life improvement in the region or even investing in solutions that provide entertainment, for example.

Considering the Central 1 rehabilitation works, the construction of Central 2 and the dam elevation/rehabilitation, the life expectation for the Cambambe operation is of another 50 years, since the times normally estimated for hydroelectric power plants service life varies between 30 and 50 years. However, there are many examples in which duly maintained power plants submitted to adjustments during their service life have much exceeded this expectation.

Therefore, the future deactivation of Cambambe, which is technically called “decommissioning”, is not foreseen to be a problem or a challenge to be faced, but as opposed to this, it will turn out a project for the integration of the dam and lake to the local landscape, in order to improve the living conditions of the population that surrounds it. At that time, dam decommissioning plans or other solutions deemed adequate will be prepared.

CHAPTER 3

INSTITUTIONAL AND LEGAL STATUS

3. INSTITUTIONAL AND LEGAL STATUS

In this chapter, the authority of several State offices that are relevant in matters related to the project's environmental and social impacts will be described, as well as the national legislation provisions and the international instruments that are relevant to the environmental impact study regarding the Cambambe Power Plant rehabilitation and expansion process.

This chapter describes the environmental and social standards that must be implemented for environmental protection and conservation purposes and to improve the quality of life of the people that might be affected and with which the project must comply. This chapter includes the following aspects:

- Institutional situation, including the administrative organizations having responsibility in the management of the environment and of aspects directly related to the project scope, which are the sectors of energy, water, agriculture and rural development;
- Legislation of environmental and social nature applicable to the Cambambe Power Plant project and its recommendations for the several actions within the project;
- Description of the multilateral environmental agreements to which Angola is party and whose guidelines and recommendations are related to the project scope; and
- Description and analysis of the performance standards required by the World Bank's and by the International Finance Corporation's (CFI) guidelines that must be considered in this project.

The reference to the standards applicable to the project was based on the report of the World Commission on Dams that considers the main environmental and social impacts of electric power producing dams (Boxes 3.1 and 3.2).

Box 3.1: Potential environmental impacts identified in the World Commission on Dams' report.

The construction of dams involves a set of significant environmental impacts, of which we point out:

- The destruction of the submerged ecosystems;
- The significant changes in the river flow and in the respective hydrologic system;
- Impacts on the river ecology, both upstream and downstream;
- Significant changes in soils, hydrologic resources and the flora, which are ecologically interconnected and have their relationship changed by flow changes in the river where the dam is located;
- The loss of fertile soils;
- Soil erosion close to the river banks, particularly downstream in rivers where the dams are built;
- The eventual loss of vegetation, negative with effects on the hydrologic resources and the climate;
- The extinction of species or the significant reduction of their population, whether due to submersion or to changes in the respective ecosystems, and also of river estuary species due to the loss of the sediments that feed the species in these ecosystems;

- The creation of disease focuses, as in the case of paludism, by the concentration of mosquitoes and flies close to the dam waters, due to the lower water speed;
- Landscape problems.

Box 3.2: Potential social impacts identified in the World Commission on Dams' Report.

The building of dams brings a set of significant social impacts, of which we can point out:

- The moving of people upstream;
- The loss of nutrition means and of goods in the affected communities;
- Disturbances in the economy and ecology of the downstream population;
- Unfair distribution of the dam benefits, for example in terms of irrigation.

The environmental and social sustainability performance standards of the International Finance Corporation were also considered (Box 3.3).

Box 3.3: CFI's Performance Standards.

Performance Standards	**Objectives**
Performance Standard 1 emphasizes the importance of social and environmental management performance along a project (any business activity that is subject to assessment and management)	1. *Impact Identification and Study.* To identify and assess the social and environmental impacts, both negative and benefic in the Project Influence Area. 2. *Mitigation.* To avoid, or when it is not possible to avoid, minimize, mitigate, or compensate the negative impacts on workers, affected communities and the environment. 3. *Stakeholder Participation.* To ensure that the affected communities are exposed in an appropriate way to the problems that has the potential to affect their lives. 4. *Efficient Management.* To promote improved social and environmental performance within the companies through the efficient use of management systems.
Performance Standard 2 acknowledges that the achievement of economic growth through the increase in employment and income generation must be balanced by the basic worker's rights.	5. To establish, maintain and improve the worker's administrative relationship. 6. To promote fair treatment and non-discriminatory and equalitarian opportunities for workers, and compliance with the national labor and contracting laws. 7. Protect the work force by denouncing infantile work and forced work.

Performance Standards	Objectives
	8. To promote safe and healthy work conditions and protect and promote worker's health.
Performance Standard 3 acknowledges that high levels of industrial activity and urbanization frequently generate high water and land pollution levels that can harm the community and the environment at local, regional and global levels.	9. To avoid or minimize negative impacts on human health and the environment by avoiding or minimizing the pollution caused by the Project activities. 10. To promote the reduction of emissions that contributes to climate changes.
Performance Standard 4 acknowledges that the activities, equipment and infrastructure of a project frequently bring benefits to the communities, including employment, services and economic development opportunities.	11. To avoid or minimize risks and impacts to the local communities' health and safety during the Project life cycle, both under ordinary and extraordinary circumstances. 12. Ensure the safety of employees and property in a fair manner that avoids or minimizes risks to the community's safety.
Performance Standard 5 defines the involuntary relocation with respect to both, transfer (relocation or loss of the house) and economic relocation (loss of goods or of the access to goods, which leads to the loss of income sources or living means) as a result of the acquisition of land for the Project.	13. To avoid or minimize negative impacts on human health and the environment by avoiding or minimizing the pollution caused by the Project activities. 14. To promote the reduction of emissions that contributes to climate changes.
Performance Standard 6 acknowledges that protecting and conserving biodiversity - the variety of life in all its forms, including genetic diversity and the diversity of species and ecosystems, including their ability to move and develop - is fundamental for sustainable development.	15. To protect and conserve biodiversity. 16. To promote sustainable management and the use of human resources with the adoption of practices that combine conservation needs and development priorities.

Performance Standards	Objectives
Performance Standard 7 acknowledges that the Indigenous People, as well as the social groups that have identities that are different from the dominant groups in the national societies, are usually among the most unassisted and vulnerable segments of the population.	17. To ensure that the development process encourages respect for dignity, human rights, aspirations, cultures and living means based on the natural resources of the Indigenous People. 18. To avoid the negative Project impacts on the Indigenous People communities, or, when it is not possible to avoid, minimize, mitigate or compensate for such impacts, and provide opportunities for obtaining the development benefits, in a culturally adequate manner. 19. To establish and maintain an ongoing relationship with the Indigenous People

	affected by the Project along the Project's life cycle. 20. Encourage good faith negotiations and the well informed participation of the Indigenous People when the projects are located in traditional or common land in use by the Indigenous People. 21. Respect and preserve the Indigenous People's culture, knowledge and practices.

3.1. INSTITUTIONAL STATUS

The characteristics of the natural resources, including the hydrologic resources, within the present context of the social, economic and energetic development of Angola, recommend the adoption of environmental protection measures that promote the implementation of sustainable development. Equally, the implementation of projects that include activities that might have a negative contribution to the environment quality and the natural resources sustainability must be regulated by the State, by means of several governmental institutions belonging to its organic structure.

Therefore, and in compliance with the legislation in force, the Government approves the awarding of concessions for the private use of hydrologic resources in the generation of hydroelectric power and the awarding of concession for the performance of hydroelectric generation activities. For the present project, the institutions responsible for environmental issues include the ministries of Environment, Energy and Waters, Agriculture, Rural Development and Fishery, and Urbanism and Construction.

3.1.1. MINISTRY OF THE ENVIRONMENT

The Ministry of the Environment (MINAMB) was created as a result of the Government's organic evolution and also as an acknowledgement of the importance of environmental preservation for the improvement of the population's quality of life. It has the purpose of encouraging sustainable development and facing the 21st century environmental challenges.

The responsibility for the coordination, execution and monitoring of the Republic of Angola's environmental policy falls on the Ministry of the Environment, which was recently endowed with a new organic structure by Decree-Law no. 4/09, of May 18. The present MINAMB attributions include the guarantee of the implementation of environmental preservation and management strategies and policies and the execution of environmental impact assessments regarding plans, projects and enterprises created by public and private entities.

In addition to its role in environmental policy matters, the Ministry of the Environment, *inter alia*, controls all actions that carry a pollution potential, «coordinates recovery actions carried out in areas considered critical», «ensures the management of the ecosystems associated to continental or fluvial waters in an integrated and sustainable manner» and promotes «nature conservation and landscape protection actions» (Dec.Law no. 4/09; art. 2nd).

The Ministry of the Environment is also responsible for conducting Environmental Impact Study (EIA) assessments for projects susceptible of potential negative impacts of environmental and social nature. Such assessments include carrying out one or more public consultations in places to be defined, close to the project's intervention area, for the submittal of the Environmental Impact Study report and of the respective non-technical summary, as well as the collection of the stakeholder's and affected party's comments and contributions.

Should the EIA be approved, the **Ministry of the Environment, through a specific request, will issue the respective Environmental Licenses** in behalf of the enterprise proponent, stating in them the mitigation measures that must be implemented.

The issuing of an Environmental License is mandatory, and includes an **installation environmental license** that has the purpose of approving, among others, the land preparation process, the hydroelectric power plant construction, the installation of equipment and the construction of the infrastructure necessary to support the dam. The **operation environmental license** approves the entering in operation of the hydroelectric power plant, after checking the accomplishment of the mitigation measures foreseen in the construction phase.

The actions described above regarding the AIA procedure, are conducted by the National Board for Prevention and Assessment of Environmental Impacts, which carries out the impact assessments, the licensing and the environmental audits as well (mentioned Dec. Law, art. 18/1). Figure 3.1 shows a flowchart representation of the Environmental Impact Assessment process (according to the environmental legislation in force in Angola).

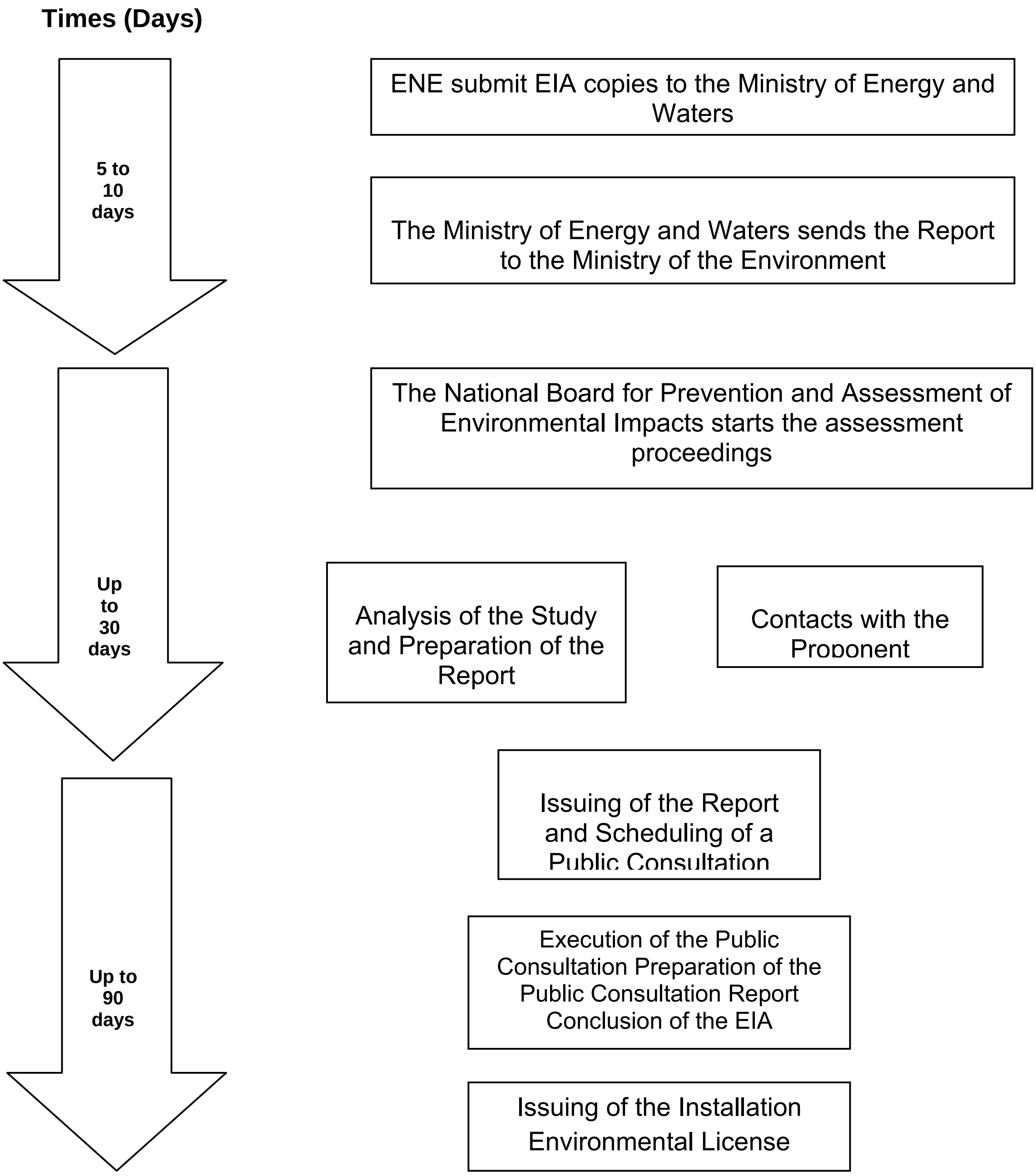


Figure 3.1: Representation of the environmental impact assessment process.

3.1.2. MINISTRY OF ENERGY AND WATERS

In addition to its role in energy and planning policy matters, the Ministry of Energy and Waters proposes the Project approval to the Government and, *inter alia*, monitors the execution of the energy generation activities and the use of the hydrologic resources (Presidential Decree no. 77/10 May 24, art. 2nd).

The National Electric Power Board «participates in the organization of the concession awarding process», prepares the «appropriate standards, regulations and technical specifications for the power generation installations», issues «quality certificates for the material to be used in the installations and conducts technical audits on the «industrial electric installations» (mentioned presidential decr., art. 15/2/f, 15/2/i, 15/2/k and 16/2/n). The National Electrification Board technically supports the power generation and distribution plants (mentioned presidential decr., art. 16/2/g).

In addition to its role regarding the policy for the use and planning of hydrologic resources, this State Secretariat proposes to the Government the approval of the concession for the private use of hydrologic resources and, *inter alia*, controls the activities related to the use of hydrologic resources and water quality (Presidential Decr. No. 77/10, art. 2nd).

The National Hydrologic Resources Board coordinates the «preparation of general proceedings for the use of hydrologic resources based on the hydrographic basin» and establishes guidelines for the preparation of plans for the integrated use of the hydrologic resources and of the hydrographic basins» (mentioned presidential decr., art. 19/2/e and 19/2/g).

3.1.3. MINISTRY OF AGRICULTURE, RURAL DEVELOPMENT AND FISHING

The Ministry of Agriculture, Rural Development and Fishing (MINADERP) is the ministerial department that has the mission of proposing the formulation, conduction, execution and control of the Government's policy for the sectors of agriculture and agro-nutritional safety, rural development, well being of the rural communities, fishing, aquatic biologic resources and forestry resources, within the sustained development perspective. This Ministry was created through the Presidential Decree no. 92/10 of June 4 and, in order to accomplish the proposed targets, in holds among others, the following attributions:

- Definition of strategies and proposing of national development programs for the sectors of agriculture, cattle raising, fishing, aquiculture, forests, nutritional safety, rural development, poverty fighting and the development of rural communities, always promoting and coordinating the necessary actions for their execution;
- Assurance of land management for agricultural, cattle-raising and forestry purposes;
- Assurance of the accomplishment of the planned policies and strategies for the sustainable management of forestry, animal and aquatic-biologic resources and those in the aquatic environment as well;
- Promotion and accomplishment of policies and strategies prepared for the constitution and management of nutritional reserves.

In order to implement such activities, this Ministry counts with a series of structures at central and provincial level, of which the following are relevant for this project: the National Fishing and Aquiculture Board, an entity that prepares the policies and strategies and promotes actions in the sectors of control and execution of the fishing and aquiculture policy in terms of fishing resources protection and development, and the Provincial Board for Agriculture, Rural Development and Fishing.

In addition to its role regarding the policy and planning for biologic-aquatic resources, the Ministry of Agriculture, Rural Development and Fishing promotes «the implementation of preservation and sustainable management measures for the biologic-aquatic resources and for the aquatic environment » (Presidential Decr. no. 92/10, art. 2/b).

The National Fishing and Aquiculture Board, particularly through the Department of Resources and Ecosystem Protection, «ensures the sustainable management, conservation and protection of the biologic-aquatic resources». The control of the handcraft fishing activities is done by the Institute for the Development of Handcraft Fishing and Aquiculture (IDPAA).

On the other side, the Cabinet for Agricultural Land Management deals with the management of adequate land for agriculture, cattle-raising and forests, and participates specifically in the «issuing of land concession titles for agricultural-forestry-cattle-raising purposes», issues «reports about agricultural, commercial and industrial enterprises susceptible of affecting the national development» and conducts a set of actions related to the land distribution structuring (mentioned presidential decr., art. 22/1-2). The Institute of Forestry Development (IDF) has the purpose of ensuring the promotion, coordination and accomplishment of the policies defined for the forestry, animal, rural and technology transfer development sectors (mentioned presidential decr., art. 28º).

3.1.4. MINISTRY OF URBANISM AND CONSTRUCTION

The Ministry of Urbanism and Construction is the entity responsible for the preparation, coordination, accomplishment and monitoring of policies regarding land use, urbanism, housing and construction (Presidential Decr. no. 74/10 of May 20, art. 1º). This institution is equally responsible for the concession of land use rights in areas larger than 1,000 hectares and smaller than 10,000 hectares (Land Act, art. 66/3).

This Ministry provides the execution of many core services, of which it is worth pointing out the National Territory Use Boards, which are responsible for implementing the territory use policy (Article 19^{th}) and the Public Infrastructures, responsible for the coordination and technical control of construction of infrastructure public, including communication channels, basic infrastructure and hydraulic works (Article 22º).

3.1.5. LOCAL STATE ENTITIES

The provincial governments follow-up the execution of public investment programs and economic intervention projects in the respective province, prepare the provincial territorial plans, prepare and approve urbanism projects, manage «the State's public and private land use sector», promote «protection measures for hydrologic and soil and water resources conservation» and for the cultural assets valorization (Dec.Law no. 2/07, art. 11/1/c, 11/2/a-b, 11/2/i, 11/6/c and 11/4/d).

The municipal administrations prepare the municipal territory use plans and the municipal development plans, ensure the preservation of sites classified as cultural asset and ensure «water maintenance, distribution and management» within the municipality (mentioned.dec.law, art. 44/2/a, 44/1/a-b, 44/3/f, 44/3/h). For this project, all municipal and communal administrations affected by the project's rehabilitation and expansion process, were informed about the project, and their opinions and comments are reflected if the environmental impact study report.

3.1.6. TRADITIONAL AUTHORITIES

The traditional authorities participate in municipal and community councils dedicated to hearing and social arrangement (mentioned.dec.law, arts 54/3/d and 76/3/c). They also hold mandatory consultation rights in the case of boundary setting and relocation of community lands (Land Act, arts. 37/4 and 51/2). For the present project, traditional and communitarian authorities were heard and interviewed about aspects related to the project, with emphasis to those communities that will be directly affected by the project.

3.1.7. ENVIRONMENT PROTECTION ASSOCIATIONS

The environment protection associations hold consultation and information rights, *inter alia* in the matter of environmental impact studies and in plans for the use of forestry and animal resources, in the participation in administrative procedures that involve environmental matters and in starting legal proceedings in court against actions that harm the environment (Act no. 3/06, arts 6º-8º).

3.2. LEGAL STATUS

This section deals with the legal provisions in force in Angola, which must be taken in consideration in the assessment of environmental impacts and, as a result, must be part of the environmental impact study (EIA). The relevant international instruments that bear some influence on the form and methodology used in the preparation of the present EIA are also mentioned. The need for environmental protection and the requirements for the achievement of sustainable development are all based on the right that all citizens have to live in a healthy and pollution-free environment, such as provided.

According to article 13th of the New Angola Constitution of February 3, 2010, the international treaties and agreements duly approved or ratified enter in force in the Angolan legal system after their official publication and validity status in the international legal system and while they bind the State internationally. The same Law supports the Environment Rights, stating that everybody has the right to live in a healthy and pollution-free environment, as well as the duty to protect and preserve it. Therefore, the State adopts the necessary measures for the protection of the environment and of the flora and fauna species nationwide, for the maintenance of the ecologic balance, for the correct localization of business activities and for the rational exploration and utilization of all natural resources, within the frame of sustainable development, respect for the rights of future generations and the preservation of the different species.

3.2.1. THE RIGHT TO LIVE IN A HEALTHY AND POLLUTION-FREE ENVIRONMENT AND TO THE BENEFITS OF THE RATIONAL USE OF NATURAL RESOURCES

As mentioned above, Angolan citizens have the right to live in a healthy and pollution-free environment (Constitutional Law, art. 24/1) and the right to the benefits of the rational use of natural resources (Act no. 5/98, the Environment Bases Act, art. 3/1).

The State must adopt the necessary measures that the citizens require to effectively exercise their rights (Constitutional Law, art. 50º), and they have the right to appeal to the courts in case their constitutional rights or rights foreseen in other laws are violated (Constitutional Law, art. 43rd).

The Environment Bases Act (LBA) establishes the generic environment protection obligations and the sustainable use of natural resources, as well as the obligation to contribute for the quality of life (arts 3/1 and 25th, where the later expressly refers to citizens and companies of the public and private sectors). Such provisions lead to several legal consequences, particularly the following:

a) Individuals or corporations must, in their activities, avoid the practice of actions that may degrade the environment or in any way impair the exercise of the fundamental right of living in a healthy and pollution-free environment, foreseen in art. 24/1 of the Constitutional Law and guaranteed in art. 43º of the same Law;

b) Considering that these are generic obligations, the persons are free to choose the adequate means for compliance with the contents of such obligations, provided there is no applicable specific legislation, even if partial.

Anyone that causes damages to the environment, is subject to the obligation of indemnify the State, according to the objective responsibility terms (LBA, art. 28º), and the individuals that had their rights of living in a healthy and pollution-free environment and the right to the benefits of the rational use of natural resources violated, pursuant the terms of the general civil liability regime foreseen in art. 483º and following, of the Civil Code (LBA, art. 23º).

For this Project, there is some legislation regulating the activities belonging to the scope of the abovementioned duties. In the cases where such legislation is absent or omissive, particularly in regard to technical specifications, the Project sponsors must appeal to international instruments about good practices in the relevant sectors, or to adequate standards in force in other countries, therefore, choosing the means to comply with some versions of the generic environmental protection and quality of life duties.

3.2.2. IMPACT ASSESSMENT AND ENVIRONMENTAL LICENSES

The Environment Bases Act establishes the obligation to carry out environmental impact assessment procedures in the case of «actions that have implications with the environmental and social balance and harmony» (art. 16/1), including those that «affect the interests of the communities» (art. 10º). Art. 4/1 of Dec. no. 51/04, about the AIA, foresees the conduction of AIAs in the case of «infrastructure» projects that «due to their nature, size or localization, have implications with the environmental balance and harmony».

In the Attachment to Dec. no. 51/04, it is expressly required, as mentioned in art. 4/2, the execution of the environmental impact assessment (AIA), in the case of projects involving «dams for hydroelectric purposes» (no. 3/k), «industrial installations destined to (…) electric power transmission by aerial cables» (no. 3/a) and «electric power transmission lines above of 230 KV» (no. 3/i).

Dec. no. 51/04 (about AIA), establishes in art. 6th, which part of the environmental impact study (EIA) must be submitted by the construction owner (art. 5th). Art. 7th of the mentioned decree imposes, within the scope of the study preparation, the execution of a series of «technical activities». Therefore, this study must observe these requirements.

The Environment Minister decision about the project («decision») is preceded by a public consultation (LBA, art. 10th and Dec. no. 51/04, art. 10th). The decision must be mandatorily complied with by the construction owner (Dec. no. 51/04, arts 13/1 and 16/c).

The Environment Bases Act also foresees in art. 17th that the projects that «due to their nature, localization or size are susceptible of producing significant environmental and social impact» are subject to licensing, being the environmental license concession based on the AIA (art. 17/2). The license is mandatory in the case of projects that, by law, are subject to the AIA. Therefore, in the case of dams, both the installation and the operation environmental licenses are required (Dec. no. 59/07, about environmental licenses, arts 3º and 4/2).

The installation environmental license refers to the «construction implementation and alteration according to the specifications that govern the execution project» (Dec. no. 59/07, art. 1/c). The operation environmental license refers to the beginning of the installation activities «after checking the compliance with all the requirements contained in the environmental impact study (mentioned dec., art. 1/d). The elements foreseen in art. 14th of the mentioned decree must be included, particularly:

a) «reference documents about the best methods and techniques applicable to the performance of the licensed activity» (art. 14/a);

b) «the limit values for the emission of pollutants» (art. 14/b);

c) «indications of measures that ensure adequate protection for the soil and underground waters» (art. 14/c).

The license is valid for a period not lower than three years and not higher than eight years, renewable after the environmental audit (Dec. no. 59/07, arts 14/g and 16th).

3.2.3. TERRITORY USE SYSTEM

In general terms, according to Act no. 3/04, the Territory and Urbanism System Act (LOTU), the use of the land must comply with municipal or special territorial plans that have, for individuals, the same kind of binding as a regulation (LOTU, art. 52/2). Individuals are granted rights of access to the information contained in these plans (art. 53/1), which matter is governed by art. 11th of Dec. no. 2/06 (General Territory, Urbanism and Rural Plan Regulation).

Art. 6/f of Dec. no. 51/04 provides that the environmental impact study must consider the contents of the governmental plans and programs, which must include the several territorial plans.

3.2.4. CULTURAL ASSETS

As a consequence of dam constructions, where large areas are submerged and also many excavations are carried out, it is necessary to check whether assets included in the Angola cultural assets will be affected.

Act no. 14/05 (Cultural Assets Act) defines cultural assets as «all material and immaterial goods that, due to their acknowledged value, must be subject to legal guardianship» (art. 2/1). These include «paleontological, archeological and architectural evidence» bearing the values of «memory, antiquity, authenticity, originality, rarity, exemplarity and singularity» and others (art. 3/1). The real estate cultural goods are composed by, *inter alia*, sites, spaces of «historic, archeological, artistic, scientific or social interest» (art. 6/1/c). The real estate cultural goods can be classified as of local, regional, national or international interest (art. 7/3).

Movable cultural property includes, among others, those that represent «the evolution of nature or of the technique», including those that are «buried or submerged or are found in places of archeological, historic and ethnologic interest and in other places» (Act no. 14/05, art. 6/2/a).

The Law establishes the duty of every citizen to «preserve, defend and value the cultural assets» and of the «public and private entities » to «promote the safekeeping and valorization» of such assets (art. 14/1-2). Anyone that, whether in public or private land, or in submerged means, «has found or finds (...) any archeological evidence», must notify this fact to the local authorities (art. 35/1). Infractions against the cultural assets are subject to the sanctions foreseen in art. 56th of Act no. 14/05.

In areas affected by dams, particularly in lakes, there may be cultural assets on the surface that get submerged and, for this reason, it is necessary to identify them and take the necessary measures for their preservation. Considering that the construction of dams also require excavations, it is convenient to bring to the builder's and his worker's attention the duty to notify the provincial cultural board or the cultural assets institute about any vestiges of paleontological or archeological nature (artifacts or others) that might bear a cultural value.

It is also necessary to check the presence in the area of any good classified as cultural or natural assets pursuant the terms of arts 6th to 23rd of Act no. 14/05. Hence, if such good is actually so classified, its demolition or destruction can only take place after a Ministry of Culture decision (mentioned act, art. 13/1).

Additionally, given the cultural rights of the affected communities (African Charter on Human and Peoples' Rights, art. 17/3, Pact on Economic, Social and Cultural Rights, art. 15/1/a) and because there is a lake with a large surface, it will be convenient to consult these communities about the existence of eventual goods, either built or natural, which hold a cultural value for these communities.

3.2.5. LEGISLATION APPLICABLE TO THIS PROJECT

3.2.5.1. WATER USAGE

The use of the Kwanza river water for dam construction raises questions from the point of view of the affected rights and the environment. The use of water is governed by Act no. 6/2 (Law of Waters) that expressly foresees the use of water for power generation purposes (art. 25/1).

The General Electricity Law establishes that the performance of power generation, transmission and distribution activities is associated to «the conception and implementation of projects, as well as the use of equipment and methods in accordance to standards for the safety of people and goods and with respect for property rights» (art. 3/1/d).

This Law includes a provision that foresees that «local communities located in areas where projects for electric power generation, transmission and distribution are implemented, have the right to compensation for eventual damages, as well as to obtain benefits for the region, according to terms to be agreed upon or in the terms of concessions or licenses awarded for such purpose» (art. 16/3). This indemnification must reflect the need to share the dam construction benefits.

The General Electricity Law also foresees the holding of public consultations in the case of concessions regarding the rights to perform power generation, transmission and distribution activities (art. 5º).

3.2.5.1.1. WATER USE RIGHTS AFFECTED BY DAM CONSTRUCTIONS

The water use rights affected by dam constructions are:

a) The rights of local communities and families that use the river water pursuant the common use regime (free and gratuitous access for subsistence purposes) foreseen in arts 21st through 23rd of the Law of Waters;

b) The rights of farmers that hold property rights and use the Kwanza's hydrographic basin waters pursuant the regime foreseen in art. 26th of the Law of Waters (free and gratuitous access to certain water bodies for farming, cattle-raising and forest plantation);

c) The private use rights of individuals that use the water for the purposes foreseen in arts 24th and 25th of the Law of Waters (access for commercial purposes not included in art. 26th).

Common use prevails over private use and concessions cannot, in principle, be awarded at the expense of common uses (Law of Waters, arts 22/2 and 33/1). Therefore, it is necessary to identify the water use rights holders, either private or common, whose right to the water will be expropriated for public utility. A fair indemnification should be negotiated within the general right terms and taking in consideration arts 6/1/c, 10th and 20/4 of LOTU, and the previously mentioned provisions of the General Electricity Law.

The Law of Waters requires the conduction of public consultations before the concession of private water use rights, *inter alia* for dam construction (art. 36th). Particularly, «user associations, local authorities, social organizations and other entities directly interested in the use of the hydrologic resources in the geographic area where the activity will be developed» (art. 36/1).

3.2.5.1.2. FISHING RIGHTS AFFECTED BY DAM CONSTRUCTIONS

People that carry out subsistence and commercial fishing in the terms of arts 42nd and 35th of Act no. 6-A/04 (Law of the Biologic-Aquatic Resources, LRBA) are one of the social groups affected by the river changes caused by the Project.

The sustainable development principles, the «protection of the fishing communities interests» and the «participation of all stakeholders in the resource management» are the general principles that govern the use and management of biologic-aquatic resources (LRBA, art. 6/3/a, 6/3/j and 6/3/h).

As a result, the Environmental Impact Study must identify the people that will have their fishing rights affected by the river changes and define the compensation measures for these people, including fishing access to the lakes. This information is available in the chapter of the environmental and social characterization of the area.

3.2.5.1.3. RIGHTS ON THE LAND SUBMERGED BY THE LAKES

The land that will be submerged can be in the possession of rural communities, which are owners of the land rights awarded by the State and owners private property rights.

In the cases of land under concession, the expropriation and the payment of a fair indemnification in the terms of art. 12nd of Act no. 9/04 (Law of Lands) and of arts 21st and 132nd of the General Land Concession Regulation, will be mandatory. The same will happen if the land is of private property.

In the case of communitarian land, the cancelling of the public utility nature will take place, which require that the traditional authorities are consulted, the land be unoccupied according to the usual land usage regime and a compensation, as foreseen in art. 37th of the Law of Lands be paid. Should the cancelling of the public utility nature not be possible, the land in question could be expropriated for public utility purposes by means of the payment of a fair indemnification (Law of Lands, art. 9/2).

3.2.5.2. ENVIRONMENTAL IMPACTS DUE TO WATER USAGE IN DAMS

3.2.5.2.1. WATER POLLUTION

The pollution of waters by any means, including the discharge of any kind of effluent, is forbidden, and must be authorized by the entity managing the basin (Law of Waters, art. 68th).

Art. 71st of the Law of Waters foresees the establishment of a protection area adjacent to the areas where water capturing takes place, where the execution of activities that lead to water quality degradation is forbidden.

The EIA must, therefore, point out the potential water pollution sources. The environmental license will indicate the limit values for the emissions of polluting substances (Dec. n.º 59/07, art. 14/b).

The EIA must also identify the new zones where water can be captured, not only to supply the dam workers but also for the new common use points for the displaced communities.

3.2.5.2.2. AQUATIC CONSERVATION AREAS AND AQUATIC ECOSYSTEM PROTECTION

There is no notice about the creation of the aquatic conservation areas foreseen in arts 78th and following of the LRBA, and therefore, no questions will be raised regarding this subject. However, the LRBA requires that the «humid zones and swamps» and the «biologic resources' spawning zones» are established as conservation areas (art. 86/a and 86/d).

As it is foreseen that ecosystems and aquatic biologic resources will presumably be affected, it may eventually be necessary, depending on the AIA, to create natural aquatic reserves, either total or partial, for the «sustainable regeneration and renovation» of the species, particularly those protected, which will be affected by the Project (LRBA, art. 82º).

3.2.5.2.3. BIOLOGIC RESOURCES AND AQUATIC ECOSYSTEMS

There is no notice that any sweet water aquatic species is listed as protected, in the terms of the LRBA (arts 69th – 71st). However, the EIA must identify the aquatic fauna and flora species that will be affected by changes in the river, particularly rare species and those under extinction, threatened with extinction or that will have its number reduced as a result of the Project implementation. Such description is made in chapter concerning the area's biodiversity characterization.

It must also foresee the adequate measures for its conservation, considering not only the AIA legislation but also the principle «of conservation and optimum utilization of biologic aquatic resources», defined in art. 6/3/c of the LRBA, which includes the National Strategy and Action Plan for Biodiversity (NBSAP). Such measures are described in the management plans.

3.2.5.2.4. LAND BIOLOGIC RESOURCES

Regarding the wild land fauna subject, the Joint Exec. Decree no. 37/99 (Finance and the Ministry of Agriculture and Rural Development) has updated provisions of the Hunting Regulation (Leg. Dip. No. 2.873 of 12.11.1957; changed by Leg. Dip. No. 86/72, of 09.20.72), forbidding the hunting of some species and restricting the hunting of others that can only be captured in quantities and times to be announced by the appropriate entity, presently the Ministry of the Environment.

In case the habitats of these animals are submerged, no hunting will be allowed, unless destined to capture the animals to move them to other habitats.

Regarding the wild flora, Decree no. 44,531, of 08.21.1962 (Forestry Regulation) contains rules about the protection of flora species. It forbids the cutting of «honey-producing species with high regional interest» and of «essences of renowned utility for the rural communities », according to lists to be adopted in each province (art. 188º). The Regulation also foresees rules about tree cutting.

The land conservation areas regime that is in force since colonial times is considered obsolete. The flora and fauna «protection zones » established in Angola in the colonial period (Decree no. 40,040, arts. 31st and 53rd, the later referred to by art. 31st) consisted of the National Park, Integral Natural Reserve, Partial Reserve and Special Reserve categories, in which the forestry reserves are included (mentioned Decree art. 31st).

The Forest Regulation (Regulamento Florestal) provides for the establishment of on-site conservation areas, the forest reserves referred to in article 31 of Decree No. 40040, as regulated by articles 24 and following of the Regulation. The Forest Regulation designates all river basins linked to water courses subject to torrentiality as total or partial reserve areas (article 62).

The Land Law (Lei de Terras) merely distinguishes between total reserves and partial reserves (article 27/3). Conservation areas are encompassed under total reserves (article 27/4-5). The Law on Territorial and Urban Planning (Lei do Ordenamento do Território e Urbanismo) provides for special plans for conservation areas (article 28/3/a). Partial reserves include «the strip of protective land around dams and lagoons» and «land occupied by (…) electric power facilities and conductors» (Land Law, article 27/7/e and 27/7/g).

3.2.5.2.5. CONSTRUCTION OF BUILDINGS

In addition to the standards governing construction of dams, the construction of buildings to serve as administrative facilities and housing for dam workers, as well as resettlement of displace persons, must comply with Decree No. 13/07 (General Regulation on Urban Buildings[*]), in particular the standards provided for in articles 14 and following of the Regulation.

3.2.5.2.6. SAFETY OF ELECTRIC POWER FACILITIES

The General Law of Electricity (Lei Geral da Electricidade) mandates that concessionaires engaged in energy production activities must, inter alia, «ensure special protection measures in their facilities against acts of sabotage or war » (article 6).

Further, the Regulation of Energy Production (Regulamento de Produção de Energia Eléctrica) (Decree No. 47/01) refers to the «proper functioning of electric power production centers», that is, good practices, including through compliance with the

[*] Regulamento Geral de Edificações Urbanas

«standards and regulations necessary to the activity» (article 15/c and 15/d).

The Regulation on Electric Energy Production (Regulamento de Produção de Energia Eléctrica) requires concessionaires to comply with «all legal provisions and technical requirements provided for by the applicable regulations in effect» (article 51) and to report all occurrences in their facilities (article 52).

Decree No. 27/01 (Regulation of the Supply of Electric Power[2]) sets forth a series of technical requirements on the supply of electric power.

3.2.5.2.7. SAFETY AND HYGIENE AT THE WORKPLACE

In regard to labor legislation, the social impact of the Project can be considered from two perspectives:

- safety and hygiene in the workplace;
- living standards of workers providing services at the dams.

Safety and Hygiene in the Workplace

The General Labor Law (Lei Geral do Trabalho) (Law No. 2/00, LGT) charges employers with the responsibility to ensure the quality of the work environment, including through adoption of «appropriate measures for safety and hygiene in the workplace» (article 43/g). Articles 85 and 53 of the law set for the specific duties of employers on this front. However, Angolan law is deficient in respective of technical safety and hygiene standards for different work environments, notwithstanding the requirements of the International Labour Organization (ILO) in this area.

Responsibility of the quality of the work environment falls on employers, whether the company exploiting the dam for electric power production or the enterprise building the dam, specifically with regard to the workers involved in the project.

Decree No. 31/94 on «safety and hygiene systems in the workplace and workplace health» enshrines the rights of workers to «a safe and hygienic work environment», receive «collective and individual protective gear and equipment free of charge» as required at their work posts, receive regular information on workplace safety, hygiene, and health related issues, and elect a committee to address the respective question with the company (articles 14/a-c and 17/1, 14/e-f and 14/d).

The Law also outlines the duties of workers, including to «safeguard their safety and health, as well as that of other persons who could be affected by their actions or omissions in the performance of the related activities» (article 13/1).

As no specific legislation exists on safety and hygiene for work at electric power production dams, the corresponding international standards, including those set out in OP.4.37 of the World Bank (No. 3.3.2.3), should be adopted.

Standards of Living of Dam Workers

[2] Regulamento do Fornecimento de Energia Eléctrica

The General Labor Law provides for «conditions under which work is performed must respect the liberties and dignity of workers, enabling them to meet their needs and those of their families satisfactorily, protect their health, and enjoy decent living standards» (article 3/4).

With respect to workers displaced from their habitual residences to provide dam services, article191/1/b of the General Labor Law sets out the obligation of employers to ensure «sufficient housing for workers and their families, on appropriate conditions and in accordance with all necessary hygienic and sanitation measures, in addition to others provided for in the respective regulations».

The dormitory housing facility provided for in the Project does not appear to meet the respective requirements and, as such, should be revised.

3.3. INTERNATIONAL SETTING

Angola has not ratified any treaties governing the use of water (regulating non-navigational uses of shared water courses, which is not the case). However, it is party to the SADC Protocols on Energy and Fisheries. In this light, in addition to the protocols above a number of provisions of the Convention on Biological Diversity (CBD), the Convention on Combating Desertification (CCD), the Bonn Convention and International Treaty on Phyto Genetic Resources for Food and Agriculture (IAPRFA), treaties to which Angola is party.

A number of international provisions pertinent to the Project are summarized below.

3.3.1. MANDATORY OBLIGATIONS

3.3.1.1. CONVENTION ON BIOLOGICAL DIVERSITY

The Convention on Biological Diversity (CBD) requires States Parties to identify and conserve biological resources and diversity (article 6), an obligation incorporated in Angolan law, as cited above. Identification and measures for the conservation of affected biological resources are set out in the chapter on environmental characterization. These measures are consistent with the National Strategy and Plan of Action for Biodiversity (Estratégia e Plano de Acção Nacionais para a Biodiversidade).

3.3.1.2. BONN CONVENTION

The Bonn Convention on Migratory Species of Wild Animals requires States to identify migratory species and «Prevent, remove, compensate for or minimize, as appropriate, the adverse effects of activities or obstacles that seriously impede or prevent the migration of the species».

3.3.1.3. INTERNATIONAL TREATY ON PHYTO GENETIC RESOURCES FOR FOOD AND AGRICULTURE

The International Treaty on Phyto Genetic Resources for Food and Agriculture (IAPRFA) requires States, through the sections that effectively implement the CBD in respect of the pertinent resources, to ensure diversity and sustainability, including the maintenance of agricultural systems hat contribute to this end (article 6).

3.3.1.4. CONVENTION TO COMBAT DESERTIFICATION

The Convention to Combat Desertification commits States to the integrated management of soils, water resources, and biological resources and to the adoption of «effective» measure to prevent and mitigate desertification. In addition, it provides for the adoption of measures to enable the «participation of local populations and communities» in all actions affecting these resources (articles 2-5).

3.3.1.5. SADC PROTOCOL ON FISHERIES

The SADC Protocol on Fisheries, applicable to all aquatic biological resources (article 2) mandates that States «regulate the use of living aquatic resources and protect the resources against over-exploitation, whilst creating an enabling environment and building capacity for the sustainable utilisation of the resources» and «ensure the participation of all stakeholders in the promotion of the objective of this Protocol» (article 4). These objectives include promoting food security, ensuring that future generation benefit from aquatic resources, and alleviating poverty «with the ultimate objective of its eradication» (article 3).

The national responsibilities of States include ensuring, through the adoption of appropriate measures, «that their nationals and juridical persons act in a responsible manner in the use of living aquatic resources» (article 5/2).

States must also promote artisanal and subsistence fisheries and facilitate their participation «in the control and management of their fishing and related activities» (article 12).

Article 14 of the Protocol sets forth the obligation of States to conserve aquatic ecosystems, «including their biodiversity and unique habitats», adopt measures to protect endangered aquatic species, and prevent pollution of waters.

3.3.1.6. SADC PROTOCOL ON ENERGY

The SADC Protocol on Energy requires States use energy to «support economic growth and development, alleviation of poverty and the improvement of the standard and quality of life throughout the Region» and to ensure that the «development and use of energy is environmentally sound» (article 2).

Annex 1 to the Protocol on the Guidelines for Cooperation between the member States provides that cooperation in the electricity sub-sector should, inter alia, strive to develop and use energy in «an environmentally sound manner» and subject electricity projects to environmental impact assessments «in conformity with agreed basic environmental standards» (No. 1).

CHAPTER 4 CHARACTERIZATION OF THE BASELINE SITUATION

4. CHARACTERIZATION OF THE BASELINE SITUATION

In this chapter information and data are submitted which characterize the baseline situation in reference to the locale proposed for the enterprise, as well as its environmental characteristics. This chapter is subdivided in accordance with three key areas, in particular the physical, biotic and anthropic environment.

THE characterization of the area of the enterprise and its surrounding area is made on the basis of data of the two (2) areas of influence defined for the rehabilitation and extension of the hydroelectric use (AH) of Cambambe. Therefore, as defined in Chapter 1 the areas of direct and indirect influence of the project are represented in the Table 4.1 .

Table 4.1: Areas of direct and indirect influence on the Project.

Provínce	Direct Influence	Indirect Influence
Bengo	Quiçama Municípal District (Left bank of albufeira in the village of Kixinje)	Quiçama Municípal District (villages of Kixinje and Muxima) Icolo and Bengo Municípal Districts (villages of Calomboloca, Catete and Bom Jesus)
Kwanza Norte	Cambambe Municípal District (Acampamanento de Desminagem, Posto Policial, Albufeira e Praia Fluvial na Comuna de São Pedro da Quilemba)	Cambambe Municípal District (villages of Zenza do Itombe, Dono and Massangano)
Kwanza Sul		Libolo Municípal District (village of Munenga including the villages of Terra Nova, Uakizulu and Kalungaand Paixão families, Comandant Kamateku)
Luanda		Viana Municípal District (villages of Calulo and Viana)

4.1 . PHYSICAL ENVIRONMENT

The characterization of the physical environment in the areas of influence of the enterprise has been done using a bibliographic case survey of the last 50 years for each of the relevant aspects of the environmental impact study (climate, oceanography, geology, geomorphology, and pedology) as described below, as well as collection of data in the field.

4.1.1. CLIMATE

The characterization of climate used data from various weather stations as well as Cambambe and Dondo. Studies of regional and of territorial scale were also consulted (Diniz, 2002; Aguiar, 1984; Azevedo, et al., 1972).

4.1.1.1 . GENERAL ASPECTS

The region of Cambambe forms part of the semiarid region of the Angolan coast (D) The distribution of rainfall, using the methodology of Thornthwaite, describes a megathermic climate, in which the mean of the relative humidity, very high in the course of the year, is at its maximum value in the dry season - the season known as "cacimbo". In The classification of climate according to Köppen, the area has a climate of dry steppe, very hot (Bsw), with rain in the summer.

In The region of the middle Kwanza, while the geographical factors (relief and altitude) lead to diversification, atmospheric factors are acting in order to create a uniform regional climate, and establishing the seasonality of the rains, with maximum in the summer and minimum in the winter.

4.1.1.2 . Weather Factors

The weather factors chosen for analysis in the study are the following:

- Air Temperature (°C);
- Precipitation (mm);
- Relative humidity (%);
- Mean Solar intensity (hours/day);
- Evapotranspiration (mm).

4.1.1.3 . Air Temperature

On the basis of the analysis of the annual isothermic contour lines, Cambambe has average annual temperatures that vary from 25°C to 26°C. The hottest period is between November and April (26°C a 27°C). July and August correspond to the coldest months, varying between 22°/23°C.

The maximum annual average temperature is 31°C, with maximum values in January and February (33°C) and a minimum value in July and August (27°C to 28°C). Temperature is relatively constant in the months of November and December and from March to May (31°C to 32°C). there is a minimum level of difference between the wettest summer periods and the dry season, with an annual difference on the order of 5°C.

The minimum annual average temperature is 21°C in the wet period and 18°C in dry period. There is a relatively stable period between November and April (21°C a 22°C), and a minimum value in the months of July and August (15°C).

For the absolute maximum temperature there are extreme values of 38°C in November. For a minimum temperature there are extreme absolute values of 8°C in June. There is an average daily variation of 9°C to 11°C in the hottest months and of 10°C to 12°C in the coldest months. May and June are the months that have the highest daily thermal fluctuations (12°C).

4.1.1.4 . PRECIPITATION

According to the rainfall contour lines, the amount of rainfall may vary from 600 to 800 mm per year and is highly variable in its distribution. The wet season is from November to April and the dry season is from May to October.

The rainy season starts promptly with the arrival of the 3rd 10-day period of October, and the dry season starts in the 1st 10-day period in May.

The occurrence of a short dry period, more or less variable (called "cacimbo") is normal during the rainy season, between the 2nd 10 days of January and the 3rd 10 days of February. The months of greatest precipitation are March and April with rainfall between 150 and 200 mm. The least rainfall occurs between January and February with values of around 75 mm.

The wettest days of the year are the 1st of April (85-125 mm) and the 3rd of the same month (75-110 mm). The least rainy days are the 2nd of January (10-20 mm) and the 2nd and 3rd of October (15-20 mm).

4.1.1.5 . AVERAGE MOISTURE CONTENT AT 9 AM

Relative humidity is characterized by the degree of saturation of the air with water vapor. The annual average value for the Cambambe region varies between 80 and 84 %, a situation that is maintained throughout the course of the year, with the exception of the months of September and October, when it decreases to values on the order of 77 to 80%.

4.1.1.6. INSULATION

According to the contour map for sunlight intensity, there is a value of approximately 2,200 hours in the region of Cambambe, the percentage is established between 45% and 50 %.

4.1.1.7. EVAPORATION

The total annual average for the region of Cambambe is established as 1,500 mm, with September and October the months of greatest evaporation (130 mm - 160 mm) and April and June the months of lowest evaporation (90 mm - 120 mm).

4.1.2 . GEOLOGY AND GEOMORPHOLOGY

According to Diniz (2002) of point of view of regional geology, the area of Mid Kwanza is inserted in an area marked by presence of extensive profound weaknesses continental. Among these failureslies the Kwanza Horst, a linear increase of the latitudinalbasement, about 300 km long and 20-50 km wide, withlithographic structures shrouded in Lower Proterozoic. The HorstKwanza separates two other important geological structures, theMaiombe Shield and Shield in the northwest of the southwestern Angola.

Regionally, a portion of the basin of the middle Kwanza, located in the vicinity of the city of the Dondo (surface *penilitorânea*), includes the rock and crystalline formations of the Ancient Mass. The majority of these rock formations is characterized by the high degree of metamorphism, including in the base complex gneisses, paragneisses, migmatites, mica schists and the granitic-gnaisses being the more abundant rocky materials. These materials are, in general, very rich in quartz, however, there are rocky outcrops of granitoids which are not metamorphized or hardly metamorphized.

Between the Upper Dondo and the Kwanza River there is an important channel of schistic rocks associated with arcósios [sandstone high in felfdspar N.T.] (included in the Series Sansikwa - Congo Western System). The formation of the overlying sediments occur first in narrow edges, and later widen significantly becoming part of the Sedimentary Basin of the Kwanza, where there are outcrops of deposits which range from the Cretaceous period to the Holocene, corresponding to the first peripheral band of the deposit and in contact with the crystalline rock complex and the more recent ones which, in large part, correspond to the low tide of the ancient ocean.

4.1.2.1. METHODOLOGY

For the description of the geology at the sites of direct influence of the project, it was necessary to carry out and develop various stages simultaneously, which involved a broad methodology as described below.

4.1.2.1.1 . BIBLIOGRAPHIC RESEARCH

This part of the methodology involved the collection of bibliographic information, mapping and geological, as well as satellite images of the area of the project and its surrounding area. The topography of the region of the dam and of the reservoir, in scale 1:5.000 , with contours at one meter intervals was used. The data for drawing up this document have been obtained by means of highly accurate measurements, based on laser technology. The report on the Studies of Pre-viability of Energy production at Cambambe produced in 2009 by the Engevix company was also used (document RAHC/EG-RT0-GEG00-0101).

A great deal of cartographic information has been obtained in mapping of charts at 1:500,000 done by the Geographical and statistical Institute of Angola (IGCA), using the UTM system of projection (Universal Transversal Mercator) referred to the ellipsoid Clarke 1880 (Datum Camacupa).

Geologic and geomorphic data, available from previous work, were collected, selected and analyzed, including environmental impact studies of the region of the Middle Kwanza, as well as government documents and reports produced by the AH of Cambambe.

This activity has been focused on the analysis of satellite images, which are interpreted together with the data of the geological maps, geomorphologic data and topography from previous work which has helped in the programming of visits to the area. A photo-interpretation analysis emphasized the following aspects:

- Interpretation of the morpho-structural units with the use of satellite images and the help of geological maps and topography;
- Analysis of morphological properties (surface water formations; variable geometry of aspects and topographical details; pattern of drainage) and morpho-metrical properties (gradient; slope; density of drainage) with the emphasis on the use of aerial photographs and topographical survey maps; and
- Interpretation of structural features, drainage anomalies and morpho-tectonic indicators.

4.1.2.1.2 . FIELD STUDIES

During the field work the emphasis was on the modeling of the origin, gradient, types of rock, potential sources of sediments, areas which are susceptible to sedimentary obstruction and floods. The field work has consisted of two separate activities:

- First, along the length of the river bed of the Kwanza River (area of Albufeira the dam of Cambambe), which have produced a commentary on the dynamics of the river, the current sedimentation levels and the dynamics of the marginal areas; and
- Second, on the Kwanza river bed (downstream from the Cambambe dam, in the region of Dondo), with the same objective.

With the identification of the lithologic units and its structural behavior, the topics which are intrinsically linked to modeling and to the processes that are taking place in the course of the geological time, it has become possible to collect the basic information necessary to delimit and define the units of study, also to establish the influence of each unit in the dynamic of the geomorphologic processes of the field study - its erosion potential and potential as a source of sediments and movements of material.

4.1.2.2. GEOMORPHOLOGIC CHARACTERIZATION

According to the Engevix study (2009) the region of the province of Kwanza-Norte is made up of a number of peneplains caused by denuding processes, which form an important set of stairstep formations from the interior of Angola to the Atlantic Ocean. The hypothesis of the formation of the peneplains only by erosive processes is controversial, as the region has suffered, in the course of the millennia, tectonic activities and adjustments from the Miocene to the present.

Jessen (1958) has identified five peneplains that have been referred to as I to V, from lowest to highest. Cambambe is situated in this field of peneplains, which covers the whole of the basin in the Kwanza river, is extending to the west, eroding into the rocks of the formations of the old, pre-cambrian sediments, as well as into the crystalline rocks of the base (Engevix, 2009). The pictures below show details of this specific peneplain (Pictures 4.1 to 4.3 ; Is 4,1).

Photo 4.1: Kwanza River Valley from the Camambe Dam. Note the *peneplanization* of the region where the river is carved in sedimentary rocks.

Photo 4.2: *Peneplanization* of the Kwanza River Valley region downstream from the dam. The valley is carved from crystalline rocks.

Photo 4.3: Kwanza River Valley downstream from the dam. Note the escarpments, carved from sedimentary rocks and the demarcation of the granitoidal outcrops.

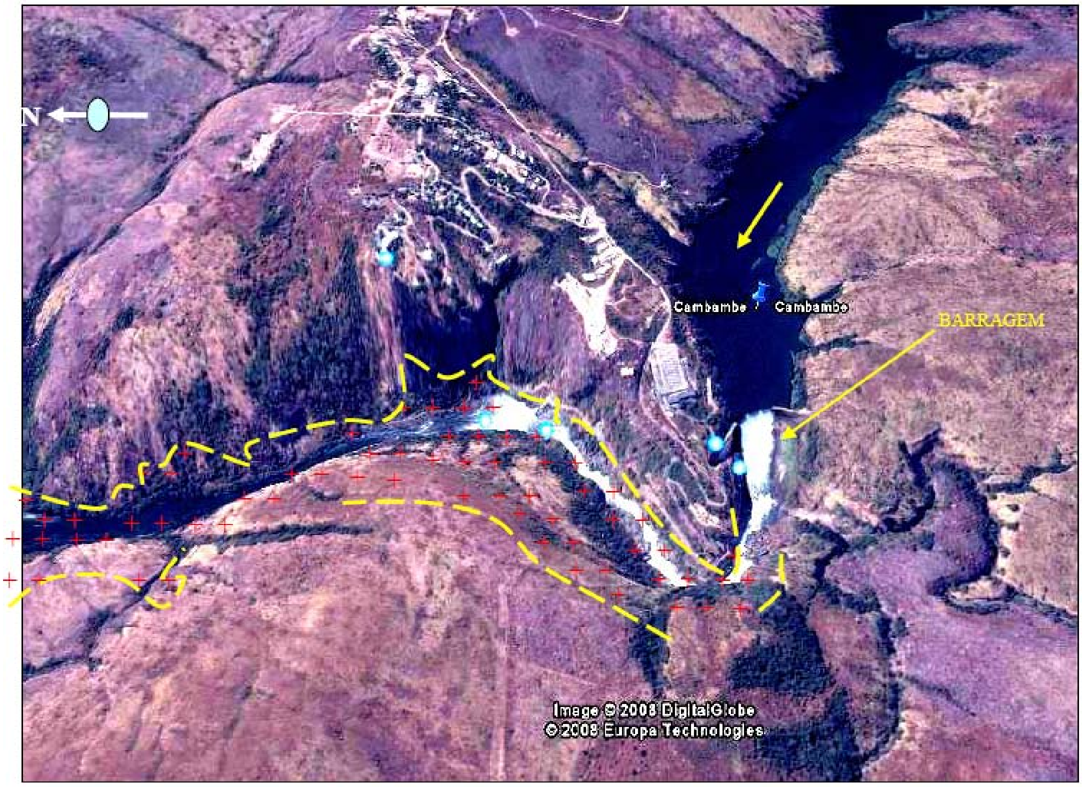


Figure 4.1: Valley of the Kwanza River carved through rocks of crystalline base (represented by the symbols in red) downstream from the Cambambe Dam

In the region of the Cambambe dam, at least four (4) families of regional fractures and faults have been discovered, produced in response to compressive forces to the NNE. They are responsible for the standard rectangular drainage of the region, as well as for the morphology of the valleys. The families have the following directional orientations:

- N-S, which together are approximately perpendicular to the maximum tectonic force movements ($\sigma 1$) with the direction of drag to the NE;
- E-W, together approximately parallel to the efforts of reaction of the collision process, parallel to the overtaking movements; and
- 45° NE and 40° NW, together crossing the direction of the maximum compressive, transtensive and transpressive forces.

The regional drainage, of the rectangular type, is within in these fracture systems (Photo 4.4 and 4.2). The meander has been contained, situated around 550 m downstream of the barrier, and is the result of a strong diversion of the river occasioned supposedly by a system of faults with an orientation of 45° NE

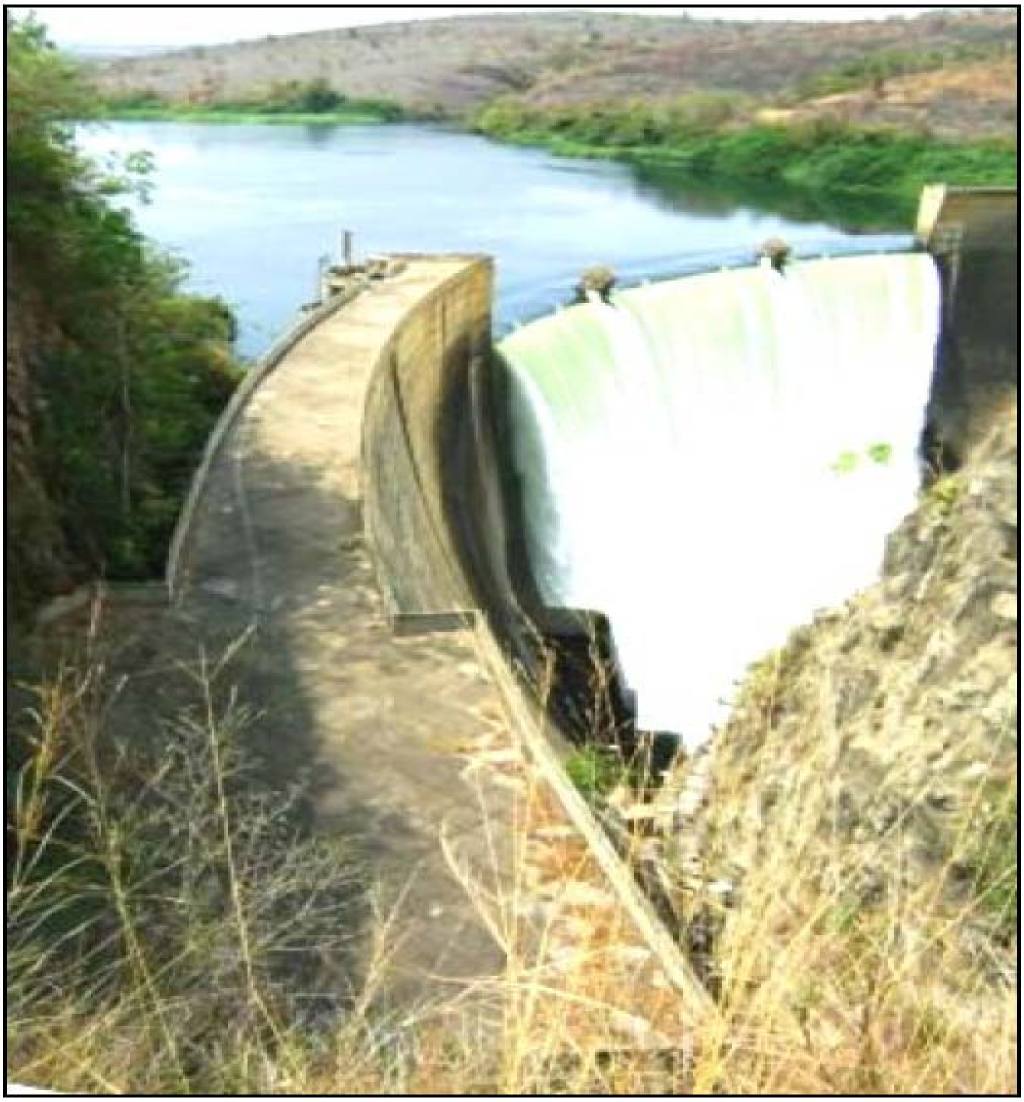


Photo 4.4: Cambambe Dam in a valley carved from sedimentary rocks.

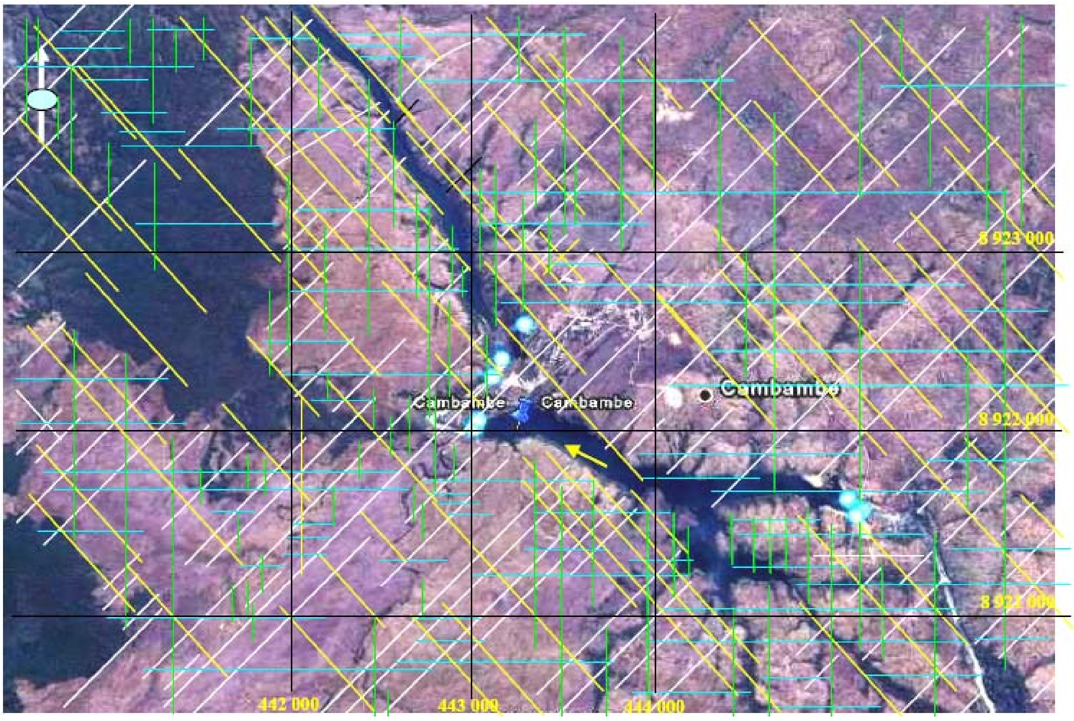


Figure 4.2: Structural layout of the dam site. Principal fracture systems. Alignments: - in white, in the direction 45° NE; in yellow, 40° NW; in green, N-S; in blue, E-W.

The valley of the Kwanza river, in the section studied, is narrow and asymmetric, with the West side more prone to this than the East.

The area of study, in particular, is part of a complex of granitoid rocks resulting from granitization of metamorphic rocks from the Early Proterozoic (Figure 4.3 and Annex 6) and of the deep remobilization of metamorphic rocks from archaic times. Such rocks are a complex of granites, porfiroblastic biotites and leucocratic granites, designated as the Quibala Granites.

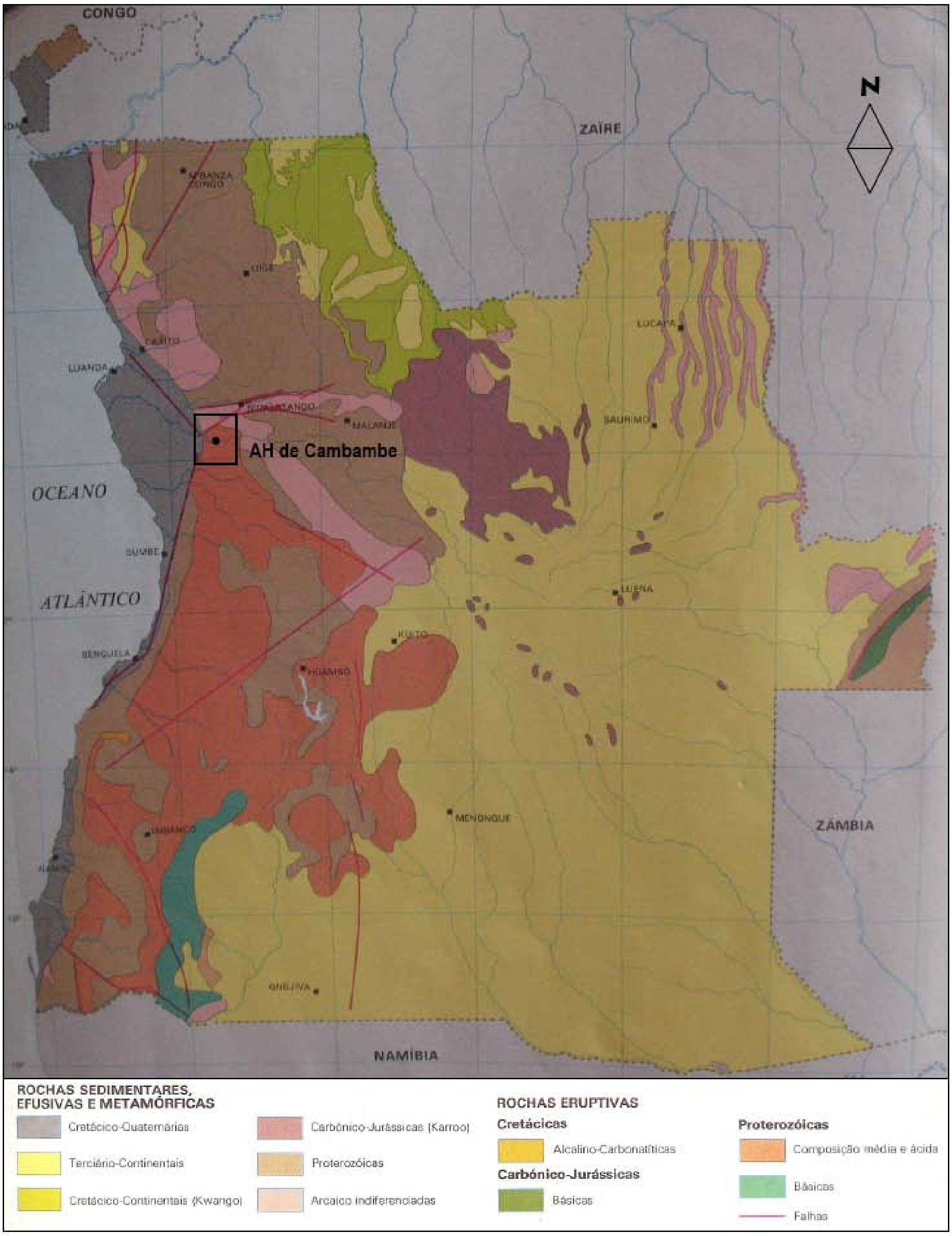


Figure 4.3: Geologic map of Angola, showing the Proterozoic Rocks In the region of this study.

The main geo-morphological characteristic of the region is the presence of the predominant role of hills and mountains caused by the dissection of the rivers that make up the basin of the Kwanza River. The relief is characterized by steep slopes. In this region are dominated by altitudes between 100 and 400 m predominate. The greatest altitudes are to the SE (see Figure 4,4).

Figure 4.4: Relief map of the area of influence created by the raising the height of the Camambe Dam, with levels between 100 and 400 meters.

4.1.2.2.1. Geologic and Geomorphic Classification

The geomorphic analysis of the mountainous characteristic of the region makes it possible to conclude that this is an area which is dominated by the erosive processes that have led to the existing forms of degradation, such as ridges, hills and mountains, formed on Proterozoic rocks (granites, granodiorites and quartzites). The topography is very undulated and the drainage is well defined, with narrow valleys and with steep slopes, at the level of the granites (Photograph 4.5), creating long interfluvial formations, consisting of layers of granite and quartzitic rocks.

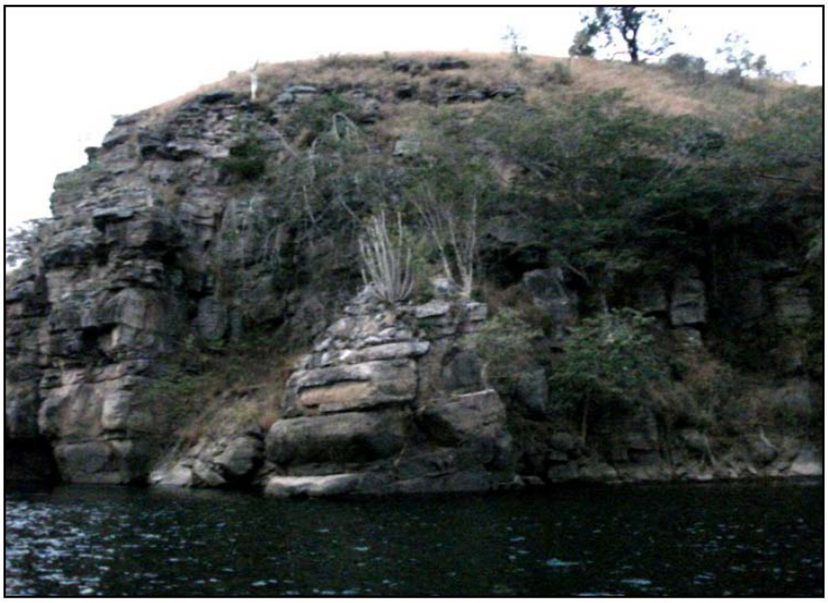


Photo 4.5: Granitic rocks which form the right bank of the Kwanza River.

The main process which has shaped the landscape is fluvial erosion. The predominance of the erosive processes over those of weathering, as well as the steep slopes and the occurrence of other types of movements of material do not allow for the formation of layers.

Deposits or accumulation of eroded material correspond, above all, to the narrow flood plains and terraces that occur along the river and some of its tributaries.

4.1.2.2.2. DYNAMICS OF THE RIVER SYSTEM AND THE HYDROELECTRIC PROJECT

In the catchment area, the characteristics of the river bed, of channels, of the standards of steady drainage, when analyzed together, suggest a peculiar dynamic of the river currents which, together with this geometry and hydroelectric power, culminates in a specific case of river erosion, transport and disposition.

In a river, the speed of the water depends on important factors such as the gradient profile of the longitudinal section of the river, the volume of the water, the shape of the cross-section, the coefficient of roughness of the river bed and the viscosity of water. The speed of the water varies in the various stretches of the channel in which it is flowing. In this sense, any obstacle influences the efficiency of the flow of water. Thus, the characteristics of the speed of the water and its flow (turbulent or smooth) are related to the river current (or force) that the river exerts, thus enabling the transport of the sedimentary load in its most varied forms (suspension, dragging and rolling), in accordance with the granularity of particulate matter (size and shape) and of the characteristics of the current.

From the perspective of a system, the susceptibility to erosion of the margins of a river, as well as the transport and disposal of sediment depends on, among other factors, the flow volume and of the nature of the river current, reflecting in an equilibrium condition (balanced) of the river channel. Any change is at odds with this stability, resulting immediately in changes in the conditions of transport erosion and deposition to a new equilibrium condition.

4.1.2.2.3. DYNAMICS OF THE KWANZA RIVER AND THE HYDROELECTRIC PROJECT

The geomorphic analysis of the fluvial dynamics of the river, both in the areas of direct influence of the hydroelectric dams, as well as the downstream characteristics and the amount, is of the utmost importance to form a predictive vision of potential environmental impacts arising from the increased height of the dam.

In the area studied between Banza do Dundo and the Dondo, the fluvial channel of the river presents a typically standard straight cut along the NW-SE line, interrupted by various changes in the direction W-E. As an example, there is the case which can be observed in Cambambe, probably linked to structural alignments (Figure 4.5). THE channel is impressive and has steep margins. These escarpments present differences that vary between 40 and 200 meters, measured from the flow at the base of the channel, which, almost coincides with the river channel because of the silting at the dam.

There is a succession of abrupt changes in the level of the river bottom, represented by rapids. These differences and the occurrence of rock outcrops in the cross-section of the river, seem to represent disruptions in the gradient of the longitudinal profile of the channel. Channels of standard predominantly straight cut, tend to have a great speed of the flow of water.

In general, the field observations have shown a remarkable morphodynamic stability of the forms of emphasis in the whole area of direct influence on the Dam. The other more predominant deformations are the escarpments which do not present evidence of erosion and/or5 significant movements of material. In the course of the river channel, there has been a broad predominance of margins in stable talude (Photograph 4.6).

Photo 4.6: Steep slopes along the Kwanza River, from atop the Cambambe Dam.

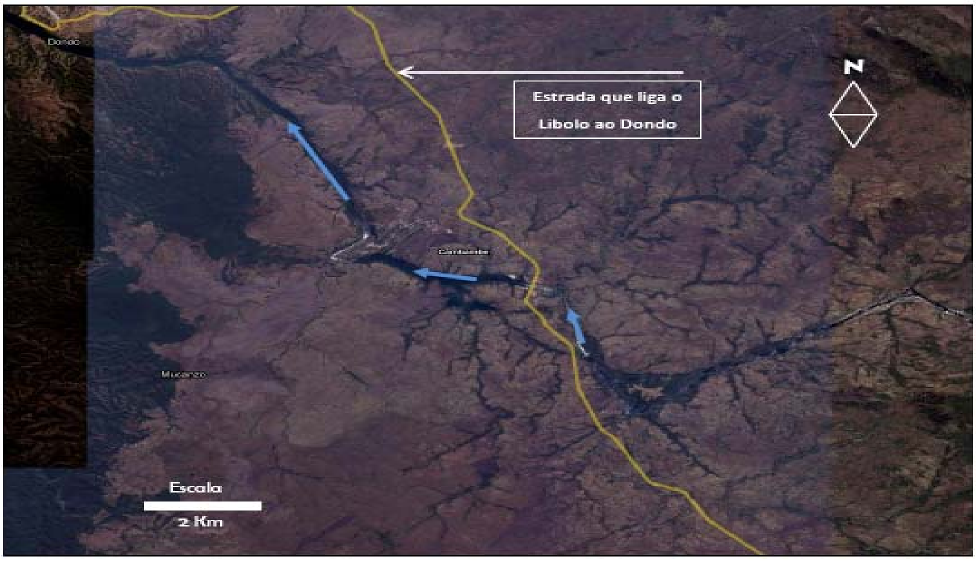


Figure 4.5: Preferential orientation of the Kwanza River (NW-SE)(blue arrows), in the stretch between Banza de Dundo and Dondo, and passing through Cambambe, with structural turns (E-W). The yellow line is the road between Libolo and Dondo.

4.1.3 . GEOTECHNICAL CHARACTERIZATION

This region is situated around on the edge of the west border of Craton of the Congo, and within the limits of this with the band of geological folds of Kaoko or Dos Damaras.
The Kaoko belt, considered as a intracratonic rifting basing of the Continent of Gondwana, is a strip of geological folds between the cartons of Congo, in Africa, and the Carton of São Francisco, in South America (forms part of the Pan-African/Brazilian Belt).

Corresponds to the NE moving plate lodged against the Congo Craton during collision events resulting in the amalgamation of the Gondwana Continent in the late Neoproterozoic (1,300 GA.) through the Cambrian (Brazilian Cycle in corresponding South American rocks, in the Dom Felician, Ribeira moving plates, dating to approximately 550 m.a.).

The 'emerald belt' Kaoko correlates to the band of folds known as Araçuaí, made up of metassedimentary neoproterozoic rocks with máfic and ultramáfic insertions. These rocks have suffered tensions in the approximately E-W direction, with stetching and doubling following th NW-SE direction.

4.1.4 . LITHOLOGIC CHARACTERIZATION

The region of the of Cambambe dam is formed by a succession of sedimentary neoproterozoic rocks (age of around 800 million years) distributed in sub-horizontal tabular sections, deposited on an igneous-metamorphic base.

The sedimentary deposits are made up of clay soils and sandy clay soils; preominantly quartzitic sands and arcosean sands (immature, feldspar), of reddish and violet colors, cross-stratification (red beds) and wave marks (ripples); and conglomerated sands. The sedimentary rocks are compact, consistent and very coherent, and cemented by sericític or silicose cement and/or iron oxide (Photographs 4.7 - 4.10).

Photo 4.7: Tabular strata of lamites and sanedstones on the slopes of the bed of the dam on the right shoulder. The CUT is approximately parallel to the fracture 40◦ NW.

Photo 4.8: Tabular Fine sandstones and lamites on the right wall of the Road cut downstream from the dam. Mirror images of the fractures in the approximate direction N-S tilted from the vertical. The plandes of the othoconal fractures are approximately E-W. The direction of the lamination is 80◦ NNE, 25◦ SE.

Photograph 4.9: Sub-horizontal tabular sedimentary strata ALONG downstream slopes of the MD of Camambe Dam.

Photo 4.10: Rock conglomerate layer at the top of an ígneo-metamorphic complex and in contact with an overlying sedimentary sequence . Road cut on the right bank.

4.1.5 . SEISMIC ACTIVITY

Angolan seismic activity is modest compared to other regions of the world. However, this factor cannot be ignored considering that, in the past, several earthquakes with magnitude above of 5,0 of the scale MSK 64 (Medvedev-sponheuer -Karnik) have occurred, indicating that there is an earthquake risk in Angola.

In spite of the earthquakes studies carried out in recent years in the context of the Global seismic risk map (GSHAP), which shows only a few areas in Angola recognized as situated in tectonically active regions, the seismicity is not yet well known. The development of areas of uniform sources is hampered by the sparse and incomplete records of earthquakes and absence of more modern seismic stations , generating uncertainty about the parameters of the earthquakes. At the moment, the country does not have an up-to-date map, perpetuating the use of a tectonic structural outline that was prepared in the colonial period. The updating of this document associated together with constant monitoring of seismic activity will make it possible to understand the probability of local earthquake activity..

However, the first fault line called Possible Deep Seismic Source (ESF-1) or the fault line of the southern Kwanza, passes about 15 km to the north of the location of albufeira of Cambambe, with the southern boundary the Horst Kwanza(1) which divides the crystalline shields of Maiombe and Angolan. The right direction is an approximate S-W, and it is connected with two earthquakes in 1968 and 1976, of magnitudes of 4,4 and 4,8 , in scale MSK 64 respectively. The depth of the focal point of this last earthquake was 33 km.

The analysis of the values of the seismic intensity of earthquake and their respective acceleration caused by various disturbances measured at the AH of Capanda, located 134 km upstream from Cambambe, indicate that the calculated parameters for the events that are contained in the international catalogues, with values of acceleration maximum residue levels below 0,02 g, are compatible with the estimated figures in the regional work carried out in recent years in the context of the GSHAP. The earthquake studies by the company Sondotécnica located their epicenters mainly in the Basin of Sedimentary Kwanza.

The values calculated for the earthquakes in the fault ESF-1, which are not included in the international records, lead to the acceleration and higher, between 0.1434 g e 0.314 g for the maximum magnitude adopted for the faults. Probably these earthquakes were registered in regional seismographic stations and are not listed in the catalogues of international records.

In the face of this fact, it is recommended to adopt the same earthquake parameters used for the project for rehabilitation and increase in output capacity of the AH of Cambambe. These parameters are related to the intensity level 7 of the scale MSK-64, corresponding to intensity VII-VIII (7,5) of the Modified Mercalli scale.

4.1.6. SOILS

4.1.6.1. METHODOLOGY

For the definition of the direct influence of the soil quality on the project, various activities have been undertaken, developed on the basis of the methodology described as follows. For the mapping of the outline of the pedologic area which affects the project, with particular emphasis on area of direct influence, in addition to widespread knowledge of a large part of the region, the detailed studies carried out by Castanheira Diniz (1973 e 2002) served as the basis, as well as the soil maps of Angola. We have also analyzed documents relating to the initial draft of the construction of the Cambambe dam.

4.1.6.1.1.CHARACTERIZATION OF THE SOIL

Comparing the pedologic outline with the geologic and lithologic, there is evidence of a close correlation between the main units of soil and the lithologic materials from which they are derived. As a result of the different mineralogical composition of the rock deposits that occur on the river valley is faced with a variability of soil, which are the litossoils associated with rocky outcrops, soil topic fersialíticos and river soils.

- **Lithosols Soils Associated with Rocky Outcrops**

These soil are of low thickness, based on sub-stratum size to 20 cm or less of depth, often associated with the material rocky road ahead of both in non solum, such as disseminating itself abundantly over the surface. The referred to soil is confined to some stains whose association usually establishes the soil and ferralitic pedogenesis. On the other hand, it is also present in the steep slopes that mark variation of one formation to another.

- **Ferrallitic Tropical Soils**

These soils represent the most common soils in the area. They are related with crystal gneissic or granite-gneissic rock formations, as well as certain types of Lower Cretaceous clayey rocks (layers of the Dondo). They are visible in well-defined strips and close to the steep slopes.

The ferrallitic tropical soils display medium-sized or fine particles, of medium thickness, almost always with a textural B horizon, more or less clearly apparent, not normally having a measurable mineral reserve, above all with the appearance of feldspar and mica. There are often levels of material of crude quartz close to the surface and characteristics "lines of stones". THE clay soil, which is made up mainly of minerals and iron and aluminum caulinitic sexquioxides, with small amounts of 2:1 minerals designated ferrallitic clay.

- **Alluvial soils**

These soils are well represented in the extensive alluvial areas downstream from the Cambambe dam.

The well drained alluvial soils are of the highest degree of fertility, distributed in general in the a strip adjacent to the river, the altitude is slightly higher than the rest of the plain. It is in these areas where the coastal communities concentrate, downstream of the Cambambe dam.

4.1.6.1.2. SUSCEPTIBILITY TO EROSION

The marginal erosion in the fluvial channel is taking place on a continuous and spontaneous basis by the action of the current of the river. It is directly linked to the changes brought about within the catchment areas. The erosion may be triggered by the action of the waves immediately downstream of the dams, normally, and is associated with the pattern of high variations of discharges. In the majority of cases, the deepening of the river bed tends to be more intense than the lateral erosion. In this case, the transversal profile of the channel is changing gradually. On the other hand, the retention of sediments can cause erosion downstream of the dam.

Since the dam already exists and has been working for more than 50 years, it is possible to see the retention of sediments in the lake, which are one of the causes of the erosive processes downstream. The other aspect which helps in this is the natural or regulated flow that it can exert on the Kwanza River.

4.1.7. HYDROLOGY

In methodological terms the research of the hydrological information consisted of visits to the area of the hydroelectric project of Cambambe, visits to the premises of the National Direction of supplies and Sanitation, of the State Bureau of the Water, as well as the HQ of the National Electricity Company (ENE). These visits served as a consultation of literature and related technical studies and surveys made for the construction of the Cambambe.

Other technical engineering material, necessary for the characterization of the hydrological summary, is detailed in the chapter on the Bibliographic references.

4.1.7.1. HYDROGRAPHIC BASIN OF THE MIDDLE KWANZA

The Water catchment area of the Middle Kwanza is one of the four sub-basin to allocate the Water catchment area of the rio Kwanza. The Water catchment area of the Middle Kwanza has an approximate area of 25,000 square kilometers. It is starts from falls of the Condo, to the South of the City of Malanje, up to the base of the rapids at Cambambe. The altitude of the basin varies between 160 and 1,000 meters.

In the upstream portion, the river runs through sandstone conglomerates of the oily schist series. In This case the river bed is suffering from a narrowing in its initial stretch and it offers a smooth descent; as a result, between Pungo Andongo and Cambambe, the Kwanza River has a greater slope, with various rapids and falls.

The main tributary of the left bank is the Gango, whose water catchment area has characteristics and geological and topographical traits similar to those of the high Kwanza (Water Studies, Evaluation of the Flood of the hydroelectric use of Cambambe, Engevix, 2009)

The rainy season is in the period of October to April, with two maximums which are marked in November or December, and another in March or April. The dry period includes the months of June, July and August, in general with values near zero, and some rain during May. The months of May and September are the period of transition between the two stations.

The weighted average annual rainfall of the basin is around 1,230 mm, with extreme values of rainfall considered on the order of 1,500 mm (maximum) and 830 mm (minimum).

The hydrometric observations of the Kwanza River were initiated in 1952, by which time hydrometric stations had been installed in Cangandala and Cambambe. There are regular hydrologic records from 1952 until 2009, with the exception of the period between 1977 and 1983, the period in which things only functioned in an irregularly.

The Kwanza River presents a very regular outlet, without major variations of altitude. The average annual flow of the Kwanza river is on the order of 540 m^3/ second, and, normally, the maximum flood occurs between the end of March and the beginning of April, and the minimum occurs in the period between the months of September and October.

Data observed in the Hydrometric Station of Cambambe indicate the range of maximum flooding of the Kwanza River ranges from 3,740 m^3 /second (as recorded on 1 April 1969) and the 787 m³ /second (as recorded in 1958), while the minimum flow is of the order of 122 m³ /second (Instituto HIDROPROJECT S. A, Moscow, 2004).

The parameters of the curve of the probability distribution of occurrence of the maximum flow of the Kwanza River, near the Cambambe dam, from the period (1952 - 2002), are set out below:

- Mean maximum Q = 1.852 m³ / second
- Coefficient of Variation, Cv = 0,43
- Coefficient of Asymmetry, Cs = 4Cv

Between the dams of Capanda and Cambambe the construction of seven additional hydroelectric power units are planned. These are the Nhangue (450 MW), Laúca (2,120 MW), Caculo Cabaça (1,560 MW), Zenza I (450 MW), Zenza II (120 MW), Tomb of the Hunter (450 MW) and Luíme (330 MW).

4.1.7.2 ANALYSIS OF CURRENT SITUATION

The Cambambe dam was built in 1960, downstream from the Water catchment area of the Middle Kwanza, in a part of the River with a relatively narrow valley, before a curve, with a natural fall of around 40,00 meters, in rapids. The technical characteristics of the initial Cambambe dam, as already indicated in the previous chapters, are the following:

a) Maximum height of the foundation: 68,00 meters;
b) Arch at the top of the dam: 300 meters
c) Thickness at the top: 7,00 meters;
d) Thickness at the base of the central console: 13,30 meters;
e) Elevation at the discharge: 102,15 meters;
f) Area of the lake: 1,3 square kilometer;
g) Maximum normal elevation of the lake: 102,15 metros;
h) Useful capacity of the lake: 28,7 x 10^6 m³; e
i) Volume of the lake: 10 x 10^6 m³.

By means of the general layout of the Middle Kwanza, the scale at 1:100.000, it can be seen that the regolfo ("fetch") created by the Cambambe dam extends to approximately six (6) kilometers upstream.

At the moment the dam has a high degree of sedimentation. Bathymetric Studies carried out in 2001, by the company PM, Consulting & Hydraulic Works, indicate that due to the high degree of silting, the storage capacity was reduced from a total of 24 million m^3 to approximately 19 million m³. This makes the dam operate with a minimum of water. This report on the Bathymetric Studies has found that "the deep discharge was out of service for around 12 years, a fact that will have contributed greatly to the high degree of sedimentation of the lake the Cambambe dam".

THE filling of the lake de Capanda began on 21 August 2002. The of Capanda dam, after the conclusion of their construction, currently guarantees, the downstream of its section, a minimum flow on the order of 500 m³ /second. This could produce changes, even if they are not significant, in the hydrological situation of the section of the Kwanza River between the dam of Capanda dam (upstream) and the Cambambe dam (the downstream).

A joint report produced by the Office for the utilization of the Middle Kwanza (GAMEK), and by ODEBRECHT Engenharia, confirms the "hypothesis that there will be no great changes in the streams between Capanda and Cambambe". Based on this information and on existing records on the region of Cambambe, calculations have been made for the determination of the main hydrologic parameters important to the heightening and rehabilitation of the AH of Cambambe, and in particular the flow going back thousands of years, as well as the ecologically acceptable flow.

4.1.7.3. HYDRIC CHARACTERIZATION

The Kwanza River has its origin in the province of Bié, and more specifically in the municipality of Soma Kwanza, it winds going through the provinces of the Bié, Malanje, Kwanza-Norte and Bengo, where it ends up draining into the Atlantic Ocean, in the town of Barra do Kwanza.

The Kwanza River has a very normal flow to the sea without any great fluctuations. The average monthly flow is on the order of 540 m^3 /second, with maximum flood usually between the end of March and the beginning of April. The minimum flow takes place in the period between the months of September and October. There are records of the maximum flow registered for the Kwanza river on the order of 3,800 m^3 /second, while the minimum recorded is of the order of 130,00 m^3 /second.

The flow of 500,00 m^3 /second has a minimum season in the Kwanza River of about four (4) months, and the permanent flow of the river varies between 65% and 100% of the annual average. With the entry into operation of the Capanda dam, the minimum flow regulated at 500,0 m^3 /second is stable during the whole year.

4.1.7.3.1. EVAPORATION POTENTIAL

The region of Cambambe is located in the geographical position: Latitude 9 □45' South, Longitude 14□ 29' at an Altitude of 187,0 meters. However, the station closer to Cambambe, where they have been recording data on the evaporation potential is the S Agro-meteorological Station of the Centre for the Study of Salazar (currently Ndalatando). This last station is located in the following geographical position: Latitude 9°20' South, Longitude 14°54' at an altitude of 800 meters.

So, for the determination of data on evaporation potential in the area of influence of the Cambambe dam, We have used the data from the former Agro-meteorological Station of the Centre for the Study of Salazar (currently Ndalatando), the former Institute of Agronomic Research of Angola (II-AA SEGUINTE). The meteorological station has records of data for 5 years (1965 - 1970). The measurements were made through the use of a class A pan evaporimeter. The data of the evaporation potential are shown in Table 4.2 .

Table 4.2: Evaporation Potential, in mm, calculated by the Thornthwaite method (1941 – 1970), calculated by Agro-Meteorological station, Centro de Estudos de Salazar (now Ndalatando).												
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total/Year**
105	97	107	102	99	73	63	64	74	94	95	100	1.084
Source: Universidade de Luanda – Cursos Superiores de Agronomía e Silvicultura – Caracterização Sumária das Condições Ambientais de Angola, Nova Lisboa, 1972.												

Data on evaporation, computed using the Piche method, as well as data measured through the Class A evaporation pan of the agrometeorological network of the former Angolan Institute of Agronomic Research (Instituto de Investigação Agronómica de Angola), are provided below.

with a view to providing a more realistic overview of the evaporation values computed using the Piche method, as well as evaporation calculated using the type A evaporation pan, Tables 4.3 and 4.4 present data recorded at the Agro-Meteorological Station of the Salazar Studies Center (Estação Agro-Meteorológica do Centro de Estudos de Salazar) (current Ndalatando).

Table 4.3: Evaporation in millimeters measured using the Piche method (1941 – 1970), computed for the Agro-Meteorological Station of the Salazar Studies Center (current Ndalatando).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total/Year
56	56	50	38	61	71	58	55	58	55	48	50	636

Source: University of Luanda – Higher Education Courses in Agronomy and Forestry – Caracterização Sumária das Condições Ambientais de Angola (Summary Characterization of Angolan Environmental Conditions), Nova Lisboa, 1972.

Table 4.4: Evapotranspiration, in mm, measured using the pan evaporimeter class A (period 1963 – 1970), calculated by Agro-Meteorological station, Centro de Estudos de Salazar (now Ndalatando).												
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total/Year**
128	125	122	109	126	114	95	85	98	116	120	125	1.363
Source: Universidade de Luanda – Cursos Superiores de Agronomia e Silvicultura – Caracterização Sumária das Condições Ambientais de Angola, Nova Lisboa, 1972.												

In an analysis of the calculated data and measurement and records of the former Agro-meteorological Station of the Centre for the Study of Salazar (currently Ndalatando), it appears that the data measured by means of an evaporimetric plan, is closer to the reality of the area of the Cambambe dam and its surroundings.

4.1.7.3.2. EVAPOTRANSPIRATION POTENTIAL

Knowledge of the evapotranspiration potential is very useful for the characterization of the climate for a certain region. In the specific case of Angola, of the methods which are generally used, the method of Penman is the most appropriate for the tropical conditions.

The application of the formula by Penman has been tested for Angola, at a time when there were few data on evapotranspiration, together with limited conditions for the use of the method of Penman. This led to part of the values being obtained by correlation with the values obtained by the method of Thornthwaite.

In the absence of measurements of the evapotranspiration potential in the area of cambambe and its surroundings, we also used the calculated data for the Agro-meteorological Station at Salazar (current Ndalatando), operated by the former Institute of Agronomic Research in Angola. These data are reflected in the Table 4.5, below.

Table 4.5: Evapotranspiration potential in mm.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total/Year
150	146	145	133	141	119	114	113	127	138	136	150	1.612

Source: Informação Científica n.º 7 – 1972, Evapotranspiração Potencial em Angola, Universidade de Luanda, 1972.

4.1.7.3.3. REAL EVAPOTRANSPIRATION

The data measured at the Station Agro-meteorological Station at Salazar (current Ndalatando), run by the former Institute of Agronomic Research of Angola, was considered as being the most accurate figures for the real evapotranspiration for the area of Cambambe and its surroundings. These data are reflected in the Table 4.6, below.

Table 4.6: Real evapotranspiration, in mm.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total/Year
116	117	146	122	112	98	98	90	93	113	123	121	1.349

Source: Informação Científica n.º 7 – 1972, Evapotranspiração Potencial em Angola, Universidade de Luanda, 1972.

4.1.7.3.4. MAXIMUM AND MINIMUM MONTHLY FLOWS

The data on the monthly maximum and minimum flow were taken from the records of the Hydrometric Station of Cambambe, whose national reference is 601908. The data refer to the period of 1945 - 1979, and are reflected in the Tables 4.7. and 4.8 .

Table 4.7: Maximum monthly flow near Cambambe, in m³ / second.												
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Mean**
3.839	2.052	2.515	2.745	1.750	900	552	399	325	354	602	1.235	1.116
Source: Estudos Hidrológicos, Avaliação dos Estudos de Cheia do Aproveitamento Hidroeléctrico de Cambambe, Engevix, 2009.												

Table 4.8: Minimum monthly flow near Cambambe, in m³ / second..												
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Mean**
235	161	104	464	162	86	56	46	39	115	117	200	186
Source: Estudos Hidrológicos, Avaliação dos Estudos de Cheia do Aproveitamento Hidroeléctrico de Cambambe, Engevix, 2009.												

4.1.7.3.5. Mean Monthly Flow and Supply

4.1.7.3.5.1 . Average monthly Flow

The average monthly flow for the study in question is reflected in the Table 4.9 below and in 4.6 .

Table 4.9: Mean monthly flow near Cambambe, in m³/second.												
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Mean**
867	942	1.152	1.406	843	453	308	244	202	217	343	532	626

Source: Estudos Hidrológicos, Avaliação dos Estudos de Cheia do Aproveitamento Hidroeléctrico de Cambambe, Engevix, 2009.

Graphic flow values, maximum, minimum and monthly means near Cambambe. m^3 /s (1945-1979)

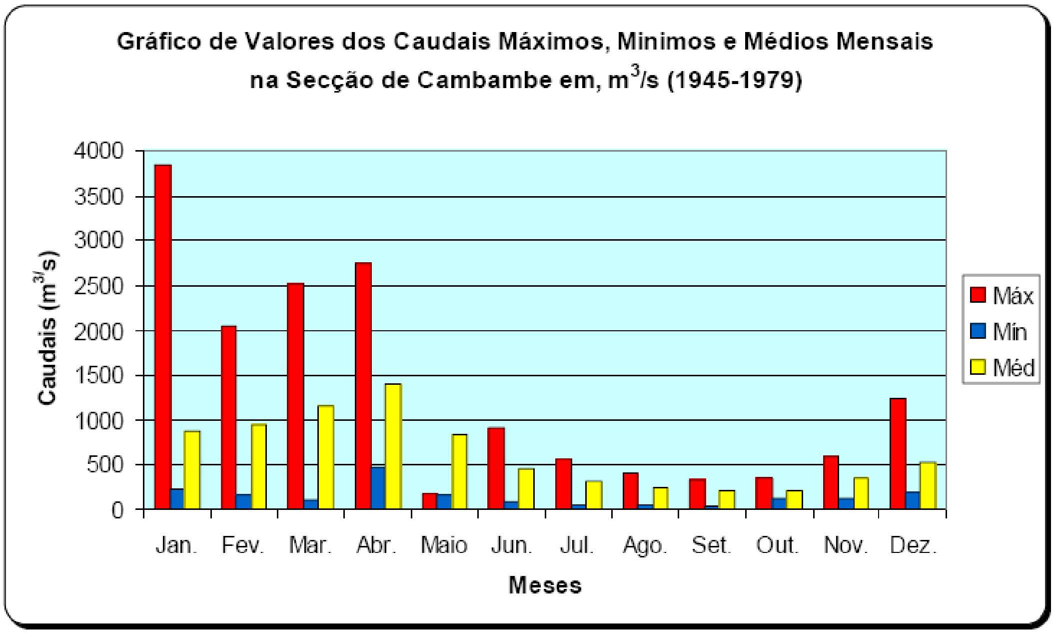


Figure 4.6: Flow Values, maximum, minimum and monthly means near Cambambe.

4.1.7.3.5.2. Monthly Volume

As has already been mentioned in the section on Analysis of the current situation, at the moment the Capanda Dam guarantees a minimum flow on the order of 500 m³ /second. This was considered as an element of the basis for the calculation of the monthly supply (Tables 4.10 and 4.11 and Figures 4.7 and 4.8). So, the Monthly Supply (AM), in m³ shall be equal to the:

- AM = The average monthly flow + 500,0 m³ /second x 86,400 x 30 days;
- AM = Disposal The average monthly Flow+ 1. 296 million m³.

Table 4.10 : The average monthly flow in the section of Cambambe, in millions of m³.

Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct
2506,9	3832,8	3858,4	3823,3	2551,3	1307,0	937,0	748,5	602,6	596,0

Source: Departamento de Planeamento de Recursos da Direcção Nacional dos Recursos Hídricos, Secretaria de Estado das Águas.

Chart of average monthly flow in the Cambambe section, millions of m^3

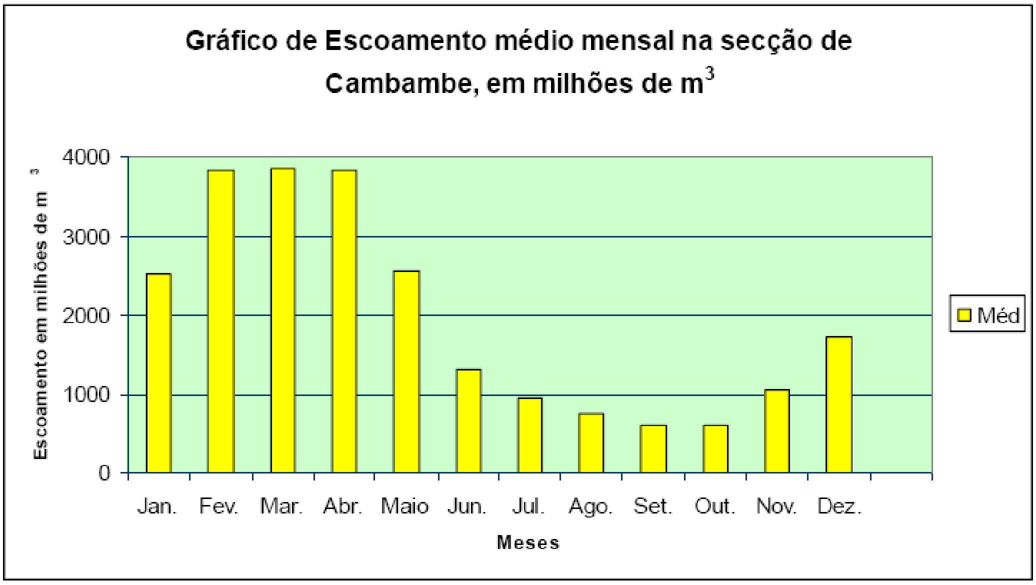


Figure 4.7: Average Monthly flow at Camambe.

Table 4.11: Monthly supply at Cambambe, in Millions of m³.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3802,9	5134,8	5154,4	5119,3	3847,3	2603,0	2233,0	2044,5	1898,6	1892,0	2348,0	3013,0

Source: Department of Resource Planning of the National Directorate for Water Resources, State Secretariat of Waters.

Monthly total in Cambambe section, millions of m^3

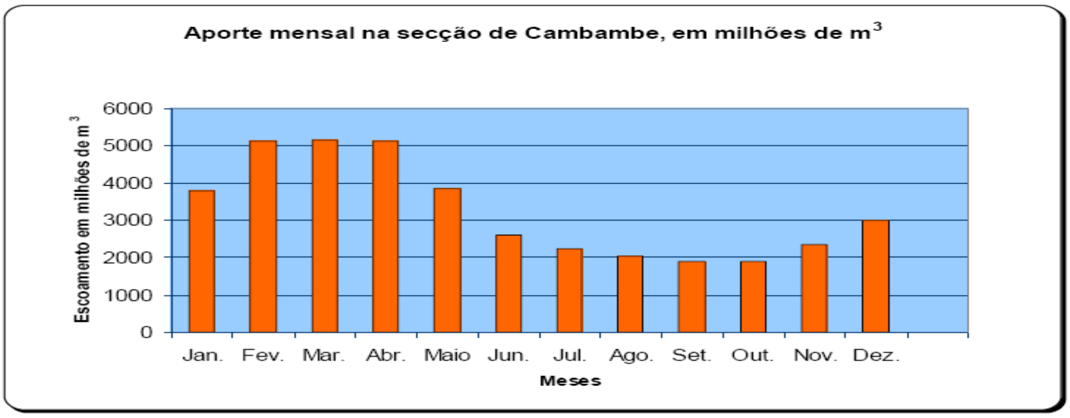


Figure 4.8: Monthly supply at Cambambe.

4.1.7.4. ECOLOGICAL TORRENT

In accordance with the Table 4.8, the minimum annual average current in Cambambe is 186 m³ /second. It is an average of values recorded before the construction of Capanda dam (Figure 4.9). Generally, the ecological flow has been considered to be the Q90, or is the one whose current, 90% of the time, is exceeded. In the specific case of the Kwanza river, in the section of the of Cambambe dam, the trend of duration of the flow per day for the period between October 1951 and September 1989, brings us to a value equal to 210 m³ /second, as pointed out in Figure 4.9 .

Size of current flow in Jan to Dec

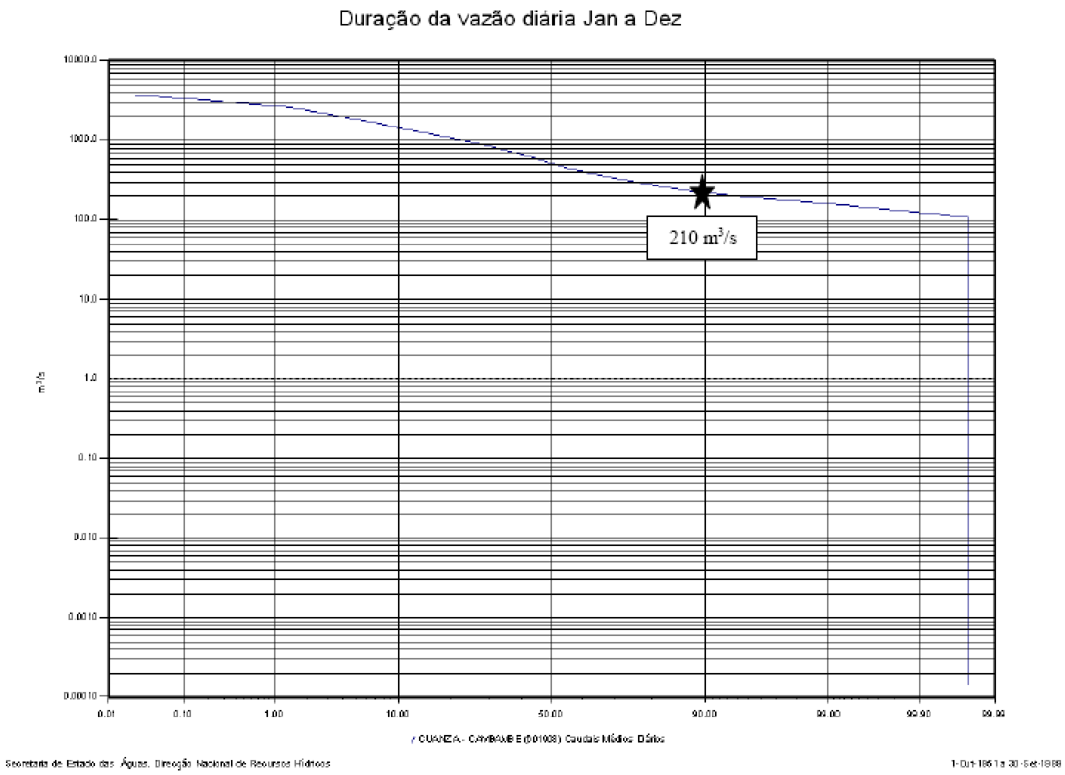


Figure 4.9: Size of current flow in m³/s.

These values no longer have any validity after the entry into operation of the Capanda dam. Bearing in mind that at the moment the Capanda dam releases a minimum flow on the order of 500,0 m³ /second, it is suggested that this value is considered to be an ecologically acceptable flow.

On the other hand, it must be considered that the Government of Angola, by means of the Ministry of Energy and Water, has a portfolio of projects for the construction of more dams in the stretch Capanda - Cambambe, in particular Laúca, Caculo Cabaça, Zenzo I and II, Tomb of the Hunter and Luime. The entry into operation of these future ventures in the medium-term, irrespective of the type, whether it be the end-of-water, or with lakes of settlement of streams, has implications which are direct and indirect in the operation of the Cambambe dam.

Given the torrentiality of the hydrological regime of the Kwanza River and its tributaries, to the extent that this is moving toward the coastal area, any kind of hydroelectric use will necessarily bring about the creation of large reservoirs for the settlement of streams.

In spite of the fact that the hydroelectric use of Capanda guarantees a regulated stream minimum on the order of 500 m³ /second, the construction of other Hydroelectric power stations, will lead to, as a result of their regulatory effects, the damping of the peaks of the floods, which may facilitate the recovery of large areas for the development of agricultural activity.

However, these types of undertakings should be mapped out in a rather sensible form from the point of view of engineering, as well as from the point of view of the environment, in a way that does not endanger the integrity of the biota of the Kwanza River, in the part that goes from the section of Capanda until the section of Cambambe.

Regardless of any technical solution to be adopted for the construction of other uses, with Hydroelectric power between Cambambe and Capanda, various consequences could arise, such as:

- Decrease in the daily and monthly amounts that have come to the Cambambe, as a result of the reduction in area of capture;
- Decrease of daily and monthly contributions arriving atCambambe, as a result of decreased catchment;
- Delaying the time of occurrence of the streams in the section to Cambambe;
- Disruption of the filling of the lake of Cambambe to its full storage capacity, since it will require more time for this purpose; and
- Definition of a minimum stream flow to ensure the full functioning of the enterprise.

4.1.7.5 . Inventories of the uses of water

There is, in the village of Cambambe, a station for pumping water to supply of the most diverse needs of this village. The capture area of the Pumping Station of is situated in the lake of the Cambambe dam. The water after being treated is stored in a reservoir with a capacity of 3.106,0 m³. The pumping station works 24 / 24 hours.

The pumping station of is equipped with four (4) electric pumps. Three of the electric pumps have a capacity (Q) of 45,0 m³ /hour. Of these three electric pumps, two function in the same time, while the third electric pump is maintained as the reserve unit.

The fourth electric pump, whose capacity (Q) is 64 m³ /hour, has the main task is the washing of filters. This electric pump works in alternating hours in, which makes an operational day of 12 hours.

In Table 4,12 , the daily volumes and annual use by the pumping station, from the lake of the Cambambe Dam, are indicated.

Table 4.12: Volume drawn from Cambambe Dam lagoon.

Capacity of the Electric Pump (m³/hour)	Daily Volume (m³)	Annual Volume (m³)	Observations
2 x45	2.160	788.400	2 pumps operating simultaneously
64	768	280.320	Used for cleaning the Filters
Total	**2.928**	**1.068.720**	

4.1.7.5.1 . INVENTORIES OF WATER USE IN THE AREA OF DIRECT INFLUENCE

The main users of water in the area of indirect influence are: the area of the Irrigado Mucoso Em, the village of Dondo and the EKA Brewery. The values of these consumptions are reflected in the Table below tabled.

- ***Irrigated Perimeter of Mucoso***

According to the direction of National Agricultural Hydraulic engineering and Agriculture, the Ministry of Agriculture, there are within the boundaries of the Irrigado Mucoso Em around 8,000 hectares of land for the culture of bananas and of the oil palm. In agreement with the Report Rapid Assessment of Water Resources and Uses of water in Angola, carried out in 2004, by the Consulting Company "SWECO Grøner", the Banana culture requires an annual volume of 13,000 m³ /ha. This same value will be use for the culture of the oil palm.

- **Table 4.13:** Annual water requirements in irrigated perimeter of Mucoso.

Type of Crop	Hectares	Water Requirement (m³/ha)	Annual Water Requirement (millions of m³)
Banana/ Palm	8,000	13,000	0.104

- **Vila do Dondo**

In accordance with statistical data on the Government of Angola, in relation to the year 2008, the estimated population of the Municipality of Cambambe was 64,278 people. On the basis of projections, it was assumed that around 70% of the estimated population lives in the area of indirect influence, which makes a total of 44,995 people. Of the total of 70% of people who live in the area of indirect influence, has was assumed that 60% live in rural areas, which makes a total of 26,997 people.

Consumption of water, is considered to be 70 liters/person/day for the urban environment, while for the rural environment, it was considered to be 30 liters/person/day.

Table 4.14: Annual water volume consumption by municipality of Cambambe.

Type of Population	Number of Inhabitants	Use (liters/day)	Annual Volume of Water (liters)	Annual Volume of Water (Millions of m³)
Urban	17.998	70,0	459.848.900,0	0,00046
Rural	26.997	30,0	295.617.150,0	0,0003
Total				0,00076

- **EKA Brewery**

According to data provided by the Technical Directorate of the EKA Brewery the plant uses daily, from the Kwanza River, a volume of water on the order of 2,600 m³. If we consider a working hours per day of 10 hours, the daily volume mentioned above will lead to an stream of approximately 73,0 liters per second. The annual volume of water consumed by EKA, in view of the industrial activity on the order of 250 days, this is reflected in Table 4,15 .

Table 4.15: Annual Volume of water consumed by the EKA brewery.

Volume taken from the Kwanza River (lts/second)	Volume taken from the Kwanza River (m³/day)	Annual Volume of Water (Millions of m³)
73,0	2.600,0	0,00065

4.1.7.6 . Estimates and models of rates of erosion and Sedimentation

The hydrosedimentologic information of the Kwanza River are still very scarce and are reporting only quantitative data relating to the carriage of solids. The only data relating to the area in study are presented in the hydrosedimentologic Studies and in the Hydrologic Directory (1988-1989) of the hydroelectric use of Capanda dam.

Based on the records available, the Hydrometeorologic Studies of the Hydroelectric Use of Capanda has put a volume of sediments in the order of 430,000 m³ /year, whose specific weight quoted is equal to 1,2 t/m³, resulting in an annual burden of 516,000 t/year. However, in the case of estimates and taking account of the amendments that may occur in the hydrological regime over the years, this study recommends the adoption of the value of 720,000 t/year.

The Annual Report of 1988/1989 on the water services carried out for the AH of Capanda has three measurements of solid streaming, carried out between 1986 and 1989, the average burden is on the order 550,000 t/year.

The sedimentology study carried out, in February 2004, by the company PM, Consulting & Hydraulic Works, indicates that "for a integral caudal of 20.000.000,00 x 10³ m³, the Kwanza River carried 1,500 x 10³ m³. The granulometric examination of samples taken indicates that are dominated by the small fine material: 57% are smaller than 60 microns and 13% are smaller than 20 microns". This study has defined 15 nutrient profiles, and 14 cross-sectional nutrient profiles and 1 longitudinal profile. The studies have been undertaken with topographic support of a Total Station, for the control of the distance of the intermediate vertical. In addition to the taking of the cross-sectional profiles, it was carried out, also, the studies of the surface water of the lake at the Cambambe dam were carried out.

However, a bathymetric report produced in March 2009, by the consortium Rehabilitation of Cambambe, indicates that since the last measurements carried out in 2001 in the lake of the Cambambe dam, the volume of sediment has increased in the order of 1,500,000m³, in other words from 19.500.000 m³ to 21.000.000 m³. This increase is an annual figure of 250,000 m^3 of sediments transported to a section of Cambambe.

The bathymetric study of the consortium Rehabilitation of Cambambe (CRC) set 14 sections (profiles) in the lake, from the wall of the dam to an upstream bridge, over a distance of 3,335 meters.

4.1.7.7 . Hydrogram of the flow of floods

During the visit to Cambambe, it was established that the only lymnograph that was the measuring the levels of water in the Kwanza River is out of service. Large part of the existing data (Figure 4.10) relate to the historic past, where the levels registered with the Kwanza River were converted into streams, by means of a graphic Q = f (H).

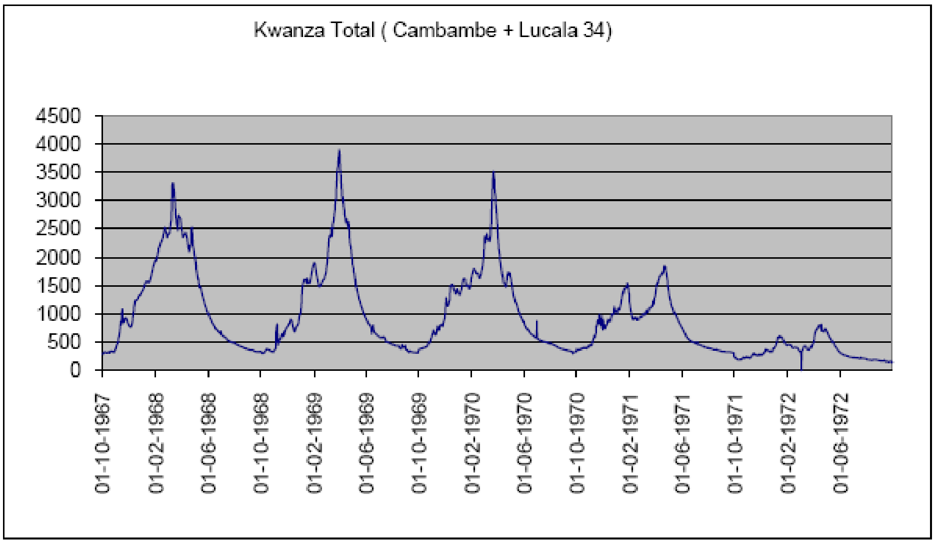


Figure 4.10: Hydrogram of flooding of the Kwanza River, with values recorded at the Cambambe and Kilómeter 34 (Lucala River) hydrometric stations between 1967 and 1972.
source: Department of Resource Planning of the National Directorate for Water Resources, State Secretariat of Waters.

4.1.7.7.1 . CALCULATION OF THE CURRENT FLOWS OF FLOODS FOR 1,000 AND 10,000 YEARS

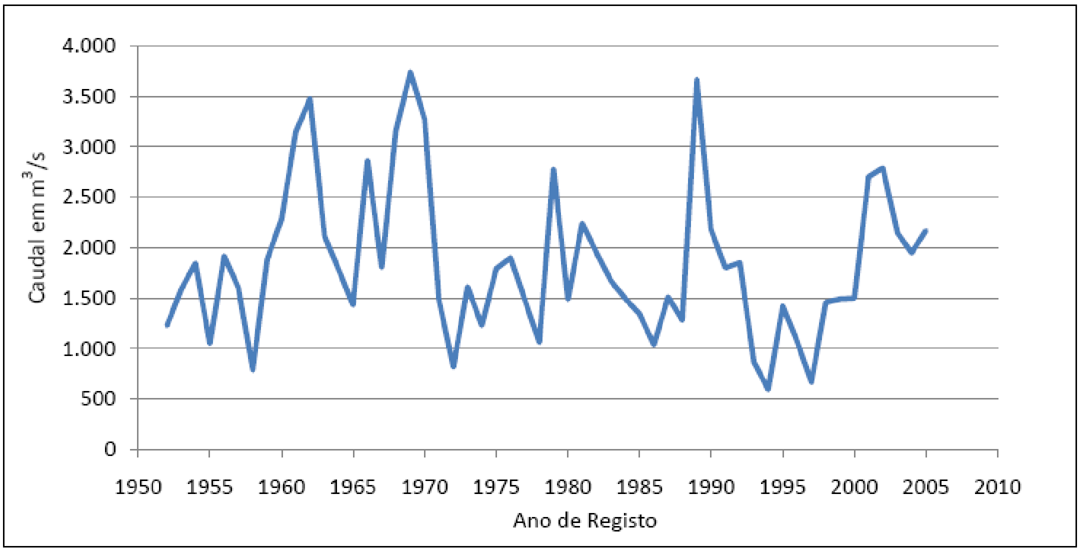
The data of the streams of maximum floods have been taken from the Report on Water Studies, Evaluation of the Flood of the hydroelectric use of Cambambe, produced by the company ENGEVIX, in 2009. These data have been arranged in chronological order (Table 4.16 and appears in 4.11).

Table 4.16 : Chronological Arrangement of a series of Records of the currents at Maximum flood.

Year of Record	Flow in m³/second
1952	1.228
1953	1.586
1954	1.846
1955	1.051
1956	1.918
1957	1.604
1958	787
1959	1.880
1960	2.283
1961	3.149
1962	3.477
1963	2.114
1964	1.779
1965	1.432
1966	2.864
1967	1.804
1968	3.158
1969	3.740
1970	3.270
1971	1.487
1972	816
1973	1.612

Year of Record	Flow in m³/second
1974	1.229
1975	1.790
1976	1.900
1978	1.060
1979	2.778
1980	1.487
1981	2.240
1982	1950
1983	1.670
1984	1.496
1985	1.344
1986	1.040
1987	1.510
1988	1.280
1989	3.668
1990	2.180
1991	1.800
1992	1.850
1993	865
1994	596
1995	1.424
1996	1.076
1997	666
1998	1.456
1999	1.492
2000	1.500
2001	2.700
2002	2.790
2003	2.148
2004	1.949
2005	2.168

Year of Record	Flow in m³/second
Total	98.087,00
Q Mean	1.850,70



Year Recorded

Figure 4.11: Chronological Graph of flood maxima.

The Foster - Hazen method has been used for the calculations of the river flow volume at 1,000 and 10,000 year intervals. It is a good method for the statistical analysis of the maximum floods. For this purpose data were used observed during 53 years (1952 - 2005).

On the basis of the value of the average flood flow calculated, and of the values of the Foster-Hazen scale, the 10.000 year flood flow has been calculated. Table 4.17 shows the values of the table of Foster-hazen , for the corrected coefficient of asymmetry (Ca'), the coefficient of dispersion (Cd) and of the average annual (Q/Mq) that have been used for the calculation of the values for the 10,000 year interval (V). The calculations were done using the following formula:

$$V = \frac{Q}{Qm} (-) 1$$

The coefficients of dispersion (Cd) are calculated using the following formula, where V represents the 10,000 year flow and n represents the number of years observed:

V² total

$$Cd = \frac{}{n - 1}$$

The coefficient of asymmetry (Ca) or of obliqueness was calculated using the following formula:

$$Ca = \frac{V^3 \text{ total}}{(n - 1) \times Cd^3}$$

The corrected coefficient of asymmetry (Ca´) was calculated using the following formula:

$$Ca' = Ca\left(1 + \frac{8,5}{n}\right)$$

Table 4.17: Values of the table of Foster-hazen for the corrected coefficients of asymmetry and of dispersion and of the annual average current flow for the calculation of the deca-millennial flood frequency (every 10,000 years).

Percentage of Time (%)	Corrective Asymmetry Coefficient	Dispersion Coefficient	Mean Annual Flow
	Deviation, Ca' = 1.4	CD Deviation = 0.401	Q/Qm
0.1	8.66	4.72	1,850.70

On the basis of the data of Table 4.17 the average deca-millenial flow (10,000-year period) equal to the 8,735 , 3 m^3 /s (Q0,01 = 4,72 x 1.850,70 m^3 /s) has been calculated. The value obtained was rounded up to <u>Q0,01 = 8.800,00 m^3 /s.</u>

On the basis of the value of the average flow calculated and of the values of the scale of Foster-hazen , the 1000-year flow (millennial) has been calculated. Table 4,18 shows the values of the table of Foster-hazen , of the coefficient of asymmetry corrected (Ca'), the coefficient of dispersion (Cd) and of the average annual (Q/Qm), for the calculation of this flow.

Table 4.18: Values of the table of Foster-hazen for the coefficients of asymmetry corrected and of dispersion and of the caudal annual average for the calculation of the decal (a period of return of 1,000 years).

Percentage of Time (%)	Corrective Asymmetry Coefficient	Dispersion Coefficient	Mean Annual Flow
	Deviation, Ca' = 1,4	DC Deviation = 0.401	

0.1	5.91	3.72	1,850.70

On the basis of the data of Table 4.18, an average flow equal to 6.884,60 m³ /s (Q0,1 = 3,72 x 1.850,70 m³ /s) was calculated. The value obtained was rounded up to <u>Q0,1 = 6,900.00 m³ /s.</u>

In view of the result obtained by means of the calculation of the current flow going back thousands of years and which are connected with the number of records of the streams of maximum full Table (4,16) it is possible to project the probability of occurrence of floods in the system in the course of time which is part of the Use of Water Cambambe as will be seen in Figure 4.12 . The probability of occurrence of floods with value more than 3,000 m3/s is of approximately 15 %. THE Figure 4.12 also illustrates the effectiveness to 500 m3/s is established with a probability of occurrence of 98 %.

Probability curve for the occurrence of floods.

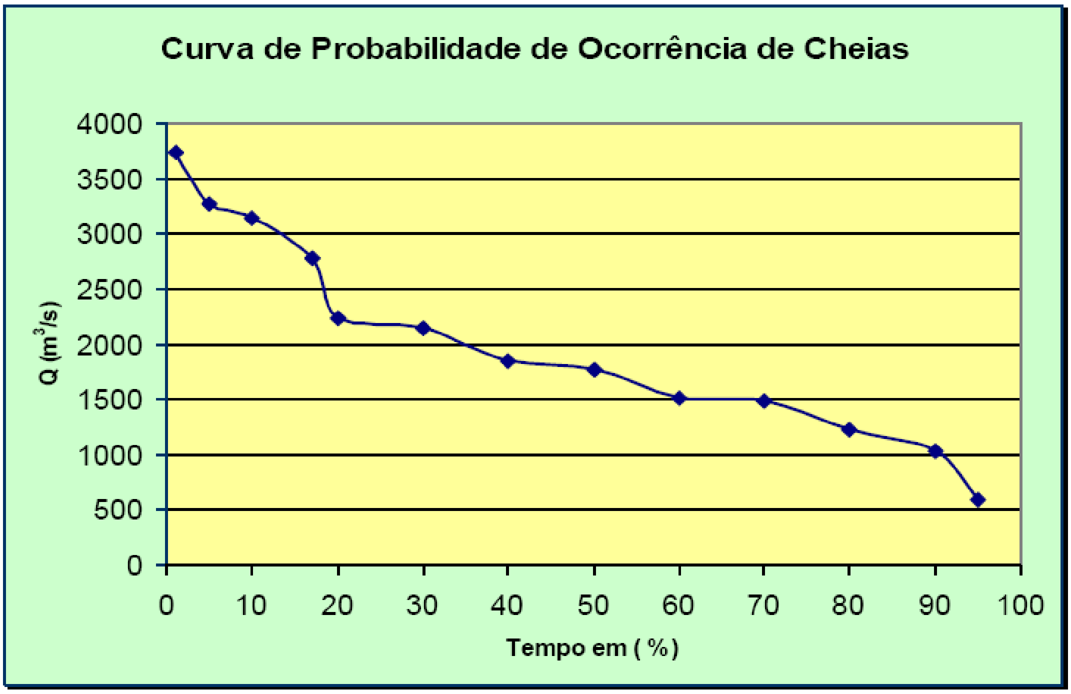


Figure 4.12: Probability curve for the occurrence of floods.

4.1.7.7.2 . Water Balance

THE water balance of any water catchment area depends on the standard of atmospheric precipitation annual, as well as of other factors and natural processes that include variations in temperature which controls the rates of evaporation and evapotranspiration of the quantity and the time of occurrence of surface outlets, vegetative cover and other factors..

THE water within the hydrological cycle has to obey the Law of Conservation of Mass. So, the equation of the water balance is the fundamental equation that "records" the whole of water (volume) in a particular region (the catchment area), and can be verbally expressed as:

"The amount of water that shall enter at a control point of the volume for a certain period of time (Entry,E), less the quantity of water subtracted from the volume controlled in the section of entry for the same period of time (discharge, D), it is equal to the alteration of the volume of water stored (∆A) during the period of time". In other words:

$$\Delta \mathbf{A} = \mathbf{E} - \mathbf{D}.$$

In the context of this work, the Water Balance of the area directly affected by the heightening of the Cambambe Dam, that is, the area upstream. For the area indirectly affected by the heightening of the dam, data will be presented indicative of the annual consumption by the main users of Water Resources of the Water catchment area of the Kwanza.

In the specific case of the area of influence of the Cambambe dam, climatic parameters such as the annual precipitation (rain), temperatures, evaporation / evapotranspiration, type of vegetation, deep infiltration, as well as the consumption of water from the lake behind the dam for various uses, are the main factors in the calculation of the water balance.

There is very little information on the losses of water by deep infiltration, which takes place in the area of the lake at Cambambe. In the light of the information we have on deep geological formations that occur in the area of the Cambambe dam, it is assumed that 10% of the annual volume of water that comes to the lake, will be lost to deep infiltration.

For the calculation of the water balance we have the following annual values:

• Annual input of water: 39.090,80 million m³;

• Annual Volume consumed for the supply of Vila de Cambambe: 1,070 million m³;

• Annual evaporation from the lake Cambambe (1,3 km² x 1,349 mm): 1,754 million m³;

• Loss of water by deep infiltration: 3.013,1 billion m³.

$$\Delta \mathbf{A} = \mathbf{36{,}074.90\ million\ m^3.}$$

4.1.7.8 . CHANGES UPSTREAM AND DOWNSTREAM

The heightening of the Cambambe dam will cause an enlargement of the area of the lake of approximately 5,5 km². The enlargement of the lake will have the following consequences:

a. the disappearance of Kiamangufo beach, an area of leisure heavily used by the local populations;
b. the flooding of the bridge (bridge of Kiamangufo) which links the Dondo the Munenga;
c. the complete flooding of the water capture station of the Village de Cambambe;

d. flooding of the fields of agricultural crops existing at or below the altitude of 130 meters.
e. the movement of animals that exist are in the upstream part of the lake.

4.1.8 . QUALITY OF THE WATER

A study will be done of the current situation of the quality of the water of the river system, and of the water catchment area of the Kwanza River (Section of Cambambe). This situation will be considered as a reference, and will be basis on which against future situations at the level of the water catchment area of Cambambe will be measured. In this section the intention was to achieve the following objectives:

- Determine the quality of water at the Cambambe Dam;
- Collect data, physical-chemical, biological, environmental and anthropic, that can have an influence on the quality of the water; and
- To assess the impact of the heightening on the quality of water, to analyze the interconnections which may result from the process of rehabilitation and increased Water Use at Cambambe.

4.1.8.1. HISTORY

The lack of data relating to the quality of water for the basin of the lower Kwanza River (Section of Cambambe), has created a situation where the greater part of the database used in this work was directly related to the sampling carried out in the field. At the same time as the basis of comparison, has been the use of the research bibliography, available in the various formats.

On the basis of a few experiences and comparisons with other water catchment areas, a prediction was made of possible impacts which could occur in the future, as a result of the process of rehabilitation and expansion that will take place at the Cambambe dam.

4.1.8.2. Kwanza River–Cambambe Section

Table 4,19 illustrates the points of sampling of the river with their respective coordinates.

Table 4.19: Samples and their respective coordinates.

Sampling Point	Location	River	Latitude	Longitude
CAMD1	Cambambe	Kwanza	09°45’ 28,30’’	14°30’ 39,00’’
CAME1	Cambambe	Kwanza	09°45’ 33,50’’	14°30’ 34,70’’
CAMC1	Cambambe	Kwanza	09°45’ 33,80’’	14°30’ 33,80’’
CAMD2	Cambambe	Kwanza	09°45’ 19,60’’	14°29’ 34,80’’
CAMC2	Cambambe	Kwanza	09°45’ 28,80’’	14°29’ 31,60’’
CAMB2	Cambambe	Kwanza	09°45’ 27,76’’	14°29’ 44,90’’

CAMD3	Cambambe	Kwanza	09°41’ 36,50’’	14°25’ 25,22’’
CAME3	Cambambe	Kwanza	09°41’ 43,10’’	14°25’ 26,10’’
CAMC3	Cambambe	Kwanza	09°41’ 41,38’’	14°25’ 25,10’’
CAMDD3	Cambambe	Kwanza	09°41’ 36,50’’	14°25’ 25,22’’
CAMEE3	Cambambe	Kwanza	09°41’ 43,10’’	14°25’ 26,10’’

Legend:
CAMD1 – Right bank Point 1 (Upstream)
CAME1 – Left bank Point 1 (Upstream)
CAMC1 – Center of Channel Point 1 (Upstream)
CAMD2 – Right bank Point 2 (Upstream)
CAMC2 – Center of Channel Point 2 (Upstream)
CAMB2 – Branch of the River Left bank(Upstream)
CAME3 – Left bank Point 3 (Downstream)
CAMC3 – Center of Channel Point 3 (Downstream)
CAMDD3 – Right bank Point 3 (Downstream) – Coliforms
CAMEE3 – Left bank Point 3 (Downstream) – Coliforms

The points presented in the table above are illustrated in Figures 4.12 and 4.13, and are the first sampling sites located upstream and the second points located downstream.

Figure 4.13: Image with projection of the sampling points downstream from AH.

Figure 4.14: Image with projection of the sampling points upstream from Camambe dam.

4.1.8.3. IDENTIFICATION OF THE PARAMETERS AND QUALITY INDICATORS OF WATER

Water contains, generally, various components, which come from the natural environment or are introduced from human activities. In order to characterize the water, there are certain parameters, which represent the physical, chemical and biological properties of water. These parameters are indicators of the quality of the water and are impurities when they achieve higher values to those established for a particular use Table (4,20).

Table 4.20: List of parameters and indicators of water quality chosen to represent each point.

Indicator number	Name of Indicator	Sampling points		
		Upstream		Downstream
		CAMD1 CAMC1 CAME1	CAMD2 CAMC2 CAMB2	CAMD3 CAMC3 CAME3
1	Aspect	×		×
2	pH	×	×	×
3	Temperature	×	×	×
4	Turbidity	×	×	×
5	Dissolved Oxygen (OD)	×	×	×

Indicator number	Name of Indicator	Sampling points		
		Upstream		Downstream
		CAMD1 CAMC1 CAME1	CAMD2 CAMC2 CAMB2	CAMD3 CAMC3 CAME3
6	Total Dissolved Solids (TDS)	×	×	×
7	Conductivity	×	×	×
8	Dry Residue	×		×
9	Total Alkalinity	×		×
10	Total Hardness	×		×
11	Oxidability	×		×
12	Free Carbon Dioxide	×		×
13	Acidity	×		×
14	Chlorates	×		×
15	Sulfates	×		×
16	Bicarbonates	×		×
17	Nitrates	×		×
18	Nitrites	×		×
19	Ammoniac Nitrogen	×		×
20	Phosphates	×		×
21	Fluorides	×		×
22	Sodium	×		×
23	Potassium	×		×
24	Calcium	×		×
25	Magnesium	×		×
26	Manganese e	×		×
27	Aluminum	×		×
28	Silicon	×		×
29	Total Coli forms	×	×	×
30	Fecal Coliforms	×	×	×
31	Fecal streptococcus	×		×
32	Sulfite Reducing Clostridiums	×		×
33	Colonies a 37ºC e 22ºC	×		×

Indicator number	Name of Indicator	Sampling points		
		Upstream		Downstream
		CAMD1 CAMC1 CAME1	CAMD2 CAMC2 CAMB2	CAMD3 CAMC3 CAME3
34	Iron	×	×	×
35	Zinc	×	×	×
36	Nickel	×	×	×
37	Chromium	×	×	×
38	Cadmium	×	×	×
39	Lead	×	×	×
40	Mercury	×	×	×

In order to cover the main characteristics of the river system (Section of Cambambe), it may be judged necessary to establish various parameters and indicators of water quality. However, three points for the collection of samples, (items 1 and 2, the amount and point 3, downstream), used a sample size of 40 (see Table 4,20).

4.1.8.4 . METHODOLOGY

For the drawing up of this section a varied methodology has been used that included the items described below.

4.1.8.4.1 . REVIEW OF THE LITERATURE

An extensive review of the literature available was undertaken to obtain a maximum of the information available on the background of the environmental basin.

4.1.8.4.2 . FIELD STUDIES

Field studies were carried out with the objective to measure, in situ, some of the physical parameters of the analysis of the quality of the water, for example: (pH, oxygen content, Conductivity, Temperature, Salinity).

Field studies were also used as an opportunity to do the sampling of the waters of the section of the river which was visited. The collection of samples of water was made with containers of two (2) liters for analysis of bromine ions in the majority and 0,5 liters for microbiological analyses and analysis for detection of heavy metals.

Samples were taken from the downstream side in relation to the dam, including two (2) points of auxiliary collection for the carrying out of analyses for total intestinal coliforms at each point.

Sampling was done in such a way that not just the surface level of the water was sampled but also a sample was taken at about 50 cm depth in order to maintain the sample homogeneous.

The physical parameters were measured, in situ, using a multiparametric ultrasonic probe, portable model, waterproof Cyber Scan 600 Series from Etch Instrumentos. While the turbidity, also determined in situ, was measured with the turbidimeter TN-100 from Eutech Instrumentos.

4.1.8.4.3. LABORATORY TESTS

These laboratory tests were made with the aim of determining the concentrations of indicators chemical, biological and inorganic compounds (heavy metals) inherent in the analysis of the quality of the water, such as: Magnesium, Calcium, Silicon, iron, manganese, Sodium, potassium, aluminum, Chlorine; hardness, Alkalinity, Phosphorus, Sulphates, Nitrates, Nitrites and ammonia, coli total and fecal material, fecal streptococci, were submitted to the laboratory of the Sonangol. For the determination of heavy metals samples have been sent to the Analytical Laboratory Services in Namibia (see results in Annex 5).

In the case of turbidity, pH, Conductivity and dissolved oxygen there was an opportunity to compare the results obtained in situ with the measurements taken the level of laboratory, and the values were very similar.

4.1.8.4.4 . PARAMETERS ANALYZED

Before turning to the presentation of the results themselves, a brief description for each indicator divided into groups will be presented. The main indicators of water quality are presented and separated under the physical, chemical and biological.

4.1.8.4.4.1 . PHYSICAL PARAMETERS

• **Temperature:** measure of the intensity of heat; it is an important parameter, because of its influence on some of the properties water (density, viscosity, oxygen dissolved), with an impact on the aquatic life. The temperature may vary according to the natural sources (solar energy) and anthropogenic sources (industrial waste and industrial waters of to cool machinery). The temperature has an important role in the control of the aquatic environment, and can influence certain physical and chemical parameters. The surface superficial is influenced by factors such as latitude, altitude, season of the year, rate of flow and the depth. So the water temperature has influence directly on a number of aquatic organisms and on the content of gases dissolved in water above all the oxygen and the carbon dioxide (White, 1986).

• **Taste and odor:** are the result of natural causes (algae; vegetation in decomposition; bacteria; fungi; organic compounds such as sulfide gas, sulphates and chlorides) and artificial causes (domestic sewage and industrial wastes). The standard of potability: water completely odorless.

• **Aspect:** is the result of the fact that, in the water, there can be substances in solution; this may be caused by the iron or manganese, by the decomposition of organic matter of water (mainly plants), the seaweed or by the introduction of sewage industrial and domestic. Standard of potability: intensity of color of less than 5 units.

• **Turbidity:** is the result of the presence of suspensions in the water, as clay, silt, finely divided organic substances, microscopic bodies and other particles. According to White (1986) when we speak about the quality of water, turbidity, in addition to be an aesthetic requirement is also a requirement of health.

• **Total of dissolved solids (TDS):** represents the sum of all the material that is not volatile at a temperature of more or less 105°C. These solids in general, are composed of clay, sand, organic matter, mineral salts and metals. This parameter is of extreme importance, because all of the impurities, with the exception of the gases dissolved, are considered to be solids suspended in bodies of water. The very high concentrations of solid in suspension to reduce the passage of sunlight, affect aquatic life and undermine the food chain (Tavares, 2005).

The variables described above, in addition to working against the quality of the rivers, are the most influenced by the seasons of the year. Carvalho et al. (2000). There is a significant relationship between the increase in temperature of the water and the solids suspended with the electrical conductivity.

• **Electrical Conductivity:** capacity that the water has to conduct electricity. This parameter is related to the presence of ions dissolved in water, which are electrically charged particles. The more the quantity of ions dissolved, the greater the electrical conductivity in water (Bernardo, 1995).

4.1.8.4.4.2. CHEMICAL PARAMETERS

• **Ph:** represents the balance between ions H+ and ions OH; varies from 7 to 14; indicates whether a water is acidic (pH inferior a 7), neutral (pH equal to 7) or alkaline (pH greater than 7); the pH of the water depends on their origin and natural characteristics, but may be amended by the introduction of waste; low pH makes the water corrosive; waters with high pH tend to form encrustations in the pipes; the aquatic life depends on the pH, and 6 to 9 is the comfortable level for living things. Ph is an important factor in the aquatic ecosystem, because it is capable of determining the dissolution, precipitation, oxidation and reduction of various substances (Bour & Loch, 1995; Gill, 1996; Weirner, 2000).

• **Alkalinity:** caused by alkali salts, especially of sodium and calcium; is the capacity of the water to neutralize acid; at high levels, it imparts an unpleasant taste to water, and has an influence on the processes of water treatment. The main portion of alkalinity in natural waters is caused by hydroxides, carbonates and bicarbonates (Apha et al., 1995)

• **Hardness:** is the result of the presence, in particular, of alkali salts (calcium and magnesium), or of other bivalent base metals, to a lesser extent, in high levels; the unpleasant taste and laxative effects; reduces the foam of soap; leads to encrustations in pipes and boilers. Classification of water, in terms of hardness (in CaC03):

- ✓ less than 50 mg/1 CaC03 – soft water;
- ✓ between 50 and 150 mg/1 CaC03 – moderately hard;
- ✓ between 150 and 300 mg/1 CaC03 – hard water; and
- ✓ greater than 300 mg/1 CaC03 – very hard water.

• **Calcium (Ca):** Calcium can be involved in a series of chemical reactions, including ionic exchange, precipitation and fixation, but its role is still not well defined. It appears that reduces the harmful effects of other ions, and in particular sodium and magnesium, when absorbed by roots (Paganini, 1997). It also interacts with magnesium and potassium in high concentrations, and may lead to the deficiency of both in plants (Days & Álvarez, 1996). For that reason, it is important to know the concentration of calcium in water in relation to sodium to assess the quality of the water for irrigation, one of the main constituents of the superficial and underground waters, has its origin in the breakdown of rocks and ionic exchange capacity of soils. Calcium + magnesium is the hardness of the water which can have an impact on cardiovascular diseases.

• **Magnesium (Mg):** Magnesium has an activation effect on the enzymes of the vegetative system of plants and has an important role in the photosynthetic activity because it forms part of the core of the molecule of chlorophyll "a" (Malavolta, 1981). In the meantime, in accordance with Ayres & Westcot (1991), the productivity of crops would appear to be less in the soil with high levels of magnesium, or when they are irrigated with waters that contain high levels of this element, even when the infiltration is adequate. This could possibly be due to deficiency of calcium induced through an excess of exchangeable magnesium in the soil. It is an indispensable element to man. Magnesium has laxative effects when in high concentrations.

• **Chlorides:** The chlorides, generally, come from the dissolution of minerals or of the intrusion of seawater; they can also emanate from domestic sewage or industrial waste; in high concentrations, they impart a salty taste to water or laxative properties (Philippi, et al., 2004).

• **Iron and manganese:** may come from the dissolution of compounds of the soil or from industrial wastes; causes red coloring, in the case of iron, or brown, in the case of manganese, of tarnishing stains clothes and other industrial products; they give a metallic taste to the water; the rusty water favors the development of the iron bacteria, which cause bad smell and color and can also obstruct pipes.

• **Nitrogen:** Nitrogen may be present in water in various forms: molecular, ammonia, nitrites, ammonium nitrate; it is an indispensable element to the growth of algae, but, in excess, can bring about an excessive development of those bodies, so-called phenomenon of eutrophication; the ammonium nitrate, in the water, can cause metemoglobinemia (a blood disease); ammonia is toxic to the fish; causes of the increase of nitrogen in the water are: domestic sewage and industrial waste, fertilizers, droppings of animals.

• **Phosphorus:** it has been in the water in the forms of orthophosphate, polyphosphate and organic phosphorus; it is essential for the growth of algae, but, in excess, causes eutrophication; its main sources are: dissolution of compounds in the soil; decomposition of organic matter, domestic sewage and industrial waste; fertilizers; detergents; droppings of animals.

• **Fluorides:** the fluorides have beneficial action for the prevention of tooth decay; in higher concentrations, may bring about changes in the bone structure or dental fluorosis (dark spots in the teeth).

• **Dissolved Oxygen:** it is essential for aerobic organisms; the water, in normal conditions, contains dissolved oxygen, whose degree of saturation depends on the altitude and of the temperature; waters with low levels of dissolved oxygen indicate that they have received organic matter; the decomposition of organic matter for aerobic bacteria is, generally, accompanied by the consumption and reduction of the dissolved oxygen of water; depending on the ability of purifying properties of the wealth, the content of dissolved oxygen can achieve very low values, or zero, extinguishing the aerobic aquatic organisms.

• **Organic matter:** the organic matter of the water is needed for the heterotrophic organisms, in their nutrition, and for the autotrophic ones as well, as a source of salts, nutrients and carbon dioxide; in large quantities, however, they may cause some problems, such as: color, odor, turbidity, consumption of the oxygen dissolved by the decomposing organisms.

Oxygen consumption is one of the most serious problems of the increase of the organic matter content, because it causes ecological imbalances, and may cause the extinction of the aerobic organisms. Generally, two indicators are used for the organic matter content in the water: Biochemical Demand for Oxygen (DBO) and Chemical Oxygen Demand (DQO).

• **Organic Components:** some organic components of water are resistant to biological degradation and can accumulate in the food chain; among these, are pesticides, some types of detergents and other chemical products, which are toxic.

4.1.8.4.4.3. HEAVY METALS

The heavy metals are inorganic micro polluters from, for the most part, from industrial effluents and are highly toxic to aquatic life. The main heavy metals present in water are dissolved cadmium, chrome, lead, mercury, nickel and zinc. In general, the concentrations of heavy metals in water are far short of quality standards laid down. On the other hand, the trend of heavy metals is to join the solid in suspension which, in turn, sedimentate to the bottom of the body of water.

One attempts to analyze the concentrations of heavy metals in the sediment, whose values can be significant and represent a threat to the biota and, consequently, to the human being, who is at the top of the food chain. The heavy metals, aside from being toxic, can accumulate in the body and can lead to different types of human disease with the ingestion of small doses, over considerable periods of time. The metals are measured, generally, in milligrams per gram or micrograms per gram, expressed in dry weight.

4.1.8.4.4.4. BIOLOGICAL PARAMETERS

Bacteria in the coliform group are used as a biological indicator of the quality of the water. The contamination of water by human feces and/or animal blood can be detected by the presence of bacteria of this group. From known relations between the results of coliform feces and streptococcal feces you can have an indication of whether the fecal material present in the water is of human origin or animal.

When the values to submit a relationship less than one (colony-forming units/100 ml) indicates that the wastes are mainly of domestic animals. If the values are higher than the four (colony-forming units/100 ml) the possible origin is linked to human waste. When the relationship is in the band between the two values the interpretation is dubious. However, there are some restrictions for the interpretation suggested.

The coliform group of bacteria is divided as an indicator of fecal contamination in the following way:

A) total Coliforms (fecal and not fecal);
B) coliform (fecal); and
C) streptococcus (fecal).

In the intestine of human beings and animals there is a large amount of coliform bacteria. To have an idea, an individual eliminates on average, 10 billion coliforms per day. In addition, there are, other intestinal bacteria, viruses, protozoa and worms, in figures significantly lower. In the intestine, pathogenic agents can live, that are harmful to humans, as some types of bacteria that can cause strong diarrhea, fever, nausea and cholera, some types of protozoa, responsible, including, for malaria and dangerous virus that can lead to infectious hepatitis, gastro-enteritis, yellow fever, malaria and infantile paralysis.

4.1.8.4.4.5. FINAL RESULTS

The final results on the quality of the water will be presented on the basis of the position of each point of sampling.

It should be noted that at the river beach which is close to the points CAMD1, CAMC1 and CAME1, anthropic action is a significant factor for solid waste and for bathing. On the other hand, on the other bank of the river one can find high concentrations of heavy metals deposited in the sands of the river beaches from, probably, the Capanda dam(see Photograph 4.11).

DARK HEAVY METALS

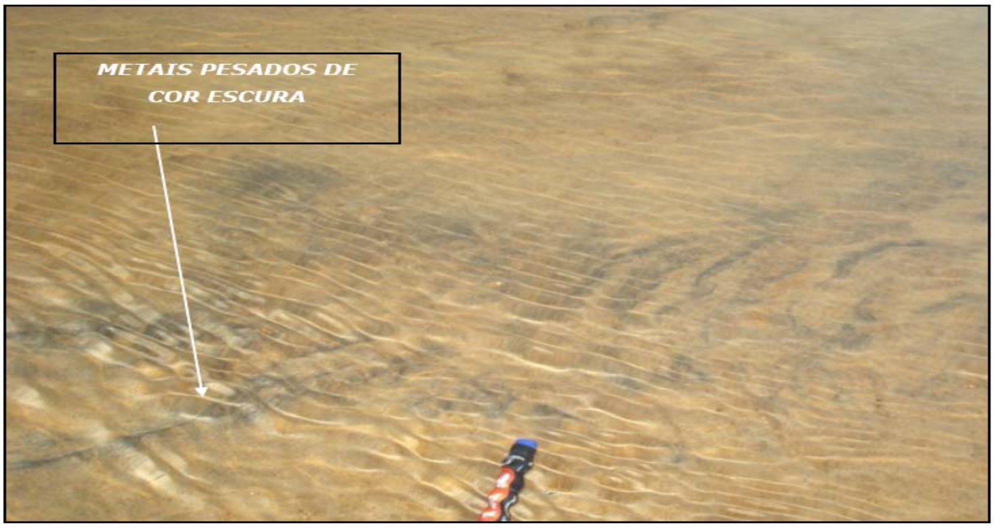


Photo 4.11: Photograph demonstrating the concentration of heavy metals upstream from the de Cambambe dam.

The values for heavy metals at the points CAMD1, CAMC2 e CAMB2 (upstream) are presented in Table 4.21.

Table 4.21: Heavy metal concentrations.

Description	**Value**		
Sampling Point	**CAMD1** (Right Bank)	**CAMB2** (Left bank)	**CAMC2** (Central Channel)
Iron	0,4 mg/l	0,2 mg/l	0,8 mg/l
Zinc	0,01 mg/l	0,03 mg/l	0,01 mg/l
Nickel	<0,01 mg/l	<0,01 mg/l	<0,01 mg/l
Chromium	<0,01 mg/l	<0,01 mg/l	<0,01 mg/l
Description	**Value**		
Cadmium	<0,01 mg/l	<0,01 mg/l	<0,01 mg/l
Manganese	<0,04 mg/l	<0,04 mg/l	<0,04 mg/l
Aluminum	0,05 mg/l	0,05 mg/l	0,05 mg/l
Lead	<0,01 mg/l	<0,01 mg/l	<0,01 mg/l
Mercury	<0,01 mg/l	<0,01 mg/l	<0,01 mg/l

The value of the concentration of Iron in point CAMD1 is above the maximum permissible value, in point CAMB2 presents the maximum ceiling of (see Figure 4.15), when compared with standard of the European Union (U. E.) and World Health Organization (WHO) and that the concentrations of cadmium and mercury are above the maximum ceiling of. The other values are within the standards of the World Health Organization and the European Union (see table in Annex 3).

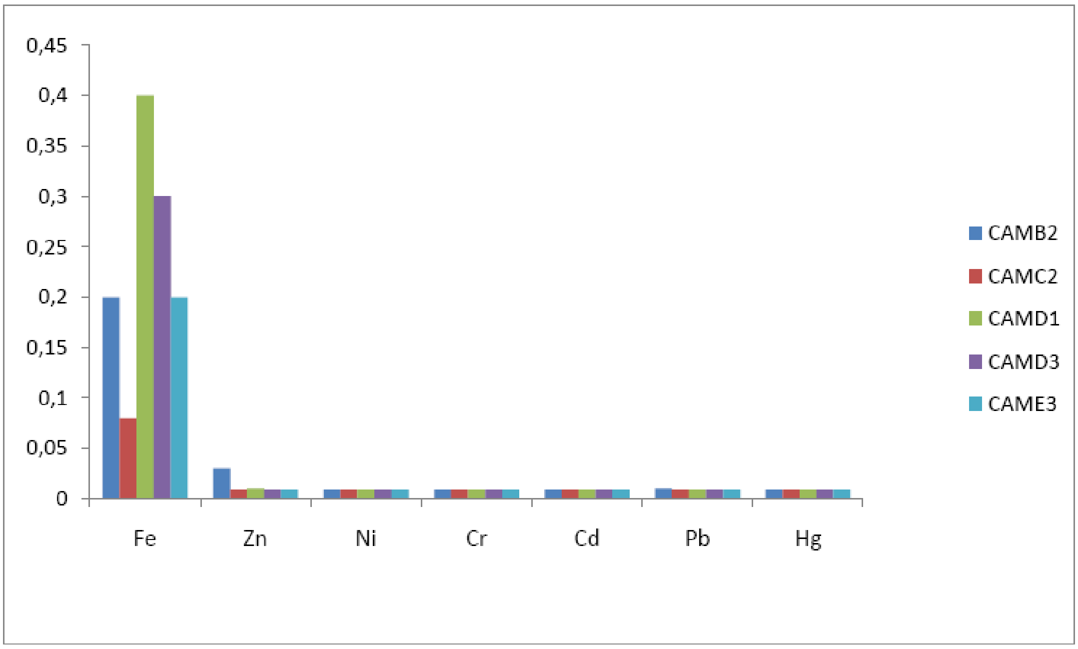


Figure 4.15: Graph showing the heavy metals in the various samples.

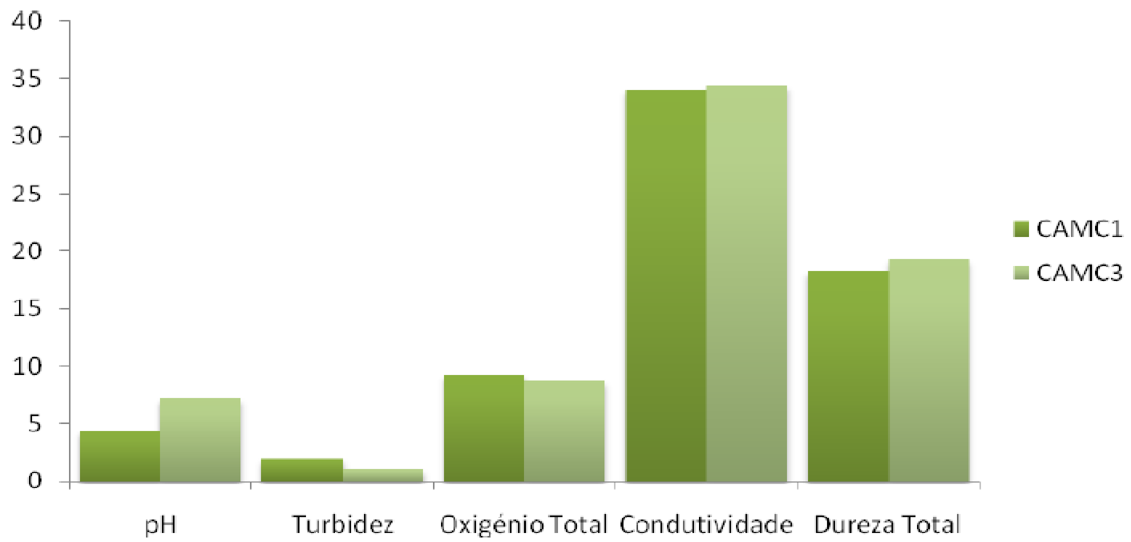
Table 4.22: Physical-Chemical Parameters for the CAMC1 sample corresponding to the center Profile 1.

Sample CAMC1-Profile-1	**Physical-Chemical Parameters**		
Parameter	**Unit**	**Result**	**Permitted Intervals (WHO)**
Appearance		limpid	
pH		4.42	6.5 - 8.5
Turbidity		2	<5 NTU
Dissolved Oxygen		9.27	<75
Conductivity	µS/cm	53	250
Total Solids in Suspension (105ºC)	mg/l	< 15	
Total Dissolved Solids (105ºC)	mg/l	< 15	
Dry Residue (180ºC)	mg/l	77	1.200
Total Alkalinity	mg/l	27.9	
Total Hardness	mg/l	18.3	500
Oxidability	mg/l	3.54	
Free Carbon Dioxide	mg/l	1.1	
Acidity	mg/l	2.5	
Chlorides	mg/l	1.77	600
Sulfates	mg/l	< 1.57	400
Bicarbonates	mg/l	34.1	
Nitrates	mg/l	< 1.1	50
Nitrites	mg/l	< 0.02	
Amoniacal Nitrogen	mg/l	< 0.15	

Sample CAMC1-Profile-1	Physical-Chemical Parameters		
Parameter	**Unit**	**Result**	**Permitted Intervals (WHO)**
Phosphates	mg/l	< 0.40	
Fluorides	mg/l	< 0.46	1.7
Sodium	mg/l	3.7	
Potassium	mg/l	1.3	
Calcium	mg/l	4.2	200
Magnesium	mg/l	1.9	150
Manganese	mg/l	< 0.04	0,1
Aluminum	mg/l	0.05	0,2
Sílica	mg/l	13.3	

The average values of the Physical Parameters at the points shown in Figure 4.16 (CAMC1 and CAMC3) were as follows: Aspect-limpid. pH-4.42. Dissolved oxygen (7.8 mg/l). Oxidability (3.54 mg/l). Electrical Conductivity (34.7 μS/cm). Turbidity (2NTU). Temperature (23.8^{o}C) and Total Dissolved Solids (30.7 mg/l).

The values of the Physical Parameters are within the permissible limits established by the World Health Organization for Water Quality except for the pH. Which is acid (Figure 4.16).



pH	Turbidity	Oxygen Total	Conductivity	Hardness Total

Figure 4.16: Graph showing the behavior of Physical Parameters measured at two points.

The following values were obtained for the Chemical Parameters: Free Carbon Dioxide (1.1 mg/l). Acidity (2.5 mg/l). Dry Residues 180ºC (77 mg/l). Sulfate (1.57 mg/l). Chlorides (1.77 mg/l). Nitrate (<1.11 mg/l). Nitrite (0.02 mg/l). Amoniacal Nitrogen(0.02 mg/l). Fluorides (<0.46 mg/l). Silica (13.3 mg/l). Phosphates (0.40 mg/l). Alkalinity (27.9 mg/l). Hardness (18.3 mg/l). Calcium (4.2 mg/l), Magnesium (1.9 mg/l). Sodium (3.7 mg/l).

Potassium (1.3 mg/l). Manganese (<0.04 mg/l). Aluminum (0.05 mg/l) and Bicarbonate (34.1 mg/l).

Comparison (Figure 4.17) of the Chemical Parameters reveals that they are within the specifications of the World Health Organization for water quality.

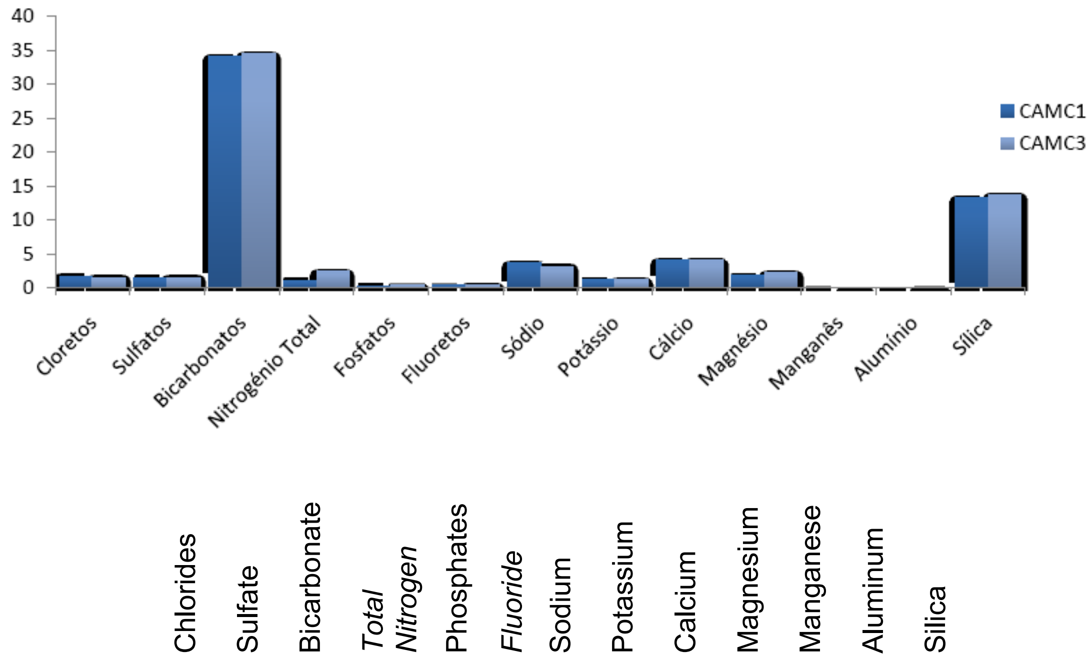


Figure 4.17: Graph showing the behavior of Physical Parameters measured at two points.

The values obtained for the Microbiological Parameters are shown in Table 4.23 below.

Table 4.23: Microbiological Parameters for sample CAMC1.

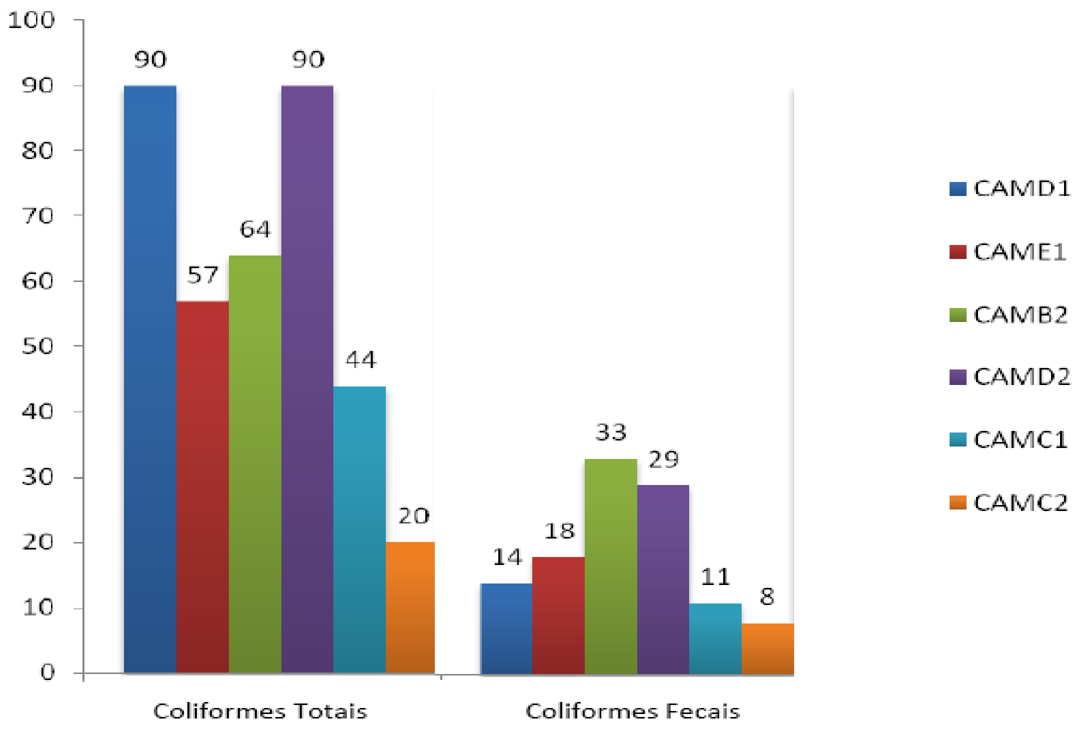
Sample CAMC1	**Bacteriological Parameters**			
Parameter	**Unit**	**Result**	**VMA**	**Analysis Method**
Total Coliforms	CFU/100 ml	44	0	ISO 9308 - 1 [MF]
Fecal Coliforms	CFU/100 ml	11	0	ISO 9308 - 1 [MF]
Fecal Streptococci	CFU/100 ml	43	0	ISO 7899 - 2 [MF]
Sulphide reducing Colistridia	CFU/20 ml	>1	0	PN - EN 26461 - 1
Colonies at 37ºC	CFU/1 ml	>300	10	ISO 6222
Colonies at 22ºC	CFU/1 ml	>300	100	ISO 6222
		CFU	Colony Forming Units	
		PN-EN	Portuguese Norm / European Norm	
		ISO	International Standards Organization	
		MPV	Maximum Permitted Value	

Comparison of the Microbiological Parameters reveals that they are not within the specifications of the World Health Organization for water quality suggesting the existence of bacterial contamination. The values obtained for the auxiliary sampling points upstream are set out in Table 4.24.

Table 4.24: Coliform values for the five upstream samples.

Sampling Points	Units	Total Coliforms	Fecal Coliforms
CAMD1	CFU/100 ml	>80	14
CAME1	CFU/100 ml	57	18
CAMB2	CFU/100 ml	64	33
CAMD2	CFU/100 ml	>80	29
CAMC2	CFU/100 ml	20	8

The values obtained for total and fecal coliform concentrations (Figure 4.18) do not comply with the norms established by the World Health Organization suggesting the existence of a certain degree of contamination.



Total Coliforms Fecal Coliforms

Figure 4.18: Graph showing anomalous behavior of the microbiological parameters.

At the sampling points downstream from the dam (CAMD3 and CAME3) anthropic action is revealed to be on a large scale and takes the form of discharging solid residues into the channel and on the banks of the river, washing clothes and bathing in the river. The values obtained for heavy metal concentrations at sampling points CAMD3 and CAME3 are set out in Table 4.25.

Table 4.25: Results of heavy Metal Analyses

Sample	CAMD3		CAME3
Parameters	**Units**	**Values**	**Values**
Iron (Fe)	mg/l	0,8	0,2
Zinc (Zn)	mg/l	<0,01	<0.01
Nickel (Ni)	mg/l	<0.01	<0.01
Chromium (Cr)	mg/l	<0.01	<0.01
Cadmium (Cd)	mg/l	<0.01	<0.01
Manganese(Mn)	mg/l	<0.05	<0.01
Aluminum(Al)	mg/l	0.06	<0.01
Lead (Pb)	mg/l	<0,01	0,2
Mercury (Hg)	mg/l	<0.01	<0.01

Iron concentrations at these points (CAMD3 and CAME3) were well above the maximum permitted levels when compared to European Union standards (0.2 mg/l) and World Health Organization standards (0,3 mg/l), as were the concentrations of Cadmium (UE: 0.005 mg/l; WHO: 0,003 mg/l) and Mercury (UE and WHO: 0.001 mg/l). The values obtained for all the others were within the limits established by the EU and WHO.

The average values obtained for the Physical Parameters at the same sampling points were as follows: Appearance-limpid, pH-7.26, Dissolved oxygen (8.75 mg/l), Oxidability (3.31 mg/l), Electrical Conductivity (34.01 µS/cm), Turbidity (NTU), Temperature (23,8^{o}C) and Total Dissoved Solids (30.80 mg/l). The values of the Physical Parameters are within the limits established by the World Health Organization for water quality. The following values were obtained for the Chemical parameters:: Free Carbon Dioxide (1.2 mg/l), Acidity (2.8 mg/l), Dry Residue at 180ºC (59 mg/l), Sulfate (<1.57 mg/l), Chlorides (1.56 mg/l), Nitrate (<2.34 mg/l), Nitrite (<0.02 mg/l), Amoniacal Nitrogen (0.015 mg/l), Fluorides (<0.41 mg/l), Silica (13.7 mg/l), Phosphates (<0.46 mg/l), Alkalinity (28.4 mg/l), Hardness (19.3 mg/l), Calcium (4.2 mg/l), Magnesium (2.2 mg/l), Sodium (3.2 mg/l), Potassium (1.2 mg/l), Manganese (<0.05 mg/l), Aluminum (0.06 mg/l) and Bicarbonate (34.6 mg/l).
Comparison of the Chemical Parameters reveals that they are within the specifications of the World Health Organization for water quality

The average values obtained for the Physical-Chemical Parameters are set out in Table 4.26.

Table 4.26: Physical-Chemical Parameterspara for sample CAMD3 taken near the right bank.

Sample CAMD3-Profile-1	Physical-Chemical Parameters		
Parameter	**Unit**	**Result**	**Permitted Intervals (WHO)**
Appearance		limpid	
pH		7.26	6.5 - 8.5
Turbidity		1	<5 NTU
Dissolved oxygen		8.75	<75
Conductivity	µS/cm	34.01	250
Total Solids in Suspension (105^{o}C)	mg/l	< 15	
Total Dissolved Solids (105^{o}C)	mg/l	< 15	
Dry Residue (180^{o}C)	mg/l	77	1.200
Total Alkalinity	mg/l	27.9	
Total Hardness	mg/l	18.3	500
Oxidability	mg/l	3.54	
Free Carbon Dioxide	mg/l	1.2	
Acidity	mg/l	2.8	
Chlorides	mg/l	1.57	600
Sulfates	mg/l	< 1.57	400
Bicarbonates	mg/l	34.6	
Nitrates	mg/l	< 2.34	50
Nitrites	mg/l	< 0.02	
Amoniacal nitrogen	mg/l	0.15	
Phosphates	mg/l	< 0.46	
Fluorides	mg/l	< 0.41	1.7
Sodium	mg/l	3.2	
Potassium	mg/l	1.2	
Calcium	mg/l	4.2	200
Magnesium	mg/l	2.2	150
Manganese	mg/l	< 0.05	0.1
Aluminum	mg/l	0.06	0.2
Silica	mg/l	13.3	

The values obtained for the microbiological parameters were as follows:

- Total Coliforms (>80CFU/100ml);
- Fecal Coliforms (>80CFU/100ml);
- Fecal Streptococci (>80CFU/100ml);
- Sulfite reducing Clostridia (0CFU/20ml);
- Colonies at 37^{0}C (>300CFU/1ml); and
- Colonies at 22^{o}C (>300CFU/1ml).

Comparison of the Microbiological Parameters reveals that they are not within the specifications of the World Health Organization for water quality suggesting the existence of bacterial contamination (Attachment 3).

The values obtained for the auxiliary sampling points upstream (CAMD3 and CAMEE3)are set out in Table 4.27. They too fail to comply with the norms established by the World Health Organization for direct use or with those of the European Union suggesting contamination (Table 4.27).

Table 4.27: Results of the total and Fecal Coliform analyses.

Parameter	**Units**	**Result**		**Permitted Values (WHO)**	**Permitted Values (UE)**
		CAMD3	CAMEE3		
Fecal Coliforms	FCU/100 ml	>80	>80	0	0 in 250 ml
Total Coliforms	FCU/100 ml	>80	>80	0	0 in 250 ml

4.1.8.4.4.6. CONCLUSIONS

Generally speaking the Physical-Chemical Parameters related to the quality of the water in the area under study are in alignment with WHO standards for except for the coliforms which seem to indicate contamination and for the pH whose values were in the acid range (4.42) upstream from the dam with a tendency to become even more so with the addition of more organic material from the vegetation in the surrounding areas resulting from the works being carried out on the dam.

A significant level of bacterial contamination was detected at all the sampling points where the average concentrations of fecal and total coliform bacteria are over 80FCU/100ml. Also, the figures obtained for fecal streptococci, sulfite reducing clostridia and colonies at 37ºC and 22ºC are above the maximum permitted levels. Those levels are associated to anthropic impacts related to fecal activities on the banks and edges of the river and the intensive use of the waters of the river in the study area by the riverside populations has produced a negative impact on the quality of the water in the form of pollution.

The concentrations of heavy metals on along the riverside beaches is probably derived from the Capanda dam upstream which means that the work making the Cambambe dam higher will probably produce heavy metals as well, that will be concentrated in the downstream areas.

The values registered for cadmium and mercury concentrations both upstream and downstream from the dam are above the maximum permitted level. The anomalous figures obtained for the concentrations of iron are probably the result of the dissolution of rocks along the margins of the river or may stem from activities at the abovementioned dam upstream.

4.2. BIOTIC MEDIUM

This section presents the results of a bibliographic review and field work to survey and study the vegetation and fauna present in the area of direct influence of the venture to expand the utilization of the Cambambe dam . In order to characterize the biotic medium in the venture's areas of influence, various field surveys were made using specialized teams and technical resources. The starting point for the elaboration of the work plan was to recognize the state of the species present and the environmental conditions in the region and more particularly in the area of direct influence of the proposed dam works. To that end a bibliographical review was made other material available for consultation in the Internet.

Compiling the information obtained in that way made it possible to make a preliminary reconnoitering of the diversity of species that probably occur in the region and establish a database of their morphological characteristics, reproductive biology, feeding habits, distribution patterns and the main impacts stemming from human activities that they are subject to.

Based on the information compiled in the office, specific methodologies were designed for each descriptor and the most appropriate sampling techniques were identified for the field work, taking into account both diurnal and diurnal captures and sampling. The equipment needed for the fieldwork was also identified during this stage of the studies and mobilized in preparation for the field work.

4.2.1. VEGETATION

This study presents the data on the vegetation and the flora in those stretches traversed during the field trips and preliminary inventories of the Biotic Medium in the Cambambe zone were made use of.

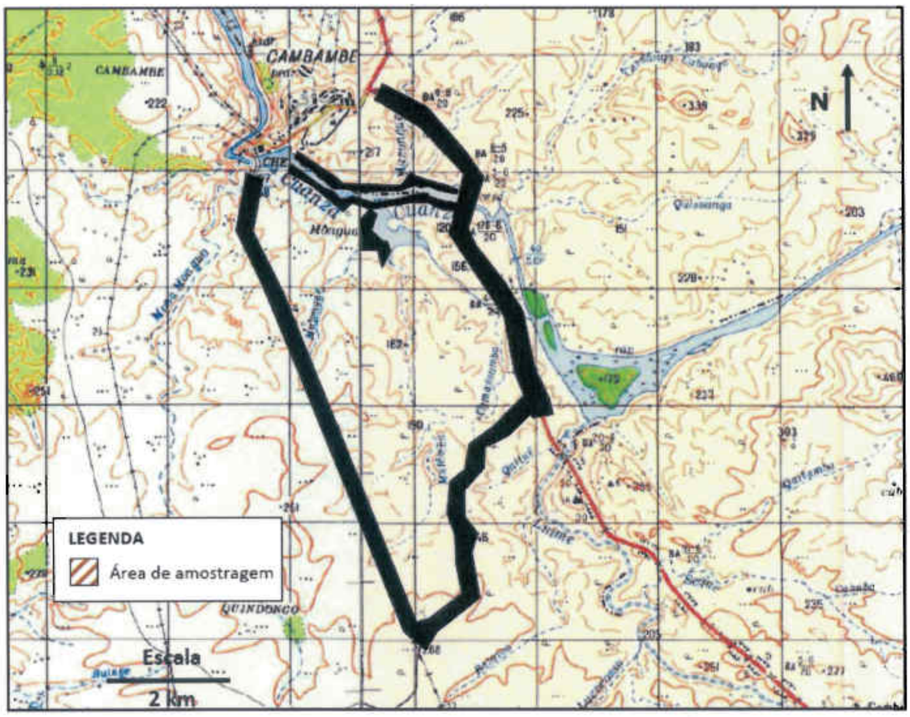
4.2.1.1. METHODOLOGY

The study was carried out in the Kwanza River and more precisely around the margins of the present Cambambe dam reservoir and the surrounding areas that will become the new edges of the dam lake. First an extensive review of the literature was made to obtain preliminary data on the vegetation formations in the Kwanza River basin in the region of the rivers middle course, or more precisely, in the Cambambe region which is where the area of influence of the project is located. Following that a field survey was made to detect the current state of the vegetation, the main indexes of abundance, dominance and the profiles of the main vegetation stands corresponding to the principal habitats in the project's area of influence. GPS equipment was used to accurately geo-reference the sampling points and points where photographs were taken and make it possible to know the exact position of he points that were analyzed.

In addition the available maps were used to make a preliminary definition of the area's most representative physiognomies and determine the sampling points. Flora surveys were made for each of the principal vegetation, physiognomies, an activity that was fundamental to obtaining qualitative knowledge of the flora that was to be investigated and to make estimates regarding possible impacts on the various plant populations and communities. Blanquet (1979) methodology was the basis for the studies of the vegetable communities enabling the choice of the most suitable method for each type of terrain and vegetation,

In this case the choice was to use transects which was the most appropriate method for the local type of vegetation cover.

However, for security reasons, in view of the fact that the area was formerly highly militarized and that there are still minefields some of which have not been properly marked, the sampling was restricted to places where the de-mining teams and local authorities were able guarantee safety and security especially in the trails opened along the ledges on the banks for the passage of vehicles which is where the sampling points were established (see Figure 4.19) and the observations of the vegetation cover to compare with the satellite images were made whenever possible. From the information obtained in this way inferences were made regarding other spots with similar appearances .



LEGEND
Sampling Area
Scale
2 km

Figure 4.19: Image with the vegetation sampling points upstream and inthe surroundings of the Cambambe dam projected on it.

Starting from a given point and going along lines parallel to the trails samples of the main plant species up the point where the land teams were allowed to circulate and this was done especially in the terrestrial roadways on both the southern and northern banks of the Kwanza river. Boat trips upstream from the Cambambe Dam Project as far as the Kiamangufo bridge were also made..

Species encountered along the way were collected at random and the material was pressed for later herbarium purposes. Abundance-dominance were determined using an adaptation of a Blanqut (1979) scale and attributing equivalence values as follows: 5-dominant; 4-frequent; 3-disperse or common; 2-rare; 1-very rare; + - sporadic.

Some of the material was identified on the spot with the help of the field guides while others were taken to the teaching Herbarium at the Agostinho Neto University's Faculty of Sciences to be identified by means of comparison with preserved material in the herbarium and the help of dichotomic identification keys and other complementary information from the literature. The Angola Phyto-geographic Charts for 1939 and 1970, and the 1998 Angola Agro-ecological zoning document as well as material produced by Gossweiler (1953) and Barbosa (2009).

4.2.1.2. PHYTOCENOTIC CHARACTERIZAÇTION OF THE MIDDLE KWANZA REGION

Generally speaking, as Diniz (2002) reports, the vegetation in the Middle Kwanza basin reflects the presents a notable xerophytic aspect as it is associated to costal and sub-coastal surfaces. Formerly the vegetation was predominantly thick and bushy and partly made up of species that shed their leaves and with and with arboreal and arborescent species dispersed among them to a greater or lesser extent.

The outstanding species in those thick formations were species of *Grewia, Combretum, Dichrostachys, Strycnus, Bascia, Diplorhyncus, Bauhinia,* and the dominant, widely disseminated arboreal species were *Adansonia digitata,* and *Acacia welwitschii.* In some places with an expressive micro-relief, the dense thicket-type cover gave way to different forms of dense dry forest with a great profusion of arboreal species dominated by *Adansonia, Albizia versicolor, Pterocarpus tinctorius, Diospyrus mespiliformis, Cynometra leonensis, Hymenostegia laxiflora, Combretum comporum* and *Acacia welwitschii.*

In turn the bottoms of the valleys and the alluvial low lying areas were covered with riparian gallery forest vegetation in which tall trees predominated, among them species like *Milletia versicolor, Diospyrus mespiliformis, Albizia glaberrima, Ceiba pentandra, Pterocarpus tinctorios* and *Adansonia digitata.*

Nowadays the dense bushy formations persist in small scattered stands and agricultural land use and occupation have resulted to a greater ort lesser extent intensive in considerable savannization so that frequently the cover now consists of typical savannah formations with shrubs, only very occasional tree species and often variable extensions of open grassland occupied by gramineous species. In the savannahs with shrubs and low arboreal species the characteristic woody species are *Piliostigma thoningii, Combretum spp., Crossopteris febrifuga, Diplorhynchus condylocarpon, Maytenus senegalensis, Heeria insisgnis, Cochlospermum angolensis, Albizia versicolor, Bridelia* sp. and *Dalbergia* sp.

Savannah land with shrubs is also typical of the land the interior zones of the sub-plateau regions naturally associated to a sub-humid climate. In some parts, Sometimes there are patches of savannah with arboreal species in evidence, or still other types of wooded savannah. In such formations it is common to find well-formed stretches of gallery forest accompany the lines of the watercourses but they are usually quite narrow and uniform and identical in their composition with the riparian forest communities in the western parts.. In the shrubby savannahs the woody tree-like representatives are few and far between and mainly represented by *Piliostigma thoningii, Cochlospermum angolensis,* but species like *Terminalia sericea, Combretum laxiflorum, C. psidioides, Maytenus senegalensis, Erytrophleum africanum, Erytrina abissinica, Crossopterix febrifugum* and *Ekbergia benguelensis* can also be found with a certain frequency. It is also worth noting the occasional scattered presence of arboreal representatives like *Sterculia quinqueloba, Diospyrus mespiliformis, Pterocarpus tinctorios* and *Adansonia digitata.*

Those patches of arboreal savannahs with the appearance of woods are usually the site of species like *Acacia sieberiana*, and *Entada abyssinica*. The herbaceous stratum is dominated by *Andropogon gayanus,* and *Hyparrhemia rufa*. Here and there the presence of *Heteropogon contortus, Panicum maximum, Digitaria milangiana and Loudetia simplex* can be registered. Sometimes well defined watercourses are accompanied by patches of dense forest in which the dominant species are *Albizia gummifera, Lonchocarpus sericeus, Milletia versicolor* and *Alchornea cordifolia*.

4.2.1.3. THE CAMBAMBE VEGETATION

In his phytogeographic division of Angola, Barbosa (2009) classifies the vegetation in the Cambambe region as vegetation type 11 –Dry Forest Mosaic predominantly deciduous and low altitude Dry Savannah. It occupies an area of transition between the coastal savannahs and cafeera forests whose most prominent aspects can be separated into two sub-types:

- Forests in valleys and galleries, tall, semi-deciduous, dense with the presence of creepers and climbers; and
- Dry savannahs with small patches of steppe-like formations intercalated.

The species that usually compose the first sub-type are *Ceiba pentandra, Bombax reflexum, Pteleopsis myrtifolia, Pterocarpus tinctorius, Diospyrus mespiliformis, Adansonia digitata, Lannea welwitschii, Albizia glabrescens, Melia bombolo, Ficus* spp, *Sterculia purpúrea, Entandrophragma angolensis*, among others.

In the cracks in the rocks and the margins of the river flooded at high water there is *Adina microcephala*, a widely distributed plant always green and always associated to riversides. In the alluvial deposits of the rivers with their fertile soils *Berchemia discolor* appears, also distributed, over an enormous area.

In the lower strata there small tees and shrubs and an abundance of creepers and climbers like *Lonchocarpus sericeus, Millettia gracilis, Quisqualis exannulata, Craibia brevicaudata, Combretum argyrotrichum, Herinis integrifolius*, etc and also some of the species reported for the savannah areas can be found there.

The second sub-type consists mainly of areas of tall vigorous grasses from 1.6 a 4 m tall, and among them are patches of open forest or scattered trees and shrubs. In those savannahs severely affected by burning the dominant species are: *Andropogon gayanus,* *Hyparrhemia rufa, H. Cymbaria, H. ruprechtii, Heteropogon contortus*, among others. Other species that deserve mention are *Panicum maximum and Brachyaria* sp.

The arboreal and shrubby elements of the savanna the forest ecotone are: *Albizia versicolor, A. adiantifolia, Piliostigma thoningii, Acacia sieberiana, Entadopsis abyssinica, Combretum comporum, C. platypelatum, C. mossambicensis*, etc.

According to Diniz and Aguiar (1998), the Cambambe region is dominated by a vegetable community of the savannah type with shrubs such as *Pilistigma, Combretum, Crossopterix, Dyplorrhincus, Maytenus and Cochlospermum*, with scattered arboreal representatives like *Adansonia digitata, Sterculia quinqueloba, Acacia sieberiana, Acacia welwitschii* and *Diospyrus mespiliformis* which are sometimes concentrated in which case the savannah takes on a wooded appearance. In some areas, thick bushy vegetation (*Grewia, Pteleopsis, Combretum*) alternates with savannah formations forming a mosaic. Along the lines of the watercourses there are tenuous strips of gallery forest.

4.2.1.4. CURRENT SITUATION OF THE VEGETATION COVER

The survey of the project's area of direct influence made it possible to observe the natural appearance of th vegetation and there was little evidence of anthropic interference with the exception of the uncontrolled fires that that devastate the savannah areas in the dry season. That is due to the fact that over the years it has been an area with very limited access due to the existence of the Cambambe Hydroelectric installations. For that reason various species of trees, shrubs and herbaceous species grow profusely in the area making it rich and diversified in taxa that occupy different habitats

35 plant species were identified distributed among 19 families among which the Fabaceae and Gramineae are best represented with 5 species each, followed by the Combretaceae with 4 Species. The main species are distributed in the various habitats and a description of them follows below The general data is set out in Table 4.28. The other tables supply information on dominance and abundance of arboreal species (4.29), shrubs species (4.30), herbaceous species (4.31) and aquatic species (4.32).

4.2.1.5. PRINCIPAL HABITAT TYPES

According to the survey that was carried out the following types of habitats and plant communities can be found in the area of influence of the project:

- **Dry savannah with scattered trees and shrubs**

This formation is typical of the greater part of the area of direct influence (Photo 4.12). The floristic composition in this formations is variable and there are representatives present in th three strata: the arboreal stratum is dominated by *Adansonia digitata, Diospyrus mespiliformis* and *combretum* sp.; the arbustive stratum is more expressive and dominate by species belonging to the genus *Combretum* (*C. collinum, C. zeiheri* and *combretum* sp.). In addition, *Acacia sieberiana, Piliostigma thoningii, Ozoroa paniculosa, Maytenus senegalensis, Carissa bispinosa* may be found in the same stratum and more rarely *Strychnos* sp. In those spots where the soil conditions are a little better the arbustive vegetation is denser and closed and some of the individual shrubs take on the appearance of small trees.

Photo 4.13: Gallery Forest with big trees inside the Project's area of influence.

- **Aquatic plant communities**

This community (Photo 4.14) consists of plants that are directly dependent on water and the majority live in direct contact with the river water, accompany the alterations and can tolerate long periods of flooding. The community contributes towards stabilizing the banks of the river protecting it from erosive actions. Among the most notable among the species that are frequently found are *Phragmites mauritianus, Polygonum odorata*a and *Hydrostachis* sp., a plant that adheres to the rocky substrate especially in places where there is a lot of turbulence.

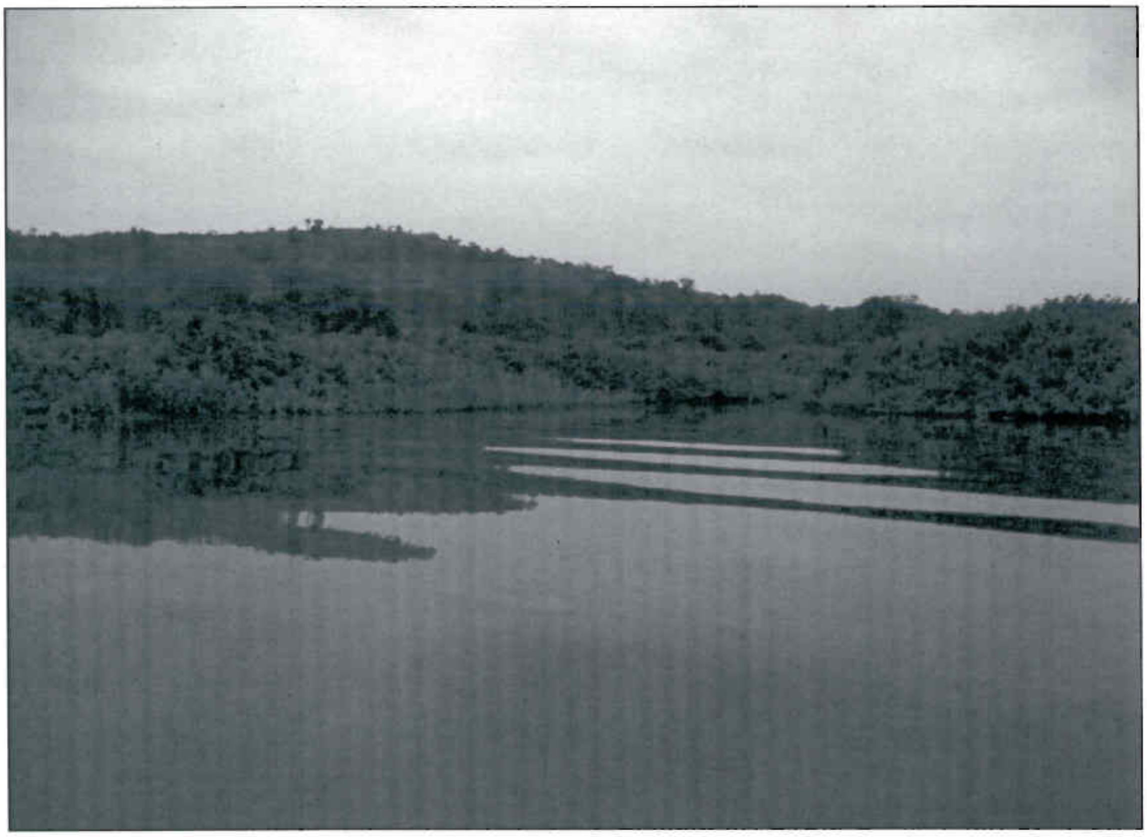


Photo 4.14: Panoramic view of an aquatic plant community in the Cambambe reservoir.

- **Plant communities on steep rock surfaces**

Pteridophytes can be found on the rocky margins formed by steep rock surfaces, and in cracks in the rocks sticking up out of the river especially species like, *Aloe* sp., *Euphorbia* sp., *Sanseviera cilindrica*, *Asclepias* sp. and other plants associated to arid conditions (Photo 4.15).

Photo 4.15: Community of rock plants on the steep banks.

Table 4.28: Main indexes identified during the field survey.

Family	Species	Biological Form
ANACARDIACEAE	*Ozoroa paniculosa*	Arbustive
APOCYNACEAE	*Carissa bispinosa*	Arbustive
ASCLEPIADACEAE	*Asclepias* sp. *Landolphia* sp.	Herbaceous Woody climber
ASPHODELACEAE	*Aloe* sp.	Herbaceous
BOMBACACEAE	*Adansonia digitata* *Ceiba pentandra*	Arboreal Arboreal
CELASTRACEAE	*Maytenus senegalensis*	Arbustive
COMBRETACEAE	*Combretum apiculatum* *Combretum collinum* *Combretum zeyheri* *Combretum* sp.	Arbustive or Arboreal Arbustive or Arboreal Arbustive or Arboreal Arbustive or Arboreal
DRACAENACEAE	*Sanseviera cilindrica*	Herbaceous
EBENACEAE	*Diospyrus mespiliformis*	Árboreal
EUPHORBIACEAE	*Alchornea* sp. *Euphorbia* sp.	Arbustive Arboreal

Family	Species	Biological Form
FABACEAE	*Acacia sieberiana* *Acacia melifera* *Albizia versicolor* *Piliostigma thoningii* *Pterocarpus angolensis*	Arbustive Arbustive Arbustive or Arboreal Arbustive Arboreal
GRAMINEAE	*Andropogon gayanus* *Brachyaria* sp. *Heteropogon contortus* *Hyparrhemia* sp *Panicum maximum* *Phragmites mauritianus*	Herbaceous Herbaceous Herbaceous Herbaceous Herbaceous Aquatic
HYDROSTACHYACEAE	*Hydrostachys* sp.	Aquatic
LOGANIACEAE	*Strycnus* sp.	Arbustive
MORACEAE	*Ficus* sp.	Árboreal
MYRTACEAE	*Syzigium* sp.	Arbustive
POLYGONACEAE	*Polygonum odorata*	Herbaceous aquatic
STERCULIACEAE	*Sterculia purpúrea*	Árboreal
TILIACEAE	*Grewia flavescens* *Grewia* sp.	Arboreal Arbustive

Table 4.29: Arboreal Species (abundance/dominance: 5-dominant 4-frequent; 3-disperse or common; 2-rare; 1-very rare; + -sporadic).

Family	Species	Abund/Dom.	Habitat
BOMBACACEAE	*Adansonia digitata*	3	Savannah and gallery Forest
FABACEAE	*Albizia versicolor*	2	Savannah and gallery Forest
BOMBACACEAE	*Ceiba pentandra*	1	Gallery Forest
COMBRETACEAE	*Combretum apiculatum*	4	Savannah and gallery Forest
COMBRETACEAE	*Combretum zeiheri*	1	Savannah and gallery Forest
EBENACEAE	*Diospyrus mespiliformis*	5	Savannah and gallery Forest
MORACEAE	*Ficus* sp.	1	Gallery Forest
FABACEAE	*Pterocarpus angolensis*	1	Gallery Forest
STERCULIACEAE	*Sterculia purpurea*	2	Gallery Forest

Table 4.30: Arbustive Species (abundance/dominance: 5-dominant 4-frequent; 3-disperse or common; 2-rare; 1-very rare; + -sporadic)

Family	Species	Abund/Dom	Habitat
ANACARDIACEAE	*Ozoroa paniculosa*	1	Savannah
CELASTRACEAE	*Maytenus senegalensis*	1	Savannah
COMBRETACEAE	*Combretum apiculatum*	2	Savannah and gallery Forest
COMBRETACEAE	*Combretum colinum*	5	Savannah and gallery Forest
COMBRETACEAE	*Combretum zeiheri*	1	Savannah and gallery Forest
EUPHORBIACEAE	*Alchornea* sp.	2	Gallery Forest
FABACEAE	*Acacia melifera*	1	Gallery Forest
FABACEAE	*Acacia sieberiana*	1	Savannah and gallery Forest
FABACEAE	*Piliostigma thoningii*	2	Savannah and gallery Forest
LOGANIACEAE	*Strychnus* sp.	1	Savannah
APOCINACEAE	*Carissa bispinosa*	+	Savannah
TILIACEAE	*Grewia flavescens*	+	Gallery Forest

Table 4.31: Herbaceous Species (abundance/dominance: 5-dominant 4-frequent; 3-disperse or common; 2-rare; 1-very rare; + -sporadic)

Family	Species	Abund/Dom	Habitat
GRAMINAE	*Andropogon gayanus*	5	Savannah
GRAMINAE	*Hyparrhemia* sp.	1	Savannah
GRAMINAE	*Heteropogon contortus*	2	Savannah
GRAMINAE	*Panicum maximum,*	3	Savannah and gallery Forest
GRAMINAE	*Brachyaria* sp.	1	Savannah

Table 4.32: Aquatic Species (abundance/dominance: 5-dominant 4-frequent; 3-disperse or common; 2-rare; 1-very rare; + -sporadic).

Family	Species	Abun/Dom	Habitat
GRAMINAE	*Phragmites mauritianus*	3	Aquatic emergent
POLYGONACEAE	*Polygonum odorata*	2	Aquatic emergent
HYDROSTACHYACEAE	*Hydrostachys* sp.	1	Aquatic emergent

4.2.1.6. FINAL REMARKS AND RECOMMENDATIONS

Because the project's area of direct influence is situated in a transition zone between dry and wet climate the vegetation also exhibits intermediate features and is highly varied, albeit the irregular rainfall patterns mean that there is predominance of xerophytic characteristics. This feature is especially notable in the areas of higher elevation whereas in the areas along the banks of the rivers the vegetation is green and lush throughout the year due to the ready availability of water.

4.2.1.6 Calculation of the Emissions Resulting from Raising of the Dam

A report was done by Green Domus (2012) in order to determine the greenhouse gas emissions in the area which will be flooded as a result of raising of the height of the Cambambe 3 dam. Note that the calculations were done on the basis that, when the reservoir is enlarged, the flooded area will be increased from 1,321 km^2, to 6,082 km^2, or in other words, 4,761 km^2 (476 hectares) will be flooded.

- **Methodology for estimation of Greenhouse Gas Emissions (Ground and Vegetation)**

In order to determine the greenhouse gas emissions resulting from the future flooded area, the methodology described in the IPCC 2003 *Good Practice Guidance for LULUCF*[1] report was used. According to this methodology, it was established that the calculations should be done on the basis of the premises explained for *Tier 1,* which provides a simplified approach, in order to estimate the greenhouse gas emissions of reservoirs, and which uses standard area data and values.

- **Calculation of emissions by the flooded area (CO2 e CH4)**
    - **Carbon dioxide(CO2) –** The method used considers the emissions caused by diffusion, because the emissions caused by the release of bubbles are not regarded as significant. The following equation was used to calculate the CO2 emissions coming from the flooded ground:

$$\Delta C_{LWflood_{LB}} = \left[\sum_i A_i x(B_{After_i} - B_{Before_i})\right] xCF$$

The annual emissions of CO2 coming from the flooded ground are **10,349 tonnes of CO2e.**

- **Methane (CH4) –** The equation used in order to calculate the emissions of CH4 coming from the flooded ground was as follows:

$$CO_2 emissions_{WW\ flood} = P \times E(CO_2)_{diff} \times A_{flood,total\ surface}$$

The estimated annual emissions of CH4 for the flooded ground are **345 tonnes of CH4**. The equivalent emissions in terms of CO2 are: **7,427 tonnes of CO2e.**4

[1] LULUCF = Land Use and Land-Use Change and Forestry

- **Estimation of the quantity of biomass existing in the area to be flooded.**

In order to calculate the methane emissions resulting from decomposition of submerged vegetation, the IPPC did not present a methodology with standard values, but only referred to development of a methodology of its own. Thus, the estimate of methane emissions was based on estimates of models selected in the bibliographic review.

The reference values for calculation of the biomass above the ground, which were supplied by the IPPC, are also generic. Due to a lack of studies with regional average results for those parameters, the IPPC suggests reference values for those parameters, the IPCC suggests reference values for all tropical climate savannahs (IPCC, 1997: p. 4.25). The mean value adopted per quantity of biomass above the ground is 6.6 t/ha for savannah environments which are changed to agricultural use, which does not correspond precisely to the regional characteristics of the area that is being studied. Thus, extrapolation of these values to the Camambe reservoir may give rise to distortions. With the aim of avoiding such distortions, we opted for refinement of the data through calculation of the total quantity of biomass existing in the area to be flooded, which leads to a more precise approximation, which is closer to the actual situation. The methodology which we found to be most suitable for study of the plant communities was the one developed by Blanquet (1979).

In order to assess the current situation in terms of plant cover, the following types of habitat and plant communities were considered: dry savannah with more or less dispersed shrubs and trees; gallery forests with high cover, sub-deciduous forest with a lot of creepers; a community of aquatic plants and a community of with more cliff-side marginal plants.

In order to estimate the biomass of the vegetation concerned, three categories were taken into consideration:

- **Group**: this separates the plant communities in which a given size of plant is dominant. For example: arboreal (> 4.5 m high); subarboreal (> 3 m and < 4.5 m); shrubby (> 1,5m e < 3 m) e sub-shrubby (< 1.5 m).
- **Class:** This describes the plant communities of different morphological natures, in decreasing order of dominant sizes, when they are identifiable, up to the third stratum.
- **Subclass:** this represents the plant cover, in terms of the percentage coverage of the surface of the ground. It is evaluated in terms of the following degrees of coverage: very dense (> 80% cover); dense (> 60 and < 80%); open (> 40 and < 60%); sparse (> 20 and < 40%) and very sparse (< 20%).

In order to study the said report, the area to be flooded will be approximately 476 ha. The total area of fragments of vegetation already amounted to 142.99 ha, and the remaining area (area of exposed ground, with ground cover amounting to less than 20% of the total flooded area) inserted into the limits of that flooded area, was 333 ha.

Starting from the characteristics of each area that has been identified, the following were determined: the Category Classification, the Size of the Areas (in ha), the *Porte* [capacity?] Index (Ip), the Coverage Index (Ir) and the Ligneous Vegetation Biomass Index.

From this data, the volume of ligneous vegetation biomass for the area to be flooded (420 ha) was found to be **6,180 m^3** (or 13.645 m^3/ha).

- **Estimate of carbon (C) emissions originating from the submerged biomass.**

In accordance with the IPCC 2006 *Guidelines for National Greenhouse Gas Inventories*, the method for estimating the change in the stocks of carbon during conversion to flooded areas assumes that the entire stock of carbon existing in the area before conversion is lost in the first year after flooding. However, it is important to note that ligneous materials, such as tree trunks, decompose slowly, and the carbon that is left in the flooded area will be emitted for many years after the flooding has taken place. However, for calculation purposes, the total value is compacted to a period of one year, the actual emissions for a year being over-estimated, but being in line with the total emissions over the process of decomposition of the submerged biomass. Thus, the methodology applied does not enable one to show the evolution of the emissions year by year. In order to do that, measurements and verifications need to be done *in situ.*

Still according to the same IPCC guidelines, the CO2 emissions in the first ten years after flooding are mainly due to decomposition of the pre-existing organic material in the lake. In the meantime, the emissions in the period subsequent to the first decade are derived from the material that is transferred to the area. If one adopts that as a premise, the CO2 and CH4 emissions attributed to the flooding process may be limited to a maximum period of ten years, after which they lose their significance in relation to the material that is brought in.

The stock of carbon before conversion may be estimated in accordance with the method for live biomass described by the IPCC, according to the following equation:

$$\Delta C_{LWflood_{LB}} = \left[\sum_i A_i x (B_{After_i} - B_{Before_i}) \right] xCF$$

The stock of carbon present in the area of the reservoir corresponds to **3,090 tonnes of carbon (C).**

- **Estimate of CO2 and CH4 emissions coming from the submerged biomass**

Having obtained the change in the stock of carbon of the biomass in the land converted to flooded ground, the CO2 and CH4 emissions are calculated.

One can see from the bibliography that different measurements done around the world indicate that in deep reservoirs, like the one at Cambambe, the methane emissions are converted into carbon dioxide along their trajectory from the bottom of the reservoir to the surface.

Accordingly, a conservative estimate of 95% was adopted, for the carbon gas emissions, and 5% for the emissions of methane in relation to the stock of biomass.

Thus, the annual emissions of CO_2 coming from the emerged biomass are estimated at **10,763 tonnes of CO_2** and **206 tonnes of CH_4,** which is equivalent to **4,326 tonnes of CO_2e.**

- **Result of total emission of CO_2e**

Taking into account the two sources of emission considered in the said report (flooded ground and submerged biomass), a total annual emission was estimated of **32,865 tonnes of CO_2e,** where:

  - The total amount for the flooded ground is **17,775 tonnes of CO_2e;**
  - The total amount for the submerged biomass is **15,089 tonnes of CO_2e.**

- **Final Considerations**

The total figure of **32,865 tonnes of carbon dioxide equivalent**, from the desirable emissions for complete decomposition of the organic material to be submerged, is achieved. This number is not really expressive and is a long way below the indirect results of reduction of emissions which raising of the Cambambe Dam may cause, and which is the subject of the plan for Certified Reduction of Emissions that is in progress

Although most of the species identified during the survey can be found in adjacent areas, the increase in the area of the dam lake resulting from the implementation of the project to heighten the Cambambe dam will inundate a huge area of habitats and lead to the loss of a great number of species, some of which are registered in Angola's Red List of Endangered Species (Costa *et al.* 2009) and on the Red List compiled by the UICN (*Acacia sieberiana, Diospyrus mespiliformis, Piliostigma thoningii and Pterocarpus angolensis*).

Although a great proportion of the species was identified by the study survey, we believe that many others exist in places that it was impossible to visit but that will in fact be affected by raising of the reservoir water level. It must be emphasized that the survey was made during the dry season at which time many annual plants are in vegetative repose and their aerial parts, which are the chief means of identification, have died down making it all the more difficult to identify them.

4.2.2. PHYTOPLANKTON

Dam construction always alters the lotic environment (in the river) and the lentic environment (in the lake formed above the dam) increasing considerably the time of water retention. Dams and reservoirs drastically and effectively alter river flows and terrestrial and aquatic systems but at the same time, they provide numerous benefits like retaining a large body of water for producing electricity, irrigation, navigation and pubic water supply (Henry, 1999).

Phytoplankton studies usually include an analysis of their quantitative aspects because the composition of these communities and their spatial and temporal variations occur as function not only of interaction among them but from the effects of environmental variables among which the most important are light intensities, Temperature, pH and electrical Conductivity of the water (Hino, 1979).

The phytoplankton inhabits the surface layers of the water that receive illumination directly from the sunlight and consists of tiny photosynthesizing organisms with little or no powers of locomotion so that their distribution depends on the movements of the waters in the rivers, lakes, seas and oceans they inhabit. They are in fact the basal production unit of organic material in aquatic ecosystems and accordingly constitute the primary stratum of the trophic chain (Wetzel, 1993).

In tropical climates important alterations in the phytoplankton may be associated to the alternation between dry and wet seasons (Beadle, 1974: Payne, 1986 *in* Dias – Jr., 1990) which means that rainfall is an especially important factor in the annual cycles of the phytoplankton Portanto (Dias – Jr., 1990).

That being so, studies of the composition and seasonal variations of phytoplankton communities and the possible links between those variations and the hydrological cycle in the zone being studied provide important supporting information for a better understanding of the ecosystems in the flood plains.

Water resource management and other aspects associated to quantity and quality need to be integrated in the river basins so that the interconnection of upstream areas and downstream areas are properly taken into account recognizing that activities in any one part of a basin should tahe into account the impacts they may have on other parts (World Bank, 1998), cited by Pereira (2002).

It is important to acquire knowledge of the composition and fluctuation of the phytoplankton community and of its trophic relations with higher trophic levels. Such knowledge supports better management in the sense of improving the productivity of a given trophic level, or for example. Avoiding the advance of eutrophication by manipulating the levels that influence that process (Vasconcelos, 1991).

The work undertaken here aims to contribute to enhancing taxonomic knowledge of the phytoplankton at the Camabe dam site and provide a base for future ecological studies.

4.2.2.1. METHODOLOGY

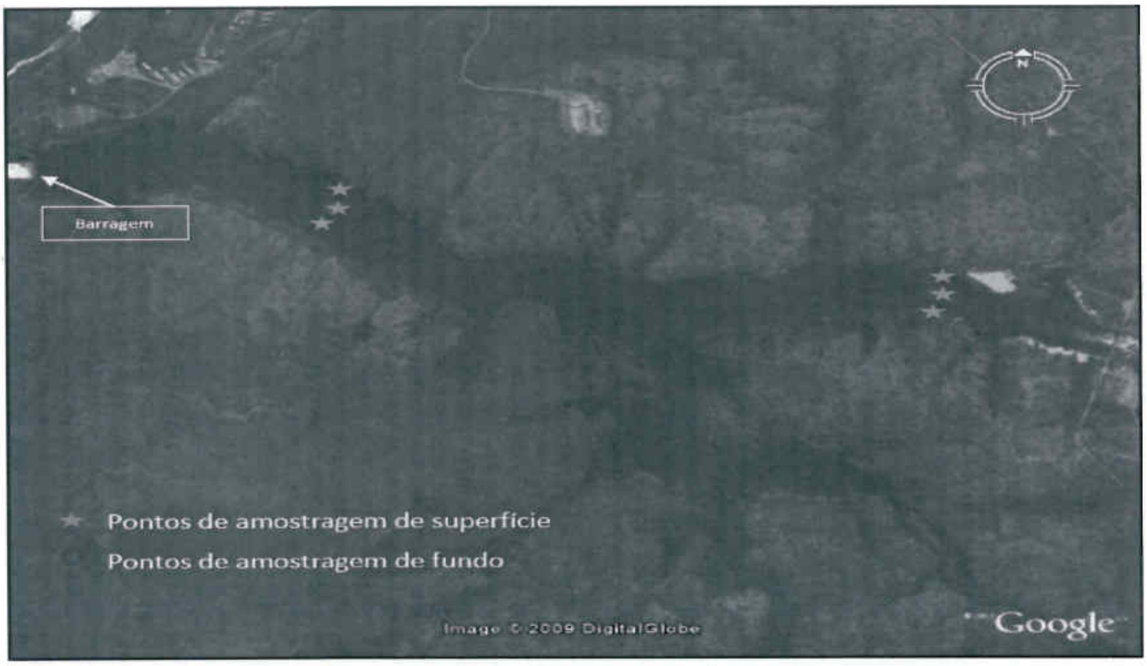
Samples were collected from the water in the areas of the Cambambe and Dondo dams at three (3) sampling stations using a rubber boat equipped with a 25HP Yamaha outboard engine (Photo 4.16). In the case of the Dondo, six(6) of the sampling points were upstream (see Figure 4.20) and three downstream (see Figure 4.21).

Photo 4.16: Boat used for sampling

The samples were taken fro the surface and the bottom in the upstream zones and from the surface only in the downstream zones due to the lotic nature of the aquatic environment there. All sampling points were geo-referenced using GPS (see Table 4.33).

Table 4.33: Phytoplankton sampling points.

Point	Location	Sample Nº	Remarks
1	Upstream	A1	Surface (Left bank)
1	Upstream	A2	Surface (Right bank)
1	Upstream	A3	Bottom (Middle)
1	Upstream	A4	Surface (Middle)
2	Upstream	A5	Surface (Left bank)
2	Upstream	A6	Surface (Right bank)
2	Upstream	A7	Bottom (Middle)
2	Upstream	A8	Surface (Middle)
3	Downstream	A9	Surface (Left bank)
3	Downstream	A10	Surface (Middle)
3	Downstream	A11	Surface (Right bank)



Dam

Surface sampling points

Bottom sampling points

Figure 4.20: Phytoplankton sampling points upstream fom the dam.

Surface sampling points

Figure 4.21: Phytoplankton sampling points downstream from Dam at Dondo.

The samples were collected at the points shown above using a 2-liter Van Dorn bottle. At points 1 and 2 (in dam reservoir) were taken from the surface and the bottom whereas at the downstream sampling point the samples were only taken from the surface due to the lotic characteristics of the waters there. The samples were accommodated in 250 ml plastic flasks and fixed using a 2% formol. The sampling period for this study was Augusta and September, 2009.

The Uthermol (1958) sedimentation method was used for identification and counting purposes. It is done by allowing sedimentation to take place in the samples accommodated for 24 hours in cylindrical polystyrene chambers of 50 ml or 100 ml capcity Identification was dmade using na "Axiovert 200" inverted binocular microscope equippped with an epifluorescence phase contrast option. Full field or transect cell counts were made according to the quantities of species found and the number of cells per liter was calculated using simple proportionality. The bibliographic references most consulted for identification purposes were Bourrelly (1966, 1968, 1970), Prescott (1964, 1978), Santos & Pires (2000).

Statistical analysis was made of density, dominance, frequency and diversity data and graphs constructed for each study period.

4.2.2.1.1. Species abundance, dominance and frequency

The criteria recommended by Lobo & Leighton (1986) were adopted to determine abundant and dominant species. According to their criteria, abundant species are those whose numerical occurrence is greater than the average number of individuals present for each of the other species present in the sample and dominant species are those species whose numerical occurrence is higher than 50% of the total number of individuals present in the sample.

In regard to frequency the criterion used was that of Gomes (1989), whereby the frequency is expressed as a percentage of the total number of samples, the number of samples in which the species occurs. The following values were attributed frequencies were attributed the following equivalencies:

- Frequent Species: F≥60%;
- Common Species: 20%≤F≤60%;
- Rare Species: F≤20%

The following formula was used to calculate frequency values:

$$F = (Pa/P)^{*} \ 100 \text{ where:}$$

Pa – nº of samples in which the species is present
P – nº total number of samples analyzed.

4.2.2.1.2. Diversity Index

Species diversity is a basic ecological concept and has been used to characterize communities and ecosystems. Differences in species diversity are to be expected at different stages of the biotic succession and at different times of the year. According to Margalef (1983), generally speaking, diversity is directly related to stability of the community and inversely related to the degree of alterations to the ecosystem.

In this study the diversity index per sample was calculated using the Shannon-Weaver (1949) index based on the equation:

$$H' = - \Sigma \, p_i . \log p_i$$

Where: the value of p_i is taken from n_i/N and represents the proportion of the total number of individuals (N) belonging to the ith Species (n_i), using logarithm base 2.

4.2.2.1.3. Trophic State

Nygaard (1949) in Perez, (1992) developed a set of five indices for trophic state based on the presumption that Cyanophytae, Euglenophytae, Diatomaceae (Order Centrales) and Chlorococcales are present in eutrophic waters and that Desmidiaceae and many Diatomaceae Pennales cannot tolerate the presence of such high levels of nutrients and so are considered to be typical features of oligotrophic waters. The most frequently used Nygaard indexes are:

- Chlorophyceae index = nº of Chlorococcales species/nº of Desmidiaceae species

- Rate for Diatomaphyceae = nº of Diatomaphyceae (order centrales) species / nº of Diatomaphyceae (Order Pennales) species

- Compound Index = nº of species of Cyanophyceaa + Chlorococcales + Diatomaphyceae Centrales + Euglenophyceae/ nº of Desmidiaceae species

If the value for the Chlorophyceae index is <1, then the lake is considered to be oligotrophic and if it is >1 it is eutrophic.

In the case of Diatomaphyceae index, if the results are in the range 0.0 to 0.2, the lake is oligotrophic and if it is in the range 0.2 a 3.0 the lake is eutrophic.In the case of the compound index if the value is <1 it is oligotrophic and if it is in the range 1.0 to 2.5, it is mesotrophic and for values >2.5, the lake is eutrophic (Esteves, 1988).

Infante (1988) states that these indices are universally applicable but that in the tropics they must be used with caution as at low latitudes Diatomcaeae of the Centrales order are relatively more abundant than those of the Pennales order but that does not necessarily mean that the lake is oligotrophic. Furthermore, blue-green algae are usually more abundant in tropical lakes anyway.

4.2.2.2. RESULTS and DISCUSSION

In this study, the analysis of the phytoplankton community's composition in the area of direct influence of the Camambe hydroelectric project detected the presence of the 37 taxa of which 23 were identified generically and 14 specifically. The distribution of the different forms that were encountered (genera and species) in the various taxonomic classes was as follows:

- Diatomaphyceae with 24 taxa (15 Genera and 9 Species);
- Chlorophyceae, with 11 taxa (8 Genera and 3 Species);
- Cianophyceae with 1 taxa (1 Genus) and Dinophyceae, with 1 taxa (1 Species).

The table below (Table 4.34) presents a list of Classes and Genera for the phytoplankton found during the study period.

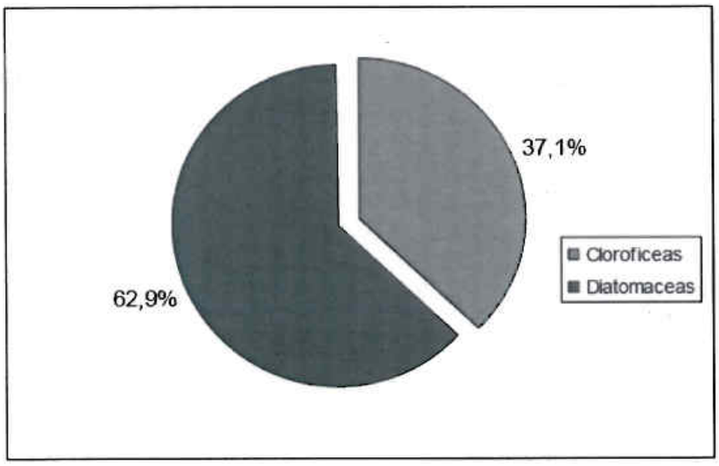
Table 4.34: Qualitative Composition of the Phytoplankton community at the Cambambe Hydroelectric Dam.

Class Diatomaphyceae	Class Chlorophyceae
Amphipleura pellucida	*Ankistrodesmus falcatus*
Amphora sp	*Ankistrodesmus fusiformis*
Aulacoseira sp	*Ankistrodesmus sp*
Cerasteria sp	*Closterium* sp
Chaetoceros sp	*Cosmarium sp*
Cocconeis sp	*Euastrum* sp
Coscinodiscus sp	*Pediastrum sp*
Cymbella cistula	*Scenedesmus* sp
Eunotia asterionelloide	*Staurastrum leptocladum*

Eunotia sp	*Staurastrum* sp
Frustula rhomboide	*Staurastrum* spp
Gomphonema sp	
Leptocylindrus mínimus	
Navicula placentula	
Navicula sp	
Nitzschia closterium	
Nitzschia longuissíma	
Nitzschia sp	
Nitzschia spp	
Pinnularia sp	
Surirella robusta	
Surirella sp	
Synedra sp	
Treubaria sp	
Classe Cianophyceae	**Classe Dinophyceae**
Anabaena sp	*Ceratium fusus*

4.2.2.2.1. Abundance and dominance

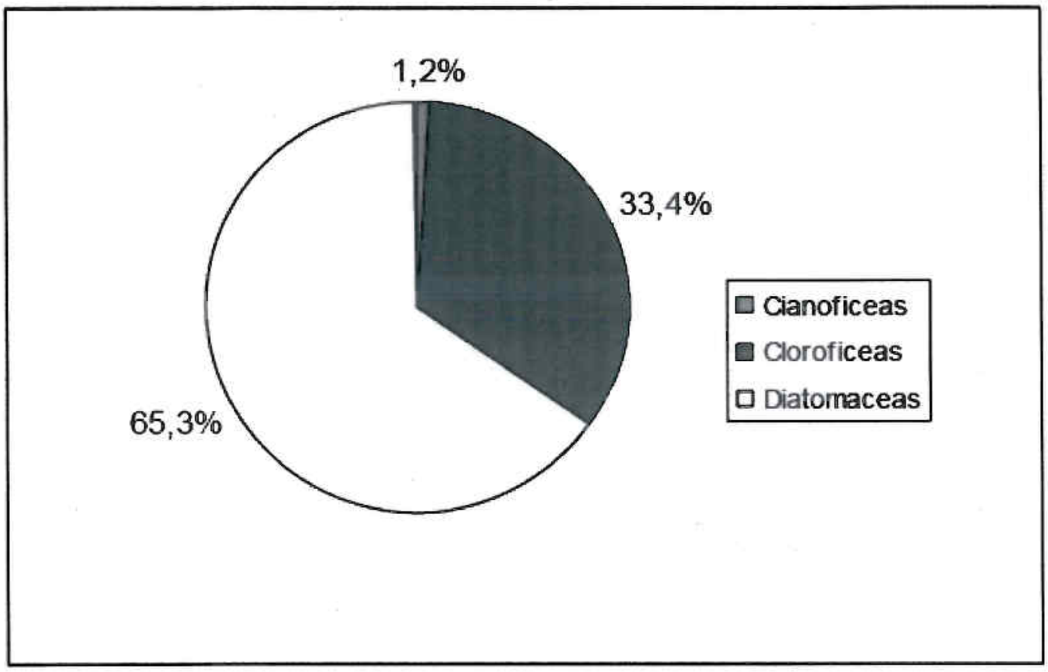
Figures 4.22 and 4.23 show the variations in abundance of the different groups of phytoplankton organisms that were sampled for this study. At the time of sampling the Diatomaphyceae were the moist representative group and they were more abundant at the upstream sampling (1 and 2). However none of the species identified were classified as abundant or dominant which indicates a fairly even individuals among the Diatomaphyceae and the Chlorophyceae which were the groups that presented the highest numbers of species.



Chlorophyceae

Diatomaphyceae

Figure 4.22: Composition of the Phytoplankton community upstream (point 1).

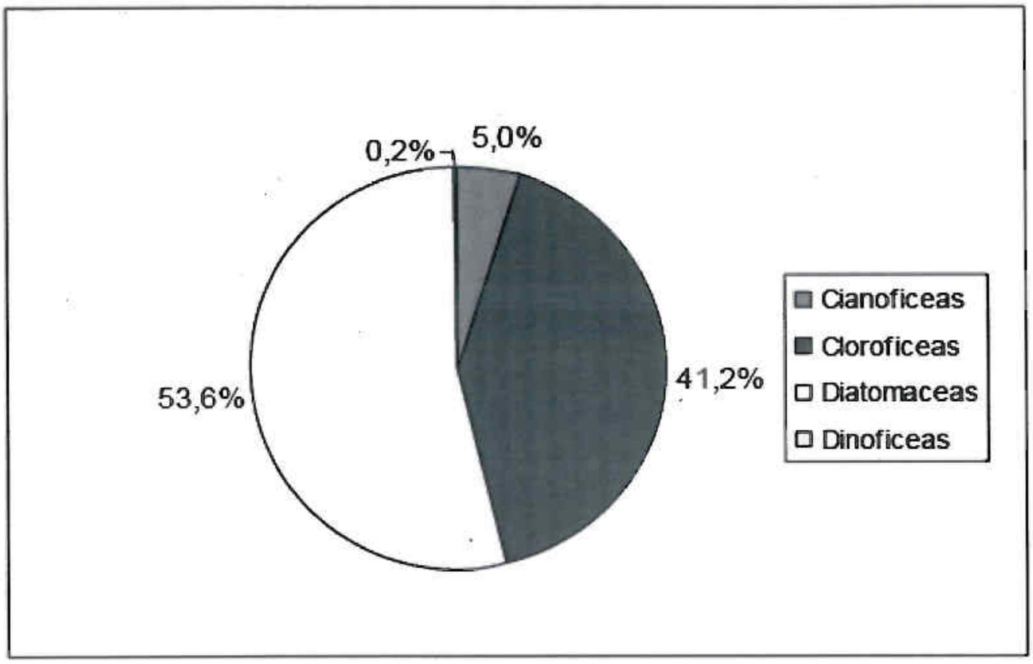


Cianophyceae
Chlorophyceae

Diatomaphyceae

Figure 4.23: Composition of the Phytoplankton community upstream (point 2).

Point one is represented by two groups only; the Diatomaphyceae with 62.9% and the Chlorophyceae with 37.1%. For point 2 three groups were registered:: Diatomaphyceae with 65.3% follwed by the Chlorophyceae (33.4%) and the Cianophyceae (1.2%). The following groups were found in the Point 23 samples: Diatomaphyceae with 53%, Chlorophyceae (41.2%), Cianophyceae and Dinophyceae with 5% and 0.2% respectively and therefore the least representative (Figure 4.24).



Cianophyceae
Chlorophyceae
Diatomaphyceae
Dinophyceae

Figure 4.24: Composition of the Phytoplankton community downstream (point 3).

Sample 4 was the one that contained the highest number of cells, around 6,130 ind/L, and the most abundant taxa was the *Aulacoseira* sp with 2,174 ind/L followed by *Ankistrodesmus falcatus* (1,043 ind/L and *Gomphonema* sp (1,022 ind/L) while the lowest number of individuals was found in Sample 11 with only 3,196 ind/L of which *Aulacoseira* sp had the highest abundance index 761 ind/L followed by *Anabaena* sp with 543 ind/L (Figure 4.25). This last genus is renowned for producing toxins (Azevedo, 2000).

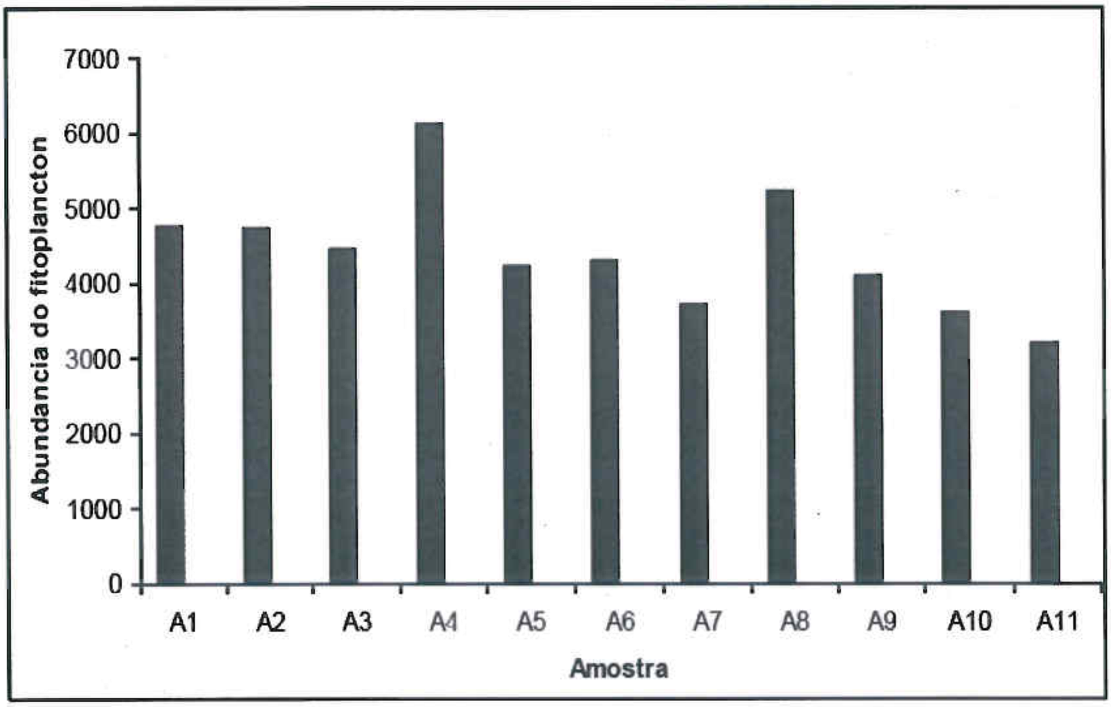


Figure 4.25: Total phytoplankton abundance at the Cambambe Dam by samples.

According to Wetzel (1993), each species has a niche within the variations of each habitat corresponding to its specific physiological necessities. The same author states that according to the Gause principal of exclusion though competition, in a relatively stable medium such as the pelagic zone of lakes where a diverse number of species competes for the same resources, it can be expected that a situation of uni-specific equilibrium would eventually be arrived. In fact what happens is not the exclusion of species, but rather that one or more species become more abundant than the others that is to say they become dominant in the phytoplankton community.

Payne (1986) reports that once a dam has been constructed, the growth of the phytoplankton community accelerates due to the lesser flow rates, greater concentration of nutrients and greater penetration of light because there is more time for materials brought down by the rivers, to settle.

The Diatomaphyceae as a whole have a highly accelerated growth rate that is favored by unstable environments so that the dam reservoirs foment their development and for that reason they are always dominant in relation to other groups (Sommer, 1988).

Sequesseque (2005) reports the finding same phytoplankton groups identified in the present study at Capanda (Diatomaphyceae, Chlorophyceae, Cianophyceae and Dinophyceae). During the period of this study the phytoplankton was found to be more abundant upstream as was the case at Capanda. Studied during the same period by Sequesseque (2005).

The impacts of the project on the phytoplankton community will probably be positive due to the greater concentration of nutrients and the greater penetration of light.

The greatest negative impacts could be eutrophy resulting from the accumulation of nutrients. Straskraba & Tundidi (2000) report accumulations of methane gas at dam installations stemming from the degradation of the submerged terrestrial vegetation and it is accompanied by an accumulation of H_2S in the hypolimnion. The resulting drop in pH at the dams downstream leads to turbine corrosion and fish mortality.

When the hypolimnetic waters become anoxic there may be significant corrosion of the dam structures and the turbines and in tropical conditions the entire water column may register dangerous concentrations of CO_2, H_2S and reach saturation level for methane. Strycker (1988), reports that at the Willow Creek dam in the United States a serious leakage problem arose because of corrosion. At the Curua Uma dam in the Brazilian Amazon the turbines had to be replaced after a mere 4 years ooperation (Straskraba & Tundisi, 2000).

4.2.2.2.2. Phytoplankton Species Frequency

Table 4.35 displays the frequency of occurrence of Phytoplankton organisms in the study samples.

Table 4.35: Composition and Frequency of the Phytoplankton community in the samples taken over the length of the study period.

Sample	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	Freq.	Freq. %

Sample	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	Freq.	Freq. %
DIATOMAPHYCEAE													
Amphipleura pellucida	p	p	p	p	p	p	p	p	p	p	p	11	100
Amphora sp	p	p	p		p	p	p	p	p	p		9	82
Aulacoseira sp	p	p	p	p	p	p	p	p	p	p	p	11	100
Cerasteria sp	p	p										2	18
Chaetoceros sp			p									1	9
Cocconeis sp			p									1	9
Coscinosdiscus sp		p										1	9
Cymbella cistula	p	p	p	p	p	p	p	p	p	p	p	11	100
Eunotia asterionelloide									p	p		2	18
Eunotia sp		p			p		p		p			4	36
Frustula rhomboide	p											1	9
Gomphonema sp	p	p	p	p	p	p	p	p	p	p	p	11	100
Leptocylindrus mínimus		p		p	p	p	p	p	p			7	64
Navicula placentula	p	p							p	p	p	5	45
Navicula sp	p	p	p	p		p	p	p	p		p	9	82
Nitzschia closterium	p	p	p	p	p		p	p				7	64
Nitzschia longuissíma			p									1	9
Nitzschia sp		p	p	p	p							4	36
Nitzschia spp	p					p	p	p	p	p	p	7	64
Pinnularia sp	p	p										2	18
Surirella robusta				p		p						2	18
Surirella sp					p							1	9
Synedra sp				p		p	p	p		p		5	45
Trubaria sp				p								1	9
CHLOROPHYCEAE													
Ankistrodesmus falcatus	p	p	p	p	p	p	p	p	p	p	p	11	100
Ankistrodesmus fusiformis			p		p				p			3	27
Ankistrodesmus sp	p	p	p	p		p		p	p	p		8	73
Closterium sp	p	p	p			p	p	p	p	p	p	9	82
Cosmarium sp		p			p	p	p	p				5	45
Euastrum sp			p				p		p			3	27
Pediastrum sp								p				1	9
Scenedesmus sp	p	p	p		p	p	p	p	p	p	p	10	91
Staurastrum leptocladum	p	p	p	p	p	p	p	p	p	p	p	11	100
Staurastrum sp	p	p	p	p	p	p	p	p	p	p		10	91
Staurastrum spp										p		1	9
CIANOPHYCEAE													
Anabaena sp					p						p	2	18
DINOPHYCEAE													
Ceratium fusus									p		p	2	18
Legend: p = present													

The sampling points were geo-referenced using GPS equipment. To obtain a better overall profile of the Kwanza River, two field campaigns were conducted during August and

September 2009. A boat with an outboard engine was used to collect the samples upstream and a simple canoe for the downstream collection The most frequently occurring species belonging to the Diatomaphyceae were *Amphipleura pellucida*, *Aulacoseira* sp, *Cymbella cistula* with 100% and therefore considered to be of constant occurrence; *Amphora* sp and *Navicula* sp with 82%; *Leptocylindrus minimus*, *Nitzschia closterium and Nitzschia* spp with 64%. As Speciess comuns foram *Navicula placentula and Synedra* sp with 45%; *Eunotia* sp and *Nitzschia* sp with 36%. The species *Cerastérias* sp, *Eunotia asterionelloide*, *Pinnularia* sp and *Surirella robusta with* 18%, and *Chaetoceros* sp, *Cocconeis* sp, *Coscinodiscus* sp, *Frustula rhomboide*, *Nitzschia longuíssima*, *Surirella* sp and *Treubaria* sp were classified as rare with 9%.

Among the Chlorophyceae the following were classified as constant *Ankistrodesmus falcatus* and *Staurastrum leptocladum with* 100%; *Scenedesmus* sp and *Staurastrum* sp with 91%; *Closterium* sp with 82% and *Ankistrodesmus* sp with 73%. *Cosmarium* sp with 45%; *Ankistrodesmus fusiformis and Euastrum* sp with 27% were classified as common. The rare species were *Pediastrum* sp and *Staurastrum* spp with 9%

Among the Cianophyceae and Dinophyceae there were only rare species *Anabaena* sp and *Ceratium fusus with* 18% each.

4.2.2.2.3. Diversity Index

Specific diversity is defined by examining the number of species present and the evenness of the distribution of individuals among those species (Margalef, 1983; Dias Júnior, 1990). That means that the occurrence of a high number of individuals of the same species denotes a situation of low biodiversity (Odum, 2001).

The value obtained for the diversity index in the present study varied from 2.73 to 3.59 bits/cél in the samples analyzed (Figure 4.26).

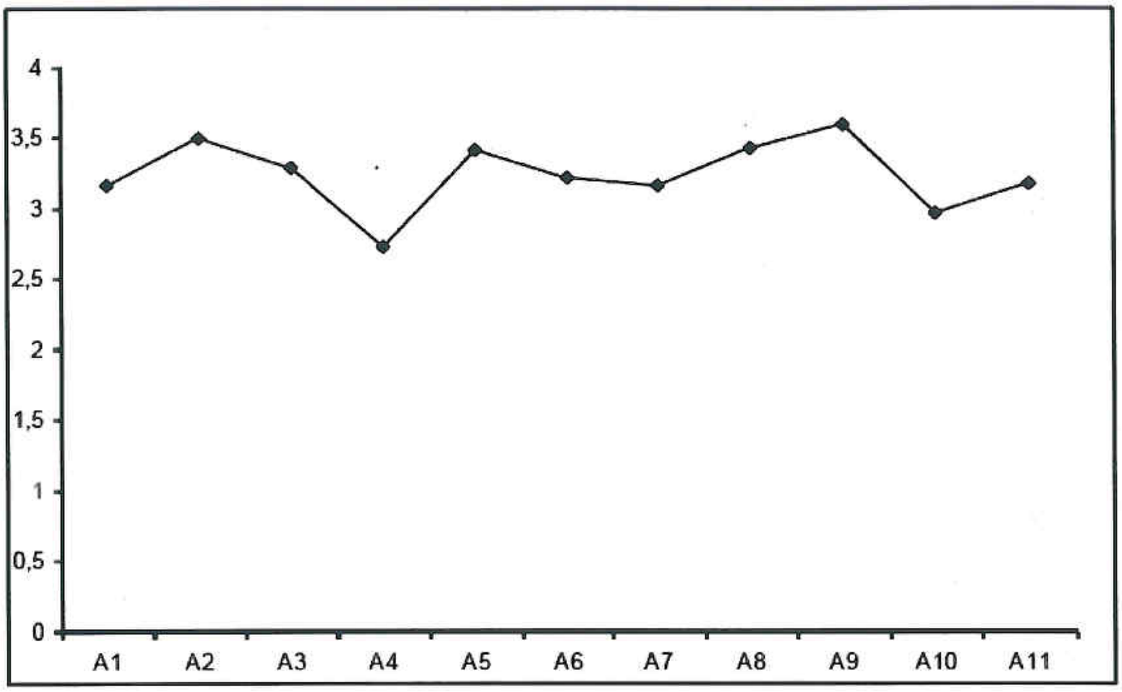


Figure 4.26: Variation of the Phytoplankton Diversity Index by samples, for the period of Cambambe dam study.

The very low diversity index registered for sample 4 in thsi study was probably due to the dominance of the genus Aulacoseira sp. Odum (1988, 1997, 2001) states that when conditions in the environment are favorable innumerable species are found with each one being represented by a small number of individuals. In such cases the diversity index is high. On the other hand, when conditions are unfavorable and the number of species found is small but there are many individuals for ech one, then the diversity index is low.

4.2.2.2.4. TROPHIC STATE

The term eutrophication was first used by Nauman, in 1919 to describe waters rich in nutrients , especially nitrogen and phosphorus (Lund, 1972). Margalef (1983) describes eutrophication as the result of interaction between the lake and the surrounding terrestrial ecosystems, intensified by the actions of man, a chronic component of succession in lacustrian ecosystems.

The calculations showed that the water examined in the study presented an index of 0.2 for Diatomaphyceae, 0.8 for Chlorophyceae and a compound index of 1.6. Thus on the basis of the studies carried out and the data gathered, the Cambambe Hydrolelectric dam area can be considered mesotrophic.

4.2.2.3. FINAL REMARKS

In this study of the phytoplankton community in the area of influence of the Cambambe dam the analysis revealed that it is composed of representatives of four (4) main groups: Diatomaphyceae, Chlorophyceae, Dinophyceae and Cianophyceae.

The Diatomaphyceae were the most abundant and dominant followed in the phytoplankton community followed by the Chlorophyceae. In regard to species diversity, Sample A9 showed the highest diversity index and the lowest was registered for sample A4.

The analysis of the results as a whole suggests that the Cambambe environment is mesotrophic and has a reasonable level of conservation given that there are few Cianophyceae and there is great richness of phytoplankton species. However a more precise verification of its trophic status would require a full long term quali-quantitative endeavor of the Cambambe area with sampling being done in different sesons (dry and wet) and including analyses of environmental parameters like Temperature of the water, pH, Electrical Conductivity, turbidity, transparency and Dissolved oxygen levels.

4.2.3. ZOOPLANKTON

Building a dam means that immediately a lotic environment will be transformed into a lentic environment because it leads to a considerable increase in the time during which the water remains in one spot. This initial transformation leads to a series of modifications to the limnological characteristics observed in the dammed area.

The limnological cycle is mainly determined by the local characteristics of the body of water and in the case of tropical and equatorial waters, seasonal variations are considerably reduced because the daylight hours are relatively uniform throughout the year and the temperature is also favorable and maintains itself above the lower limiting levels. IN freshwater environments the fauna component is made up of a variety of organisms representing almost all the taxonomic groups and performing na extremely important functional role within the aquatic ecosystem.

The term plankton is used to denominate the entire set of organisms that lives floating in the water and that has the power of autonomous locomotion, albeit with limited swimming capacity and incapable of swimming against currents. The set of animal organisms that make up part of the plankton community is referred to as the Zooplankton and the individuals can range in size from 40µm to 2.5 cm or even larger. The zooplankton plays a central role in the dynamics of aquatic ecosystems especially in cycling nutrients and in the energy flows. The production of a zooplankton population consists of the sum of the growth of all the species that compose it.

In aquatic environments qualitative and/or quantitative alterations in the community's structure may have important significance for the various other components of the ecosystem and may make the water unsuitable for a variety of uses. The zooplankton community, whose structure and dynamics are influenced by biotic and non biotic factors is directly affected by any alterations to the system.

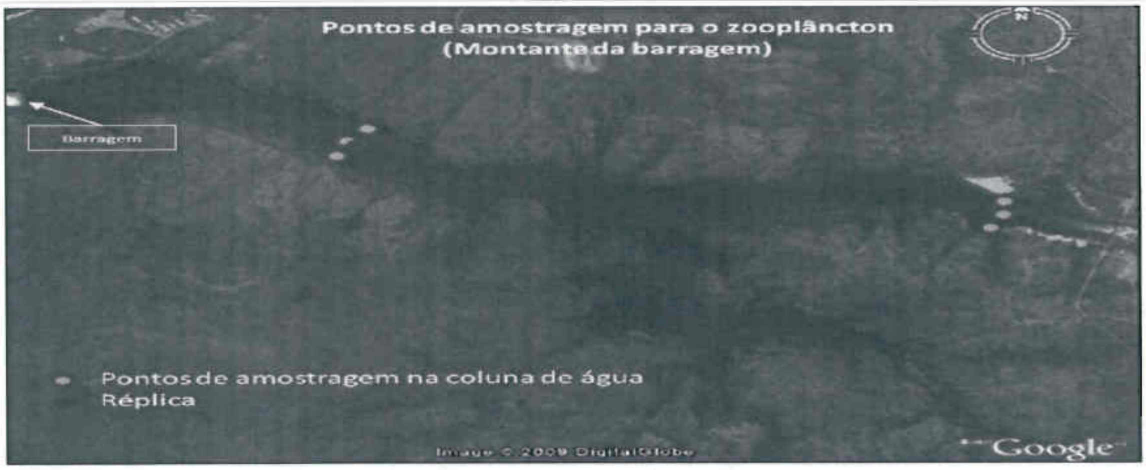
That sensitivity on the part of zooplankton organisms to environmental variations and the various ways they respond to them such as changes in the species or abundance composition of the community make it possible to use them As bio-indicators and to characterize aquatic environments, especially when there are changes in the trophic state of the waters. Thus the study of the composition, abundance and diversity of zooplankton communities is highly relevant, not only for acquiring greater knowledge of the fauna, but also to offer indications as to environmental conditions and the functioning of the system baring in mind that these organisms live in direct contact with the aquatic medium.

The freshwater zooplankton is represented by two main Phyla: Rotifera and Arthropoda. In the latter the Orders Cladocera and Copepoda, both belonging to the Class Crustacea are the most representative. The Cladocerans, together with the Copepods and Rotifers, are responsible for most of the secondary zooplankton production in fresh water and also are part of the natural diet of young and adult fish belonging to Plankton eating species. Getting to know the composition, density and structure of the zooplankton community in the area being studied will contribute towards gaining a better understanding and characterization of how the system works.

This study aims to determine the composition, structure and density of the zooplankton community in the study area and in that way, generate limnological information that will delineate the main functional forces at work in this system.

4.2.3.1. METHODOLOGY

Taking into account the feature of the study zone the following sampling points were defined for sample collection: two upstream from the dam and one downstream (Figures 4.27 and 4.28). These points were geo-referenced with the assistance of GPS. For purposes of more effective characterization of the River Kwanzaun the study area, two campaigns were conducted in August and September 2009. Water collection was accomplished using a motorized vessel upstream and a canoe downstream.



Dam

Zooplankton sampling points
(Upstream from the dam)

Water column sampling points
Replica

Figure 4.27: Zooplankton sampling points upstream from the dam.

Zooplankton sampling points
(Upstream from the dam)

Water column sampling points
Replica

Figure 4.28: Zooplankton sampling points upstream from the dam.

The qualitative and quantitative determination of the zooplankton community was done by sampling the water column using a standard plankton net with a 67µm mesh. The samples were fixed and preserved in 4% formol and kept in 250 ml plastic flasks for later qualitative and quantitative analysis.

Zooplankton identification and counts were done at the Ecology laboratory of the Agostinho Neto University's Faculty of Sciences using a counting chamber an optical microscope and a binocular magnifying glass.

To determine the numerical density of crustaceans, (Cladocera and Copepoda), 10 ml sub-samples were taken from previously determined volumes of the main sample. The organisms were counted using an acrylic counting chamber In the case of the Rotifera sub-samples of 1 ml were taken and the counting was done in a Sedgwick-Rafter chamber under the binocular microscope.

The specialized literature was consulted for the purpose of identifying the zooplankton community. Analysis of dominance (D), and abundance (A) among the species encountered was determined using Lobo & Leighton (1986) criteria. According to those authors, the Taxa whose numerical occurrence is greater than the Medium of the numbers of individuals present for all the other taxa present in the sample are considered to be abundant. Dominance (D) is attributed to those groups or species whose numerical occurrence is higher than 50% of the total number of individuals present in the sample.

Species frequency was determined according to the ratio between occurrence of the various taxa and the total number samples and expressed as a percentage. According to the criteria of Gomes (1989), the taxa are considered to be constant when the frequency (F) is higher than 50%, common when $10<F<50\%$, and rare when frequency is below 10%. The following equation was used to calculate frequency:

$$F = (Pa/P).100$$

Where:
Pa = number of samples where the species is present
P = total number of samples analyzed

Statistical analysis made use of the Medium values obtained for the variables and graphs were traced for the time period of the study.

4.2.3.2. RESULTS

The zooplankton community that was sampled is very poor, with low representativity. 16 species were detected of which 11 belong to the Phylum Rotifera and 5 to the Phylum Crustacea. Of these last, 3 belonged to the Order Cladocera and 2 to the Order Copepoda (see Table 4.36). In open ecosystems with unidirectional flows the plankton is hardly represented at all. The zooplankton is normally made up of short-lived species that multiply rapidly, adjusting themselves to the speed of the current and the greater or lesser degrees of turbulence and thereby managing to maintain a certain population 'stock'.

Table 4.36: Composition of the zooplankton community in the area studied and Taxa frequency during the sampling period.

GROUP	SPECIES	FREQUÊNCY (%)
ROTÍFERA	*Keratella cochlearis*	*40*
	Monostyla bulla	*10*
	Keratella quadrata	*20*
	Keratella valga	*30*
	Colurella sp	*30*
	Synchaeta sp.	*10*
	Lecane sp.	*20*
	Trichocerca sp.	*10*
	Lecane elasma	*10*
	Asplancna sp.	*10*
	Tricocerca loginseta	*10*
CLADOCERA	*Bosmina hagmanni*	*10*
	Bosmina sp.	*10*
	Moina micrura	*20*
COPEPODA	*Parastenocaris starrelli*	*20*
	Termociclops decipiens	*40*
Nauplial forms	Nauplial foprms of Cyclopods	
	Nauplial forms of Calanoids	

Limnological studies conducted in 2002/03, (Andrade, 2003) indicate the existence of a great variety of zooplankton organisms in the region of the middle course of the Kwanza both upstream and downstream from the Capanda dam, and refer to the presence of 39 taxa of which 26 taxa belong to the Phylum Rotifera and 13 to the Phylum Arthropoda, Class Crustacea. Of the Crustaceans, 8 belong to the Order Cladocera and 5 to the Order Copepoda.

The poor representativity of the zooplankton in the area studied is probably related to the lack of diversity among the phytoplankton as well as the intrinsic characteristics of the place itself, although there are many factors that can influence the density and composition of the zooplankton. To determine the real causes would require further, continuous, interdisciplinary, in-depth studies which lie outside of the scope of the present work.

At the group level, the Rotifera were predominant in all the sampling points albeit there were variations in the abundance of species from one point to another, results consistent with those obtained by other studies conducted in environments formed by damming rivers in tropical regions. Studies of reservoirs have shown that one of the main characteristics of such systems is the dominance of the Rotifera over other zooplankton groups in terms of population densities (See Figure 4.29).

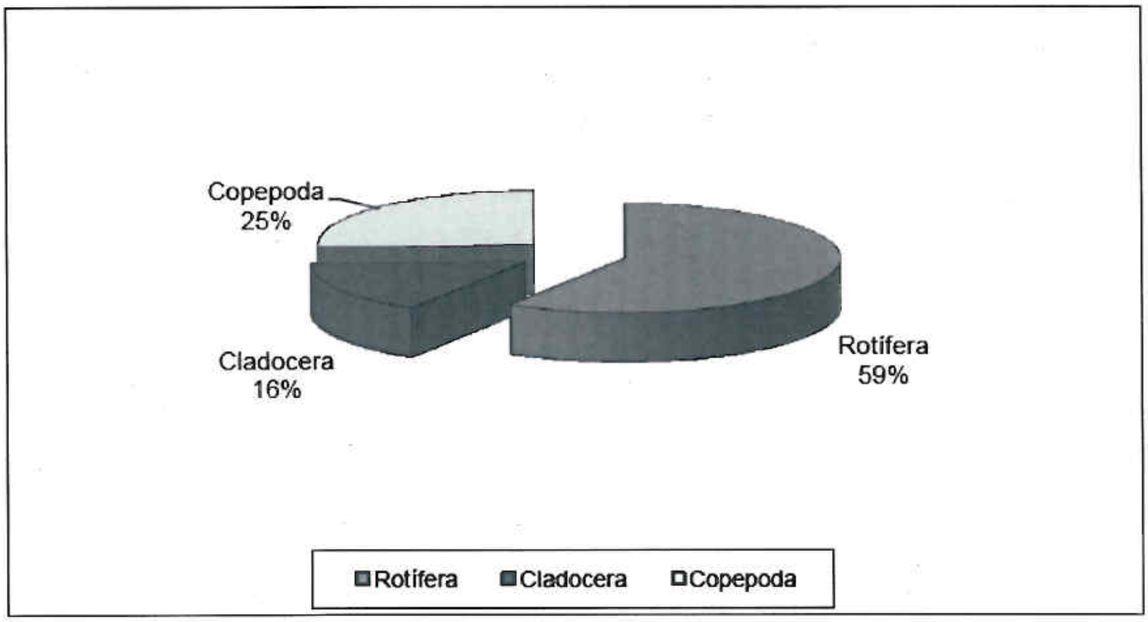


Figure 4.29: Distribution of the zooplankton community sampled

It must be stressed that in the light of the criteria adopted no dominant species were identified, only some species that were abundant and predominated in comparison to the others. The predominant species found amog the Rotifera were *Keratella cochlearis* and *Keratella valga*, for the Cladocera, *Bosmina hagmanni*, was the predominant species while among the Copepodathe following species were predominant: *Termociclops decipiens* and *Parasteronocaris starrelli*. However, it was found that the species composition of the zooplankton varieed from one sampling point to another and that species belonging to the

Cladocera and Copepoda groups were found near to the shores both upstream and downstream from the dam. Copepoda and Cladocera are associated to backwaters, riverside lakes or stretches of water where the rate of flow is very low because the speed of the current is a limiting factor for these slower organisms.

At the sampling spots the zooplankton was found to be very poorly represented and made up of just a few species of rotifers, probably due to the fact that these organisms are capable of adjusting to the speed of the current and that they multiply very fast.

The current is one of the main factors influencing the composition of the communities most of which have adaptations that enable them to avoid drifting down towards the mouth of the river and are also adapted to the physical and chemical conditions of the system such as water temperature, dissolved oxygen levels and nutrient loads which can also influence the distribution of the communities.

Among the Copepods, the sub-orders Calanodia and Cyclopodia are indicative of the trophic state of aquatic systems. In oligo-mesotrophic systems the Calanodia are dominant while in highly eutrophic systems the dominance of the Cyclopodia is usually found. At the sampling points juvenile organisms belonging to the two sub-orders were found but with no evident dominance of either which leads us to the conclusion that the system may be mesotrophic.

4.2.3.3. FINAL REMARKS

Under this heading it is important to underscore the fact that at the points where sampling was done the zooplankton was very poorly represented. The greatest species density and diversity were shown by the Rotifera indicating that the zooplankton community in the area is basically made up species belonging to this particular group. In regard to the trophic state of the reservoir it is mesotrophic as shown by the organisms that are indicators of trophic state.

4.2.4. BENTHON

The benthic macroinvertebrates composing the benthon, macrozoobenthos or benthic macrofauna consists of a group of organisms with sizes of 1 mm or greater that have a direct relationship with the bed or bottom and that condition imposes a certain uniformity in their ways of life in spite of their distinct phyllogenetic origins (Day *et al*. 1989).

The evaluation of water quality in bio-monitoring programs is done by studying the organisms that make up the benthon because they clearly reflect the state of conservation or degradation of the respective ecosystem.

Among the features that make these organisms so efficacious in that kind of study are: their abundance in aquatic systems, low mobility, greater time of remaining in a given environment (because they can remain alive for weeks or months in the sediments on the bottom making it possible to explain time-related patterns of the alterations resulting from disturbances); wide variety of tolerance to various types and degrees of pollution; functionality as indicators of environmental given their presence before, during and after disturbances (Rosenberg & Resh, 1993). Furthermore there are other advantages to using them as biological indicators: rapidity and efficiency in delivering results, low cost, and the possibility of evaluating the quality of the water in an ecosystem without having recourse to analyses of its chemical and physical parameters (Queiroz *et al.*, 2000).

Thus short term investigations are often made to provide preliminary information on the diversity and general conditions of the Biota. Such assessments make it possible to evaluate verify the biological values and state of conservation of the ecosystem under study (Willink *et al*. 2000 *apud* Galves *et. al.*, 2007).

When a human intervention of great intensity occurs, as is the case with dam construction, the longitudinal equilibrium of the river is broken. Any kind of barrier in the channel of a river interferes with its lotic system (currents) so that it becomes a system with lentic characteristics (still or almost still waters in the reservoir. That kind of interference produces a chain of effects which may be irreparable, depending on the magnitude of the area involved (Cunha, 1995, 2001a). Dams also represent a barrier to the transportation of sediments leading to a reduction in the material that would normally be carried on down to the coast and modifying the quality of the water, its temperature, and salinity. As well as incrementing erosion downstream from the dam.

Among the biological effects of dam construction are the extinction of some species in the river, the increase in the density of other species and an overall reduction in the diversity and/or abundance of the biotic communities. The Reservoir's macrobenthos show little complexity and low population densities being made up of less than a hundred different types of known but with complicated taxonomy, especially in the case of the bivalves, oligochaete worms and quironomid flies.

The aim of this study was to make a survey of the macrobenthic communities, as they are an important tool for any studies designed to evaluate water quality.

4.2.4.1. METHODOLOGY

The first sampling was carried out on August 22. Samples were taken upstream (Figure 4.30) and downstream from the dam (Figure 4.31), but as no organism was found a second campaign was planned. During the first sampling attempt the presence of intense human activity on the banks was observed (informal trading, washing clothes) and a very high level of sediments was detected mainly consisting of coarse sand.

Sampling points

Replicas

Figure 4.30: Benthos sampling points upstream from the dam.

Sampling points

Figure 4.31: Benthos sampling points downstream from the dam in the Dondo.

Due to the high degree of silting up observed during the first sampling effort downstream the second sampling campaign was only carried out upstream and there a greater variety of substrate types was found. It is well known that sedimentation levels in a river increase from upstream to downstream.

In the second sampling process, samples were taken from the Cambambe dam on September 6 of this year (Photo 4.17). Three transects were established from one bank to the other and another in the central region. Each transect corresponded to a sampling station. Three samples were collected for each station so that 9 samples were collected altogether. The sediment was collected using a Van-Veen dredge and immediately after collection they were washed using sieves with 5 and 1 mm meshes. The material retained by the sieves was fixed in 4% formol and stored. In the laboratory the samples were screened using a stereoscopic microscope. The material used to examine the Benthic samples at the Cambambe Hydroelectric Dam included:

- Sieves with and5 mm, 1 mm and 0.5 mm meshes;
- Van-Veen dredge;
- 4% Formol;
- Plastic Flasks;
- Metal Spoon;
- Leica binocular magnifying glass; and
- Labels.

Photo 4.17: Sample collection at the dam using a Van-Veen dredge.

4.2.4.2. TYPE OF SEDIMENT

As the sample bulletin in Attachment 4 shows the sediments at the sampling stations was largely made up of gravel, fine sand and mud. At station 1 (samples 2 and 3), station 2 (sample 1) and station 3 (sample 3) the sediment consisted largely of fine sand and mud. This kind o deposit was found in parts where the water is calm with less movement and that propitiates the sedimentation of sand and fine sediments. At the other stations the sediment was made up of sand and gravel with a stronger presence of gravel. During the screening process small amounts of human artifacts were found such as bits of sponge and plastic which suggests that they are spoil deposits and that the human population has ani impact on the reservoir .

According to the classification system of Flanning & Flanning (*apud* Peloggia, 1998), deposits are spoil deposits when they stem from silting up processes resulting from accelerated erosion of areas where human artifacts exist but in small quantities.

According to Carvalho (1994) sedimentation is a process derived from the sediment that encompasses erosion, transportation in the water courses and deposition of the sediments. That means we must take into account questions of land use, erosion and sedimentation in the reservoir. The sediments are preferential formations for the deposition of mineral and organic materials (nutrients, heavy metals, pesticides, bacteria), which are subsequently released into the water column.

Judging by the quantity and nature of the sediments sampled it can be stated that the dam reservoir may be undergoing a sedimentation process and the deposits involved may be of either autochthonous origin or allochthonous origin. That may be explained by the forms of land use employed by the populations upstream.

Te population that live on the banks of the Kwanza river depend directly or indirectly on the river. They engage in agricultural and livestock raising activities as their means of livelihood and to that end the deforest large areas to form pastureland and to farm and in most cases no protection is left for the water courses.

Over the medium and long term, mechanization and the use of fertilizers and pesticides may cause damage to the environment. Inadequate use of riverside lands leads to alterations in the freshwater systems such as: reduction and alteration of the aquatic habitats, reduction in the quantity of water, impoverishment of the quality of water, exposure and erosion of soils thereby accelerating the overall sedimentation process.

4.2.4.3. MACROBENTHIC FAUNA

33 larvae were recovered from the station sampled all belonging to the family CHIRONOMIDAE. At the station farthest from the dam not one individual was found. At station 2 18 individuals were collected and at station 3 a total of 15 individual as shown in Table 4.37.

Table 4.37: Number of individuals collected at the sampling stations.

Station 1	**Samples**	**Nº Individuals**
	1	**0**
	2	**0**
	3	**0**
Total		**0**
Station 2	**Samples**	**Nº Individuals**
	1	**0**
	2	**8**
	3	**10**
Total		**18**

Station 3	**Samples**	**Nº Individuals**
	1	**11**
	2	**4**
	3	**0**
Total		**15**

Chironomidae is a family of mosquitoes belonging to the Diptera order. It is one of the few insect families that colonize the benthos of the marine shores and can be found at depths of as much as 40 meters. Among the genera there are some with terrestrial or semi-terrestrial larvae.

Insects of the Chironomidae family are important components of the lotic and lentic benthic communities and colonize a wide variety of biotopes living under the most varied environmental conditions (Pender, 1986). They can also be found in a variety of freshwater environments often achieving high population densities. Their larvae (Figure 4.32) are an important of the diet of many fish and they can also serve as indicators of the quality of the environment (some species are very specific in regard to their environmental requirements while others are relatively tolerant of a variety of pollutants).

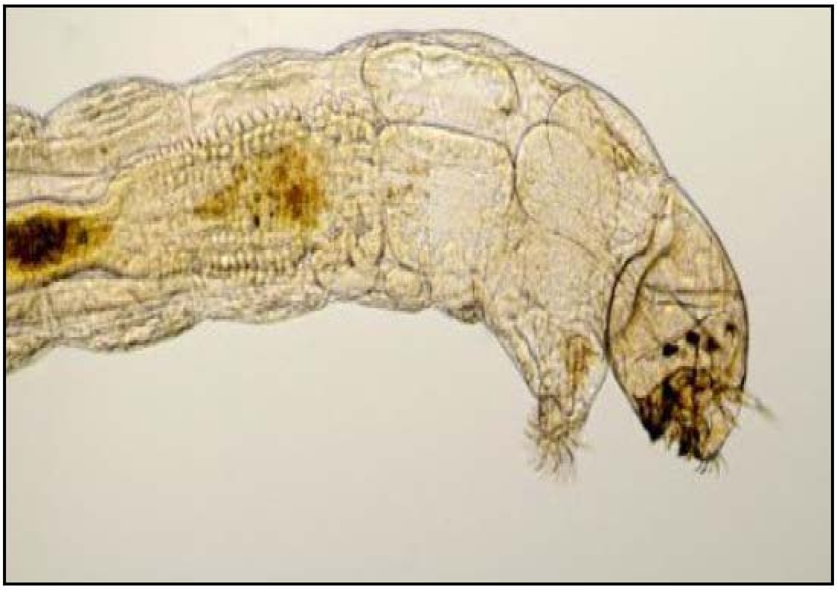


Figure 4.32: Chironomidae larva 3 mm long (X 10).
Source: www.wikipedia.com.

The work of classifying organisms was done at least to the taxonomic level of Family. According to papers published regarding water qualkity assessment studies the identification of benthic communities does not call for very specialized knowledge to identify organisms down to Family level, but whenever possible we carried the taxonomic identification process on down to lower levels to obtain conclusive results.

The fact of the Chironomidae larvas' being the only organism found at the sampling stations seems to indicate that anthropic activities are having an impact on the benthic communities because larvae of the Chironomidae family are considered to be strong bio-indicators for the quality of water. In spite of the total dominance of this particular biological indicator in the samples collected it is important to conjugate that information with the study of the physical-chemical parameters for the subsequent consolidation of results and the possible identification of those activities.

4.2.5. ICHTHYOFAUNA

Generally speaking biological diversity is positive and valuable in its own right. Certain key species are important for the sustainability of others within a given community and many have associated economic value.. On the other hand, in addition to that intrinsic value linked to the maintenance of various trophic chains, fish also serve as a link between aquatic and terrestrial food chains as they are the nutritional base for many other animal species like fishing birds and other species associated to aquatic environments.

Knowledge of the ichthyofauna is essential for the purposes of this work considering that fish are important regulators of the zooplankton and phytoplankton and also control some species of macrophytes, converting vegetable protein into animal protein and serving as a source of nutrition for the riverside populations.

A high degree of fish to some extent contributes to their In regard to aquatic systems insofar as they serve as good biological indicators of the health of the respective ecosystem.

Among the economic Part of the economic importance of the ichthyofauna lies directly in their value for consumption, because thay are widely eaten locally. There are other values involved however because some of the fish captured from their natural surroundings are commercialized. Among the species involved in this latter process the groups of Cichlidae and Claridae are the most important. A large part of the population living along the banks of the watercourse especially downstream from Cambambe relies on fish as a source of animal protein in its diet.

While it is true that geographic considerations can influence distributions among river systems the distribution of various species will be more likely to depend on the geomorphology of each river section.

Various authors address this issue by distinguishing the different zones of a river especially fast flow zones and backwater zones. The former usually consists of shallower waters where the velocity of the current ensures that the bed of the river remains free of sediments and quite firm.

These zones are inhabited by benthic or periphytic organisms that remain fixed are adherent to the firm substrate and by vigorous swimmers including fast swimming fish. The second zone consists of deeper waters where the current is sluggish and the suspended materials tend to settle on the bottom giving rise to a soft stratum unsuitable for surface adherent benthos but favorable for organisms that dig or burrow, to the nekton and even in some cases to the plankton.

Thus in observing the fish communities we can distinguish those communities typical of fast flow zones and other communities more typical of backwaters although a certain degree of exchange may be established between them , all the more so because certain components of the backwater fauna like to penetrate to the rapids to reproduce. The fish that inhabit the rapids, on the other hand tend to remain static inside their zone of preference and that means they are more affected by the transformation of lotic environments into lentic environments as is the case when dams are constructed. It must also be noted that the fish that inhabit still or slow waters can be divided into two very distinct groups on the basis of their behavior:

- The fish belonging to the **first group** (areas of rapids) avoid the difficult conditions of the floodplain during the period when the waters are receding by migrating into the main channels and than by undertaking long migrations to zones far away from where they come from. Species belonging to the Cyprinidae family are examples of such behavior as are species belonging to the Mormyridae family, also endowed with migratory habits. Nevertheless, there are some species that remain in the channels throughout the year and entirely avoid entering the flood plain: and

- The **second group** from the still water zones made up of limnophyllic species that can tolerate very low levels of dissolved oxygen in the water (they are also referred to as dark fish). Their movements are more limited than those of the white fish which are more demanding in terms of the quality of their habitat. The dark fish remain in still waters throughout the dry season and if they do happen to move into the river, they remain at the edge, in contact with the vegetation or in swampy pools left by the river when its flow has gone down considerably. Almost all the Siluroids belong to this category.

Although the distinction between white fish and dark fish may appear somewhat vague it is very useful as a rule of thumb measure for a preliminary ecological classification of the fish species. The responses of the two groups are quite different from one another and they have important implications for establishing order in the ecosystems and for fishery resources.

Many tropical rivers show a considerable alternation of fast flow zones and slack water zones and so the two fauna groups alternate in an analogous manner down the course of the river which leads to a kind of zoning that is simply based on the conditions of flow or the nature of the river bed, but such a classification cannot be taken to be the rule.

The problems associated to the variations in the river flow regime can be taken into account in the different impacts that they have on the fish communities, that is there are various manifestations that may occur according to the group of fish and its bio-ecological specificities, or if the beginning of the floods after a dry period is earlier or later than usual, if the water levels are higher or lower than usual, or the dry season goes on for longer than normal, or if the period of transition between wet and dry seasons should extend over a shorter period than normal, that is the hydrographic profile presents a sharper aspect or a shallower aspect, if the beginning of the humid period begins earlier or later than normal in which case the synchronization with the rainy season may be altered, if any alteration occurs to the natural proportions of the various types of inundation, if the transition period to the dry season begins earlier or later than normal or if it lasts longer or shorter than normal.

Among all the different aspects of impacts is the fact that they affect the productivity of the ecosystem and accordingly also affect the temporal development of new contingents, the availability of habitats conditioned in this way may restrict the movements and survival of individuals, affect the availability of food, make migrations difficult to achieve as well as the reproductive process. They can affect the time taken to attain maturity, or lead to the disqualification of some segments of the habitat due to the changes in the quality of the water among many other possible impacts.

In short, these impacts may affect the maintenance of the populations and those populations that reside in small water courses or in the numerous floodplains to be found downstream from the Cambambe hydroelectric plant are drastically affected. Even though these changes in the river flow regimes obey natural periodic cycles, water infrastructure engineering works like dams, whatever their purpose, may produce intense impacts resulting from the alterations to the river flows so that it is essential to take into account possible mitigation actions including the establishment and maintenance of ecological flows.

4.2.5.1. METHODOLOGY

To characterize the ichthyofauna in the venture's direct and indirect areas of influence in order to be able to identify potential impacts stemming from it, first a review was made of the respective literature consisting mainly of scientific reports and environmental impact studies made of the same system and other similar systems.

On the other hand, because of the gap in information and with the intention of validating existing information sampling was planned for different points in the area of direct influence (Table 4.38 and Figure 4.33), tasking care to ensure the representativity of the various types of habitat found and the different trophic strata of the fish communities. Data gathering was done from August 23 to 26 and from September 9 to 11, 2009.

Table 4.38: Sampling points in the Cambambe Reservoir.

Sampling Point	Capturing Equipment	Latitude	Longitude
P1	Seine net and Butterfly net	9º45'35.41''	14º30'47.98''
P2	Gill net	9º45'35.42''	14º30'42.29''
P3	Seine net	9º45'27.61''	14º30'35.34''
P4	Gill net	9º45'22.01''	14º30'18.74''
P5	Gill net	9º45'39.37''	14º30'04.14''

Cambambe Dam

Sampling Points

Figure 4.33: Sampling Points in the Venture's Direct influence Area.

These surveys were carried out along two lines. The first consisted of informal interviews with those local riverside communities (Photo 4.18) that make direct use of the river with special attention to the fishermen who made it possible to obtain a panoramic vision of the species present, the time of greatest abundance of fish and their importance from the economic and social point of view taking into account the fishing mechanisms employed. The second line was in the form of sampling using passive (Photos 4.19 and 4.20) and active methods (Photo 4.21) employing different types of equipment, namely três (3) multi-mesh gill nets (12 panels 3 x 1.5 meters with meshes from 5 to 55 mm); one (1) seine net nº. 0.5 (1.5 X 6 meters); and one (1) butterfly net.

Photo 4.18: Informal interviews with riverside and fishing communities.

Photo 4.19: Multi-mesh gill net. Passive sampling method.

Photo 4.20: Multi-mesh gill net. Passive sampling method.

Photo 4.21: Seine net. Active sampling method.

In the passive sampling done with the gill nets an attempt was made to partially block one of the flooded inlets of the reservoir and the vegetated water's edge and encompassing the whole height of the water column. The nets remained set for 24 hours but they were examined after the first 12 hours , This method was used to capture mobile fish species although there are disadvantages to it in the case of more generalized inventorying insofar as the size of the net mesh limits the catch to certain size ranges of the fish population. To compensate for that effect panels with a variety of mesh sizes were used in a single sequence.

The active sampling method using a seine net was used to capture pelagic species and small-sized demersals as well as the fry of larger species in open areas of the system, sandbanks with swift currents or very little flow and water edges with vegetation. The advantage of this technique is that it can be adapted to many situations and provides supporting information for determining the biodiversity of small-sized fish species and also information on the extent to which the larger species use the area of the system for raising their fry. The technique also makes it feasible to take several samples in a short space of time.

The use of the fine-meshed butterfly net was designed to capture small fish species and the fry of larger species especially in zones with rocks on the bottom that made it difficult to use the other types of net, and it too contributed to expanding knowledge of fish biodiversity.

Complementary surveys based on informal questioning of members of the fishing communities in the areas surrounding the project and upstream from the venture provided information on population dynamics and the dynamics of new contingents and enabled an understanding of the importance attributed to fish throughout the length of the lower Kwanzo river system. The specimens captured and collected during the information gathering process were photographed and preserved in 10% formaldehyde. Most of the species were identified locally with the assistance of identification keys and the knowledge of specialists, while others were identified more carefully in the laboratory.

4.2.5.2. Habitat description

The description of the habitat at the sampling points is set out in Table 4.39 (Figure 4.33). In this case an effort was made to cover all kinds of habitats in the system that would be directly affected by increasing the height of the dam.

Table 4.39: Description of habitat types at the Sampling point.

Sampling Point	Substrate	Vegetation	Flow	Depth	Sampling method
P1	Rocky and sandy	Marginal	Médio	0.3 – 1 m	Seine net and butterfly net
P2	Sandy rocky	Marginal and submersed	Médio	1 - 2 m	Gill net
P3	Sandy	-	Baixo	0.5 – 1 m	Seine net
P4	Muddy sand	Marginal and submersed	Baixo	0.5 -2 m	Gill net
P5	Sandy mud	Marginal	Baixo	0.5 – 5 m	Gill net

4.2.5.2.1. Fish diversity and position in the system

The capture of specimens in the Cambambe reservoir using the various fishing techniques resulted in the identification of 31 distinct species (Table 4.40, Figure 4.33 and Photos 4.23 to 4.26), belonging to the Families: Cyprinidae, Characidae, Hepsetidae, Claroteidae, Mochokidae, Schilbeidae, Mochokidae, Clariidae, Cichlidae, Mormyridae and Mastacembelidae. It must be mentioned that, species of the Cyprinodontiformes, Clupeidae and Kneridae families have also been reported and described for this river system but none were captured during the sampling period.

Table 4.40: Species captured at the various sampling points.

Family/species	Sampling point	Nº of individuals captured
Mormyridae		
Marcusenius sp.	P5	2
TOTAL		**2 (1.03%)**
Cyprinidae		
Barbus cf. *musumbi*	P1, P3	2
Barbus cf. *mattozi*	P3	3
Barbus radiatus	P2	3
Barbus holotaenia	P1, P3, P5	24
Barbus barnardi	P1	3
Barbus thalamakanensis	P1, P3	4
Barbus afrovernayi	P2	2
Barbus cf. *paludinosus*	P1, P3	3
Barbus cf. *argenteus*	P5	2
Labeobarbus sp.	P5	1
Labeo cf. *annectens*	P2, P4, P5	5
Labeo cf. *chariensis*	P5	12
Varicorhinus sp.	P5	1
Opsaridium zambezense	P1, P3	42
TOTAL		**107 (55.15%)**
Characidae		
Rhabdalestes maunensis	P3, P5	12
Bricynus lateralis	P3, P5	32
TOTAL		**44 (22.68%)**
Hepsetidae		
Hepsetus odoe	P2, P4, P5	3
TOTAL		**3 (1.55%)**
Claroteidae		
Chrysichthys macropterus	P4, P5	8

Family/species	Sampling point	Nº of individuals captured
Parauchenoglanis ngamensis TOTAL	P2	1 **9 (4.64%)**
Schilbeidae Schilbe bocagei TOTAL	P5	4 **4 (2.06%)**
Clariidae Clarias ngamensis Clarias gariepinus TOTAL	P2 P5	1 1 **2 (1.03%)**
Mochokidae *Synodontis* sp. TOTAL	P2	1 **1 (0.52%)**
Masacembelidae Mastacembelus sp. TOTAL	P1	1 **1 (0.52%)**
Cichlidae Oreochromis andersonii Tilapia rendalli Tilapia sparmanii *Pharyngochromis* sp. Hemichromis fasciatus Oreochromis angolensis	P4 P5 P5 P1, P5 P5 P5	3 2 3 8 4 1
TOTAL		**21 (10.82%)**

Photo 4.22: Specimen of *Brycinus lateralis*.

Photo 4.23: Specimen of *Tilapia rendalli*.

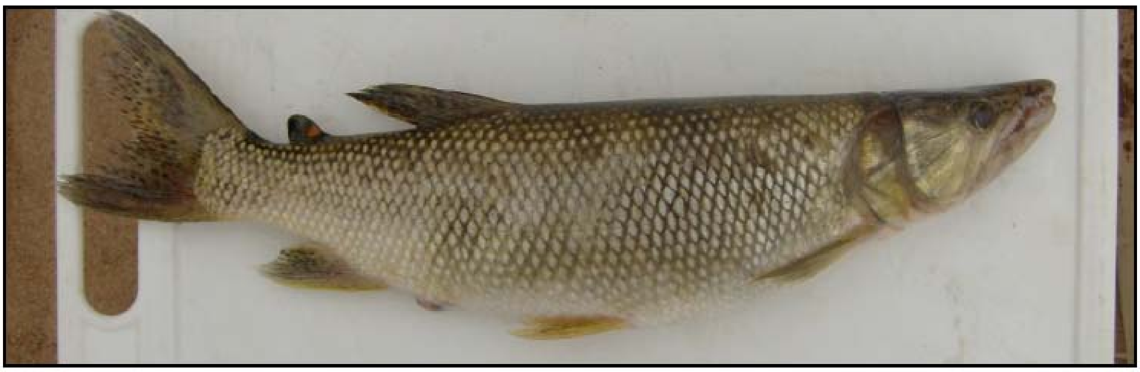


Photo 4.24: Specimen of *Hepsetus odoe*.

Photo 4.25: Specimen of *Opsaridium zambezense*.

The Cyprinidae and Cichlidae families showed the greatest specific diversity and the greatest numerical abundance (density) followed by the Cyprinidae (Figure 4.34). It should be noted that the species representing those two families are inserted in the lowest trophic levels of the system and therefor the greater part of the energy entering the food chain is concentrated in them.

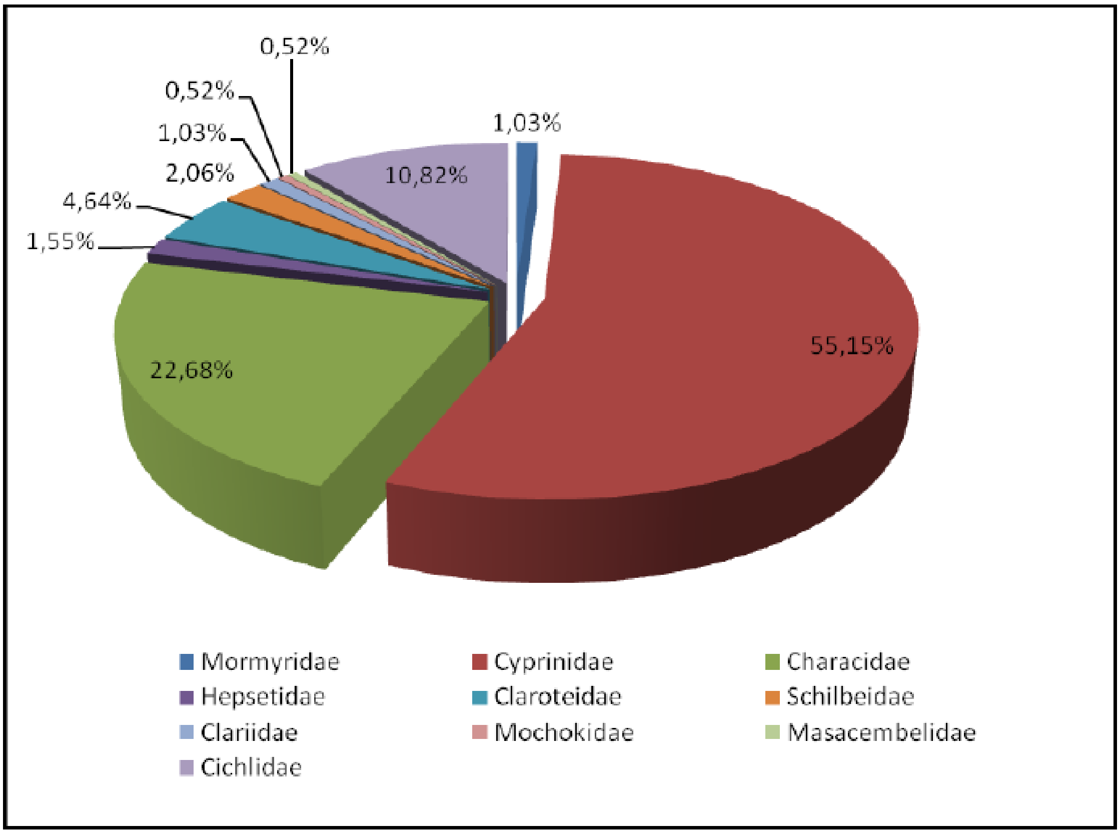


Figure 4.34: Abundance of fish species found in the Cambambe reservoir.

Taking into account the level of information available, including the range of relevant literature, the specific diversity of the Kwanza system is high and there is a suggestion of possible endemism given that the Kwanza river basin has a singular location in Angolan territory and its biodiversity is apparently not completely known.

From the Bio-ecological point of view that diversity is evident in the presence of species occupying different niches in the Kwanza system that are ecologically adapted and that may therefore be susceptible s in their state associated to physical alterations to the conditions of their environment. The case can be analyzed using as indicators the responses of populations of the more sensitive species or those that are easiest to diagnose. It should be noted that that the fish inhabiting the river have varied reproductive habits that enable them to adapt to the changed conditions that exist along the course of the river and to difficulties in growing the young inherent to a river where the water levels fluctuate rapidly and frequently.

In regard to the informal surveying of fishermen downstream in the Kenza (n=25), there was unanimous affirmation about the migration at the beginning of the rainy season of most of the species we found and that was reflected in the very low rates of capture for many species and even total absence of others, during the high-water period. There are some species however that can be found in relative abundance during the different seasons of the year as is the case with *Opsaridum zambezense.*

Another result of the informal inquiries backed by the catches was the identification of period when the waters first begin to recede, that is, the months from May to August as the one when the best results were obtained for capturing fish which is evidence of the return of the fish communities to the main water courses and the presence of new contingents of young fish. Among the majority of t species that were identified directly on the spot were those that have commercial value especially belonging to the genera *Clarias* sp., *Serranochromis* sp.*, Tilapia* sp. and *Oreochromis* sp*..*

During the period when the waters are rising due to heavy rainfall in the Kwanza basin and the consequent increase in the flow of the river flooding can be observed where the river banks are low. Due to the great volumes of water coming down huge masses of vegetation break off and form floating islands dragged along by the waters.

The riverside vegetation and the floating islands provide protection for the very young fish and other species that are small by nature and by accompanying the vegetation they manage to distribute themselves throughout the system. During the dry period the sedentary species usually migrate to the main channels as the flood waters gradually recede and they take their place in various habitats along the course of the river. Some of these refuge habitats can be a very long way from the main flood zones.

Also during the dry season the fish tend to separate into groups according to depths, type of river bed and type of vegetation present. Those secondary watercourse that maintain communication with the main channel often become lentic and acquire the characteristics of flood zones. In those situations there is an accumulation of organic material that makes it possible to maintain the continuity of primary production so that such protected areas of are particularly important in regard to the concentration of ichthyomass they represent.

Intensive feeding during the periods of abundance enables the fish to store great amounts of fat and that in turn not only enables them to face the less fecund season that follows but also contributes to the process of maturing their gonads in preparation for reproduction. According to Daget (1956), desnutrition during the dry period makes the fish lose weight. However the observations of Willoughby and Tweddle (1977) indicate that nutritional peaks are achieved at different times of the year by different species. Food consumption by *Clarias gariepinus* in the Shire river system, for example, reaches its peak immediately before the waters start to rise. On the other hand, *Oreochromis mossambicus* feeds most intensely when the waters first start to recede from the inundated areas. A third species, *Claria ngamensis*, feeds at a constant rate throughout the year. Nevertheless the consumption of food by all three species is at its lowest when the waters are also at their lowest

4.2.5.2.2. PROTECTED SPECIES

According to the basic presupposition of conservation, all species deserve to be adequately conserved and managed and not to be exposed to biodiversity loss especially in cases of species that are confined to endemic populations or threatened with extinction.

In regard to official protection for fish species in Angola’s continental waters, there is no specific legislation or any type of decree that concedes any particular conservation to the range of species found in this study even though signs of endemism are recognizable so that more in depth taxonomic studies are needed to confirm the true status of the species identified and the kind of protection they should be afforded.

4.2.5.2.3. INDICATIVE ATTRRIBUTES

Considering the range of representative fish species of the Kwanza system and in particular of the Cambambe dam and surrounding, while not exactly justifying a claim to endemism in relation to the different indicative attributes associated to their life cycles and correlation with the flows, we can highlight the following species: fish (1) inhabiting channels and making longitudinal migrations, (2) those making lateral migrations into inundated zones (small and large fish)), (3) those inhabiting shallow protected environments with submerged vegetation. (4) those inhabiting rocky zones, (5) those inhabiting waterside vegetation in channels draining the areas of inundation and (6) sandbank specialists.

4.2.5.2.4. INDICATORS

Tables 4.41 to 4.43. display the main characteristics of the different indicators previously identified the representative species for each of them, the attributes associated to their life cycles and their obvious connections with the river flow conditions.

Based on the presupposition that the biology of each species is known it is possible to foresee what will happen according to the different variations in the flows although predicting the magnitude of the impact will depend on the existence of a more detailed analytical base. That analysis is reflected in Tables 4.44 at 4.49 which set out the predicted changes in each indicator associated to the various possibilities of changes in the torrent flows.

However, an analysis that seeks to measure the distribution and area of occupation or exploitation from the perspective of biological needs of the different species in the selected locations, will actually be a valuable for gaining a broader understanding of the impacts on the ecosystem that may ocurr.

Table 4.41: Main characteristics of the indicators.

Nº	Indicator	Representative Species	Main characteristics of the indicator
1	Channel inhabitants undertaking longitudinal migrations	*Brycinus lateralis, Labeo*, sp.	These fish require a specific environmental flow in which seasonal changes are included but always with good quality water. They remain in the meanders of the river most of the time throughout their lives but undertake longitudinal migrations. Thus the biology of these representative species for this indicator is directly linked to the conditions in the main channels and depends on the level of the water flows. It is possible to describe the relationship between the indicator an the flows because it is possible to analyze changes in abundance, area or concentration. Another important characteristic is that the representative species are identified as being important to the maintenance of other species of interest in regard to the fishing activities in the main river courses carried out by some community residents.
2	Lateral migrants into inundated zones	*Tilapia rendalli,* Tilápia spp., *Oreochromis* spp.. *Schilbe bocagei, Serranochromis* spp., *Marcusenius* sp., *Clarias gariepinus, Barbus paludinosus*	The representatives for this indicator lie in the main channels but make lateral migrations into inundated areas s soon as conditions allow. The migrations are typified by being associated to the level of the rising waters and they are associated to feeding needs and reproductive activities. Thus there may be signs of abundance related to flooding levels in the river systems. The absence of any flood surfaces can considerably reduce fishery because it affects reproduction strategies. These representative species as biological indicators of alterations to the normal functioning of the ecosystem are identified as being important to artisanal fishing activities
3	Inhabitants of shallow environments with submerged vegetation	*Tilapia sparmannii, Pharyngochromis* sp., *Hemichromis* sp.	This indicator contemplates representatives that prefer to inhabit specific areas of the ecosystem and they are able to show a response in the form of alterations to their distribution and density whenever there is any modification or alteration to the functioning of the river

			system flows. On the other hand the species mentioned are commonly used in artisanal fishing activities

Nº	Indicator	Representative Species	Main characteristics of the indicator
4	Inhabiting rocky zones	*Parakneria* sp. (referred to in the literature)	The representative associated to this indicator occupies a particular niche in the ecosystem which is liable to suffer profound alterations with any drastic alterations in the flow whether it be a reduction or limitations to the current. A prolonged reduction in the flow could mean loss of habitat and a consequent reduction in the species population.
5	Inhabiting marginal vegetation, emerging from channels and inundated areas	*Synodontis* spp., *Barbus* sp. *Rhabdalestes maunensis*	The representative species for this indicator depends directly on the condition of the marginal vegetation. That means there is an effective correlation with the inundation levels in the main watercourse and adjacent zones. Some of the species are the target of subsistence fishing
6	Sandbank specialists	*Opsaridium zambezense*	Their preference for very specific habitats within the river systems indicates the suitability of the species mentioned as an indicator of changes in the caudal flows especially in the aspects of distribution and concentration and affecting in that way the trophic levels above them.

Tabela 4.42: Life cycle aspects of indicator representetives.

Nº	**Indicator**	**Representative Species**	**Life cycle aspects**
1	Inhabiting channels. longitudinal migrations	*Brycinus lateralis, Labeo* sp.	The species *Brycinus lateralis* forms shoals around sandbanks in shallow waters near to the banks of rivers with little current and with considerable vegetation. They feed on tiny aquatic and terrestrial organisms and migrate upstream during the rainy season to reproduce. The species *Labeo* sp. Prefers regions downstream from rocky stretches ion the main channels and at the bottom of large lakes during the dry season feeding mainly on algae and detritus. When the rains begin and the flooding starts they migrate upstream to reproduce in inundated areas near the banks. This takes place in the summer
2	Migrate laterally into flooded floodplain areas	*Tilapia rendalli,* Tilápia spp., *Oreochromis* spp.. *Schilbe bocagei, Serranochromis* spp., *Marcusenius* sp.,*Clarias gariepinus,* *Barbus paludinosus*	The representatives of this indicator basically inhabit the main channels and the deepest parts of small lakes during the dry period and migrate to inundated areas as the waters rise and flood the land This generally occurs from January to April which is the spawning season. From the trophic point of view, the representative species for this indicator species occupy different levels and feed on the most varied supplies they find in the environment. They stay in the flood areas that form normally after the rainy season (May to August) and move back into the main channel of the river keeping to the edges where there is plenty of vegetation and a good depth of water..
3	Inhabit shallow waters,	*Tilapia sparmannii, Pharyngochromis* sp., *Hemichromis* sp.	From the trophic point of view the representative species for this indicator can occupy differ but fundamentally they are between the primary and secondary levels. It should be noted that some of the species can feed on a great variety of food t be found in the environment (omnivores) as is the case with *Tilapia sparmannii*. Reproduction begins at the beginning of summer and extends right though to the end. The period is marked by flooding and consequently the availability of more sheltered areas for spawning. They require tranquil waters in order to build their nests and deposit their eggs.

Nº	Indicator	Representative Species	Life cycle aspects
4	Inhabit rocky zones	*Parakneria* sp. (reported in the literature)	Prefer rivers with rocky beds, clear water and strong currents, feeding on algae adhering to the surfaces of the rocks and diatoms.
5	Inhabit riversides with vegetation emerging from channels and inundated areas	*Synodontis* spp., *Barbus* sp., *Rhabdalestes maunensis,*	The representatives of this indicator live mainly at the edges of the channels and in inundated areas where there is plenty of vegetation iand feed on detritus, algae insects, snails and small fish. The presence of vegetation along the river banks is important for their survival and any loss of it results in impacts on the group. Most of them reproduce in the summer which coincides with the rising of the level of water in the rivers.
6	Specialists in sandbanks	*Opsaridium zambezense,*	They forms shoals over sandbanks in shallow waters near to the banks of rivers with little current and with considerable vegetation feeding on aquatic invertebrates and grass seeds. They reproduce during the summer.

Tabela 4.43: Atributos do ciclo de vida dos representantes do indicador.

Nº	Indicator	Representative Species	Relations between indicators and flow characteristics
1	Longitudinal migrants inhabiting channels	*Brycinus lateralis.* *Labeo sp.*	Habitat requirements – Deep beds, large flows and well oxygenated water. The presence of submerged and emergent vegetation is important for in their immature stages of life.
			Reproduction – Good flow volume necessary to permit longitudinal migration and create inundated areas for growth of young fish in the early stages. Feeding in dependence on material coming in from zones of high productivity, inundation zones and also on the flow volume conditions
2	Lateral migrants to inundated zones – Big fish	*Tilapia rendalli,* Tilápia spp., *Oreochromis* spp.. *Schilbe bocagei, Serranochromis* spp., *Clarias gariepinus, Barbus paludinosus*	Habitat requirements – Moderately deep beds, calm waters with good presence of vegetation in inundated areas during the flood period (January to April). The beginning of the flood period is very important for these species as it can affect the success of their reproduction. POn the other hand inundation gradients are also important to stimulate reproduction of the different species Reproduction – Sufficient flow volume to allow for lateral migration and the formation of inundated areas to permit reproduction and development of young. The periods of greatest flooding correspond to significant increases in the biomass present in the ecosystem. Feeding – During the reproductive period the primary production established in the inundated areas becomes of primordial importance for secondary production in the system and that includes the entry of nutrients for the development of the species.
3	Inhabitants of shallow sheltered waters with submerged vegetation	*Tilapia sparmannii, Pharyngochromis* sp., *Hemichromis* sp.	Habitat requirements – flow volumes that ensure the formation of shallow, protected inundated areas with plenty of vegetation. Permanently sheltered waters. Reproduction – Spawning takes place in inundation zones with sandy bottoms and plenty of vegetation

4	Inhabitants of rocky zones	*Parakneria* sp. (reported in the literature)	Habitat requirements – Flow volume sufficient to keep the rocky substrate submersed in the areas they inhabit Reproduction – sufficient flow volume to allow for longitudinal migration upstream in the rivers they inhabit to reach the spawning areas during the rainy season. Feeding – water quality sufficient to maintain the plant communities and presence of algas on the rocky substrate.
5	Inhabiting emergent vegetation on thee rivers edge and in areas liable to flooding	*Synodontis* spp., *Barbus* sp, *Rhabdalestes maunensis,*	Habitat requirement – Flow volume sufficient to maintain the vegetation at the edges. Reproduction – Flow volume sufficient to allow for lateral migration and the formation of inundated areas to support the entire reproduction and development process. Feeding – During the reproductive period primary production established in the inundated areas becomes secondary production in the system including the influx of nutrients for growth and development of the species. The periods of greatest flooding correspond to significant increases in the biomass present in the ecosystem. During the period when flow volume is low this group becomes more susceptible to predation if their habitat becomes deprived of vegetation. On the other hand, feeding opportunities become more restricted given that most of them feed on insects and other invertebrates so that flow volume becomes a factor restricting the spatial distribution of food

Nº	Indicator	Representative Species	Relations between indicators and flow characteristics
6	Sandbank specialists	*Opsaridium zambezense,*	Habitat requirements – This group prefers areas of clear shallow water over sandbanks with a slight current and the presence of plenty of vegetation. They need flow volumes sufficient to guarantee the maintenance of the sandbanks along the system especially during the dry period. Reproduction – The representatives of this group need a certain minimum flow volume to permit their reproduction and any alteration to it is liable to affect the reproduction of this species

Table 4.44: Expected responses of Indicator 1 to possible changes in the flow characteristic upstream and downstream from Cambambe.

Question Nº	Period	Possible change in flow characteristics	Expected indicator response	Reliability of forecast
1	Dry/low water	The beginning occurs is earlier or later than normal	Earlier – may affect time of development of new contingents. Later – No effect.	Medium
2		The water levels are higher or lower than normal	Higher – Not really relevant Lower – May affect habitat availability and condition distribution.	Medium
3		Lasts longer than normal	May make migration difficult retard reproduction and affect its success. May condition the availability of food.	Medium
4	Transition	Lasts longer or shorter than normal – i.e.The hydrography becomes more abrupt or more extended	Longer – May affect the migration process as well as successful reproduction and development.	Medium

6	Inundation	The beginning occurs is earlier or later than normal – synchronization with the rains may be altered	Earlier and not synchronized with the rains – May affect the period of attaining maturity. Later may be reflected in the development of the new contingents.	Medium
7		The natural proportions of the different types of annual flooding are altered	If not very expressive may reduce ecosystem productivity and thus affect population dynamics in regard to the new contingents.	High
8	Transition 2	The beginning occurs earlier or later than normal	Earlier - may affect development of the new contingents.	Medium
9		The duration is longer or shorter than the natural - ie it hydrographybecomes steeper or minor depth	Shorter may influence the development of new recruitment.	Medium

Table 4.45: Expected responses of Indicator 2 to possible changes in the flow characteristic upstream and downstream from Cambambe.

Question Nº	Period	Possible change in flow characteristics	Expected indicator response	Reliability of forecast
1	Dry/low water	The beginning occurs earlier or later than normal	Earlier – May affect the time of development of the new contingents. Later – Benefits development with greater efficacy of the new contingents	Highg
2		The water levels are higher or lower than normal	Lower – May restrict movements and affect individual survival.	High
3		Lasts longer than normal	May affect habitat availability and survival success.	High
4	Transition1	Lasts longer or shorter than normal – i.e.The hydrography becomes more abrupt or more extended	Longer – May affect the migration process as well as successful reproduction and development.	Medium

Question Nº	Period	Possible change in flow characteristics	Expected indicator response	Reliability of forecast
5		The volume flows are more or less variable than normal	May affect the success of reproduction and development (Higher means greater success)	Medium
6	Inundation	The beginning occurs is earlier or later than normal – synchronization with the rains may be altered	Earlier and not synchronized with the rains – May affect the achievement of maturity thereby affecting reproduction Later – may be reflected in the development of the new contingents.	High
7		The natural proportions of the different types of annual flooding are altered	If not very expressive may reduce ecosystem productivity and thus affect population dynamics in regard to the new contingents.	Alta
8	Transition 2	The beginning occurs is earlier or later than normal	Earlier – may affect the development of the new contingents.	Medium
9		Lasts longer or shorter than normal – i.e.The hydrography becomes more abrupt or more extended	Shorter - may influence the development of the new contingents	Medium

Tabela 4.46: : Expected responses of Indicator 3 to possible changes in the flow characteristic upstream and downstream from Cambambe.

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Question Nº	Period	Possible change in flow characteristics	Expected indicator response	Reliability of forecast
1	Dry/low water	The beginning occurs is earlier or later than normal	Earlier – may affect the vegetation and habitat conditions which may affect the fish. Later – Benefits fish development and survival.	Medium
2		The water levels are higher or lower than normal	Lower – May restrict movement and access to food and refuge.	Medium
3		Lasts longer than normal	May affect survival success.	Medium
4	Transition 1	Lasts longer or shorter than normal – i.e. The hydrography becomes more abrupt or more extended	Longer – May restrict movements to important food sites and refuges and may affect reproduction	High
5		The flow volumes are more or less variable than normal	May affect successful reproduction and development Higher = more successful	Medium

Question Nº	Period	Possible change in flow characteristics	Expected indicator response	Reliability of forecast
6	Inundation	The beginning occurs is earlier or later than normal – synchronization with the rains may be altered	Earlier and not synchronized with the rains – May affect the achievement of maturity thereby affecting reproduction Later – may be reflected in the development of the new contingents.	High
7		The natural proportions of the different types of annual flooding are altered	If not very expressive may reduce ecosystem productivity and thus affect population dynamics in regard to the new contingents.	High
8	Transition 2	The beginning occurs earlier or later than normal	Earlier – may affect the development of the new contingents.	Medium
9		Lasts longer or shorter than normal – i.e. The hydrography becomes more abrupt or more extended	Shorter – May restrict movements and influence development of new contingents	Medium

Table 4.47: Expected responses of Indicator 4 to possible changes in the flow characteristic upstream and downstream from Cambambe.

Question Nº	Period	Possible change in flow characteristics	Expected indicator response	Reliability of forecast
1	Dry/low water	The beginning occurs is earlier or later than normal	Earlier – may affect time of development of new contingents Later – Benefits new contingent developmentd.	Medium
2		The water levels are higher or lower than normal	Lower – May restrict migratory movement.	High
3		Lasts longer than normal	May make migration difficult , retard reproduction and affect its success.	High
4	Transition 1	Lasts longer or shorter than normal – i.e. The hydrography becomes more abrupt or more extended	Longer – May affect migration and consequently successful reproduction and development	High

Question Nº	Period	Possible change in flow characteristics	Expected indicator response	Reliability of forecast
5		The flow volumes are more or less variable than normal	May affect successful reproduction and development Higher = more successful	Low
6	Inundation	The beginning occurs is earlier or later than normal – synchronization with the rains may be altered	Earlier and not synchronized with the rains – May affect the achievement of maturity thereby affecting reproduction Later – may be reflected in the development of the new contingents.	Low
7		The natural proportions of the different types of annual flooding are altered	If not very expressive may reduce ecosystem productivity and thus affect population dynamics in regard to the new contingents.	Medium
8	Transition 2	The beginning occurs earlier or later than normal	Later – may affect the development of the new contingents.	Medium
9		Lasts longer or shorter than normal – i.e. The hydrography becomes more abrupt or more extended	Shorter – May influence development of new contingents	Medium

Table 4.48: Expected responses of Indicator 5 to possible changes in the flow characteristic upstream and downstream from Cambambe.

Question Nº	Period	Possible change in flow characteristics	Expected indicator response	Reliability of forecast
1	Dry/low water	The beginning occurs is earlier or later than normal	Earlier – may affect time of development of new contingents Later – Benefits new contingent development.	Medium
2		The water levels are higher or lower than normal	Lower – May affect spatial distribution related to habitat availability.	High
3		Lasts longer than normal	Affects habitat availability and individual survival. May impair lateral migration and cause severely non harmonic ecological relations	High
4	Transition 1	Lasts longer or shorter than normal – i.e. The hydrography becomes more abrupt or more extended	Longer – may affect habitat availability, migration and reproduction and development processes	medium

Question Nº	Period	Possible change in flow characteristics	Expected indicator response	Reliability of forecast
5		The flow volumes are more or less variable than normal	May affect successful reproduction and development Higher = more successful	Medium
6	Inundation	The beginning occurs is earlier or later than normal – synchronization with the rains may be altered	Earlier and not synchronized with the rains – May affect the achievement of maturity thereby affecting reproduction Later – may be reflected in the development of the new contingents.	High
7		The natural proportions of the different types of annual flooding are altered	If not very expressive may reduce ecosystem productivity and thus affect population dynamics in regard to the new contingents.	High
8	Transition 2	The beginning occurs earlier or later than normal	Later – may affect the development of the new contingents.	Medium
9		Lasts longer or shorter than normal – i.e. The hydrography becomes more abrupt or more extended	Shorter – May influence development of new contingents Longer may disqualify some habitat segments due to changes in water quality	Medium

Table 4.49: Expected responses of Indicator 6 to possible changes in the flow characteristic upstream and downstream from Cambambe.

Question Nº	Period	Possible change in flow characteristics	Expected indicator response	Reliability of forecast
1	Dry/low water	The beginning occurs is earlier or later than normal	Earlier – may affect time of development of new contingents	Low
2		The water levels are higher or lower than normal	Lower – May affect spatial distribution -.	medium
3		Lasts longer than normal	May affect reproductive period	medium
4	Transition 1	Lasts longer or shorter than normal – i.e. The hydrography becomes more abrupt or more extended	Longer – may affect habitat availability, migration and reproduction and development processes	Low
5		The flow volumes are more or less variable than normal	May affect successful reproduction and development Higher = more successful	Low

Question Nº	Period	Possible change in flow characteristics	Expected indicator response	Reliability of forecast
6	Inundation	The beginning occurs is earlier or later than normal – synchronization with the rains may be altered	Earlier and not synchronized with the rains – May affect the the ecosystem required by the bio-ecology of the species Later – may be reflected in the development of the new contingents.	medium
7		The natural proportions of the different types of annual flooding are altered	If not very expressive may reduce ecosystem productivity and thus affect population dynamics in regard to the new contingents.	medium
8	Transition 2	The beginning occurs earlier or later than normal	Later – may affect the development of the new contingents.	Medium
9		Lasts longer or shorter than normal – i.e. The hydrography becomes more abrupt or more extended	Shorter – May influence development of new contingents	Medium

4.2.6. BIRDS AND MAMMALS

This section will report on the bird and mammal fauna found in the area of the Cambambe Hydroelectric Installations and surrounding areas.

4.2.6.1. METHODOLOGY

The difficulties encountered due to areas specificities to conduct a truly systematic and well distributed sampling process were similar to those that faced the flora survey: access difficulties, physical-geographic difficulties, and, above all, the danger and insecurity represented by the strong suspicion of the existence of land mines and other explosive devices in the area. They made it impossible to establish transects or randomly distributed sampling points or to associate them to the soil types or forms of land use identified.

Those conditioning factors disqualified the use of methodologies normally used for this type of work. As an alternative it was decided to use all the access ways existing in the area and establish sampling points (see Figure 4.35) along their routes at spots identified as ‘notable’ [for fauna presence].

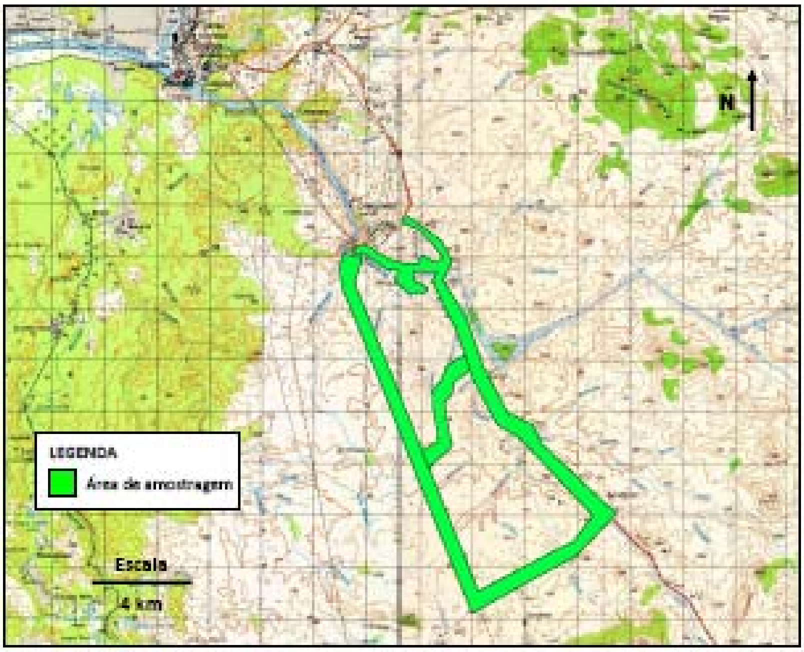

Figure 4.35: Image with the bird and mammal fauna sampling areas projected onto it upstream in the areas surrounding the Cambambe dam.

However, in spite of the aforementioned difficulties the study managed to adapt the Rapid Ecological Assessment method (Sobrevilla e Bath, 1992), which consist of making every effort to obtain as much information as possible in the time available for field work and integrating the assessments of the various expert and the specialists by having their sampling done in the same locations. To make further integration of the data feasible, all information was duly geo-referenced and the species encountered were photographed.

The teams undertaking the identification and characterization work used two distinct sampling methods which were:

- **Direct sighting:** identification on the basis of direct observation, always done early in the morning and late in the afternoon in random excursions through the landscapes most typical of the region and in harmony with the times of day when the birds and animals are usually most active. The instruments used were binoculars and searchlights, and the work was backed by bibliographic consultations at the camp: and

- **Indirect registration:** interviews with Cambambe employees, military personnel posted in the region, people on the rivers and beaches and some of the residents from the surrounding areas. The interviews were informal and the opportunity was taken to interact with the groups of interviewees. Whenever it proved difficult to identify a particular species, photographs of the species involved were used with care being taken not to induce responses or confirmations a to ensure the accuracy of the registrations. The results of such interviews however, were only used to consubstantiate other material evidence that had been collected.

O the other hand top get around the difficulties portrayed above, a preliminary survey of secondary data was made (previously compiled lists, other studies carried out in the area and surroundings, interviews with local people and SONEFE data).

The collection of primary data,(including capture and directs observation of vestiges like nests and droppings) were done in two different seasons, the dry season (August 2009) and the wet season (December 2009).

4.2.6.2. BIRDS

Routes were defined that would take in all the places where access was unrestricted and fixed sampling points were selected according to the various categories of land use that had been identified.

The following equipment was used to identify birds:
- Swarovski Binoculars 10X42;
- Tasco Binoculars 10X50;
- Swarovski HD SD 80mm telescpic zoom 10-50X;
- Edirol R99 Sound recorder/player and Sony column;
- Field Guide “Birds of Africa” Sinclair, I. & Ryan, P.;
- Field Guide “Checklist of African Birds” Van Perlo, B.; and
- Checklist “Birds of Angola” Dean, R.

The sampling locations were visited by vehicle. All the accessible ways were traveled along slowly (10 km/h in the tracks and 2o km/h ion asphalted roads and two observers made the observations and registered them. Whenever doubts arose as to identification the vehicle was stopped and the bird was observed more closely. Altogether sixteen km of tracks and trails were defined for the study purposes (mostly south of the Kwanza River) and 9 km of asphalted roads (see Table 4.50).

Table 4.50: Routes traveled

Local	Lengtho	Nº times	Total Distance
Track	16 km	4	64 km
Paved road	9 km	6	56 km
Rio	4 km	2	8 km

Other trips were made by boat on thee stretch of river from the bridge to the dam with just one observer. Both banks were examined with the boat going very slowly to facilitate identification of the birds.

Six (6) fixed points were established and referred to as: dam, township, beach, wood, savannah and muxito. Each one was representative of different types of vegetation, relief, land use features that had been identified in the study area and so it was expected they would reveal different ornithological structures.

At each of the sampling points all the bird calls and songs heard were registered and whenever the identification was in doubt the recorded song was played back to attract the bird and thereby ensure a correct identification. Some excursions on foot were also made to the sampling point to contribute to the data gathering.

At all sampling points data was collected in the first two hours after daybreak and the last two before dark, which is when the avifauna is usually most active. Exceptionally one sampling was done at Vila de Cambambe and two at Praia in the middle of the day. At all of the sampling points (Table 4.51) at least 30 minutes were spent during sampling work. All the Photos included in the present document are the results of those surveys.

Table 4.51: Sampling Points.

Location	Descrption	Coordenates	N
Dam	Escarpment on both sides of the dam wall	S09°45'12''; E014°28'52''	3
Township	Cambambe township	S09°44'30''; E014°29'46''	4
Beach	Beach near Kwanza bridge	S09°45'20''; E014°30'52''	6
Woods	Open forest with *Acacia sp*	S09°48'42''; E014°30'45''	2
Savannah	Open savannah with *Combretum sp*.	S09°47'22''; E014°29'24''	2
Muxito	Drainage line in thick forest	S09°48'14''; E014°30'45''	2

Note = Nº of samples taken at each point

4.2.6.2.1. RESULTS AND DISCUSSION

The area of the project and its surroundings display significant richness of ornithological diversity and it includes the presence of some species and genera that are not very common or whose distribution is limited.

The fact that the Dondo region where the project is located in the zone of confluence of three biomes (see attachment 6) certainly contributes to the occurrence of a multitude of species at the boundaries of their distribution zones and also contribute to a certain degree of unpredictability as to the composition of the avifauna.

The geographic location is close to the Guinean tropical forest biomes found along the Angolan escarpment and reflect the fact of being inserted in a “break” or interruption in that escarpment so that those forest formations can be found just a little to the north in the Ndalatando zone, or a few kilometers to the south in Calulo. Due to the interruption in the escarpment in this location the region finds itself exactly in the principal gradual cleavage between the coastal plane and the inland plateau, which means that it also shares in a notable way, in characteristics of the dry savannah biomes of the semi-arid coastland and the humid savannahs of *Brachystegia* belonging to the plateau.

4.2.6.2.1.1. AVIFAUNA STRUCTURE

40 Avian Families were registered of the 80 that can be found in Angola (see Table 4.52), so at family level representation was 50%. One curiosity that was observed is that when representativity was structured in terms of passeriformesand non passeriformesa 50% representation was found in both cases - 25/50 non passeriformes families, and 15/31 in the passeriformes families.

Another surprise in regard to the non passeriformeswas that certain families were not represented at all, like the *Anatidae* and *Charadriidae*, andn only one representative was recorded of the *Scolopacidae*. These are families that include groups like ducks, sandpipers and other waders which one would expect to be common in the in the fluvial ecosystems of the middle Kwanza. Various factors may be the explanation for this fact, like sampling difficulties in strictly fluvial areas, the seasonally cryptic behavior of some species and the fact that most of the species belonging to these families are migratory and relatively less present at the time of year the first sampling was done.

In spite of that, other families were notably well represented and beyond expectations among them, *Accipitrinae, Columbidae* and *Alcediniidae*, which reveals good levels of diversity in those group and also reflects well on the sampling efforts.

A notable absence among the non passeriformeswas the *Alaudidae* and the poor representation of the *Sylvidae* family. That asymmetry once again, may have been due to the time of year as the time of the first sampling corresponds to a period when species of those families are inactive and difficult to detect or they may be absent entirely because they are merely seasonal visitors.

On the other hand families like the *Pycnonotidae, Ploceidae* and *Estrildidae* were very well represented.

4.2.6.2.1.2. BIODIVERSITY

89 avian species were identified (Photo 4.27 to 4.39), corresponding to 9.7% of the known number of species for Angola. Bearing in mind the limitations imposed on the sampling process and the fact that data gathering only took place at one time of the year and furthermore, that period coincided with the period of non reproduction of most of the

species and with the absence of most of the migratory birds then the results can be considered very reasonable.

Some species were found to be of frequent occurrence and even abundant, outstanding among them the palm nut vulture (*Gypoherax angolensis*), the red-eyed dove (*Streptopelia semitorquata*), cape turtle dove (*Streptopelia capicola*) emerald spotted wood dove (*Turtur chalcospilos*), African palm swift (*Cypsiurus parvus*), red-backed mouse bird and red faced mouse bird (Colius *castanotus* and *Urocolius indicus*), wire tailed swallow and lesser striped swallow (*Hirundo smithii* e *Hirundo abyssinica*), dark-capped bulbul (*Pycnonotus tricolor*), bubbling cisticola (*Cisticola bulliens*), Gabon boubou (*Laniarius bicolor*), estorninho-de-ombro-violeta (*Lamprotornis nitens*), or the red-billed quelea (*Quelea quelea*). All of these species are common in Angola, and in the biomes where the study area is inserted so that there abundant in the area was no surprise. In consonance with that fact, none of them are on the UICN's Red List.

Photo 4.26: Specimen of square-tailed nightjar (*Caprimulgus fossii*).

Photo 4.27: Specimen of little bee-eaterAbelharuco-dourado (*Merops pusillus*).

Photo 4.28: Specimen of Egyptian plover (*Pluvianus aegyptius*).

Photo 4.29: Specimen de Crowned hornbill (*Tockus alboterminatus*).

Photo 4.30: Specimens of red-necked spur fowl (*Pternistes afer*).

Photo 4.31: Specimen of Red-faced mouse bird (*Urocolius indicus*).

Photo 4.32: Specimen amethyst sunbird (*Chalcomitra amethystina*).

Photo 4.33: Specimen of lark-heeled cuckoo (*Centropus superciliosus*).

Photo 4.34: Specimen of woodland kingfishers (*Halcyon senegalensis*).

Photo 4.35: Specimen of African pied wagtail (*Motacilla anguimp*).

Photo 4.36: Wattled starlings (*Creatophora cinerea*) on the top branch and glossy starling (*Lamprotornis nites*) on the bottom branch

Photo 4.37: Specimen of yellow-throated greenbul (*Chlorocichla flavicollis*).

Photo 4.38: Specimen of giant kingfisher (*Megaceryle maxima*).

Table 4.52: Bird Species Registered in the Area.

Common Name	*Scientific name*	*Family*	Status	Angola	Area
Long-tailed cormorant	*Phalaccrocorax africanus*	*Phalacrocoracidae*	DA	C	U
Goliath Heron	*Ardea goliath*	*Ardeidae*	DA	U	C
Purple Heron	*Ardea purpúrea*	*Ardeidae*	DA	C	U
Green-backed heron	*Butoroides striatus*	*Ardeidae*	DA	C	C
Hammerhead Stork	*Scopus umbretta*	*Scopiidae*	DA	C	C
Open-billed Stork	*Anastomus lamelligerus*	*Ciconiidae*	DA	C	U
Yellow-billed kite	*Milvus aegyptius*	*Accipitrinae*	DA	C	C
Fish eagle	*Haliaetus vocifer*	*Accipitrinae*	DA	C	C
Palm nut vulture	*Gypohierax angolensis*	*Accipitrinae*	DA	C	C
Bateleur	*Terathopius ecaudatus*	*Accipitrinae*	DA	C	C
Harrier hawk	*Polyboroides typus*	*Accipitrinae*	DA	C	C
Lizard Buzzard	*Kaupifalco monogrammicus*	*Accipitrinae*	DA	C	U
Peregrine Falcon	*Falco peregrinus*	*Falconidae*	DA	U	U
Helmeted Guinea Fowl	*Numida meleagris*	*Phasianidae*	DA	C	C
Red-necked spur fowl	*Pternistes afer*	*Phasianidae*	DA	A	C
Small button quail	*Turnix sylvatica*	*Turnicidae*	DA	C	U
Spotted thick knee	*Burhinus capensis*	*Burhinidae*	DA	C	C
Egyptian plover	*Pluvianus aegyptius*	*Glareolidae*	DA	R	U
Common sandpiper	*Actitis hypoleucus*	*Scolopacidae*	DA	C	C
Rock pigeon	*Columba livia*	*Columbidae*	DA	C	C
Red-eyed dove	*Streptopelia semitorquata*	*Columbidae*	DA	C	C
Cape turtle dove	*Streptopelia capicola*	*Columbidae*	DA	C	A
Laughing dove	*Streptopelia senegalensis*	*Columbidae*	DA	C	U

Common Name	Scientific name	Family	Status	Angola	Area
Green-pigeon	*Treron calvus*	*Columbidae*	DA	C	C
Emerald spotted wood dove	*Turtur chalcospilos*	*Columbidae*	DA	C	C
Tambourine dove	*Turtur tympanistria*	*Columbidae*	DA	C	U
Ruepells parrot	*Poicephalus ruepelli*	*Psittacidae*	NE	C	U
Red´-crested Turaco	*Tauraco erythrolophus*	*Musophagidae*	E	C	U
Klaa`s cuckoo	*Chrysococcyx klaas*	*Cuculidae*	DA	C	U
Lesser coucal	*Centropus senegalensis*	*Cuculidae*	DA	C	U
White-browed coucal	*Centropus superciliosus*	*Cuculidae*	DA	C	C
Square-tailed nightjar	*Caprimulgus fossii*	*Caprimulgidae*	DA	C	C
Palm swift	*Cypsiurus parvus*	*Apodidae*	DA	C	C
House swift	*Apus affinis*	*Apodidae*	DA	C	C
Red-backed mousebird	*Colius castanotus*	*Coliidae*	E	C	C
Red-faced mousebird	*Urocolius indicus*	*Coliidae*	DA	C	C
African hoopoe	*Upupa africana*	*Upupidae*	DA	C	U
Black scimitarbill	*Rhinopomastus aterrimus*	*Phoeniculidae*	DA	U	U
Woodland kingfisher	*Halcyon senegalensis*	*Alcedinidae*	DA	C	U
Giant kingfisher	*Megaceryle maxima*	*Alcedinidae*	DA	C	C
Pied kingfisher	*Ceryle rudis*	*Alcedinidae*	DA	C	C
Swallow-tailed bee-eater	*Merops hirundineus*	*Meropidae*	DA	C	U
Little bee-eater	*Merops pusillus*	*Meropidae*	DA	C	C
Crowned hornbill	*Tockus alboterminatus*	*Bucerotidae*	DA	C	C
Black-collared barbet	*Lybius torquatus*	*Capitonidae*	DA	C	C
Greater honeyguide	*Indicator indicator*	*Indicatoridae*	DA	C	C
Rock martin	*Hirundo fuligula*	*Hirundinidae*	DA	C	C
Wired tailed swallow	*Hirundo smithii*	*Hirundinidae*	DA	C	A
Common Name	***Scientific name***	***Family***	**Status**	**Angola**	**Area**
Lesser striped swallow	*Hirundo abyssinica*	*Hirundinidae*	DA	A	A
Pied wagtail	*Motacilla aguimp*	*Motacillidae*	DA	U	C
Fork-tailed drongo	*Dicrurus adsimilis*	*Dicruridae*	DA	A	C
Pied crow	*Corvus albus*	*Corvidae*	DA	C	C
Dark-capped bulbul	*Pycnonotus tricolor*	*Pycnonotidae*	DA	A	A
Yellow throated greenbul	*Chlorocichla flavicollis*	*Pycnonotidae*	DA	U	C
Yellow necked greenbul	*Chlorocichla falkensteini*	*Pycnonotidae*	DA	U	U
Yellow bellied greenbul	*Chlorocichla flaviventris*	*Pycnonotidae*	DA	C	C
White-browed Robin-chat	*Cossypha heuglini*	*Turdidae*	DA	C	C
Rufous-tailed palm	*Cichladusa ruficauda*	*Turdidae*	DA	C	C

thrush					
Forest scrub-robin	*Cercotrichas leucosticta*	*Turdidae*	NE	C	U
White-browed scrub robin	*Cercotrichas leucophrys*	*Turdidae*	DA	C	C
Sooty chat	*Myrmerocichla nigra*	*Turdidae*	DA	C	C
Bubbling cisticola	*Cisticola bulliens*	*Sylviidae*	NE	C	C
Hartert`s camaroptera	*Camaroptera harterti*	*Sylviidae*	E	C	U
Batis-de-Angola (Portuguese)	*Batis angolensis*	*Platysteiridae*	DA	C	U
Black-backed puffback	*Dryoscopus cubla*	*Malaconotidae*	DA	C	U
Brown-crowned tchagra	*Tchagra australis*	*Malaconotidae*	DA	C	C
Gabon boubou	*Laniarius bicolor*	*Malaconotidae*	NE	C	A
White-crested helmetshrike	*Prionops plumatus*	*Prionopidae*	DA	C	U
Cape glossy starling	*Lamprotornis nitens*	*Sturnidae*	DA	A	C
Violet-backed starling	*Cinnyricinclus leucogaster*	*Sturnidae*	DA	C	C
Wattled starling	*Creatophora cinerea*	*Sturnidae*	DA	C	C
Amethyst sunbird	*Chalcomitra amethystina*	*Nectariniidae*	DA	U	C
Western violet-backed sunbird	*Anthreptes lounguemarei*	*Nectariniidae*	DA	U	U

Common Name	*Scientific name*	*Family*	Status	Angola	Area
Purple banded sunbird	*Cinnyris bifasciatus*	*Nectariniidae*	DA	C	C
House sparrow	*Passer domesticus*	*Passeridae*	DA	C	C
Grey-headed sparrow	*Passer griseus*	*Passeridae*	DA	C	C
Holub`s golden weaver	*Ploceus xanthops*	*Ploceidae*	DA	C	C
Lesser-masked weaver	*Ploceus intermedius*	*Ploceidae*	DA	C	C
Village weaver	*Ploceus cucullatus*	*Ploceidae*	DA	A	C
Red-billed quelea	*Quelea quelea*	*Ploceidae*	DA	C	A
Golden-backed bishop	*Euplectes aureus*	*Ploceidae*	E	U	U
Green-winged pytilia	*Pytilia melba*	*Estrildidae*	DA	C	U
Orange-winged pytilia	*Pytilia afra*	*Estrildidae*	DA	U	U
Palle-billed firefinch	*Lagonosticta landanae*	*Estrildidae*	NE	C	U
Bronze mannikin	*Spermestes cucullatus*	*Estrildidae*	DA	A	C
Blue-breasted cordon-bleu	*Uraeginthus angolensis*	*Estrildidae*	DA	A	C
Orange-cheeked waxbill	*Estrilda melpoda*	*Estrildidae*	DA	U	U
Common waxbill	*Estrilda astrild*	*Estrildidae*	DA	C	C
Cinnamon breasted rock bunting	*Emberiza tahapisi*	*Emberizidae*	DA	C	U

Legend
Status
E Endemic – Only occurs in Angola
NE Quasi-endemic – Occurs in Angola and sparingly in neighboring countries
DA Wide Distribution
Angola/Area
A Abundant C Common U Uncommon R Rare

Some of the species deserve special mention as they are fairly uncommon in Angola but were actually found quite frequently in the area , such as the giant heron (*Ardea goliath*), the African pied wagtail (*Motacilla aguimp*), yellow-throated greenbul (*Chlorocichla flavicollis*) and the amethyst sunbird (*Chalcomitra amethystina*). Another special mention for the unexpected presence of the Egyptian plover (*Pluvianus aegyptius*), a very rare species in Angola which is at the very southernmost limits of its global distribution.

On the other hand, equally surprising was the absence of species like the cattle egret (*Bubulcus ibis*), white-faced whistling duck (*Dendrocygna viduata*), common kestrel (*Falco tinnunculus*), ringed plover (*Charadrius hiaticula*), small sandpipers and shanks (*Tringa stagnatilis, Tringa nebularia* and *Calidris minuta*), grey go away bird (*Corythaixoides concolor*), eastern yellow-billed hornbill (*Tockus flavirostris*), rufous-naped lark (*Mirafra africana*) and the African black-headed oriole (*Oriolus larvatus*), and species of warblers (*Sylvidae*).

In terms of species with restricted global distribution the occurrence must underscored of four (26.7%) of the 15 bird species endemic to Angola They were the red crested turaco (*Tauraco erythrolophus*), red-backed mouse bird (*Colius castanotus*), Harterts camaropter (*Camaroptera harterti*) and the golden-backed bishop (*Euplectes aureus*). Among them the greatest surprise was the presence of the turaco (*Tauraco erythrolophus*), considering that it is a relatively uncommon species and usually associated to escarpment forest ecosystems.

Some other species should also be singled out because they are almost endemic (they occur chiefly in Angola but their distribution extends to parts of neighboring countries). They are the Ruppells parrot (*Poicephalus ruepelli*), rufous-tailed palm thrush (*Cichladusa ruficauda*) forest scrub robin (*Cercotrichas leucosticta*), bubbling cisticola (*Cisticola bulliens*), Gabon boubou (*Laniarius bicolor*) and the pale-billed fire finch (*Lagonosticta landanae*). The biggest surprise here was the presence of the forest scrub robin (*Cercotrichas leucosticta*) which like the turaco is usually associated to escarpment forest ecosystems.

Mention must be made of the structure of the habitat along certain drainage lines and the confirmation of certain endemisms, which suggest that there may be other endemic species or quasi-endemic species there, that it was not possible to detect; such as the grey-striped francolin (*Francolinus griseostriatus*), Monteiros bush shrike (*Malaconotus monteiri*), Angola helmet shrike (*Prionops gabela*), pale olive greenbul (*Phyllastrephus fulviventris*) and the white-fronted wattle eye (*Platysteira albifrons*).

In regard to species with distributions limited, according to ‘Bird Life’ , to the Guinean forest biome (which in Angola is represented by the escarpment forests) the only ones found were the yellow-necked greenbul (*Chlorocichla falkensteini*), and the already mentioned forest shrub robin (*Cercotrichas leucosticta*) and the bubbling cisticola (*Cisticola bulliens*). In terms of the Zambesian biome the otstanding associated species were the red crested turaco (*Tauraco erythrolophus*), red-backed mouse bird (*Colius castanotus*) and the golden-backed bishop (*Euplectes aureus*).

According to the UICN’s Red list, of all the species registered,only two are globally threatened, namely the peregrine falcon (*Falco peregrinus*) and the golden-backed bishop (*Euplectes aureus*), both deserving of their classification as ‘vulnerable’.

4.2.6.3. MAMMALS

The difficulty of observing and identifying mammals is obviously greater than is the case with birds in view of all the aforementioned restrictions and being unable to access most of the area.

It was decided to register any observations of mammals made during the rounds of the bird sampling observation points and later to complement those observations with two nocturnal excursions (32 km) through the trails using a searchlight.

Apart from the direct observations the presence of any traces or remains encountered were recorded whenever they enabled a probable identification to be made. Two traps were set for rodents but nothing was caught. Also, as has been stated above, local people were interviewed to confirm other data obtained through sightings, vestiges, tracks and droppings collected on the spot.

4.2.6.3.1. RESULTS AND DISCUSSION

As was expected the number of mammal species registered was very small, just ten (10), and they are presented in Table 4.53 below.

Table 4.53: Mammal Species registered

Common name	*Scientific name*	Sightings	Location	Remarks
Yellow-footed squirrel	*Paraxerus cepapi*	2	Woods	Sighted at thhe fixed point in the woods
Common porcupine	*Hystrix africaeaustralis*	0	Savannah	Identified by vestiges found (spines) at the fixed point in the savannah
Savannah hare	*Lepus crashawi*	14	trail	Spotted at night with the flashlight
African civet	*Civectitis civetta*	0	trail	Tracks and droppings in the trail
Serval	*Felis serval*	1	trail	Spotted at night with the flashlight
Genet	*Genetta sp.*	0	Dam	Droppings on the dam
Rock Hyrax	*Procavia capensis*	8	River	Spotted from the bost on the steep stone banks of the river
Bush duiker	*Sylvicapra grimmia*	1	Trail	Spotted at night with the flashlight
Bushbuck	*Tragelaphus scriptus*	1	Trail	Spotted at night with the flashlight

No small rodents were registered although they were expected to be abundant (two individuals were observed but it was not possible to identify them), neither were any Chiroptera spotted. Along the edges of the rive searches were made for signs of river animals like otters but they were equally unsuccessful.

The most interesting observations were one of a serval (*Felis serval*), another of a bush duiker (*Sylvicapra grimmia*, Photo 4.39) and a bushbuck (*Tragelaphus scriptus,* Photo 4.40) both spotted at night along the trail using a spotlight. It is likely that the apparently common presence of these species in the area is because it is a restricted access zone for security reasons. The abundance of hares (*Lepus crashawi*, Photo 4.41) and the rock hyrax (*Procavia capensis*) was somewhat surprising.

Not one observation was made of any mammal species with a restricted distribution or a threatened species on either local or international endangered species lists.

Photo 4.39: Specimen of a bush duiker (*Sylvicapra grimmia*).

Photo 4.40: Specimen of a bushbuck (*Tragelaphus scriptus*).

Photo 4.41: Specimen of a savannah hare (*Lepus crashawi*).

4.3. ANTHROPIC MEDIUM

This section contains an analysis of the socioeconomic profile of the populations integrated in the project's zones of direct and indirect influence. It also provides succinct information on the provinces where the zones lie.

4.3.1. METHODOLOGY

To make the diagnosis of the Project's areas of direct and indirect influence (see Tables 1.9 (AII), 1.10 (AID) and 4.1), in addition to the data gathering procedures to obtain primary data, secondary data were also obtained on the basis of bibliographic research. For the directly affected area visits were made to the communes and during which authorities and the parties affected were interviewed. Contacts and interviews were made with villagers and other persons affected by the Cambambe project under analysis here with a view to obtaining information on current living conditions of the local population both upstream and downstream from the dam (see attachments 1 and 2).

The quantitative and qualitative procedures carried out for this study combined the technique of using quantitative indicators (data) and qualitative indicators (information):

i) Individual interviews with key informants like municipal administrators and commune administrators, traditional community leaders known as 'sobas', and heads of families with properties directly affected (peasants, farmers or their representatives), members of fishermen's associations;

ii) Interviews with focal groups of residents in affected localities (fishermen and farmers) whose fisheries or fields may be affected by the expansion of the dam lake (upstream) or by the reduction in the flow volume of the river downstream;

iii) Walking around making direct observations and taking photographs of properties: houses, crops, work instruments, fruit trees etc, and registering the geographic coordinates with GPS equipment of all the locations studied.

The first phase of this process of acquiring information about the place took place in August and September 2009 in some of the areas (communities that will be affected directly or indirectly by the project) in the municipalities of Libolo (South Kwanzo) Cambambe (North Kwanza) and Quiçama (Bengo). The second phase took place in December 2009 and January 2010.

As set out earlier in Chapter 1 the area of indirect influence in the anthropic medium was defined as including those municipalities whose territories in one way or another will be affected by the implantation of the venture, namely Quiçama, Icolo and Bengo in Bengo, Viana in Luanda, Cambambe in North Kwanza and Libolo in South Kwanza (Table 1.9).

The area of indirect influence are those downstream from the dam and they are liable to be affected by fluctuations in the volume flow of the river due to the opening or closing of

the dam sluices at the two dams on the middle course of the Kwanza, Capanda and Cambambe. Accordingly, it includes all the communities on the margins of the Kwanzo river from the dam down to the mouth of the river and encompasses the municipalities of Cambambe (North Kwanza), Quiçama (Bengo), Icolo and Bengo (Bengo) and Viana (Luanda).
In regard to the area of direct influence again in accordance with the explanation in Chapter 1, it corresponds to all the areas that will be liable to suffer direct impacts, whether positive or negative, and for which a suitable monitoring program will be developed as well as mitigation measures The anthropic medium was defined as consisting of the communes set out in Table 1.10, whose territories will be hosting Cambambe expansion: the communes of Kixinje in the municipality of Quiçama and of São Pedro da Quilemba in the municipality of Cambambe. Within the Cambambe commune it includes the camp of the de-mining teams, the police station the Kiamangufo bridge and the Cambambe township.

On the other hand the area of direct influence corresponds to the area that will be inundated by the new dam lake that will result from raising the height of the dam structure to a level of 132 meters which will inundate the present Kiamangufo bridge and the river beach just downstream from it, so that a new bridge will have to be built to get access to Libolo from Cambambe. It also includes the areas where the new dam structure will built and installed , especially the workshop, the new power house, and the system for supplying water to the Cambambe township.

However for study purposes the sample of communities selected was those along the course of the river in the stretch between Dondo and Muxima. The communities belong to the municipalities of Cambambe and Quiçama, in which the communes of Massangano, Kixinje and Muxima lie. Figure 4.36 shows the principal places considered in the collection and analysis of social-economic data.

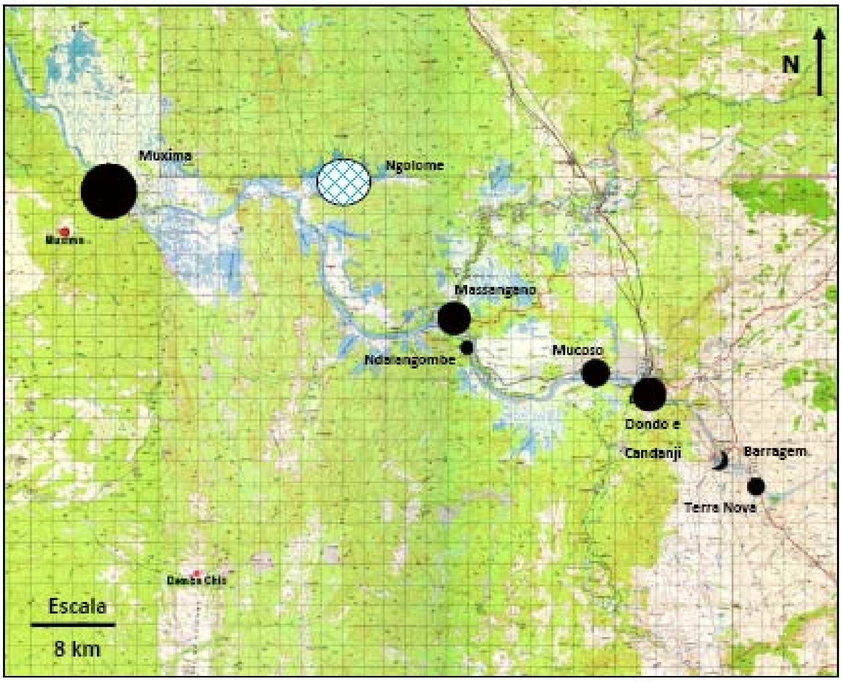

Figure 4.36: Map of the Socio-economic Data gathering

An evaluation was also made of social aspects and the local and Provincial economies to gain a perception of the wider context including demographic data, institutional and cultural aspects, main social and economic activities, employment and unemployment, family income, legal land tenure, relations with the Kwanza river in the areas of indirect influence The performance of all the above resulted in a more appropriate definition of the area to addressed in the study of the area of indirect influence (Figure 1.5) and the final definition of the area was as follows:

i) Municipality of Libolo (South Kwanza province): in the Munenga commune where the Commune administrator was interviewed as well as the leaders and members of the Terra Nova community;

ii) Municipality of Cambambe (North Kwanza Province): Central commune and the Massangano commune where the sobas and opinion formers of Kwanzo and those of the Lake of the Ngolome that will be affected by the heightening of the Cambambe dam;

iii) Municipality of Quiçama (Bengo Province): Kixinje and Muxima communes. Here the Municipal Administrator was interviewed as well as 12 key informants from communities along the margins of the river between Kixinje and Muxima.

The list of all those that were interviewed and those that took part in the focal groups is set out in Attachments 1 and 2). In addition to all the visual observations, many photos were taken whenever it was allowed and they are attached to the interviews and focal groups report (see Photos 4.43 to 4.46). In the vulnerability analysis the Equator Principles were taken into account to ensure that its requirements were included in the final report.

Photo 4.42: Interview with the Ngolome Soba.

Photo 4.43: Kamaketu Farm Manager.

Photo 4.44: Focal Group Session with Terra Nova residents.

Photo 4.45: Interview with Ngolome fishermen.

This section will present the activities undertaken as part of the social and economic survey against the background of the Project to Rehabilitate and Expand the Cambambe dam. As mentioned, this survey investigated the areas of direct influence and the areas directly affected upstream and the areas of indirect influence affected downstream and of indirect influence upstream affected by project for the expansion of the Cambambe dam. The venture is located in the middle course of the Kwanza River at the borders between the provinces of North Kwanza and South Kwanza.

4.3.2. CHARACTERIZATION

The first brief portrayal is of the provincial sphere characterizing the provinces of South Kwanza, North Kwanza and Bengo. It is basically a brief sketch of the geography, demography, political and administrative division and the infrastructure and social and economic services in place. The second characterization is a descriptive inventory of properties, goods, livelihoods and services that that will be directly or indirectly affected by the expansion of the dam reservoir.

4.3.2.1. SOUTH KWANZA PROVINCE

4.3.2.1.1. GEOGRAPHIC MEDIUM, POPULATION AND ADMINISTRATIVE DIVISION

Most of the South Kwanza province's territory has the geographic aspect of a transition zone in this case from the coastal plains to the inland plateau region that is central Angola.

The regional climate is marked by teo distinct seasons, rainy and dry and the rain usually last for seven months (October to April) with rainfall levels usually in the range of 1.100 – 1.300 mm. The months with the heaviest rainfall are November and March. There is sometimes a short dry period sometime in the period from December to February but it is irregular. It may affect the normal development of the agricultural crops.

In many cases the vegetation has the aspect of dense humid forest and is known locally as 'mata' but it never attains the exuberance of the forests in the north of the country where the rainfall is higher. To the east in Mussende the forest is less developed and more open and it is known as mata de panda.

South Kwanza is one of the provinces with the greatest potential for agricultural and livestock production and for that reason extensive areas have been deforested to make way for pastures. Agriculture and livestock ventures are now clearing forest land in Libolo and the water courses do not always receive the protection nor are the local populations' fields, pastures or places of collective memories preserved.

According to the Provincial Government's Annual Report for 2008, the population of South Kwanza is an estimated 2,294,069 inhabitants. Ethnolinguistic composition is dominated by the Kimbundus peoples, (speakers of the Ngoia language) and Ovimbundus followed by Bakongos (usually in the cities).

South Kwanza Province is divided into 12 municipalities: Sumbe, Porto Amboim, Amboim, Kilenda, Seles, Ebo, Mussende, Libolo, Quibala, Cela, Conda, and Kassongue and 36 communes.

4.3.2.1.2. INFRASTRUCTURE AND SOCIAL SERVICES

4.3.2.1.2.1. EDUCATION

The provinces education network consists of 545 schools. In 2008 there were 301,692 students enrolled in the various schooling levels of which 124,029 were females including 21,755 in schooling initiation classes. There are another 51,000 outside the system. Teaching is done by 7,775 teachers of whom 2,729 are females.

According to the Report of the National Children's Institute monitoring fulfillment of the 11 Commitments the number of children per teacher is 40. In the fields of literacy training there are various actions under the aegis of a project entitled "Literate Angola" ("*Angola Bem Alfabetizada*"), with a time frame through to 2015.

In 2008, 17,500 people lacking basic reading, writing and calculating skills were provided with training. The number of people learning to read and write in module 1 Literacy training is 350, corresponding to roughly 24 persons per instructor.

4.3.2.1.2.2. HEALTH SERVICES

The public health network is made up of 181 units, of which, 16 are hospitals, 12 health centers, and 137 primary health care units. The admissions capacity of the network is 1,145 beds.

In terms of Human resources, the health sector has a staff of 2,488 of which 143 are doctors, 1,546 nurses, 110 laboratory technicians and therapists, and 689 are administrative personnel (including various assistants). The most frequently diagnosed diseases are: Malaria, Conjunctivitis, acute diarrhea, acute respiratory infections and typhoid fever.

4.3.2.1.3. INFRASTRUCTURE AND PRODUCTIVE ACTIVITIES

4.3.2.1.3.1. PRINCIPAL LIVELIHOODS

The main livelihoods are agriculture, livestock raising, odd jobs(agricultural laboring, charcoal burning, and peddling goods along the roads or in markets) hunting, fishing and charcoal burning.

The most commonly cultivated agricultural crops are; manioc (cassava), maize, beans, sweet potato and ‘rena’ potato as well as market garden species and fruit trees. The province has enormous agricultural and forestry potential and currently the agricultural products most commercialized are coffee, banana and market garden crops.

Market access is relatively easy for residents in the municipal centers. However, the same cannot be said for certain communities and settlements, above all those furthest removed from the coast.

The most common domestic animals raised by villagers are chickens, goats, and pigs, which serve, on the whole, as reserve assets. In some areas (free of gadflies and tsetse flies), traditional beef cattle is raised.

4.3.2.1.3.2. INDUSTRY, TRADE, TRANSPORTATION, AND COMMUNICATIONS

The industrial park of Kwanza Sul province is significantly limited. According to the Provincial Government’s 2008 report, there are 218 industrial production units (mostly small- and medium-sized) enterprises engaged in processing agricultural and forestry products, 183 of which are currently operating, while another 35 are not in service.

The provincial capital (Sumbe) may be accessed by ground, air, or water. Some municipalities, such as Sumbe, Porto Amboim, Gabela, Celes, Quibala, Libolo, etc., are interconnected to each other and to municipalities in neighboring provinces by paved roads. Further, communities and settlements are accessible via smooth and rough dirt roads.

The broadcasting signal of Angolan National Radio (Rádio Nacional de Angola – RNA), Angolan Public Television (Televisão Pública de Angola – TPA), and TVZimbo reach all areas of the province. Movicel and Unitel, the region’s telephone service providers, operate antennas in some municipal centers. However, communications systems are of very poor quality.

4.3.2.2. NORTH KWANZA PROVINCE

4.3.2.2.1. Geographic context, population and administrative division

The North Kwanza Province is located in central and is bordered to the north by the Bengo Province, to the south by the Malanjem provinces, to the west by the South Kwanza and Bengo Provinces and to the East by the Provinces of Uíge and Bengo respectively. The Kwanza River and the Lucala River traverse its territories.

The surface area of North Kwanza is 24,110 km^2 and the population is estimated as 654,000 inhabitants. The province is divided into ten (10) municipalities, namely: Ambaca, Banga, Bolongongo, Cazengo, Golungo Alto, Gonguembo, Lucala, Quiculungo, Cambambe and Samba-Cajú.

The climate is humid tropical and the average annual temperature is between 22 and 24^0C. The soild are quite fertile and appropriate for growing manioc, peanuts, maize, palms, pineapples and horticultural crops.

The vegetation cover on the plateau consists essentially of open forest known locally as "mata de panda" and savannah with shrubs with the former generally being found on the higher elevations while the latter is more associated to the sub-plateau areas where there is a fairly frequent occurrence of small woods and forests accompanying the lines of water courses (*muxito*).

The effects of human activity on the forests are notorious and agriculture, charcoal burning and firewood extraction and burning the land have led to the formation of large clearings and savannahs.

The destruction of the open forest that used to typify the region is a symptom of environmental degradatioon and at the same time it facilitates and intensifies the degradation and erosion of the soils especially the clayey ferraltic soils. The fauna is scarce because of the war and clandestine hunting although some presence of wild animals can be observed and it is widely supposed that they are returning from the areas where they sought refuge.

4.3.2.2.2. INFRASTRUCTURE AND SOCIAL SERVICES

4.3.2.2.2.1. EDUCATION

Data for 2001 shows that at that time the province's schools network consisted of 503 schools of which 479 offered primary education (level I), 14 level II, 5 level III and 5 offered senior high school education.

The North Kwanza provincial Government's Annual report for 2008 registers the construction of 110 new classrooms in that year representing in increase in school vacancies of 9,000.

Also an Agrarian technical Institute at senior high school level was built in Camuaxi, 11 km from Ndalatando, with 20 classrooms, 3 buildings to accommodate boarders and 17 residences for teachers. IN the 2008 school year there were 107,520 students matriculated in the Province's schools.

4.3.2.2.2.2. HEALTH SERVICES

In 2001, one year before peace was established, the public health network in the province consisted of 3 hospitals, 11 medical centers, 53 primary health care units, 1 dispensary for rtrypanasomaisis and 1 for tuberculosis.

The presence of the Tsetse fly and the Horse Fly is a strong inhibitor of livestock raising and a serious risk to human health.

4.3.2.2.3. INFRASTRUCTURE AND PRODUCTIVE ACTIVITIES

4.3.2.2.3.1. MAIN LIVELIHOODS

The primary livelihoods are in agriculture, fishing, hunting, animal husbandry, miscellaneous labor (including outsource work on crop fields and coal production), and commerce.

The most commonly cultivated agricultural crops are; manioc (cassava), maize, various kinds of fruit, sweet potato, coffee as well as market garden crops, various kinds of beans, peanuts, etc

River fishing which is exclusively artisanal is carried out on the Kwanza and Lucala and in the various lakes, especially the lake of the Ngolome.

The presence of the Tsetse fly (North Kwanza id one of the provinces where it occurs) discourages livestock raising nevertheless there are many families that raise cattle, goats and pigs.

4.3.2.2.3.2. INDUSTRY, TRADE, TRANSPORT AND COMMUNICATIONS

The biggest industrial park is located in the Dondo (Cambambe) and it consists of the Cambambe Hydroelectric installation, the EKA brewery, the Santa Isabel water bottling plant, the Vinu manufacturing company and the cotton plant, but the last two are no longer operational.

The province has a rail connection with the cities of Luanda and Malanje and there are roads linking it to Luanda, Huambo, Malanje, South Kwanza and other provinces. The airport in the provincial capital is not in a condition to receive aircraft.

The signals of the Angola National Radio and the Angola Public Television channel TPA and the Zimbo TV channel can be received throughout the province.

Mobile telephone service operators Movicel and Unitel have antennas installed in some municipalities but outside of the main urban centers communication is poor.

The province also has huge agricultural and forestry potential and coffe and wood are the main products that are exploited commercially, however, it has not proved possible to obtain any figures on the particular industrial production sector. Golungo Alto and Caculama have the largest timber reserves in the province with areas of around 558 and 800 km^2 respectively.

4.3.2.3. BENGO PROVINCE

4.3.2.3.1. GEOGRAPHIC CONTEXT, POPULATION AND ADMINISTRATIVE DIVISION

Bengo Province is also located in the north and border to the north by the province of Uíge and the border with Zaire. To the east and south it borders on North Kwanza province and South Kwanza province and to the west it borders the province of Luanda. Its capital is the city of Caxito in the municipality of Dande. It has 500,000 inhabitants and na area of 41,000 Km^2 which gives it a population density of 12.2 inhabitants per km^2.

Administratively it is divided into eight (8) municipalities:: Dande, Ambriz, Icolo e Bengo, Nambuangongo, Quiçama, Dembos, Pango Aluquém and Bula Tumba; 32 communes and 466 villages.

Most of the population belongs to the Ambundu ethnic group and dedicates itself to subsistence agriculture and local industry is paralyzed.

4.3.2.3.2. INFRASTRUCTURE AND SOCIAL SERVICES

4.3.2.3.2.1. EDUCATION

The school network consists of 2,149 schools, of which 1,533 offer primary education, 513 cycle I and 103 cycle II and Higher Secondary education. In 2008, the number of students enrolled in initial education was 2,104 of whom 1,090 were boys and 1,010 girls; in primary education, 34,664 of whom 20,542 were boys and 14,122 girls; in the first cycle of lower secondary education, 2,167, of whom 1,687 were males and 480 females; in adult education 3,720, of whom 2,351 were males and 1,369 females; and I higher secondary education, 2,160 of whom 1,430 were males and 730 females.

In the school year 2008 there 44,000 enrolled students of whom 27,104 were males and 17,711 females. Outside the official education system there were 7,012 enrollments of which 3,522 were in primary education, 584 in the first cycle of lower secondary education, and 187 in higher secondary education.

4.3.2.3.2.2. HEALTH SERVICES

The provincial public health network consists of 9 hospitals, 10 health centers, 109 primary health care units and the number of beds for hospital admission is 500.

Currently in terms of national medical staff, there are 18 doctors, 6 university trained technicians, 650 nurses, and 97 diagnosis and therapy technicians. Under the aegis of overseas cooperation, in the provincial hospitals there are 18 foreign doctors of whom 7 are Korean and 17 Vietnamese. Even so the total number of 36 doctors in Bengo province means that there is only one doctor for every 14,000 inhabitants.

The most frequently diagnosed diseases are malaria, tuberculosis, leprosy, trypanosomiasis, schistossomiasis, HIV/AIDS, acute respiratory diseases, diarrhea and blenorragia.

4.3.2.3.3. INFRASTRUCTURE AND PRODUCTIVE ACTIVITIES

4.3.2.3.3.1. PRINCIPAL LIVELIHOODS

The main ways of gaining a living are agriculture, fishing, hunting, raising livestock, and odd jobs (including agricultural laboring and charcoal burning) and trading. The main crops cultivated are manioc (cassava), maize, various kinds of fruit including cashew, sweet potato, coffee, tobacco, market garden varieties, various kinds of beans, peanuts, etc.

In 2008, 61,039 hectares of land were cultivated of which 13,104 hectares were cultivated by the corporate sector (21.4%) and 47,935 hectares by the peasant farmer sector, involving a group of 12,630 peasant families and 412 small and medium-sized agricultural companies. The overall production of various products was 264.3 [thousand] tons of which 64.5 (24.4%) were produced by the corporate sector and 199.9 by the peasant farming sector. The activity is supported by more than 60 thousand farming family ventures, 400 small and medium-sized agricultural companies, 90 peasant farmer associations and 7 agricultural cooperatives.

The Bengo Provincial Government's annual report for the year 2008 shows that peasant farmers cultivated 47,935 hectares that yielded a harvest of 199.8 tons of a variety of products.

The preferred animal for human consumption is the chicken because the presence of the Tsetse fly (Bengo is one of the provinces where it is endemic) discourages livestock raising nevertheless there are many families that raise cattle, goats and pigs.

4.3.2.3.3.2. INDUSTRY, TRADE TRANSPORT AND COMMUNICATIONS

The activities of the few industrial entities that existed in colonial times are totally paralyzed. The Coca-Cola and Águas do Bom Jesus companies are the only ones in operation. Most of the cities that are the site of municipal government are linked to one another r and to neighboring provinces by asphalted roads (except for Quiçama) and that has facilitated the circulation of people and goods. However, access to communes and hamlets is by tracks and trails only.

The signal of the national radio station *Rádio Nacional de Angola* (RNA) and Angolas public TV channel can be received throughout the provcince; acces to the newspaper *Jornal de Angola* is limited to the provincial capital and mobile phone signals of the operators Movicel and Unitel is limited to municipal centers.

4.3.3. CHARACTERIZATION OF THE AFFECTED PARTIES

To portray the social and economic situation a preliminary activity was carried out to define the populations that could be directly affected by the expansion of the dam reservoir to the level foreseen in the project to raise the dam, and also identify those that could be indirectly affected. There now follows an outline of the places and populations involved.

4.3.3.1. AREA OF INDIRECT INFLUENCE

The Area of Indirect Influence (see Table 1.9 and Figure 1.5) is defined as the area where the customs and habits of the population may be affected by raising the level of the Cambambe dam but where there will not be any need for resettlement.

4.3.3.1.1. POPULATION AND SOCIAL INFRASTRUCTURE

Several villages were identified in the area in question with a total of 105 residents belonging to the Munenga commune (Libolo, South Kwanza). 37 of them are men, 37 are women and 31 are children as shown in Table 4.54.

Table 4.54: Population census for the area of indirect influence.

N°	Village/location	Population			
		Men	**women**	**Children**	**Total**
1	Terra Nova	25	30	22	77
2	Kalunga Family	4	3	3	10
3	Comandante Kamaketu	1	1	3	5
4	Uakizulu	6	2	2	10
	Total	**37**	**37**	**31**	**105**

The following items of social infrastructure are entirely absent from these communities: schools, public health units, electricity supply, water supply and sewage system (sanitation).

As there are no schools some of the children are not in the education system. Children whose parents have relatives in Dondo pass the week with the relatives and only come home on weekends. In regard to health issues, the less serious cases of sickness are treated with local herbal medicines and the more serious ones are sent to the Dondo Hospital or they may end up dying through lack of proper medical attention or proper medicines.

The absence of schools and health services referred to above is due to the very small size of the communities, their wide dispersal and the fact that their existence is only recent. For their energy needs these people use firewood and charcoal for cooking (see charcoal production in Photo 4.46) and kerosene or diesel for illumination. The villages use the Kwanzo river as their water supply and for fishing (rarely) and agriculture. As for dwellings most of them are made of precarious materials: wood, clay and grass.

Photo 4.46: Charcoal Production.

The Terra Nova village, two kilometers from the bridge (see Photo 4.47), consists of a group of families that came there when they fled from the military insecurity in the Cambingo and Bungo areas. It is the largest group of residents in the area with 77 inhabitants and it will not be affected by the Cambambe dam improvements project.

Photo 4.47: Detail of the Terra Nova village.

Table 4.55 below sets out the names of the places, and the number and type of residences to be found in them. It is certain that their locations and distance from the future level of the water in the dam reservoir means that they will not be submerged by the raising of the level of the reservoir waters resulting from the Cambambe Dam improvements project. They are situated in a radius of 1 and 3 km from the Kwanzo River and the bridge respectively.

Table 4.55: Dwellings in the area of indirect influence.

Type of construction								
N°	**Village**	**Blocks + roof**		**adobe + roof**		**stakes + roof**		**total**
		metal sheets	**grass**	**metal sheets**	**grass**	**metal sheets**	**grass**	
1	Terra Nova	1	0	9	13	0	8	31
2	Família Kalunga	0	0	1	2	0	1	4
3	Cdte. Kamaketu	1	0	1	0	0	0	2
4	Uakizulu	0	0	0	0	1	7	8
Total		**2**	**0**	**11**	**15**	**1**	**16**	**45**

Regarding sanitation, and solid waste management, the villages of SONEFE, Alto Dondo, Dondo and Muxima have sewage networks that discharge sewage directly into the Kwanzo River. They also have waste collection systems but they are inadequate. For lack of any proper landfill, the waste that is collected, including hospital waste, is dumped in the open air or into the river.

The inhabitants of the surrounding rural areas do not have any electricity supply nor are there any sewage installations. For their energy needs they use firewood and charcoal for cooking and kerosene or diesel for illumination.

The two tables below (4.56 e 4.57) show the populations present in the area under study (area of indirect influence) and the outstanding feature is the close location of Dondo, and Massangano in the municipality of Cambembe and Zenza do Itombe in the municipality of Quiçama as well as Candanji (in the Kixinje) and Muxima, as all of them are located next to the Kwanzo River.

Table 4.56: Population in the area of Indirect Influence.

Tabela 4.56: População existente na área de influência indirecta.

Municipality	Location	Men	Women	Total
Cambambe	Dondo	28.439	26.653	55.092
	Massangano	11.529	13.279	24.808
	Zenza de Itombe	2.550	3.053	5.603
	Total	**42.518**	**42.985**	**85.503**
Quiçama	Cadanji	-	-	4.657
	Muxima	-	-	5.618
	Total	-	-	**22.308**

Source: Municipal Authorities of Cambambe and Quiçama (2009).

Tabela 4.57: Population of Dondo and Massangano.

N.º		Locatione	Men	Women	Total
1	Comuna sede (Dondo)	Cidade Zona 4	2.595	2.640	5.232
2		Cerâmica zona 6	5.145	6.276	11.421
3		Mucozo zona 9	712	682	1.394
4		Kafuma	995	1.054	2.049
5		Quissanga	4.170	4.260	8.430
6		Cassesse I e II	5.382	5.531	10.913
7		Alto Dondo	2.821	2.960	5.803
8		Quibululo	1.950	2.009	3.959
9		Cazenga	1.623	1.692	3.315
10		Sonefe (Vila de Cambambe)	1.260	1.335	2.595
		Total	**28.439**	**28.439**	**55.092**
11	Comuna de Massangano	Mucozo	778	823	1.601
12		Ngolo	194	187	381
13		Carinda	77	93	170
14		Cassequele	330	297	627
15		Cambondo	402	344	746
16		Quixingango	112	114	226
17		Massangano (sede)	222	189	411
18		Lola	89	113	202
19		Maculumbi	78	86	164
20		Mulende	94	94	188
21		Musseque e Ngolome	283	210	493
22		Ngola kiluanji	244	229	473
23		Canguenhe	239	203	442
24		Calengue	331	381	712
25		Cassoalala	3.941	5.382	9.323
26		Banze	299	269	568
27		Nova Oeiras	259	266	525
28		Kingimbe	570	668	1.238
29		Nova cassoalala (Km 34)	372	469	841
30		Aldeia Nova	681	613	1.294
31		Camongoa	229	251	480
32		1º de Maio	166	158	324
33		Capungo	209	243	452
34		Quixoto	123	84	207

35	Cambunze	204	155	359
36	Bondo	157	141	298
37	Cazanga	199	224	423
38	Km 7 (Kalawenda), Km 13	205	182	387
39	Aldeia Piloto do Kiombe I e II	442	811	1.253
	Total	**11.529**	**13.279**	**24.808**

4.3.3.1.2. AFFECTED LIVELIHOODS

Agriculture, fishing, hunting, selling food, and selling industrial products acquired in Luanda are the main livelihoods of the inhabitants of this zone. Another important source of family income is transporting people by road or river.

According to the local fisherman that were interviewed, 10 years ago each fishing family used to capture around 3,000 fish a day as compared to the 300 they catch now, and that is due to the constant fluctuations in the level of the water brought about by the Capanda dam. The phenomenon only appeared when the Capanda Dam went operational. The fish catches are sold fresh, dried or smoked and dried fish is the predominant form in which it is sold. The fishing carried out in the waters of the Kwanzo and the respective lakes, especially the lake of the Ngolome, that according to the fishermen that were interviewed, it is sold , not only in Luanda but in Lundas and Cabinda in the neighboring Democratic Republic of the Congo and in Namibia. There are around 354 in fishermen's associations 500 non associated families that pursue fishing activities either in the river or the lakes and the lake of the Ngolome is the most important site [3].

[3] Over half the fishermen registered with Provincial Fishing Authority and associations ****

Some of the workers at the Cambambe installations that live in these localities and the families that live in the nearby communities (Terra Nova and Uakizulu) that will be indirectly affected have relative and properties there. Furthermore they are the main markets for all the fishing and peasant agriculture communities in the areas studied (direct and indirect influence).

In addition to those that make 'informal' use of the Kwanzo River (peasants, fishermen and boatmen), downstream there are some industrial units installed that extract large volumes of water from the river , namely: the EKA brewery, the Águas Santa Isabel bottled water plant, the Coca-Cola company, the Bom Jesus water factory, etc.).

Many of those that have some kind of professional qualification work as civil servants or iare employed in the EKA, ENE and Águas Santa Isabel companies.

The public squares in the towns of Alto Dondo, Dondo, Km 34 and Cassoalala are also important means of livelihood for many families that peddle rural or industrial products.

There will be no direct impacts stemming from raised or lowered water levels on SONEFE or Alto Dondo but Dondo and Candanji and the other places downstream will be affected if there are any significant variations in the flow volume of the river.

According to people that were interviewed along the course of the river (from Dondo to Muxima, see Figure 4.36), before the Capanda dam went into operation the river used to overflow its banks but this no longer happens and they fear the increasing the size of the Cambambe reservoir will reduce the river flow to such an extent that the lakes in the lower Kwanzo will no longer receive sufficient water.

4.3.3.1.3. CULTIVATED LAND

There are two farms on the right bank of the river in the Uakizulu area, near to Terra Nova, belonging Luís Cambenda and José Eduardo (Zé Mavenda farm).

On Luís Cambenda's farm there are two (2) made of stakes covered with dried grass occupied by a couple (farmworkers) with two children (a boy and a girl). On the Zé Mavenda farm there are three house occupied by five men and a woman (farm workers).

There are two more farms on the right bank in the Terra Nova area, one belonging to Commander Kamaketu and the other two to families: the Kalunga family and the Paixão family. On the Kamaketu farm there is rough dwelling made of blocks and roofed with metal sheets inhabited by a couple (farm workers) and their three children. The 4-hectare farm has various fruit trees: orange trees, papaya, edible wild fruit trees and a pig pen with three pigs.

The farms belonging to the Kalunga and Paixão families occupy roughly 20 hectares each (see Photos 4.48 and 4.49) are currently undergoing a process to legalize tenure and they already have their descriptive technical memorial and the necessary declarations issued by the Commune Administration and by the traditional.

Both farms have fruit trees: orange, papaya, mango, edible wild fruit trees. And cultivate a variety of market garden crops (onions, carrots, tomatoes, greens, cabbage, etc.).

Photo 4.48 Kalunga and Paixão Families.

Photo 4.49: Cultivated area of the Kalunga family.

The cultivations maintained by the inhabitants of Terra Nova are on the right hand of the road (heading south) and lie in an area that will not be affected by the dam lake and neither will the expansion of the lake affect the Kalunga and Paixão family farms. Their crops and planted areas and their points of access to water will also be unaffected by the expansion of the lake.

4.3.3.1.4. SACRED SPOTS

The Terra Nova community buries its dead in a common cemetery (Photo 4.50) that is amere 500 meters from the village itself. Neither the village, nor the cemetery will be submerged by the raising of the water level in the new reservoir.

Photo 4.50: Kalunga Family cemetery.

The Kalunga family inherited their land from their parents and their ancestors have been buried theie for three generations so that in addition to its economic importance the spot has spiritual importance for them. The cemetery however will not be affected by the project. Uakizulu is merely an area of fields and farms (see Photo 4.51), the families merely go there to work so that there are no cemeteries associated to the area. The residents that were interviewed did not know whether there were any other sacred spots, monuments or archeological sites that might be of national interest.

Photo 4.51: A Farm in Uakizulu.

The map that follows shows the contour line corresponding to the height of the waters in the new dam reservoir and the location Terra Nova village (Figure 4.37). It also shows a river beach that will completely submerged in the process of expanding the dam lake up to the maximum projected reservoir height of height of 130 m.

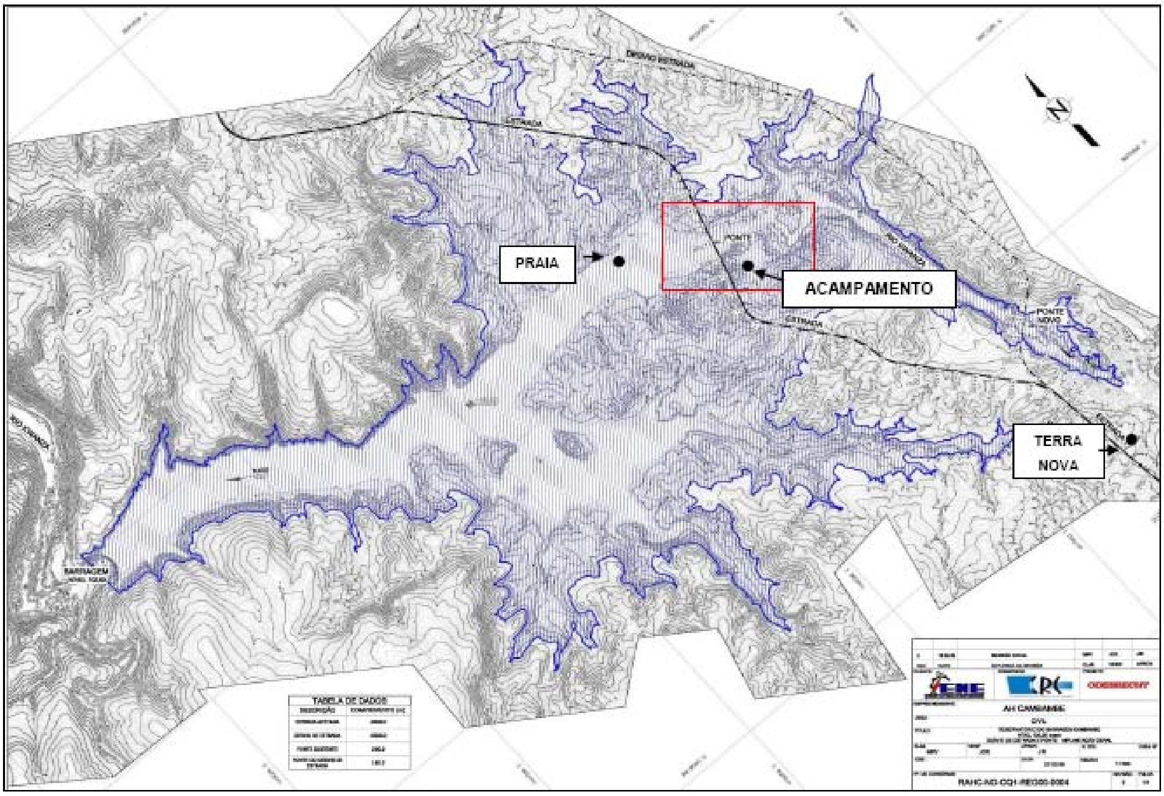

Figure 4.37: Map showing the projected level of the reservoir waters after the dam is raised and the position of the Terra Nova village.

4.3.3.2. AREA OF DIRECT INFLUENCE

The area of direct influence (see Table 1.10 and Figure 1.6) comprises those areas where the populations and their habits and custom will be directly affected by the process of rehabilitation and expansion of the Camabambe Hydroelectric Installations. In this case the populations that came under consideration were those at Vila de Cambambe (2,595 inhabitants), at the military de-mining Camp (50 people) and the Police station. No information was supplied on the number of staff at the police station at the Kiamangufo Bridge because it is considered to be a strategic spot.

4.3.3.2.1. POPULATION AND SOCIAL INFRASTRUCTURE

There is a military camp beside the Kiamangufo Bridge with several tents and occupied by the de-mining team. There are also two brick structures with metal sheet roofs one of which is the military canteen. The camp is of a temporary nature because, according to the officer in charge, its mission and work are part of the project to expand the dam reservoir at Cambambe.

One of the areas that will definitely be affected by raising the water level but where there are no residents, is the river beach downstream from the Kiamangufo bridge. Dondo ,Alto Dondo and Vila de Cambambe residents often use the beach at weekends.

During the field trips made by the various teams of experts it was observed that the beach was used mainly for leisure purposes although there were also a few fishermen and other people from nearby areas that went there to draw water (Photo 4.52) or to load charcoal onto boats for transportation (Photo 4.53).

Foto 4.52: River beach where people draw water

Foto 4.53: River beach used to load and unload charcoals for transportatio by boat

Table 4.56 sets out the details of the dwelling structures in the area of direct influence that will be directly affected by the inundation caused by the dam.

Table 4.58: Dwellings in the area of direct influence.

		Type of construction						
N°	**Village**	**metal sheets**	**grass**	**metal sheets**	**grass**	**metal sheets**	**grass**	
		Blocks + roof		**adobe + roof**		**stakes + roof**		**total**
		metal sheets	**grass**	**metal sheets**	**grass**	**metal sheets**	**grass**	
1	Demining teams camp	2	0	0	0	0	0	2
2	Police station at Kiaman-gufo bridge	1	0	3	2	2	0	8
Total		3	0	3	2	2	0	10

On the other hand among the urban areas that will suffer the direct influence of the dam waters is Vila de Cambambe

4.3.3.3. CONCLUSIONS

The area that has been studied is on the territorial borders of three provinces: South Kwanza, North Kwanza and Bengo, and the area of project implantation is situated in a transition zone between the coastal plain and the inland plateau.

The river is navigable up to this point The communities found in the area of indirect influence have only recently settled there and in the case of Terra Nova it sprung up after 1992 because of the war. Others are temporary like the military camp for de-mining teams at the Kiamangufo bridge and the Uakizulu community made up of the farm laborers and *EIA* charcoal burners which means that they are largely inhabited by men only and have no education or health infrastructure installed.

The downstream communities have been there much longer and date back to colonial times so that they are solid settlements provided with education services (primary schools) and some health services (primary health care units)

To enable their children to further their studies or to access specialized health services the inhabitants in both the areas that were studied rely on Dondo where they often have residences on the urban perimeter.

All communities in the area make use of medicinal plants to treat certain diseases even when there are primary health care units in their area.

Malaria and water borne diseases and infections are common - the Kwanzo river in the region of Dondo can be considered to be polluted because the riverside communities in the urbanized parts of the small towns, industries and hospitals alike, deposit their waste and sewage in the river.

The Tsetse fly (*Glossina palpalis*) is endemic in the study area and there is an analysis laboratory and tratment center in Dondo to treat ‘’sleeping sickness’..

In general the communities are unaware of the project to rehabilitate and expand the Cambembe dam installations and as soon as they are informed about it, express concern with the risk it may pose to their means of living which may become altered or even completely destroyed by the projects. With the exception of the Kalunga and Paixão families who are demanding compensation most of the people interviewed appeal to those in authority, the decision makers to consider measures that might alleviate the impacts on their livelihoods and properties.

However, it must be stressed that there will be no displacement or resettlement of villages or ‘senzalas’ caused by project implementation.

CHAPTER 5

IMPACT ASSESSMENT AND MITIGATION MEASURES

5. IMPACT ASSESSMENT AND MITIGATION MEASURES

This section presents a description of the possible environmental and social impacts of the Cambambe Hydroelectric Power Plant Rehabilitation and Expansion Project located in the North Kwanza / South Kwanza province, which includes (1) the dam rehabilitation, (2) the construction of the second power house, (3) the dam elevation to the 132 level, (4) the construction of a lateral spillway, (5) the construction of the new bridge and road belonging to the National Highway 230 section to be rebuilt, and (6) the construction of work yards and lodging quarters.

The methodology to be used in the analysis of the main environmental impacts resulting from the project is also presented in this section. Such methodology presents the main environmental impacts and defines the mitigation measures for the potential negative impacts originated from the implementation of the mentioned project.

In the impact assessment phase, the information generated by the different components has to be integrated and placed in the same context as the forecast results and the significance of the impacts. Therefore, the analysis is conducted based on two different project phases, and according to its components, considering the preparation/construction phase and the exploration/operation phase.

The project under analysis, due to its characteristics and size, will always present significant environmental impacts (positive and negative) with non-uniform intensity for all components. Therefore, the impact assessment synthesis has the purpose of defining a common base for the integration of the generated information making much easier its use in the decision making process, thus allowing the identification of interactions and the carrying out of comparisons between environmental components.

5.1. ENVIRONMENTAL ASSESSMENT METHOD

In the majority of the environmental impact studies, the assessment of the impacts is conducted with the help of interaction matrices that correlate the enterprise actions with the environmental characteristics or conditions. These matrices are used in the obtainment of a quantitative classification of the environmental impacts as a way of planning the mitigation measures for the significant negative impacts.

For the present environmental impact study, matrices were developed both for the construction phase and for the operation phase. The impact analyses were split into the following project components:

- **Component 1:** Dam elevation and the construction of the lateral spillway, dam rehabilitation and expansion, filling of the lake up to the full storage level at the 130-m level and the Cambambe Hydroelectric Power Plant operation; and
- **Component 2:** Construction of the new bridge and road as well as the further operation of this two infrastructure pieces.

However, the description of the impact and mitigation measures includes a description of the two components, because this will allow an overall comprehension of the project in its construction and operation phases, particularly if such two components described above are intrinsically connected.

In order to carry out this environmental impact study, an option was made to adapt the use of the matrix proposed by Christopher M.R. Pastakia, of the Danish Water Quality Institute in Denmark, published with the name of *Rapid Impact Assessment Matrix (RIAM)*. It is worth noting that this matrix has been in use since 1998 in several countries of Europe, Asia, South America and Africa.

The principle of the RIAM Method is to distribute the selected variables into four environmental components to be analyzed, which are:

a) **Physical and Chemical (FQ):** Covers all physical and chemical aspects capable of changing the environment, including non-renewable resources and the environment's physical degradation. The air quality, noise and the quality of effluents and residues produced are aspects to be considered in this component.

b) **Ecologic / Biologic (EB):** Covers all biologic and ecologic aspects capable of changing the environment, including non-renewable resources, biodiversity effects, inter-specific relationships and pollution effects on the ecosystem.

c) **Social Cultural (SC):** Covers the human individual, social, cultural and religious aspects. This component deals with ethnic differences, religious habits, the local society's cultural structure, as well as its habits and behaviors.

d) **Economic / Legal (EL):** Has the purpose of identifying and quantifying the economic activity consequences, as well as the complexity of the project management operations from the legal point of view, such as: local employment generation, acquisition of local goods and services, power and water consumption, road traffic, protected areas, etc.

With the inclusion of the variables in the four matrix components, the evaluation of each variable results in an environmental classification. For this assessment, the analysis is split into two groups as shown in Tables 5.1 and 5.2.

Table 5.1: Group A Environmental Components.

A1 – Importance of the Condition		A2 – Change Magnitude	
Score	***Classification***	***Score***	***Classification***
4	Importance of national / international interest	+3	High positive benefit
3	Importance of regional / national interest	+2	Significant *status quo* increment
2	Important for internal and surrounding areas	+1	*Status quo* increment
1	Important only for the local condition	0	No *status quo* change
0	No importance	-1	Negative *status quo* change
-2		Loss or significant negative change	
-3		Loss or high negative change	

Table 5.2: Group B Environmental Components.

B1 – Permanence		B2 - Reversibility	B3 –Cumulative effects
Score	***Classification***	***Classification***	***Classification***
1	No change / No applicability	No change / No applicability	No change / No applicability
2	Temporary	Reversible	Not cumulative / Singular
3	Permanent	Irreversible	Cumulative / Synergetic

The environmental classification (CA) calculated for each variable may vary between -108 and +108, and the calculation is made using the following expression:

CA = (A1 x A2) x (B1 + B2 + B3)

Therefore, according to the environmental classification (CA) obtained and once classified into the proper category, it is possible to have a description of the importance of the impact arising from the action regarding a certain variable of the condition under analysis. The environmental classification with the different categories and the category description regarding the impacts is given in Table 5.3.

Table 5.3: Description of the categories regarding the impacts.

Environmental classification RIAM	Category description regarding the impacts
72 to 108	High positive changes
36 to 71	Significant positive changes
19 to 35	Moderate positive changes
10 to 18	Positive changes
1 to 9	Small positive changes
0	No change
-1 to -9	Small negative changes
-10 to -18	Negative changes
-19 to -35	Moderate negative changes
-36 to -71	Significant negative changes
-72 to -108	High negative changes

The impact importance criteria, in an analysis of the assessment result can be expressed in a brief and easily understandable way, as follows:

High positive changes: Very significant improvement of the existing situation. Very relevant improvement of the status of a resource or population. Total satisfaction of a long-term perceived /predictable need.

Significant positive changes: Very significant improvement of the existing situation. Considerable improvement of the status of a resource or population. Total satisfaction of a medium-term perceived /predictable need.

Moderate positive changes: Significant improvement of the existing situation. Improvement of the status of a resource or population. Partial satisfaction of a perceived need.

Positive changes: Improvement of the existing situation. Small improvement of the status of a resource or population. Partial satisfaction of a need.

Small positive changes: Barely significant improvement of the existing situation. Very slight improvement of the status of a resource or population. Partial satisfaction of a need.

No change: Any kind of impact on the mean and the population is registered.

Small negative changes: Influence in low importance resources or low degree of influence. No loss of usage.

Negative changes: Influence in locally important resources or low degree of influence. Usage changes take place.

Moderate negative changes: Influence in locally or regionally important resources or medium degree of irreversible influence. Usage losses take place.

- **Significant negative changes**: impact on resources with regional and national importance or with medium-high impact degree of irreversible nature. There is significant usage loss.

- **High negative changes**: impact on resources with national and international importance or with high impact degree, with high magnitude and of irreversible nature. There is very significant usage loss.

There was an attempt to adopt an impact scale with enough number of values as to allow the representation and establishment of distinctions between the different situations under analysis, however, without being excessive, in the sense of not introducing errors into the assessment process when describing non-significant impact value differences (according to the available information accuracy).

5.2. ENVIRONMENTAL IMPACT AND MITIGATION MEASURES

Any activity of human origin is always associated to impacts that can be negative and/or positive. Because it could not be different, the project under study will cause impacts on the local environment, although the initial project planning has taken into account the environmental questions. However, the dam elevation will guarantee the expansion of the power generation potential in the operation phase.

This section describes the main environmental impacts resulting from different actions, with respect to the physical and chemical, biologic and ecologic, social and cultural, and economic and legal components during the construction and exploration phases. The impact analyses in the following sections are conducted based on the presentation of the following:

- Impacts (where the main impacts resulting from the project actions are described);
- Impact assessment (where an impact assessment is made based on matrix information); and
- Mitigation measures (where the main mitigation measures are described).

A detailed summary of the matrices according to their importance is shown in Table 5.12.

5.2.1. PHYSICAL AND CHEMICAL COMPONENTS

a) Construction Phase

- ***Impacts***

During the construction process, the excavation and inert material handling actions, with the objective of preparing the land for accesses, future spillway, downstream inert material extraction, land preparation for the future village and the new national road section connecting the North Kwanza to the South Kwanza provinces, may cause negative impacts. This fact is due to direct and indirect influences on certain portions of the ecosystem's physical and chemical means that change their functionality. These actions result in dust emissions, loss of soil characteristics, change in geo-morphology due to changes in the natural draining and the large volume of transported sediments.

In terms of atmospheric pollution, the air pollution at the construction site is presently insignificant due to low population density, absence of large industries and low traffic. However, during the construction phase, the emission of dust and other pollutants as NO_X and SO_2 is foreseen due to land cuts and vegetation removal, opening of access ways, vehicle and machinery circulation, use of explosives, excavation, and material transport and processing in the quarry, crushing and concrete production zones. Such emissions will be probably concentrated close to the construction site.

Due to favorable atmospheric dispersion conditions (open spaces and presence of winds) and the low presence of population, significant impacts associated to the emission of dust and other pollutants are not expected, and will be limited to some specific areas.

The increase in noise and vibration levels during the construction phase is expected due to the construction activities. A significant increase in noise and vibration emission is also expected, associated mainly to the processes of excavation, road opening, demolition with explosives and material transport and processing. Impacts resulting from vibration and noise caused by machinery are also expected, affecting the construction process in the same way as in land preparation and mining. At work site level, the noise will be restricted to the emission places and adjacent areas. The low population density at the construction site and the dispersion of the emission places will contribute to the maintenance of sound emissions within acceptable limits out of the work areas.

Also within the construction process, residual effluents from different processes, in some measure associated to previous actions and influenced by rainwater draining from the concrete and the crushing stations, as well as the highway section paving process, will be susceptible of causing negative impacts, mainly in the aquatic means. Additionally, the large quantity of solid residues produced in the different activities, including the presence of workers involved in the construction, can also be a potential impact source, with emphasis for water and soil contamination.

The potential impacts due to contamination in the construction phase may be caused by the transport and storage of gasoil, gasoline, lubricants, oils, explosives, concrete additives and tar. Accidental pollutant spills may reach superficial waters due to draining and water tables through percolation. Additionally, earth moving, excavation, deforesting, vehicle and machinery circulation, might cause the water stream contamination due to the increase of solids in suspension in the water. The main impacts on the hydrologic means are related to the hydrologic regime change, the morphology's solid transport regime, the temperature and the water quality.

In the construction phase, when the transport of large volumes of inert material is usually made and important excavation is carried out, the quantity of sediments moving along the river downstream from the construction site increases significantly.

The water quality is expected to undergo some changes in the construction phase, mainly due to erosive processes, excavation, earth moving, machinery and vehicle circulation, and sewage discharge into the lake, which will have a significant influence on the temporary water turbidity increase.

The launching of sewage directly into the lake, without any previous treatment, will boost the negative impacts, since a large volume of residual water is expected during the construction phase. The total number of employees during the construction phase is expected to reach 2,700 during the peak period, which corresponds to an average consumption of 100 liters per day per person, where 80% will correspond to the discharge of residual waters.

Given the enterprise nature, climate changes are not expected during the construction phase. The probable changes will occur when the lake expansion starts, therefore potential impacts on the construction phase are not expected.

- ***Impact assessment***

Generally, it is assumed that during the construction phase, in this component of the project, the most significant impacts will be related to moderate negative changes resulting from pressures associated to excavation, emission of effluents, moreover from the concrete station, and the water contamination potential. These impacts will be of importance for the project's adjacent and surrounding areas, with significant negative changes, however temporary and reversible, but cumulative. Negative changes without the loss of usage or with usage changes are expected from most actions, as well as the consequent pressures during the construction phase on the system's physical and chemical component.

- ***Mitigation measures***

The mitigation measures regarding impacts resulting from the construction phase of the enterprise physical and chemical components are presented in Table 5.4. below.

Table 5.4: Mitigation measures for the physical and chemical components during the construction phase.

Physical and chemical component (Construction phase)	
Impacts	**Mitigation measures**
Air quality change due to gas and particulate material emissions	• Periodic maintenance of equipment producing gas emissions, seeking better combustion process control; • Periodical humidification through controlled water spray in the places where strong dust dispersion may occur; • Packed transport of inert materials; • Covering of earth and debris piles to avoid spreading due to the wind; • Start the exploration and explore the reclaimed areas, quarries and surplus material deposits according to the operation's technical specifications.

Physical and chemical component (Construction phase)

Impacts	Mitigation measures
Noise pollution and vibration	• Keep the machinery used in the construction in good operating conditions; • The equipment must have its sound power well identified and in compliance with the limits deemed acceptable; • Avoidance of noisy activities in the night period in work areas close to inhabited zones; • Conduction of regular noise monitoring activities; • The use of explosives must be carried out in a controlled manner, with previous notice to the surrounding population.
Water quality changes	• Implementation of a separate residual water collection and treatment system before the launching into the lake; • Deforesting of the area to be flooded through the previous exploration of the existing vegetation cover, thus avoiding the proliferation of a large quantity of decomposing vegetal organic matter that will affect the water quality; • Guidance the drain effluents from the crushing and concrete production zone to a decanting basin; • Adequate storage of pollution-susceptible chemical products used in the construction works; • Impermeabilization of the fuel storage and distribution areas; • Implementation of a draining system that allows the isolation of toxic and hazardous products in the work yard; • Implementation of environmental actions to the works and water quality monitoring.
Soil contamination and change	• Implementation of a residual water collection and treatment system before the launching into the lake.

Physical and chemical component (Construction phase)

Physical and chemical component (Construction phase)

Impacts	Mitigation measures
	• Control effluent discharges containing oil and other toxic substances; • Guidance the drain effluents from the crushing and concrete production zone to a decanting basin; • Adequate storage of pollution-susceptible chemical products used in the construction works; • Impermeabilization of the fuel storage and distribution areas • Implementation of a draining system that allows the isolation of toxic and hazardous products in the work yard; • Adequate packing according to acceptable residue parameters; • Establish routes for machinery circulation avoiding soil compacting; • Carry out excavations in an adequate and controlled manner, ensuring construction safety conditions and excavation product management.
Hydrologic regime changes	• Ensure the ecologic maintenance flow.
Solid transport regime changes	• Periodical analysis of banks and landfills and assessment of the reutilization of material resulting from excavation; • Implementation of a temporary draining system to intercept, capture and conduct superficial waters; • Installation of devices to minimize sediment dragging.
Morphological changes	• Keep excavation strictly within the necessary area; • Provide land modeling in all areas subject to earth moving.
Increase in erosive processes	• Implementation of a temporary draining system to intercept, capture and conduct superficial waters; • Installation of devices to minimize sediment dragging. • Recovery of the vegetation cover in the zones to be indirectly affected by the construction, to minimize the occurrence of erosive processes. • Monitoring of the zone surrounding the enterprise, seeking the treatment and recovery of degraded areas and

Physical and chemical component (Construction phase)

Impacts	Mitigation measures
	erosion focuses; • Adoption of preventive stabilization and protection solutions for slopes and river banks.

b) Exploration phase

- ***Impacts***

Part of the impacts that are susceptible of taking place in the construction phase, will be diluted in the exploration phase, when other impacts that require some study and mitigation measures will show up.

Normally, the concentration of large masses of water brings local micro-climate changes, depending on climate conditions, geographic and topographic localization and the reservoir size.

The Cambambe Dam elevation will increase the lake surface from 1.3 km^2 to 6.08 km^2 this fact will influence the local micro-climate, mainly due to the increase of the air relative humidity resulting from the lake body water evaporation, and can also increase the frequency of fog and mist in the adjacent zones, as well as the possible reduction of the thermal variation range. Additionally, there will be an increase in the absorbed radiation due to the lower water reflection power, since a large area previously occupied by the vegetation will covered by the water mass that will increase as the lake expands.

The impacts associated to micro-climate changes, due to the lake expansion, will not very significant, because such changes will be confined to a narrow stripe in the zone adjacent to the lake, and will be a consequence of the increased water covered surface.

As the enterprise enters in operation, water flow changes may constitute the strongest impacts, which will affect it in many different manners, with more accurate consequences on the ecosystem and biotic component. Sediment retention in a cumulative way will have erosive consequences downstream. Changes in the reservoir and downstream water quality due to the lake's eutrophication and organic matter build-up will cause changes in the local physical component and chemical parameters, with potential to cause impacts.

The lake filling up to the130-m level without the flooded zone deforesting may create a temporary anaerobiosis situation, as well as an increase in the primary and secondary production, followed by a later reduction, when an increase in the system's trophysm can be expected to occur and generate eutrophication (due to nutrient build-up), mainly during a humid season, thus producing a negative impact on the water quality and on the reservoir's aquatic life, due to considerable increase in algae biomass, reduction of the water transparency and oxygen depletion the deeper waters. Additionally, methane gas build-up may occur due to the submerged vegetation degradation followed by a H_2S build-up in the hypolimnion. Consequently, there may be a pH fall downstream, generating strong corrosion in the turbines and fish mortality.

That situation may be analysed by a specialist firm, which will define the actions that are necessary in order to mitigate the impacts mentioned above.

Another important process that must not be neglected is the Cambambe lake water mass stratification. The stratification occurrence and duration in a reservoir depends on several factors, of which the most outstanding are tributary discharge, total reservoir volume, morphology and climate conditions.

The Cambambe lake stratification may take place as a result of the temperature difference between the superficial water and the deeper water layers. The organic matter decomposition will contribute to reduce the dissolved oxygen content in the deeper layers, thus creating favorable anoxia conditions in the deeper portion of the reservoir during summer, with negative impact on the aquatic life.

The water mass stratification may influence the water quality downstream, since either warmer or colder waters may be discharged (depending on the season) with lower oxygen content with respect to the natural river conditions. However, the dissolved oxygen will quickly increase due to the turbulence and natural aeration effects as soon as the water is discharged downstream.

Discharges resulting from the power generation process and turbine cooling will cause water quality changes in the first kilometers downstream of the dam. The volume of residual effluents in the lodging and office areas, if not appropriately treated, may become a contamination focus for the lake and for the main bed water stream.

During the exploration phase, an increase in the erosive phenomena is foreseen due to the reduction of the transported solids flow, because the lake will act as barrier, retaining most of the sediments. The occurrence of erosive processes in the zone surrounding the lake is equally foreseen due to water level changes and the erosion of the downstream banks due to the reception of the turbine flow waters.

The filling of the lake from the present 102-m level to the full storage level of 130 m, will equally bring erosive and sedimentation processes. The reduction of the flow speed in the lake will gradually cause the stopping of the bottom sediment transport close to the reservoir areas. Under wind and flood conditions (flooding), the material transported from higher zones will be deposited in the reservoir.

The deposit of approximately 250,000 m^3 of sediments annually is expected for the Cambambe section. The reduction of the sediment flow towards the seashore is expected, since the dam elevation will produce cumulative effects in the sediment retention.

The strong production of solid residues resulting from the enterprise maintenance activity, workshops, offices and the residential area, if badly packed and processed, may become a potential polluting source for the soil and water streams, with effects on the environment quality. Potential contamination impacts may be generated by spills and/or the bad packing of lubricants, gasoil, hydraulic oil and transformer oil.

During the exploration phase, significant noise emissions are not expected, except for the noise emitted by the dam discharge and the equipment used in its operation and maintenance. Additionally, noise and vibration emissions associated to the traffic in the surrounding zones and in the new accesses are expected.

The construction of dams with large reservoirs may cause induced seismic phenomena due to overload conditions resulting from the reservoir filling process; therefore, induced seismic movements must be considered, influenced by the water table elevation. The Cambambe lake is located in a zone that, under the regional geology point of view, is inserted in an area marked by the presence of long deep faults. Tectonic activity, although not common, was already registered in the Medium Kwanza in 1968 and 1976, with magnitudes between 4.4 a 4.8 respectively, in the MSK-64 scale (Medvedev-Sponheuer-Karnik).

During the exploration phase, the river flow will loose its transport capacity after reaching the dam lake's upstream sector, depositing the coarser sediment fractions in the zone closer to the lake and almost completely inhibiting the passage of sand to the downstream river section. Additionally, through the elimination or minimization of high-water events and high-water peaks, the dam will inhibit or minimize sand exportation to the seashore platform, which may have a negative influence on the sediment supply to the seashore, with the consequent coastal erosion and seashore line retreating.

Due to the enterprise nature, negative impacts on the air quality are not expected during the exploration phase, since the generated power will be considered clean, with positive impacts on the air quality.

- ***Impact assessment***

Among the expected impacts, the most evident will be related to moderate negative changes associated to the lake expansion, and the water flow regularization resulting from the dam operation, which will bring effects of local and regional importance. The impacts will be temporary and reversible, but cumulative.

Sediment retention, erosion, increase in superficial flow, emission of residual effluents, change in water quality and emission of solid residues, will be among the potential impacts on the mean.

- ***Mitigation measures***

The mitigation measures for the impacts resulting from the enterprise operation/exploration phase of the physical and chemical components are shown in the Table 5.5. below.

Table 5.5: Mitigation measures for the physical and chemical components during the operation/exploration phase.

Physical and chemical component (Operation/Exploration phase)	
Impacts	**Mitigation measures**
Water flow changes	• System's seismic monitoring; • Maintenance of a flow that reproduces the natural regime variations; • Maintenance of the ecologic flow during the lake filling period up to the full storage level of 130 m.
Water quality changes	• Monitoring of water quality and stratification processes.

Increase in erosive phenomena	• Recovery of the vegetation cover in the zones indirectly affected by the construction, to minimize erosive process events; • Monitoring of the zone surrounding the enterprise, seeking the treatment and recovery of degraded areas and erosive processes; • Adoption of preventive slope and bank stabilization and protection solutions.
Upstream sediment retention	• Execution of hydro-sedimentation studies that will point out the need or not to take direct control actions, as the sandy sediment dredging; • Monitoring of the sediment level in the lake, to decide about the periodic bottom discharge opening to allow the discharge of sediments downstream.
Water and soil contamination	• Establishment of a residual water capturing and treatment system before the discharge in the lake, with the implementation of an ETAR. • Control the discharge of effluents containing oil and other toxic substances; • Implementation of water quality monitoring and environmental actions.
Induced seismic activity	• Seismic monitoring following the seismologic monitoring program.

5.2.2. BIOLOGIC AND ECOLOGIC COMPONENT

a) Construction phase

- ***Impacts***

Enterprises of this nature always have a negative influence on the biodiversity and on the overall ecosystem dynamics. Such negative influence does not always take place in a direct way, but it sometimes causes indirect changes that many times are not repairable.

Due to the project implementation, vegetation losses may occur in specific cases during the construction phase, associated to spillway area deforesting, quarries and the future building of villages, as well as the opening of the new road and the building of the new bridge. These pressures may bring changes, fragmentation and, in some cases the pollution of habitats in a cumulative manner, thus producing impacts that, also in a negative way, will disturb the fauna. Fauna problems in this phase are associated to direct actions and impacts in both the land means and aquatic means.

During the construction phase, an increased vegetation loss will take place in the zones subject to the direct construction intervention. The laying of dust and atmospheric pollutants on the construction's surrounding zone vegetation will produce impacts on the more sensible species.

The lake expansion will bring a very strong impact due to the destruction of the vegetation cover, particularly on the species belonging to the International Union for Conservation of Nature (UICN) Red List, such as the *Pterocarpus angolensis,* and the species belonging to the Angolan threatened species list, as the *Acacia sieberiana, Diospyrus mespiliformis* and *Piliostigma thoningii* (Costa *et al.* 2009).

At the land fauna level, the disturbance will occur due to the destruction of the refuge and feeding areas, and the most affected animals will be those with restricted mobility. The emission of noise and vibration and the visual impact during the construction phase will produce a general impact on the fauna.

Many of the impacts identified in the construction phase will remain in the exploration phase. At the aquatic ecosystem level, some structural and functional changes may occur. Although such changes will not be very strong, because of the existing lake that, to a certain extent, has already caused the water speed reduction and the system's eutrophication and stratification.

The water quality change will be associated to a process resulting from the construction practices, where the materials are susceptible to contamination, as for example, the presence of heavy metals that are harmful to the ecosystem's health. The change of ecologic parameters due to different toxicity levels may have an adverse influence on the ecosystem integrity and on its dynamics.

The problems arising from flow regime changes can account for different impacts on the fish fauna, which can be studied under several perspectives, meaning that several phenomena may occur on different groups of fish and on their bio-ecologic specificity should high-water events after a dry period start earlier or later than usual, should water levels be higher or lower than usual, should the dry period extend for a longer time than usual, should the transition period between the dry and humid periods be shorter than usual, thus making the water depth higher or lower, should the humid period start earlier or later than usual, thus changing its synchronism with the rainy period, should a change in the natural proportion of the different types of flood occur, should the transition to the dry period take place earlier or later than usual, or should its duration be longer or shorter than usual.

Among the different impacts we can point out the influence on the ecosystem productivity that can affect the timely development of new recruiting, the habitat availability that can restrict distribution, the restriction of movements that can affect the individual survival, the availability of food and the possibility of successful survival, it may adversely influence on the migration process and successful reproduction as well, it may affect the maturation period resulting in the disqualification of some habitat segments due to water quality changes, among other possible impacts.

Such impacts can, in a general way, reflect on the maintenance of the population within the ecosystem, and can dramatically affect the population living in small water streams, as in the many plains subject to flooding that can be found downstream of the Cambambe Hydroelectric Power Plant. Although such flow regime changes follow natural periodic cycles, the flow regularization that will take place at the Camambe dam can be extremely impacting on certain living species due to flow changes, so it will be unavoidable to have in store some mitigation measures.

- ***Impact assessment***

Regarding the biologic and ecologic component and considering the pressures on the indicators analyzed in the reference situation, there is a strong possibility for the occurrence of moderate to significant negative impacts, being the later caused by the high index of ecosystem quality change due to several pollution aspects. This fact will influence the resources regarding their regional importance, meaning a significant loss of them. However, much of these changes are considered temporary and reversible, although cumulative aspects may show-up.

Moderate impacts will be a result of the disturbance acting on the fauna and of habitat changes as well. The later will present higher importance in the adjacent and surrounding areas, bringing significant negative changes in resource usage in both temporary and permanent ways, and in some cases, reversible and irreversible, and unique.

- ***Mitigation measures***

The mitigation measures for impacts on the biologic and ecologic component resulting from the enterprise construction phase are shown in Table 5.6.

Table 5.6: Mitigation measures for the biologic and ecologic component during the construction phase.

Biologic and Ecologic Component (Construction phase)	
Impacts	**Mitigation measures**
Vegetation loss	• Implementation of seedling nurseries and recovery of degraded areas using the native vegetation; • Collect and preserve seeds of the species registered in the UICN Red List (*Pterocarpus angolensis*) and in the Angolan threatened species list (*Acacia sieberiana, Diospyrus mespiliformis* and *Piliostigma thoningii*) for conservation and later spreading on areas adjacent to the new lake; • Restrict the actuation area to the minimum indispensable, thus protecting the surrounding zone.

Biologic and Ecologic Component (Construction phase)

Impacts	Mitigation measures
Habitat destruction and disturbance	• Restrict the actuation area to the minimum indispensable, thus protecting the surrounding zone; • Recovery of inert material exploration areas, surplus material deposits and soil quarries. • Guidance of drain effluents from the crushing and concrete production zone to a decanting basin; • Adequate storage of pollution-susceptible chemical products used in the construction works; • Impermeabilization of the fuel storage and distribution areas; • Control the discharge of effluents containing oil and other toxic substances; • Guidance of drain effluents from the crushing and concrete production zone to a decanting basin; • Adequate storage of pollution-susceptible chemical products used in the construction works; • Monitoring of the system's water quality based on an environmental management program.
Impacts on the fauna	• Do an analysis by a specialist firm, of the possibility of rescuing the fauna during the period in which the reservoir is filled, up to the full storage level at a height of 130 m; • Monitoring of the fish fauna based on the proposed program; • Carry out awareness campaigns for the adequate preservation and management of the affected and rescued fauna.

b) Exploration phase

- ***Impacts***

In the exploration/operation phase, part of the impacts observed in the construction phase will be diluted by imposition of the means resilience. Hence, interferences on the ecosystem dynamics can be devised, as well as disturbances on the existing fauna. This aspect will be associated to the imposition of the controlled water flow made available downstream, which will directly affect part of the aquatic biodiversity dynamics and its distribution.

One of the main impacts is associated to the downstream water flow that will be regulated, capable of increasing or reducing as required, which, associated to speed changes, solid transport regime, water quality, may affect the ecosystem characteristics change with strong influence on the living species, since the flow is fundamental for the system operation and the maintenance of the living species structure and diversity. After the conclusion of the works, a significant reduction of the downstream flow will be experienced, due to the lake expansion process. Such barrier effect on the “natural” draining system will produce strong negative impacts on the downstream ecosystems, particularly on the fish fauna.

In terms of the emissions of greenhouse gases (carbon dioxide and methane), as a result of filling of the reservoir, that process will have a negative impact, because of decomposition of a greater quantity of biomass. In the meantime, there are favourable effects, from the point of view of greenhouse gas emissions, which are of very considerable and which offset the negative impact that has been pointed out.

Other impacts on the fauna may occur and will be associated to the change in the hydrologic regime, deterioration of the water quality, downstream water level variations and increase in fish mortality associated to their entrance into the hydraulic circuit.

Also in the exploration phase, there is the possibility of the appearance of pollution sources basically associated to the discharge of effluents and the returning of the water to the river after the passage through the turbines, which may affect habitats, and therefore, the ecosystem quality. However, the emission of large quantities of pollutants to the habitats is not expected. The pollutant emission volumes will not be relevant and the risks will be low.

- ***Impact assessment***

The impacts on the biologic and ecologic component in the operation / exploration phase will reside on the higher potential of the moderate negative influence, resulting from pressures for the interference on the ecosystem dynamics and fauna disturbance, thus affecting resources of local and regional importance with the possibility of loss of habits.

The majority of the impacts will be restricted to the area surrounding the project, presenting generally significant, temporary and reversible negative changes, with cumulative effects.

- ***Mitigation measures***

The mitigation measures for impacts resulting from the operation/exploration phase of the enterprise biologic and ecologic component are shown in Table 5.7. below.

Table 5.7: Mitigation measures for the biologic and ecologic component during the operation/exploration phase.

Biologic and Ecologic Component (Operation/Exploration Phase)

Impacts	**Mitigation measures**

Biologic and Ecologic Component (Operation/Exploration Phase)

Impacts	Mitigation measures
Changes in the biodiversity dynamics	▪ Recovery of the margin areas affected during the construction phase through the implementation of the proposed environmental management program; ▪ Carry out the vegetation cover recovery in the access ways that will not be necessary during the exploration phase.
Destruction and disturbance of habitats	▪ Keep a flow that reproduces the variations existing in the natural regime; ▪ Monitoring of the water quality; ▪ Carry out the ecologic restoration of the degraded areas.
Impacts on the fauna	▪ Monitoring of the fish fauna according to the proposed program.
Emission of greenhouse gases (CO2 and CH4)	• To have an analysis done by a specialist company, of the possibility of removing the plant cover from the area, before that area is flooded, so that the carbon emissions are only due to the biomass that is dragged along with the sediments or drainage flow. This would also enable the neighbouring populations to make use of different types of wood and other materials. ▪ •To maintain a stable water level over the course of a year, in order to discourage the growth of vegetation in the places which are exposed during the periods at which the water level is at its lowest, thereby avoiding its immediate decomposition, which may significantly increase the levels of methane during operation of the dam.

5.2.3. SOCIAL-CULTURAL COMPONENT

a) Construction phase

- ***Impacts***

During the construction process negative and positive impacts are expected, associated to the social and cultural component. The negative impacts will be basically related to the temporary arrival and presence of workers, demographic changes, relocation of the affected population, change in health quality and visual landscape change.

After the temporary arrival and presence of workers, a change in habits, behaviors, usage and practices may take place in the local community due to the interaction with the construction workers, with the risk of the social disaggregation of this population, as well as an increase in the prostitution indexes that will reflect in the increase of the sexually transmissible diseases with a greater incidence of the AIDS cases.

The migration flow, added to the environmental changes caused by the construction, will create favorable conditions for the proliferation of pathogenic vectors and agents. Additionally, the lake expansion will favor the formation of humid areas that will create an adequate environment for the procreation of disease transmission vectors that can increase the cases of malaria and other water-associated diseases.

Significant negative impacts associated to the affected population relocation are not expected, since the area to be flooded does not include any populated zone, so it will only be necessary to remove some temporary structures associated to the monitoring and control services located in the perimeter of the area to be flooded.

The landscape change will form the basis for the modification of the landscape elements characterized by the occupation and morphologic modification of the land and by the removal of vegetation and extraction of inert material, as well as by the flooding of a large land surface.

Aspects connected to cultural changes and the loss of archeological and historic sites are not considered as possibly affected.

Pressures concerning employment, resulting from improvement in social conditions and the demand for goods and services, will be deemed as positive impacts.

It is worth noting that the project will provide an additional 2,700 work places that directly and in directly will increase the demand for goods and services, with a projected improvement in the local community social conditions.

- ***Impact assessment***

Generally, part of the negative impacts arising during the construction phase, for the social and cultural component will only consist small negative changes (without loss of habits) and/or negative changes (with loss of habits).

These impacts present in their majority, a negative *status quo* condition, of a temporary and/or permanent, reversible and/or irreversible nature, with unique and synergetic effects.

In this component, the employment availability and the improvement of social conditions will present moderate positive, changes with emphasis on the areas adjacent and surrounding, with a *status quo* increment, and a preferentially temporary and reversible nature, however cumulative.

Mitigation measures

The mitigation measures for impacts resulting from the construction phase of the enterprise social and cultural component are presented in Table 5.8. below.

Table 5.8: Mitigation measures for the social and cultural component during the construction phase.

Social and Cultural Component (Construction phase)	
Impacts	**Mitigation measures**
Disintegration of the community's social organization	• Implementation of the social communication sub-program; • Promotion of the local habits and practices valorization; • Promotion of local culture valorization events.
Demographic changes	• Implementation of the social communication sub-program; • Promotion of the implementation of the basic water, sanitation and health infrastructure in the enterprise area, to support the employees and prevent the overloading of the public sanitary institutions; • Preference to the local population in terms of employment, in order to reduce the unemployment levels.
Health quality changes	• Promotion of actions regarding basic and environmental sanitation; • Promotion of the establishment of epidemiological control programs; • Promotion of the health system improvement at local level; • Promotion of the communities' awareness regarding the main water-associated diseases; • Formation of workers in the area of occupational health and safety; • Implementation of vector control programs.
Social and Cultural Component (Construction phase)	
Impact on the landscape	• Recovery of degraded areas and environmental compensation, focused on the recovery of equivalent areas. • Implementation of the work yard, reclaimed zones and quarries in places with low visual impact; • Landscape recovery in the affected zones.

b) Exploration phase

Impacts

During the exploration phase, negative impacts associated to demographic changes and residue production will be those potentially considered.

Regarding demographic changes, the increase of pressure on the areas surrounding the lake must be pointed out, due to occupation and establishment of the resident and floating population, considering a valorization that such areas will undergo due to their localization.

The increase in waste will be directly associated to the demographic change, which can bring potential negative impacts on the physical space.

Positive impacts will remain in this phase resulting from employment offer, demand for goods and services and the perspective of the improvement of the social conditions of directly affected workers and their families.

The offer of specialized employment will remain in the exploration phase, which will provide the social conditions improvement of the people involved.

The demand for goods and services will encourage the creation of small businesses in the surrounding zone, both directly and indirectly, which will contribute for the social strengthening of this region.

- ***Impact assessment***

In the exploration phase, part of the potentially expected impacts will be from a positive to a moderately positive nature, which will present a significant improvement with respect to the existing situation, an improvement of the resource status with the partial satisfaction of the perceived needs.

They will have a regional importance, with an increase of the *status quo*, with a permanent and irreversible condition with cumulative effects.

The perceived negative impacts will present mostly small negative changes, with little influence upon the resources and low impact.

- ***Mitigation measures***

The mitigation measures for the impacts resulting from the operation/exploration phase of the enterprise social and cultural component are shown in Table 5.9. below.

Table 5.9: Mitigation measures for the social and cultural component during the operation/exploration phase.

Social and Cultural Component (Operation/Exploration phase)	
Impacts	**Mitigation measures**
Demographic change	• Implementation of the social communication sub-program; • Promotion of professional formation and

Social and Cultural Component (Operation/Exploration phase)

Impacts	Mitigation measures
	qualification courses for temporary workers to improve their participation in the employment market; • Promotion of the implementation of basic water and sanitation infrastructure.
Emission of residues	• Promote the establishment of an adequate solid residue collection and disposal system; • Implementation of informative educational campaigns to promote environmental and public health awareness, as proposed in the environmental education and awareness sub-program.

5.2.4. ECONOMIC AND LEGAL COMPONENT

a) Construction phase

- ***Impacts***

During the construction phase, negative and positive impacts will show up concerning the economic component, which will be associated to the overload of the residue collection structure, overload of the road and electric power infrastructure, increase in the social-economic dynamics and interaction with development policies.

The increase in the floating population may increase considerably the residues originated from the new dynamics of the commerce and services activity at local level, thus overloading the residue collection structures, which are presently very poor. The pressure exerted will reflect on the increase of waste resulting from commercial and service rendering activities, and also from the increase in domestic waste. Therefore, special attention must be given to aspects related to the production of residues.

Some impact is foreseen on the traffic infrastructure due to the increase in the circulation of heavy vehicles, overloading the existing roads, with the resulting increase in the emission of noise and atmospheric pollution, therefore affecting the population living conditions, and the possible traffic increase in the zones surrounding the enterprise, which may also cause an increase in the vehicle accident levels.

Due to the enterprise nature, strong negative impacts associated to the overloading of the electric power infrastructure during the exploration phase are not expected, since the enterprise already exists and supplies power to the area surrounding the dam, so it will not be necessary to resort to alternative sources for the power supply to the village and other work fronts involved in the work of repairing and elevating the Cambambe Dam.

Together with the Cambambe Dam rehabilitation and elevation, many employment places will be created, moreover for national workers that will find in this construction an opportunity for professional qualification and to support their families. Additionally, the arrival of labor force will contribute to indirectly strengthen the commerce and services activities at local level, thus improving the average income of the local families, also promoting the creation of new employment places.

The Cambambe Dam repair works have the purpose of increasing the hydro-energetic production capacity, particularly in the northern region, and generally in the country. The mentioned enterprise was considered a priority at the Electric Sector level and results from guidelines originated in the development policies, considering that such repair will become an important contribution to the economic development, with highly significant positive consequences.

- ***Impact assessment***

It is foreseen that negative impacts associated to the construction phase will be only of importance for the local conditions, bringing *status quo* changes of a temporary nature, usually reversible, with unique and synergetic effects.

Generally, small negative changes are expected without the possibility of usage loss. However, negative changes that will result in usage changes due to the majority of the actions will also be observed, with the consequent pressures on the economic component during the construction phase.

In this component, the positive impacts are associated to the social-economic dynamics and the interaction with development policies, producing significant positive changes that are relevant for the adjacent and surrounding areas, with a *status quo* increase and a of normally temporary and irreversible nature, although synergetic.

- ***Mitigation measures***

The mitigation measures for impacts resulting from the construction phase of the enterprise economic and legal component are shown in Table 5.10. below.

Table 5.10: Mitigation measures for the economic and legal component during the construction phase.

Economic component (Construction phase)	
Impacts	**Mitigation measures**
Overloading of the traffic infrastructure	Install adequate traffic signaling on the new section; Carry out traffic awareness campaigns.

b) Exploration phase

- ***Impacts***

During the exploration phase, the impacts will have a definitive nature and can be negative, concerning mainly the overloading of the residue collection infrastructure, and positive, associated to the social-economic dynamics and the interaction with development policies.

The enterprise localization, the area morphometry, associated the present low occupation and the reduced presence of human activities, allow the judgment that the expected negative impacts associated to the overloading of the sanitation and solid residue collection infrastructure will be low relevance.

In terms of social-economic dynamics, the electric power generation, considered as clean energy, will contribute to the increase in the national power generation capacity, thus reducing, on one side, the population's pressure for firewood and charcoal manufacturing, and on the other side, restricting the emission of gases that promote the greenhouse effect, and the flow regularization will allow the assurance of an increase in water availability to supply the population living upstream, for irrigation and tourism, and also contributing to control extreme phenomena, mainly high-water events, thus promoting in an indirect way the national economy diversification.

- ***Impact assessment***

Usually, the impacts identified in the exploration phase bring highly significant high positive benefits, with great importance from the national interest point of view, which are permanent, irreversible and cumulative, of great magnitude, thus contributing in direct and indirect ways to the national economy diversification and strengthening.

- ***Mitigation measures***

The mitigation measures for impacts resulting from the operation/exploration phase of the enterprise economic and legal component are shown in Table 5.11. below.

Table 5.11 Mitigation measures for the economic and legal component during the operation/exploration phase.

Economic component (Operation/Exploration phase)	
Impacts	**Mitigation measures**
Overloading of the residue collection infrastructure	• Promote the establishment of an adequate solid residue collection and disposal system; • Implementation of informative educational campaigns to promote environmental and public health awareness, as proposed in the environmental education and awareness sub-program; • Execution of agreements with the entities authorized to manage solid residues.
Increase in traffic accidents	• Install adequate traffic signaling on the new section; • Carry out traffic awareness campaigns; • Implementation of preventive measures together with the road users and the neighborhood;

5.2.5 ENTERPRISE ENVIRONMENTAL CLASSIFICATION

Table 5.12 presents a summarized environmental classification of the analysis carried out in the Cambambe enterprise, based on the RIAM methodology, for the construction and operation phases, covering the four components proposed by the methodology, which are: i) physical and chemical, ii) biologic and ecologic, iii) social and cultural, and iv) economic and legal.

Table 5.12: Enterprise environmental classification.

Phases	Environmental components	Pressure	Importance	Magnitude	Permanence	Reversibility	Cumulative effect	Environmental classification
			A1	A2	B1	B2	B3	CA
CONSTRUCTION PHASE	Physical and Chemical Component	Excavations	2	-2	2	2	3	-28
		Inert material moving	2	-1	2	3	2	-14
		Loss of soils due to superficial impermeabilization	2	-1	3	3	3	-18
		Emission of dust	2	-1	2	2	2	-12
		Emission of vibration	2	-1	2	2	2	-12
		Emission of noise	2	-1	2	2	2	-12
		Changes in the natural draining	2	-1	2	2	3	-14
		Risk of inducing erosive processes	2	-1	3	3	3	-18
		Emission of residual effluents	2	-2	2	2	3	-28
	Environmental components	Production of solid residues	2	-1	2	2	3	-14
		Release of atmospheric pollutants	2	-1	2	2	2	-12
		Disposal of pollutants on soils	2	-1	2	2	3	-14
		Disposal of pollutants on water	2	-2	2	2	3	-28
		Changes in limnologic characteristics and water quality	2	-2	2	2	3	-28
	Biologic and Ecologic Component	Loss of vegetation	2	-1	2	3	2	-14
		Disturbance of the aquatic and land fauna	2	-2	2	2	2	-24
		Change of habitats	2	-2	3	3	2	-32
		Fragmentation of habitats	2	-1	3	3	2	-16
		Pollution of habitats	3	-2	2	2	3	-42
		Preservation of protected areas	3	-1	2	2	2	-18
		Preservation of endemic or threatened species	3	-1	2	2	2	-18
	Social and Cultural Component	Employment	3	2	2	2	3	42
		Arrival and temporary presence of population	1	-1	2	2	3	-7
		Demographic changes	1	-1	2	2	3	-7
		Cultural aspect changes	0	0	1	1	2	0
		Policemen relocation	1	-1	3	3	1	-7
		Demand for goods and services	2	1	2	2	3	14
		Improvement in social conditions	2	2	2	2	3	28
		Health quality disturbances	2	-1	2	1	2	-10
		Risk of loss of archeological and historic sites	0	0	1	1	1	0
		Visual landscape modification	2	-1	2	2	3	-14
	Economic omponent	Social-economic dynamics	3	2	2	3	3	48
		Overloading of the sanitation infrastructure	1	0	2	2	3	0

Phases	Environmental components	Pressure	Importance A1	Magnitude A2	Permanence B1	Reversibility B2	Cumulative effect B3	Environmental classification CA
		Overloading of the residue collection infrastructure	1	-1	2	2	3	-7
		Overloading of the road infrastructure	2	-1	2	2	3	-14
		Overloading of the electric power infrastructure	1	-1	2	2	3	-7
		Interaction with development policies	3	2	3	3	3	54
OPERATION PHASE	Physical and Chemical Component	Water flow regulation	2	-2	2	2	3	-28
		Climate changes	1	0	3	3	1	0
		Emission of vibration	1	-1	1	1	1	-3
		Emission of noise	1	-1	2	2	2	-6
		Increase in superficial draining	1	-1	2	2	3	-7
		Retention of sediments	2	-1	3	3	3	-18
		Erosion	2	-1	3	2	3	-16
		Induced seismicity	2	-1	3	3	3	-18
		Increase in the lake stratification	1	-1	3	3	3	-9
		Emission of residual effluents	2	-1	3	2	3	-16
		Emission of solid residues	1	-1	3	2	3	-8
		Changes in limnologic characteristics and water quality	2	-1	2	2	3	-14
	Biologic and ecologic component	Interference in the ecosystem dynamics	2	-2	2	2	3	-28
		Fragmentation of habitats	1	-1	3	3	2	-8
		Changes in living species	1	-1	2	2	3	-7
		Proliferation of aquatic macrophytes	1	-1	2	2	3	-7
		Preservation of protected areas	2	-1	2	2	3	-14
		Preservation of endemic or threatened species	2	-1	1	1	1	-6
		Fauna disturbances	2	-2	2	2	3	-28
		Pollution of habitats	2	-1	2	2	3	-14
	Social and Cultural Component	Employment	3	1	3	3	3	27
		Demographic changes	1	-1	3	3	3	-9
		Demand for goods and services	1	1	3	3	3	9
		Increase in waste	1	-1	3	2	3	-8
		Development of the area	1	1	3	3	3	9
		Improvement in social conditions	3	1	3	3	3	27
		Health quality disturbances	1	0	1	1	1	0
	Economic component	Social-economic dynamics	3	2	3	3	3	54
		Overloading of the sanitation infrastructure	1	-1	1	1	1	-3
		Overloading of the residue collection infrastructure	1	-1	1	2	3	-6
		Overloading of the road infrastructure	0	-1	1	1	1	0
		Overloading of the electric power infrastructure	0	0	1	1	1	0
		Interaction with development policies	3	3	3	3	3	81
		Increase in the risk of accidents	1	-1	2	2	2	-6

CHAPTER 6

ENVIRONMENTAL MANAGEMENT PROGRAM

6. Environmental management program

This chapter was prepared based on the environmental impact assessments conducted in the previous chapter, where impacts/changes were identified and a series of mitigation measures were recommended to face them. The matrices prepared using the *RIAM* methodology, as described in chapter 5, have contributed with the preparation of this chapter. Additionally, the Environmental Management Program (PGA) here proposed is based on the national legislation about the subject, as well as in documents and studies about the construction and operation of Hydroelectric Power Plants.

The present Environmental Management Program is intended to establish a precise set of guidelines (mitigation measures and actions) that will allow the enterprise sponsor to monitor its activities (in the construction and operation phases), thus making it possible to reduce or smoothen its impact on the environment and on the quality of life of the population and its workers.

Therefore, and due to the multi-disciplinarity of the project under study, this chapter presents the different environmental management plans and programs that have the purpose of avoiding, minimizing or compensating the identified impacts. Such plans and programs follow a specific organizational structure, as shown in Figure 6.1. The Environmental Management Program is implemented by means of five (5) Sub-Programs described below, which are:

- Social Communication Sub-Program;
- Education and Environmental Awareness Sub-Program;
- Social Support Sub-Program;
- Construction Support Sub-Program;
- Bio-physical Monitoring Sub-Program.

Environmental Management Program (PGA)				
Social Communication Sub-Program;	Education and Environmental Awareness Sub-Program;	Social Support Sub-Program;	Construction Support Sub-Program;	Bio-physical Monitoring Sub-Program.

Figure 6.1: Organizational Structure of the Environmental Management Program proposed for the Cambambe AH Rehabilitation and Expansion.

This structure starts with the Environmental Management Program (PGA), which will provide the coordination of the inter-institutional actions necessary for the proper operation of the other Sub-Programs. This Program will provide the follow-up of the actions foreseen for all the other Environmental Sub-Programs, keeping integrated the different agents that will be responsible for its implementation. This Program must be implemented together with the mitigation measures presented in the previous chapter.

The measures presented here are related to the actions that must be conducted both in the initial preparation and construction phase, as well as in the operation phase of the Cambambe Hydroelectric Power Plant.

The **Social Communication and Environmental Education and Awareness Sub-Programs** will form the basis from which the information flow will be disclosed to the proposed enterprise, both within the construction and in its surroundings. The actions to be implemented by other Environmental Sub-Programs (**Social Support, Construction Support and Bio-physical Monitoring**), thus ensuring the communication between the enterprise sponsor, the public and private agencies with direct interest on the project (at national and provincial levels) and the population in general, with emphasis to the direct users of the fluvial system (downstream fishermen and farmers and lake users).

The implementation and development of these Sub-Programs is of the entrepreneur's responsibility, who when performing the actions here proposed, will be benefited by the power plant implementation and operation, with low impacts and costs thanks to the control of the significant environmental elements.

The application of these Environmental Sub-Programs will also count with the participation, whenever possible, of the affected communities and the country's public agencies, universities and research institutions.

6.1. PGA TARGETS

The Environmental Management Program (PGA) target is to suggest actions and plans intended to mitigate potential negative environmental impacts, maximize the project's positive points and introduce good practices along the construction and operation phases of the project under study. The PGA for the Hydroelectric Power Plant's Rehabilitation and Expansion project was prepared to ensure that the following requirements are fulfilled:

- Legal obligations pertaining to the environmental and the energy and water sector legislation in force in Angola;
- Accomplishment of Multilateral Environmental Agreements related to the sector under study;
- Implementation of the mitigation measures proposed in the present environmental impact study; and
- Environmental, Health and Safety Standards and Procedures of the Cambambe Rehabilitation Consortium.

6.2. SOCIAL COMMUNICATION SUB-PROGRAM

6.2.1. JUSTIFICATION

The Social Communication Sub-Program is an important tool for the support to the relationship between the company responsible for the implementation of the Cambambe Hydroelectric Power Plant and the several social segments affected and/or interested in the enterprise.

This Sub-Program will guide the business procedures that must be placed in practice together with the discussions that take place during the construction programming, and extend during the entire period of the Hydroelectric Power Plant Rehabilitation and Expansion and its operation. The later requires the creation of efficient communication channels for information and announcement of the actions and Environmental Sub Programs of social interest foreseen in this study.

The Sub-Program will be directed to the AID communities (see Table 1.10), traditional authorities, representatives of the Quiçama and Cambambe municipalities and of the Kixinje and São Pedro da Quilemba communities, contributing for the reduction of uncertainties and doubts concerning the enterprise implementation. Emphasis must be given to the lake users, bridge and fluvial beach, as well as to the people use the fluvial system directly.

It is important to point out that the actions foreseen by the project will also benefit the population of the cities and communities that might be attracted by the announcement of the construction and, consequently, by the announcement of the availability of work places, particularly during the construction phase.

Due to the Cambambe Hydroelectric Power Plant Rehabilitation and Expansion processes, the indirect area of influence corresponds to the areas that will be subject to indirect impacts, both positive and negative, for which an adequate monitoring program and mitigation measures were developed. For the **physical and biological means**, the area of the existing physical structures was considered, including the buses, infrastructure related to the enterprise, work yard and living quarters, added by a surrounding zone of five hundred (500) meters defined as a buffer zone.

For the **anthropic mean** were defined the communities of Kixinje and Muxima in the Quiçama municipality, the communities of Calomboloca, Catete and Bom Jesus in the municipalities of Icolo and Bengo, the community of Munenga in the municipality of Libolo, the communities of Zenza do Itombe, Dondo and Massangano in the municipality of Cambambe and the communities of Calulo and Viana in the municipality of Viana.

The project may affect the activity of around 354 associated fishermen and 500 families dedicated to the subsistence fishing, both in the Kwanza river and in the surrounding lagoons downstream of the dam, with emphasis to the Ngolome and Cagia lagoons. It may equally affect the farming production in the downstream “nacas” due to the lack of water for natural irrigation and the local fluvial traffic.

Another problem that requires periodic and permanent contact with the traditional population living in the sanzalas is the implementation of programs for mitigation or compensation of the impacts caused by the construction.

At the time of the lake expansion the flooding of certain areas as the Kiamangufo bridge, the fluvial beach and the military and police infrastructure existing there will take place, therefore, a permanent dialog with the users of this infrastructure and governmental institutions responsible for it is recommended.

This Sub-Program is also justified by the need to alert the population for the risks of sexually transmissible diseases, especially AIDS, as a result of the contact with the workers that do not live in the area.

6.2.2. TARGETS

6.2.2.1. GENERAL TARGETS

The main target of this Sub-Program is to establish communication channels that allow a permanent flow of information about the enterprise, its rehabilitation, expansion and operation, as well as about the associated Sub-Programs that must be implemented in the region.

This Sub-Program also intends to mitigate the impacts concerning the creation of expectations by the population regarding the generation of employments and the implementation of structural improvements in the Indirect Area of Influence communities. It will also help to keep the population informed about the Environmental Sub-Programs implementation process foreseen in the project.

The Social Communication Sub-Program also has the purpose of defining information and guidelines concerning the construction demobilization phase, when the number of employments fall and, consequently, the economic activities associated to them will be significantly reduced.

6.2.2.2. SPECÍFIC TARGETS

The specific targets of this sub-program include:

- Keeping the population correctly informed about the enterprise, the characteristics of the actions, their impacts and the programs proposed to mitigate them, avoiding diverging information from many agents;
- Minimize the lack of confidence and safety of the population and the users of the road, fluvial beach and bridge, with respect to the changes proposed in this enterprise;
- Avoid information distortions making it more transparent and accessible to the interested parties;
- Promote the involvement of the local population in specific programs, to make possible a more efficient implementation, follow-up and continuation of the necessary actions;
- Improve the relationship between the entrepreneur and the several social sectors affected/interested in the enterprise; and
- Promote the institutional relationship between the entrepreneur, the sub-contractors, the local institutions, churches and NGOs.

6.2.2.3. METHODOLOGICAL PROCEDURES

This Sub-Program must inform the population of the surrounding villages, the Cambambe Village and the City do Dondo about the project characteristics, the time foreseen for the Cambambe AH Rehabilitation and Expansion, the construction stages, the foreseen impacts and the measures in place to mitigate them or compensate for them. This Sub-Program must be of a permanent nature, remaining active after the construction demobilization and the beginning of the Cambambe AH operation, providing assistance for the displacement of the temporary workers from the enterprise area.

Special attention must be given to the lake expansion period, when humid areas will form and will create an adequate environment for the procreation of disease transmitting vectors and, therefore, increase the potential for malaria cases and other water-associated diseases.

The target public for this program includes the rural communities living and working in the Indirect Area of Influence, including the districts of Terra Nova and Uakizulu; institutional agencies of the Direct Area of Influence; enterprise workers; and newly-arrived immigrants originated from many places. This activity will also extend to the population of Dondo that frequently uses the fluvial beach.

The actions composing this Sub-Program are the following:

- Formation of a team responsible for the sub-program implementation;
- Organization of the relevant information about the enterprise characteristics and about the environmental measures proposed for the mitigation of the impacts that might be generated by the enterprise. Such organization can be conducted with the help of posters and leaflets;
- Selection and production of the material (posters and leaflets) announcing information about the enterprise, in accordance to each target public defined, as well as the definition of the strategies for such announcement, also taking advantage of the local communication means and of the local language when deemed necessary;
- Publication of the characteristics of the enterprise, environmental studies and the construction schedule, as well as the employment availability for the enterprise; and
- Holding meetings with the affected communities to present and discuss the general guidelines of this sub-program, with emphasis to the communities close to the road and the communities of Terra Nova and Uakizulu.

A schematic representation of the actions described above and the respective expected results is shown below (Figure 6.2).

Actions	Expected Results
Create team	• Created implementation capacity
Organize the relevant information	• Database available
Select and produce the announcement materials	• Leaflets and posters produced
Publish the enterprise and studies characteristics	• Target public properly informed
Hold meetings with the people affected	• Assurance of the transmitted information

Figure 6.2: Representation of the social communication sub-program's actions and expected results.

6.3. ENVIRONMENTAL EDUCATION AND AWARENESS SUB-PROGRAM

6.3.1. JUSTIFICATION

Environmental education and awareness are considered here as part of a transversal, participative and comprehensive process in which the environmental questions that affect individuals and communities are emphasized, seeking the promotion of a balanced environment, and particularly healthy, which will result in an improvement of the population's living conditions.

The main point that must be highlighted in the environmental education and awareness process is the focus on the building of attitudes and values. To be effective, an environmental education and awareness sub-program must promote, in addition to the knowledge of questions and the social and environmental dynamics, the mastering of procedures, the development of attitudes, taking of actions and the building of values. These are necessary conditions to allow the learning methods to generate healthy and adequate ways of relationship with the environment. Another fundamental aspect is associated to the knowledge of the local social-environmental reality. Therefore, the region where the people live must be the subject and context of a work, so the environmental problems can be effectively solved.

Among the many definitions of environment, this work holds the premise that the environment is a set of conditions (physical, biological, political, social-cultural and economic) that involve the living beings in a certain place, allowing their survival. And, among such living beings are, logically, the human societies, with emphasis to the most destitute.
The assumption of the Environmental Education and Awareness Sub-Program for the Cambambe AH areas of influence here presented, considers that the environment comprises the relationship between human beings and their mean in an indissoluble way, and intends to encourage the development of sustainable alternatives for the activities of the locally living communities. It also seeks and supports solutions for the serious social and environmental problems presently affecting such communities, and also promotes the minimization of the negative effects arising from the enterprise implementation and the strengthening of its positive reflexes.

Therefore, a sub-program capable of informing the **workers** about the cares with the environment becomes necessary, especially with respect to disturbances of the fauna and flora and its importance for the neighboring communities, as well as the need to respect the communities' culture.

However, as important as the awareness and sensibleness of the workers the same is valid for the **local population** (living in the Cambambe Village and in the City of Dondo) and the immigrants, since their living conditions, already very precarious, will be directly affected. Therefore, the Environmental Education and Awareness Sub-Program that will cover economic, social-cultural and health problems, will be divided in two intervention areas with specific methodologies, where one will be dedicated to the construction workers and the other to the local population and the areas mostly used by them.

6.3.2. TARGETS

6.3.2.1. GENERAL TARGETS

The Environmental Education and Awareness Sub-Program has as main target to bring to the population, the Direct Influence Area users and the enterprise workers, relevant formation and information actions seeking life quality improvement and environmental preservation at the site and its surroundings.

The program actions seek to mitigate impacts such as the risk of accidents (outside and inside the construction), health risks as the transmission of sexually transmissible diseases (AIDS and others) and encourage communitarian relationships and social life and guidelines concerning social relationship, considering the arrival of immigrants looking for work.

6.3.2.2. SPECIFIC TARGETS

The Sub-Program specific targets concerning the **workers** are the following:

- Promote the workers awareness about the environmentally adequate procedures related to the construction, health and safety and the relationship with the neighboring communities;
- Sensitize the workers for the seriousness of the prostitution problem, particularly the infantile one;
- Alert and make the workers aware about possible disease transmission vectors, with emphasis on the risks of the STDs and their prevention means;
- Provide the workers with adequate knowledge about the possibility of accidents involving the environment and their own safety;
- Alert about the possibility of accidents with potentially dangerous animals and the need to use the protection equipment;
- Alert about the risk of fire, pointing out which are the most common causes of these events and the guidelines about the measures to be adopted;
- Guide the workers and the lake users during the enterprise operation, by means of adequate signaling and enforcement about the dangers of accidental fires and the legal regulations that forbid hunting and fishing;
- Sensitize and make the workers aware about the environmentally adequate procedures concerning the construction, health and safety, the relationship with the neighboring communities and environment preservation.

The Sub-Program targets with respect to the **population and users** of the infrastructure affected by the construction are the following:

- Contribute to the prevention and minimization of the environmental and social impacts arising from the enterprise and the construction;
- Inform the population and users about the foreseen environmental changes (with emphasis on the lake expansion, the use of explosives, the construction of the new road) and the mitigation and compensatory measures to be implemented;
- Make the population aware about the importance of environmental conservation and recovery.

6.3.2.3. METHODOLOGICAL PROCEDURES

In order to accomplish the targets established in this Sub-Program, which will be directed both to the workers involved in the construction and to the local population and users, a coordination structure will be established as shown below:

- Definition of the team responsible for the Sub-Program technical implementation;
- Establishment of a training/formation methodology for the different themes to be covered in the courses;
- Preparation of the lecture program, recycling periodicity, definition of media usage (television and radio, among others) and the creation of basic materials as leaflets, posters, didactic material for schools, audiovisual pieces, etc.;
- Monitoring of the results obtained, rearrangement and updating of the program themes; and
- Establishment of partnerships with governmental entities and NGOs, whenever necessary and possible, in order to optimize the program results.

6.3.2.4. INTERVENTION WITH THE WORKERS

Periodic programs involving training actions must be carried out, composed by lectures and other interactive activities for the workers, intended to present and discuss the Workers Behavior Code and the construction's environmental and technical standards adopted in the enterprise.

The worker's orientation and formation program must start at the time the worker is hired by the contractor and/or sub-contractors, before beginning his activities in the construction, and must include periodic recycling, where specific activities and actions are carried out in case problems are identified during the construction.

Didactic posters must be prepared and placed in the lodging quarters, including clarifications about the region (for example, a map showing the Kwanza river outline, indicating the existing species that cannot be disturbed, the localization of villages, medicinal plants, the road system and the localization of the medical station), information about the local population culture, information about STD prevention, etc. A monthly report must be prepared by the monitor or the person responsible for this Sub-Program, covering the registered events and the way they must be solved.

The actions here foreseen must be conducted in an integrated way with the Environmental Construction Support Sub-Program with respect to the training activities.

6.3.2.5. INTERVENTION WITH THE POPULATION AND USERS

The educational activities have the purpose of introducing and strengthening environmental preservation notions and improving the families' life quality. These activities can include the teaching of domestic economy knowledge and techniques; basic family health and hygiene cares; improvement of adequate environmental conditions around the house (construction, maintenance and cleaning of septic tanks and latrines, appropriate disposal and destination of domestic residues, etc.) and valorization of local experiences.

Such actions must be carried out whenever possible in a participative way and integrated to the communities, thus promoting the actual involvement with the sub-program and enforcing the intended results. In order to accomplish these results the following themes must be considered:

- Identification of the main problems and the local social-environmental potentialities;
- Identification of effects and consequences (both positive and negative) of the dam rehabilitation and expansion;
- Presentation of sustainable technologies and uses and alternatives for the natural resources seeking the improvement of environmental quality and the population life; best practices concerning sanitation and hygiene; and
- Health protection and prevention against disease transmission, with emphasis to STDs, AIDS, paludism, water-transmitted diseases and family health and hygiene.

In addition to these basic themes, new themes can be included during the sub-program development, when relevant, to be discussed with the communities and users. Training actions should also be carried seeking the qualification of teachers and monitors on environmental problems, in the schools located in the AII districts. Specific didactic material must be supplied together with the training for teaching activities concerning environmental education, with emphasis to the importance of healthy environments for the people's quality of life and for environmental preservation, always focused on the local reality.

Environmental promotion centers can be created for the qualification of multiplication agents in some strategic villages, as a way to reinforce and expand the program results. A schematic representation of the actions described and respective expected results is shown below (Figure 6.3).

Actions	Expected Results
Formation of the technical team	• Created implementation capacity
Establishment of methodologies	• Implementation efficacy
Preparation of the lecture program	• Opportunity for comprehensive education and awareness
Monitoring of the results	• Assurance of the sub-program implementation efficacy
Establishment of partnerships	• Greater participation in the communities

Figure 6.3: Representation of the environmental education and awareness sub-program actions and expected results.

6.4. SOCIAL SUPPORT SUB-PROGRAM

6.4.1. JUSTIFICATION

Sanzalas and villages that may be affected by the project are neither in the Dam's direct influence area nor in the directly affected area, particularly concerning the lake expansion.

The downstream population, including the fishing communities, will also not be directly affected by the project, and only some indirect impacts of low magnitude will take place as a result of the higher traffic of light vehicles, and mainly the heavy ones, of the arrival of people seeking work, of the use inhibition of the fluvial beach and the future flooded areas.

Additionally, there will be positive impacts related to the possibility of increasing work places, access to some basic services and the improvement of the population life conditions, thanks to the actions foreseen in the environmental Sub-Programs established in this study and also to the economic impulse provided by the enterprise.

The deep change expected in the social-economic dynamics and in the local demography justifies the implementation of a social support sub-program, based on the enterprise sponsor's social responsibility. Therefore, this Sub-Program looks forward to minimize the negative impacts and encourage the life improvement opportunities arising from the new enterprise.

6.4.2. TARGETS

6.4.2.1. GENERAL TARGETS

This Sub-Program has the purpose of strengthening the communities located in the dam surrounding areas, as well as the fishing communities downstream of the Cambambe Hydroelectric Power Plant, in order to promote new training actions for access to the recently opened work places, support handcraft fishing and the development of social projects associated to the education and health sectors.

6.4.2.2. SPECIFIC TARGETS

This Sub-Program that provides social support to the surrounding community has the following specific targets:

- Create technical and basic training actions to qualify the population and provide employment opportunities in the enterprise;
- Guide and support the participation of social groups around the implementation of basic sanitation systems and good personal hygiene practices by providing training actions in the environmental sanitation sector;
- Guide and support the introduction of improvement and stimulation techniques for the handcraft subsistence fishing;
- Stimulate and insert the social groups into the formal and environmental education;
- Support the rehabilitation initiatives and the supply of materials and equipment for schools and health care stations in the surrounding area; and
- Qualify the local work force for civil construction works.

6.4.2.3. METHODOLOGICAL PROCEDURES

Based on the knowledge of the surrounding population's living conditions and subsistence means, and on the characterization of this area's social status, work should be developed together with the local institutions in Dondo seeking to identify the main actions that should receive the enterprise's support. Such identified actions should equally benefit the activities belonging to the Social Communication and Environmental Education and Awareness Sub-Programs. The possible training courses or support to the education and health sector should undergo a detailed analysis concerning their financial needs. Some of the actions belonging to this sub-program are listed below:

- Establishment of the team responsible for the Sub-Program's technical implementation;

Meetings with governmental institutions and communities for the identification of projects in the priority social areas (health, education and training, environment);

Definition of the implementation methodology for the identified projects and resource availability;

Establishment of partnerships and implementation of projects with integration to the social communication and environmental education sub-programs; and

Assessment and announcement of the implemented actions.

A schematic representation of the actions described above and the respective expected results is shown below (Figure 6.4).

Actions	**Expected Results**
Create technical team	• Created implementation capacity
Hold project identification meetings	• Priority projects identified and approved
Definition of implementation methodology	• Implementation process defined and resources available
Establishment of partnerships and project integration	• Partnerships developed and projects implemented
Result assessment and publication	• Social benefit fully accomplished

Figure 6.4: Representation of the social communication sub-program's actions and expected results.

6.5. CONSTRUCTIONSUPPORT SUB-PROGRAM

6.5.1. JUSTIFICATION

For the Cambambe Hydroelectric Power Plant rehabilitation and expansion, around 2,700 workers will be necessary. Therefore, the Cambambe Rehabilitation Consortium (CRC) work yard will be implemented under satisfactory conditions and capacity to carry out the construction in its several stages, including the facilities listed in Table 2.7.

The construction activity of the work yard, buildings, yards, service networks, structure rehabilitation, including streets, work yards and urbanization, will be performed according to the execution projects and specifications prepared by the Consortium. Therefore, given the construction magnitude, work support activities must be developed.

6.5.2. TARGETS

6.5.2.1. GENERAL TARGETS

This Sub-Program has the purpose of supplying technical elements to make the construction feasible at the lowest environmental and financial cost possible, and it must provide for the contractor and sub-contractors all the environmental criteria to be followed during the several rehabilitation and elevation stages of the Cambambe Hydroelectric Power Plant and for the workers, standards for a correct environmental behavior.

6.5.2.2. SPECIFIC TARGETS

The specific targets of this sub-program include the following:

- Promote the development and integration of the environmental sub-programs;
- Reduce, mitigate or avoid the interferences generated by the construction on the site and on its surroundings;
- Establish environmental criteria and guidelines for the performance of the works;

- Prepare a Behavior Code for the workers;
- Analyze the technical specifications with respect to works that present risks to the environment to the workers health and safety;
- Prepare environmental guidelines to be included in sub-contractor and service provider agreements; and
- Promote the integration between the proposed programs and the enterprise owner's environmental policies.

6.5.2.3. METHODOLOGICAL PROCEDURES

Considering the work performance guidelines from the environmental protection and worker safety point of view, some work should be done together with the sub-contractors and workers for the identification of the main implementation mechanisms and the accomplishment of the activity schedule. Such identified actions must be equally incorporated to the agreements with sub-contractors and to the Behavior Code to be adopted by all the construction workers. The actions for the implementation of this sub-program are shown below:

- Establishment of the team responsible for the Sub-Program technical implementation;
- Definition of the methodology for the implementation of the measures and the associated costs;
- Meetings with sub-contractors and workers seeking the integration of environmental standards and guidelines and the Behavior Code preparation;
- Planning and implementation of the environmental standards and guidelines in each one of the programs defined in this sub-program, as well as the Behavior Code; and
- Review and adequacy of the proposed activities and actions, when necessary.

A schematic representation of the actions described above and the respective expected results is shown below (Figure 6.5).

Actions	Expected Results
Create technical team	• Created implementation capacity
Definition of implementation methodology and costs	• Implementation process defined and costs clear
Hold meetings with sub-contractors and workers	• Environmental guidelines and Behavior Code established and known
Planning and implementation	• Programs and Behavior Code effectively implemented
Review and adequate programs	• Execution of works with mitigated environmental risks/impacts

Figure 6.5: Representation of the construction support sub-program expected actions and results.

This Sub-Program includes four specific programs (Figure 6.6) concerning the Cambambe rehabilitation and elevation (Table 6.1), instability of slopes and soils (Table 6.2), construction of the new road and bridge (Table 6.3) and recovery of degraded areas (Table 6.4).

Cambambe Rehabilitation and Elevation

Recovery of Degraded Areas

Construction Support Sub-Program

Instability in slopes and soils

Construction of the new road and bridge

Figure 6.6: Structure of the Construction Support Sub-Program

The tables below show the actions foreseen for each construction support sub-program and covers the recommendations present in the mitigation measures presented in Chapter 5, as well as other sub-program actions referred to in this chapter.

Table 6.1: Actions for the Cambambe rehabilitation and elevation.

Cambambe Rehabilitation and Elevation	
Justification	In the Cambambe Hydroelectric Power Plant Rehabilitation and Expansion component, several aspects that will be environmentally affected were identified. These aspects include actions concerning draining; geo-technique and earth moving; water capturing and supply;

sanitary, domestic and industrial sewage; collection and disposal of solid residues; traffic, machine and equipment operation and signaling; deforesting and vegetation recovery; noise pollution; vibration; labor mobilization and utilization; hygiene, health and safety; and soil use and occupation. Regarding each one of these aspects, criteria and guidelines must be developed to guide contractors and sub-contractors.

Targets	To mitigate impacts arising from general Cambambe rehabilitation and elevation activities. Prepare environmental guidelines and the worker's behavior code. Identify the best possible civil construction techniques. Manage the work yard in an adequate and environmentally healthy way.
Methodological procedures	• Training and qualification of a specialized team to implement the program's monitoring actions; • Detailing of the program actions and preparation of specific recommendations for each area; • Performance control and inspection actions concerning work, extraction of inert materials and the work yard; • Preparation of periodic reports; and • Follow-up, interpretation and announcement of the results.
Remarks	Concerning the work yard implementation, operation and demobilization, the following must be considered: susceptibility to erosive processes with emphasis to the inert material extraction areas, spillway construction and tunnel excavation with its rugged topography, surfacing water table subject to

floating and management depending on the hydrologic regime and the control upstream of the Capanda Dam; capturing place for the human consumption water and the production of sanitary effluents; collection and disposal dos solid residues and liquid effluents, with emphasis to hazardous and toxic residues; procedures for work force mobilization control, human resources management and work force demobilization with the conclusion of the construction phase of the several project components; and aspects concerning occupational safety conditions, including the constant use, where necessary, of individual and collective protection equipment.

Regarding the opening of access roads, particularly the access to the spillway construction zone and to the surplus material deposit zones, the susceptibility to erosive processes and the specific draining system must be considered.

The aspects that must be considered during the earth moving actions include geological and geotechnical aspects; the vegetation cover and the existing crawling fauna; the natural water draining and flow; noises and vibration generation, the risk of accidents and the movement of machines and equipment.

In the operation of machines, vehicles and equipment, attention must be given to the generation of effluents originated from the fueling, washing and maintenance of machines and equipment.

(fuel, oil, lubricants, cement, etc.), risk of accidents as well as the generation of noise and vibration and the generation of particulated material and dust.

Table 6.2: Slopes and soils instability monitoring actions.

Instability of slopes and soils

Justification	The instability of bank slopes and the loosening of soils are associated to erosive phenomena that are reactivated during the lake expansion and operation, due to the water table elevation, including the zones of construction (spillway, Cambambe 2) and inert material extraction. Water wash in the banks is the main erosion agent, which can produce ravines, mainly on the lake shore. These effects, added to the partial submersion of the slopes, can also trigger slope slide events and the disposal of sediments into the lake. The detailing and mapping of areas susceptible to erosion and collapse will allow the guidance of the mitigation measures that will be applied to contain the future lake shore slopes as well as soil retention.
Targets	To mitigate impacts arising from the lake shore slopes and the construction and inert material extraction zones. To map and monitor the areas susceptible to erosion and soil disaggregation; generate information for the planning of direct intervention actions designed to protect the slopes against erosive processes.

Instability of slopes and soils

Methodological procedures	• Hiring of a specialized team for the implementation; • Program detailing; • Performance of land investigations, installation of instrumentation and performance of laboratory trials; • Execution of photo-interpretation and geological-geotechnical mapping, follow-up of the field investigations and interpretation of the results; • Slope stability analysis and sizing of solutions for erosion control and contention; • Study of protection measures against superficial laminar erosion, deep erosion, soil sliding and the washing of waves on the lake slopes; and • Follow-up of the stability and erosion conditions in the shore and shore slopes created by the lake expansion, in addition to the water table elevation and its variations during the lake expansion.
Remarks	The geological-geotechnical characterization includes the use of the information surveyed in the inventory and detailing phases, and their complement by activities concerning photo-interpretation, field mapping and the execution of manual auger sounding, inspection shafts and percussion sounding, the execution of laboratory trials to determine the geotechnical characteristics of the materials representing different types of soil and rock, laying of topographic marks to control materials subject to instability; and determination of critical areas and their order according to a priority scale.

Instability of slopes and soils

The reading frequency of the installed instruments varies along the time; two months before the lake expansion and in the two subsequent months, a fortnightly reading is recommended, after this period, the frequency becomes half-yearly. Should heavy rain fall, the inspection of the stability and erosion conditions is also recommended.

Table 6.3: Monitoring actions for the construction of the new road and bridge.

Construction of the new road and bridge	
Justification	The construction of new infrastructure is susceptible to causing potential impacts on the means where it is inserted. They can act with different magnitudes and in some cases with some significance. This fact means that corrective and preventive measures must be taken in order to mitigate impacts during the different implementation phases. The construction of roads and bridges is associated to a large displacement of human resources, inert material and vegetation cover, and therefore, environmental procedures must be established before the beginning of the construction, to safeguard the environment and the safety of workers and means users. The old road and bridge were built in an area that will be directly affected by the lake expansion. This bridge and part of the existing road will undergo adverse impacts due to the lake expansion. Therefore, this will cause

Construction of the new road and bridge
soil usage losses, with emphasis to the fluvial beach downstream of the Kiamangufo bridge and the Kiamangufo bridge control. However, these areas do not have resident population.

Targets	To mitigate the environmental impacts resulting from the road and bridge construction. To define procedures to protect the environment, the workers and the mean users. To develop environmental approaches for the maintenance of the work yard, inert material extraction places and the surplus material deposit.
Methodological procedures	• Hiring of a specialized team for the implementation; • Definition of an implementation strategy that integrates with the environmental conservation programs; • Distribution of responsibilities for the implementation and for informing the contractors about their commitments and obligations concerning the program; and • Execution of the program including work supervision and follow-up actions.
Remarks	The new road must be built to replace the one that will be set aside due to the lake expansion. The vegetation removal for the road building will constitute one of the significant impacts, with indirect influence on the fauna, flora, natural draining and soil structure. Therefore, special attention must be given to the necessary actions, in order to smoothen the aggressions to the ecosystem. All protection elements and structures necessary for the control and safe use of the road and bridge must be carried out and foreseen in construction's execution project. This project should aim at minimum interference with the environment, seeking to make the draining easier and avoiding setting of erosive processes or unnecessary deforestation. The road should, as much as possible, follow the equal level curves, crossing them in a smooth way, only where necessary. In the cases where a steep slope is not avoidable, the spreading of a stone or gravel layer should be foreseen to make the traffic easier and avoid erosion. Transverse slopes should be foreseen in platforms and shoulders, to guarantee good road draining. The new road construction should be followed by draining works, to avoid the setting of erosive processes. All slopes produced by cutting or landfill should be drained by channels, with the use of steps and energy dissipation boxes, where necessary. To reduce, or even eliminate, the possibility of environmental degradation derived from the road construction earthmoving services, the geological-geotechnical characteristics of the

local soils and their susceptibility to erosive processes should be observed during the planning phase. The access ways to the road construction zone should be maintained in permanent good traffic conditions for the bridge construction and erection equipment and vehicles. All the definitive road signaling, necessary to ensure the road and bridge safety and operation

should be carried out according to the execution project and the Road Code in force. All road sections that cross important biodiversity areas should be adequately signaled during the construction phase to allow traffic blockades where necessary and the passerby safety regarding the traffic of machines, etc. Other safety measures may be taken concerning traffic and signaling in the areas close to existing substructures. The machine and equipment operators should be adequately instructed to drive carefully in areas that present risks for people and animals.

All workers should be transported in buses, thus avoiding transportation in vehicle cargo platforms. Both contractors and subcontractors should receive from the Consortium appropriate standards intended to minimize the aggression exercised on the environment by machine traffic, thus avoiding the unnecessary destruction of the vegetation existing in the road sides and forbidding the discharge of any material, as fuel, lubricants, parts or pieces on the fields or the river. Any damage caused by the traffic of persons, vehicles, etc., to the roads, crossings and other existing resources, should be repaired at the contractor's and subcontractor's expenses. The repair should be immediate in the cases of accidental damages and unnecessary to the work progress, or during the regular maintenance, in the case of damages to the roads and other resources affected by the rough normal use during the works.

The maximum speeds allowed should be adequate to the areas crossed, to avoid accidents of any kind involving people whether or not working in the construction. The responsibility for accidents and the adoption of safety measures falls on the contractor, and will be subject to periodic inspection.

Table 6.4: Actions to recover degraded area.

Recovery of degraded areas	
Justification	The work yard implementation, the reclaimed areas, the surplus material deposit zones, accesses and some areas surrounding the future lake can cause environment degradation, involving damages to the vegetation, isolated soil deterioration, development of erosive processes, the silting of water streams and the reduction in aquifer water renovation. Therefore, the planning of degraded area recovery actions will be necessary in the different phases of the enterprise construction, both during the use in the construction period and during the later recovery after the end of the exploration in each area.
Targets	To establish a recovery program for the areas degraded during the construction and operation period. To identify and map the priority areas for reforestation. To define the most recommended vegetation species and the planting techniques and methods. To specify the criteria for the recovery of reclaimed areas and other areas degraded by the works.

Methodological procedures	• Hiring of a specialized team for the implementation; • Detailing of the program and the intervention methodology including the creation of seedling nursery, reforestation and landscaping recovery actions; and • Execution of the program.
Remarks	The earthmoving services for the implementation and exploration of reclaimed areas should be adequately planned, to avoid not only the occurrence of erosive processes during their utilization, but also to allow later recovery. All slopes generated in the reclaimed areas and in the surplus material deposit areas should be adequately protected against the erosive action of rain water until such areas are definitively recovered. At the end of the construction works, all slopes excavated in these areas should be protected with the planting of underbrush or arboreal vegetation, according to the proposed mitigation measures. In the surplus material deposit areas, all the material excavated and not used should be spread and compacted, and finally, the scattering of a superficial layer rich in organic matter should be performed. Simple structures adapted to temporary facilities can be used, provided the necessary actions to avoid the carrying of material to the nearby water streams and channels are taken. Regarding the earthmoving services, the environmental criteria refer mostly to the mandatory inclusion in the planning and performance of these services of erosion prevention techniques, of the maintenance of the implemented protection systems and the monitoring of their effectiveness. Regarding reforestation actions, surveys should be carried out in the priority areas with the recording of information such as the location, degree and kind of intervention. This information will be necessary for the sizing of reforestation measures to be adopted. It is equally important to define the kind of vegetation cover management that should be adopted in the area, considering the reforestation approaches, enrichment with native species and the option of natural regeneration.

6.6. BIOPHYSICAL MONITORING SUB-PROGRAM

6.6.1. JUSTIFICATION

The Cambambe Hydroelectric Power Plant Rehabilitation and Expansion requires a management structure capable of ensuring the performance of the environmental Sub-Programs in an adequate and integrated manner. In this sense, the Biophysical Monitoring Sub-Program should establish efficient mechanisms that guarantee the performance and control of all activities planned in all environmental Sub-Programs, as well as the adequate conduction of project works during the rehabilitation and expansion phases and, also, the operation. This is intrinsically connected to the mitigation measures proposed in the previous chapter, and for this reason must be included in the enterprise sponsor priorities.

The Sub-Program will define an adequate management structure that will guarantee that environmental protection measures established in the Study report of Environmental Impact are correctly implemented, and that will make feasible the follow-up of the environmental Sub-Programs implementation not directly associated to the works, providing a deeper integration among the different agents, companies, consultants and public and private institutions involved in the process.

6.6.2. TARGETS

6.6.2.1. GENERAL TARGETS

This Biophysical Monitoring Sub-Program has the main purpose of ensuring the elimination, mitigation or compensation of the environmental impacts foreseen in the surveys and studies performed.

6.6.2.2. SPECIFIC TARGETS

The specific targets of this Sub-Program include the following points:

- Promote the development of the environmental programs associated to the monitoring of several biodiversity indicators;

- Reduce, mitigate or avoid the interferences generated by the works on the natural and built environments;

- Promote the integration among the proposed programs avoiding duplication and maximizing the results; and

- Sign agreements for the accomplishment of the environmental programs with local partners.

6.6.2.3. METHODOLOGICAL PROCEDURES

The actions that compose this Sub-Program are, concisely, the following:

- Permanent dialogue with the persons responsible for the development of the environmental sub-programs and the mitigation measures foreseen in the present study;

- Integration of the professionals involved in the preparation and performance of the specific environmental protection and monitoring sub-programs;

- Planning and cost estimating for the development of the activities necessary for the Sub-Programs implementation;

- implementation of the Sub-Programs; and

- Revision and adaptation of the proposed activities and actions, when necessary.

A schematic representation of the actions described above and the respective expected results is shown below (Figure 6.7).

Actions	Expected Results
Interaction with the sub-program monitoring teams	• Consolidated and effective implementation of the environmental sub-programs
Integration of professionals in the implementation	• Monitoring and management planned according to the PGA
Planning and cost estimating	• The activities have the resources available
Sub-program implementation	• Programs implemented as planned – impact minimization
Sub-program review and adjustment	• PGA implementation with quality certification

Figure 6.7: Representation of biophysical monitoring sub-program actions and expected results.

The specific Biophysical Monitoring Sub-Program proposals are presented below according to Figure 6.8.

These Sub-Programs include aspects related to biophysical aspects monitoring actions with emphasis to the climatology (Table 6.5), seismology (Table 6.6), hydrogeology (Table 6.7), limnology (Table 6.8), flora (Table 6.9), terrestrial fauna (Table 6.10) and ichtyofauna (Table 6.11) areas.

(Figure)
Climatology
Seismology
Hydrogeology
Limnology
Ichtyofauna
Flora
Terrestrial Fauna
Biophysical Monitoring Sub-Program

Figure 6.8: Structure of the Biophysical Monitoring Sub-Program.

Table 6.5: Climatological monitoring actions.

Climatology

Justification	The actual assessment of climatic changes can only be made by comparing the conditions before and after the construction. Therefore, it is important to have thermal-pluviographical and meteorological stations available. The installation of such equipment before the beginning of the works will provide a series of data corresponding to the phase prior to the lake expansion, which can be later compared to that of the operation phase, thus allowing the identification of the climatic modifications occurred during the transition time. This procedure, besides allowing the follow-up of possible local microclimate and climate changes, will also make feasible the study of the mentioned climatic effects on the lakes. They are equally useful in the modeling of the ecosystem climate interactions, as for example, the wind action recording that is an important factor in the determination of the thermal and erosive instability of any lake and the resulting nutrient recycling and vertical distribution of phyto and zooplankton.
Targets	To mitigate impacts resulting from possible changes in the hydrologic balance and the climate. To evaluate possible climate alterations resulting from the lake expansion. To generate data for studies on the impacts of these changes and create models for climate interactions with the environment.
Methodological procedures	• Hiring of a specialized team for the program implementation; • Detailing of the program actions; • Acquisition and installation of the meteorological and thermal-pluviograph cal stations; and • Follow-up, interpretation and publication of the results.
Remarks	The analysis of the data to be obtained should be preferably made together with the National Institute of Meteorology and Geophysics of Angola – INAMET). The thermal-pluviographical or micro-meteorological stations should be installed in locations close to the lake and at variable distances. Preferably, close to the Cambambe Hydrological Power Plant axes. Other sites could be chosen according to the land relief, at distances lower than 5 km from the lake, according to the accessibility and safety conditions. The automatic stations to be installed should contain a data acquisition system and sensors for temperature, humidity, wind, atmospheric pressure, pluviometry, solar radiation, soil temperature, and if possible water temperature, depending on its proximity to the lake.

Table 6.6: Seismological monitoring actions.

Seismology	
Justification	The lake area is situated in a region with a history of earthquakes associated to two deep regional faults. Studies in the medium Kwanza region point the region as a natural seismic area that should be taken in consideration. Old records indicate that in 1914 an earthquake of 6.54 of magnitude took place together with two smaller ones with magnitudes of 4 and 6. In the years of 1968 and 1976 two other earthquakes were recorded, with magnitudes of 4.4 and 4.8, respectively.
Targets	To mitigate impacts resulting from induced seismicity. To evaluate natural and induced seismic activities within the lake influence areas. To detect the occurrence of eventual induced earthquakes and obtain the correlation between earthquakes and the geological and tectonic features of the area and the determination of epicenters, intensities, magnitudes, seismic accelerations and their area of influence.

Methodological procedures	• Hiring of a specialized team for the program implementation; • Detailing of the monitoring program and technical specifications; • Acquisition and installation of the seismographic station; and • Program follow-up, interpretation and publication of the results.
Remarks	The evaluation of seismic activities should be taken in consideration a year before the lake expansion, and be followed by two or more years during the dam operation. Seismic activity should be continually monitored by means of seismogram generation. The explosive excavations in the Cambambe Hydroelectric Power Plant Rehabilitation and Expansion works and in other works located within lake influence area should be monitored and recorded. A seismographic station should be installed in the lake area, equipped with recorder, seismometer and data broadcasting radio equipment, in a location to be carefully selected and sheltered with protection devices. A technician that will carry out the periodical maintenance of the equipment will be necessary to operate the station, including the eventual collection of seismograms, should a radio broadcasting system not be available. Data analysis will be conducted every two months and in the event of an earthquake, and according to the first analysis results, it must be checked whether the installation of more seismographic stations is needed to enable the localization of the seismic event epicenters.

Table 6.7: Hydro-geologic monitoring actions.

Hydrogeology	
Justification	The water table level changes resulting from the lake formation and operation are relevant for the more precise characterization of the predicted impacts, corresponding to the increase in the underground water productivity, to the formation of humid and flooded zones, to the increase in susceptibility and instabilities and erosion in the shore slopes. The variety of impacts caused by the water table level has an ambiguous effect, sometimes positive, sometimes negative. In both cases the factors and parameters that influence the water table level changes and the confined underground waters are very variable, as well as their initial conditions. Therefore, the hydro-geological monitoring enables the planning of preventive and negative impact mitigation actions, and those that stimulate the positive effects as well.
Targets	To mitigate the impacts derived from sediment retention; the formation of humid and flooded zones; and the water table level.
Methodological procedures	• Hiring of a specialized team for the implementation; • Detailing of monitoring and sampling program; • Installation of meters and field investigation; • Level measurement, sample collection and analyses of underground waters; and • Program follow-up, interpretation and publication of the results.
Remarks	In order to measure the water level depths, monitoring wells must be perforated in the locations indicated in the program detail. The depths should be converted into absolute levels so the potentiometrical surface of the free and confined aquifers can be found. The survey performed for the

installation of piezometers will be used in the collection of samples and in the geological, geotechnical and hydro-geological characterization of the material layers, and also in the determination of parameters such as the hydraulic conductivity.

The water level reading frequency should follow different standards according to the enterprise phase. In the construction phase, at least half-year readings should be made, one in the dry season and another in the humid one. Two months before the expansion and up to two months after, fortnightly readings should be made. In the operation phase, the readings should be again half-yearly, one in the dry season and another in the rainy season. This follow-up should last at least for two years, the period in which the need to continue the program should be assessed.

Collections and analyses from the monitoring well waters should also be made. With half-year periodicity in the rehabilitation, expansion and operation phases, and with monthly periodicity in the semester the expansion will take place.

In the water capture places identified for human consumption, collections should be carried out and the analyses of the parameters used in the definition of potability, namely: water aspect, smell, color, turbidity, dry residue, pH, alkalinity, presence of hydroxides, carbonates and bicarbonates, total hardness, oxygen consumed, ammoniacal, albuminoidal and nitrous nitrogen, iron, chloride, fluoride, arsenic, copper, lead, zinc, barium, selenium, manganese, cadmium, chromium VI, cyanides, organic residues and microbiological characteristics. Tests that cannot be made in Angola can be sent to renowned laboratories abroad.

Table 6.8: Limnology monitoring actions.

Limnology	
Justification	Actions predicted for this project will lead to several changes in the Kwanza river aquatic environment. Such changes could result in degraded water quality, thus affecting its suitability for many uses, as well as the survival of the local aquatic fauna. Therefore, a program that monitors the water quality before and after the lake expansion becomes necessary, and that is also capable of generating useful information that backs the taking of eventual mitigation and/or of compensation measures. Physical, chemical and biologic data (phyto and zooplankton) should be analyzed. Based on the collected samples, it will be possible to identify factors that interfere in water quality, such as the presence of fecal coliforms, chlorophyll, oxygen, ammonia, phosphorous sediments, water temperature and turbidity, and others. The study of these parameters will help to determine the existence of possible polluting sources, the lake capacity to remove pollutants and the lake water quality.
Targets	To characterize the Kwanza river water limnological behavior before and after the lake expansion, the nutrient balance, the throphic potential and the thermal stratification/destratification, the anoxia of the lake to be formed. To assess the physical-chemical conditions and their variation in

	time, the bacteriological conditions and the water stream hydro-biology. To mitigate the impacts resulting from the change in limnological and water quality characteristics, upstream and downstream of the enterprise, due to the transformation of the river lotic characteristics; to the increase in water turbidity; to the flooding of the terrestrial vegetation growing in the river banks, which accelerates the aquatic system deterioration; to the lake stratification; to changes in the aquatic organism communities downstream of the dams and the possible proliferation of aquatic Macrophytes.
Methodological procedures	• Hiring of a specialized team for the implementation; • Detailing of monitoring program, sample collection and laboratory analyses; • Acquisition of sampling equipment and field analysis sets; • Scheduled sampling carried out weekly or monthly; and • Execution of the program, interpretation and publication of the results.
Remarks	This monitoring program should be initiated soon after the installation of the construction site, with regular samplings. The water samples should be collected at the banks, preferably in locations with at least 30-cm deep and with running flow. The program should also be extended to the lake with the analysis of the recommended physical and chemical parameters. The use of accredited laboratories is also recommended to ensure the sampling results credibility. For analyses that cannot be made in Angola laboratories accredited abroad should be identified.

Table 6.9: Terrestrial fauna monitoring actions.

Terrestrial fauna	
Justification	Human activity in natural environments, including the dam rehabilitation, expansion, construction and operation, leads unavoidably to the breaking of the green areas physical continuity. This fragmentation can reduce the biodiversity at local and regional levels, because it eliminates habitats and breaks the genetic flow of the populations, increasing the harmful effects of competition and other kinds of negative interactions within the fragments. For the adoption of any intervention strategy in the communities, including the rescue and release of the animals in adjacent zones and according to provincial institutions' guidelines, it is necessary to bear in mind that there is no ideal methodology to solve the problems derived from the lake expansion. It is necessary to have the primary data in hands and test the methodologies, checking the consequences in small scale before selecting any intervention strategy. The precise knowledge of the regional fauna is the starting point for the accomplishment of all conservation work. Only through this knowledge it will be possible to verify the population's structure and dynamics and to estimate the potential risks to the fauna derived from the lake expansion. Such studies will build the basis that will make the rescue operation or any other kind of management feasible. Therefore, the accomplishment of a fauna conservation program, structured in a knowledgeable way, will not only mitigate impacts on the

	population, but it will contribute to improve the fauna knowledge in the area and to update the environmental impact study data.
Targets	To mitigate the impacts derived from the reduction in habitat diversity and size that changes the ecosystem stability; the displacement of the terrestrial fauna to adjacent areas; the increased risk of accidents with animals.
Methodological procedures	• Hiring of a specialized team for the implementation; • Detailing of the monitoring and inventory program, fauna rescue and movement of the species during the lake expansion; • Preparation of the methodology and making the rescue equipment available; and • Execution of the program, interpretation and publication of the results.
Remarks	Based on the results obtained during the field surveys for the preparation of the environmental studies, together with previous experiences of this nature, the fauna conservation program should be divided into three distinct phases, that includes the updating of the fauna inventory based on the environmental impacts study data (phase 1), fauna rescue operation, whenever necessary (phase 2) and monitoring of the animal population during the expansion phase (phase 3).

Table 6.10: Flora monitoring actions.

Flora	
Justification	The diversity of the vegetation species living in the region, whose initial studies suggest they are representative, associated to the fact that the lake formation will flood species whose genotypes can be unique and necessary for future use, are the main justifications for the implementation of efforts intended to ensure flora conservation actions. It is important to point out that the genotypes of the flooded species populations might not be found in the remaining population, either around the lake or in other places of its distribution areas. Thus, the impacting agent could cause the vegetation suppression. These facts can be partially minimized, and in certain cases reverted, by rescue actions and further preservation ex situ. The knowledge improvement on the most relevant species to be conserved, their reproduction abilities, the distribution and restructuring for the protection of the bank areas also are essential aspects in this program.
Targets	To mitigate the impacts due to vegetation suppression in the civil work area, lake expansion; suppression of native vegetation, with the consequent loss of the vegetation species' genetic variability; and changes in the communities located in the lake shore areas. To minimize the impact the project will impose on the vegetation and the flora.
Methodological procedures	• Hiring of a specialized team for the implementation; • Detailing of the program for investigation, reforesting, minimization of the vegetation suppression and landscape recovery in the areas subject to intervention; • Definition of the implementation methodology and establishment of a seedling nursery; and • Execution of the program, interpretation and publication of the results.

Remarks	Initially, some survey should be carried out in the intervention areas to check the possible exploration of inert materials and the disposal of surplus material, being the information recorded, such as the area localization and characterization, kind of intervention, soil characterization and use, status of the natural regeneration and identification of erosive processes. Such information is necessary for the sizing of the conservation measures to be adopted. It is important to define the kind of management that should be adopted in the area, where three lines of action were suggested, namely: • New vegetation (recovery): should be adopted in areas that lost their natural regeneration capacity, although, due to the location, they favor the connection between fragments with autochthonous vegetation. The new vegetation can promote the formation of ecological corridors that will allow the fauna displacement and the genetic flow among the populations. It can also aim the mere landscape value that is important under the human point of view, thus renewing degraded areas close to settlements and to the work routine; • Enrichment: areas that still keep the natural regeneration capacity should be enriched through the introduction of native species that attract the pollinating and seed dispersing fauna, aiming at increasing the area's biodiversity; and • Natural regeneration: in those areas that still keep good natural recovery capacity, presenting new blossoms, seedling and seed banks in the soil, being the elimination of the degradation factor sufficient.

Table 6.11: Ichtyofauna monitoring actions.

Ichtyofauna	
Justification	The conduction of ichtyofauna studies in the dam construction helps to understand the actual system modification. Its monitoring is essential in the obtainment of information based on biological Ichtyofauna indicators, especially the one that which occurs in the influence area, but also including the Ichtyofauna present in the main tributaries. Such studies are necessary to compare the Ichtyofauna composition in a careful way, before and after the planned works. The program also includes Ichtyofauna monitoring studies, starting with the lake expansion from 1.3 Km^2 to 5.5 Km^2 and during the Cambambe Hydroelectric Power Plant operation.
Targets	To mitigate the impacts resulting from of the fish species' migratory flow interruption; fish mortality downstream of the lake due to the water flow reduction during the lake expansion; and changes in the Ichtyofauna composition in the lake area.
Methodological procedures	• Hiring of a specialized team for the implementation; • Detailing of the monitoring and sampling program; • Acquisition of sampling and conservation equipment; • Scheduled sampling; and • Execution of the program, interpretation and publication of the results.

Remarks	The field work in the lake should be accomplished in two campaigns during the first year under different flow conditions, both in the dry and flood periods, to cover possible seasonal variations. The field work will include well-known sampling points, according to the methodology used in the study, both upstream as downstream of this area. All the sampled points will receive geo-reference. The different kinds of environment will be photographed for recording and further correlation with the sampled kind of Ichtyofauna. A quick characterization of the sampled location will also be made, regarding the vegetation cover, submerged vegetation, bed structure, bank characteristics, etc. All the sampled collection points and environments will be photographically documented. The collections will be made, in their majority, during the day period, however, eventually also during night with the specific intent to capture the Ichtyofauna presenting predominant night activity. The samples collected will be immediately fixed in formaldehyde at 10%. Small samples of muscular tissue could be collected from certain individuals for future molecular analyses. Material with intense or striking colors and with relatively small size should be photographed while alive in an aquarium in the same collection location. A more precise identification of the species will be made in the laboratory, based on the pertinent literature and on comparison with material deposited in scientific collections in institutions of other countries.

CHAPTER 7
FINAL CONCLUSIONS

7. FINAL CONCLUSIONS

In consideration of the energy deficiencies prevailing in the country and the weaknesses of the electric power supply, the National Electricity Company (ENE) is proposing the rehabilitation and expansion of the Cambambe Dam in the province of North Kwanza. Due to this project, an additional value of 80 MW is expected to be added to the national power system by power house 1 (the so called Cambambe elevation) and of 520 MW by power house 2 (the so called Cambambe 2). Such amounts are still short of meeting the present power demand. This project was already foreseen in the initial dam Project, when the dam was designed and built.

The Cambambe Hydroelectric Power Plant project foresees many actions related to the Cambambe Dam planning, construction, expansion, rehabilitation and operation, which take in consideration pressures on the physical, biotic and anthropic means. Such actions will exert certain pressures on the natural and built environments.

Therefore, along more than eight months, a set of bibliographic researches and technical surveys were carried out in the field, in the project's direct and indirect areas of influence, seeking the performance of an environmental analysis of the impacts arising from the Cambambe Hydroelectric Power Plant implementation, presented in this Environmental Impact Study. The results of this work are described in the several chapters of this study.

These studies, together with the existing knowledge about the Cambambe and Dondo regions and besides the thorough analysis of the pressures and impacts resulting from the Cambambe Hydroelectric Power Plant actions concerning the environmental and social aspects, also produced information that will contribute in a significant way to the knowledge about the biodiversity in the area and in its surroundings.

This information is equally useful to compensate for the inexistence of similar information in the region that will be used to follow-up the evolution of the Cambambe Hydroelectric Power Plant and of other enterprises that might be implemented in this area, particularly those designed for the medium Kwanza and Dondo regions. Therefore, the chapter covering the area's environmental characterization, both from the anthropic and the biodiversity points of view can be used as a basic diagnosis of the reference situation in the area. This diagnosis will allow the future analysis of the modifications that might be performed as a result of the present project, as well as by other enterprises or initiatives that might show-up in the area under study.

The surveys of the physical and biotic means conducted both upstream and downstream of the dam showed the existence of a significant environmental diversity, although not limited to the study area. Additionally, these surveys have indicated the existence of an anthropic pressure on the region's natural resources, including the aquatic biological and botanic resources.

As described in the previous chapters, this project, both in the construction phase (infrastructure inside the Dam, new road and bridge) and in the operation phase, will exert certain pressures on the environment, with different degrees of intensity, which will result in an environmental classification compose by negative and positive impacts, of varied importance and magnitude, and whose intensity is not uniform for all the components.

The analysis of the main impacts of this project was conducted based on the nature and size of the enterprise under study, as well as the reference situation in the proposed site that was already changed due to the existence of the Cambambe Dam and Lake. Its present localization and operation was also considered, as well as its surrounding areas both downstream and upstream of the dam. Emphasis was given to the areas that will be flooded by the dam elevation, which are the Kiamangufo bridge, the fluvial beach in that site, the vegetation area and part of the National Road 230, in an approximate extension of 5,500 meters, as well as some military and police structures existing in the surrounding area.

The analysis of the environmental impacts caused by the project was conducted with the help of the *Rapid Integrated Assessment Matrix (RIAM)* methodology developed for large projects, with emphasis to those associated to hydrologic resources. Consequently, some matrices were developed based on the results obtained through this methodology, where such matrices were developed for the components of construction works (including the dam rehabilitation and elevation and the construction of the new road and bridge) and for the operation phases of the Cambambe Hydroelectric Power Plant and its supporting structures.

In this context and after analyzing the pressures of the several project actions on the terrestrial and aquatic environment and their impacts on the environment, no significant impact was identified that could place in doubt the project implementation at the proposed site, or for which no appropriate mitigation measures exist. The analysis of these impacts covered general activities, which are the dam elevation and the construction of the lateral spillway lateral, the rehabilitation and expansion works, the construction of the new bridge and road and the later dam operation.

To make the matrix development and the later description of the main impacts and mitigation measures easier, the assessment methodology covered two fundamental aspects of the project: one phase that includes the dam and the machinery house rehabilitation, the dam elevation, the spillway construction and the construction of the second power house, as well as the work yards, workshops and the civil construction areas, and another phase associated to the construction of the new road and bridge. This methodology allowed a separate analysis of the impacts and mitigation measures, thus allowing a better perception of the extension of each one of the Cambambe Hydroelectric Power Plant Rehabilitation and Expansion project works.

In a general way, impacts related to the biotic mean were identified during the construction process due to the great quantity of inert materials and other materials necessary for the construction, to the management of solid residues and liquid effluents and to the management of the enterprise's surplus material deposit zones. For all impacts, appropriate mitigation measures were identified, proposed and described in the present report of environmental impact study, which will attenuate and mitigate the impacts previously described. An environmental management program was equally proposed including many sub-programs, which are the Social Communication, Environmental Education and Awareness, Social Support, Construction Support and Biophysical Monitoring sub-programs.

From the social point of view, the enterprise will provide direct employment to 2,700 people, of which the majority will be locally recruited and, as a result of the dam construction and operation process, other work places will be created. From the economy and social point of view, considering the number of employments made available and all the services associated to the work yard and lodging zone operation, this project will have an outstanding role in the regional and national development, and therefore, positive impacts are expected. These associated services are connected to an offer of material and equipment, fuel and lubricants, food, etc.

The increase in the electric power supply is one of the main benefits of this project, which will be inserted into the national development strategy for the energy sector. The Cambambe Hydroelectric Power Plant is considered an environmentally feasible enterprise that features high social-economic value.

From the technologic alternatives point of view and after the analysis of the construction systems and the materials and methods to be placed in use for the expansion, rehabilitation and construction process, a conclusion was reached that they are compatible with the appropriate materials for this type of construction. Additionally, the study presents plausible alternatives and justifications both for the lateral spillway construction and the elevation to the 130-meter level, and for the second power house as well. Equally, the project presents valid and environmentally accepted alternatives and options concerning the management and treatment of solid residues and liquid effluents, internal transport systems, extraction of inert materials and also the Cambambe Hydroelectric Power Plant operation mechanisms.

In a general way, the negative impacts highlighted in the present environmental impact study report can be either mitigated and/or avoided, provided the as mitigation measures proposed in this document are complied with, as well as the application of good environmental management practices to the dam construction and operation process. An extensive environmental management program is also proposed, encompassing many project intervention areas, which are construction, environmental education, flora and fauna protection, etc., as described in chapter 6. Therefore, with the implementation of the mitigation measures and the execution of the environmental management program, the residual impacts will be either minor and/or insignificant. In order to make this possible there must be strict compliance with the proposed mitigation measures, both those concerning environmental protection as those that ensure the worker’s safety on the site.

Considering that the enterprise extension was already foreseen in the area where the enterprise implementation is foreseen, and considering that the enterprise under study was specifically developed for this area, in no case an alternative project localization will be proposed. However, as previously mentioned, alternatives for the localization of the second power house, for the elevation level and the spillway technical specifications were previously analyzed as well, therefore, the alternatives that will be presented are those that bear the lowest environmental impacts, better safety and execution conditions and the best profitability

Therefore, and considering the magnitude of the enterprise, the implementation, monitoring and regular revision of the Environmental Management Program proposed in this document is considered fundamental. This program will encourage the mitigation of environmental and negative social impacts resulting from the enterprise construction, rehabilitation and peration, thus making feasible the enterprise implementation in the proposed site and with the characteristics described in this document.

The program equally assigns responsibilities to each one of the main parties involved in the several project phases. It also includes the mitigation measures proposed in the study, which are aspects concerning the management of solid residues, liquid effluents and the environmental management aspects of the task book, necessary for the several works and enterprise stages, also including an occupational safety and hygiene plan.

It is equally recommended, for the strict compliance with the mitigation measures proposed in this document and, in order to ensure the worker’s safety and environmental protection, for the proponent to implement the plans proposed in the Study. The sub-contractors involved in this construction must equally comply with this Consortium document.

Given the environmental and social impacts identified in the Environmental Impact Study and based on the practicability of the mitigation measures, on its environmental management program and on the associated documents, the execution of the **Cambambe Hydroelectric Power Plant Rehabilitation and Expansion project is recommended within the awarded limits, which are the Cambambe Dam limits, as well as the construction of the road and bridge as proposed in the outline,** provided their execution follows the mitigation measures proposed in the document to minimize and/or avoid the potential negative impacts described in this Environmental Impact Study.

CHAPTER 8

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ATTACHMENTS

Attachment 1

Nominal list of the people interviewed in the social, economic and hydrologic survey

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List of the Cambambe Municipality fishermen associations

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Attachment 1

Nominal list of the people interviewed in the social, economic and hydrologic survey

ATTACHMENT 1 – Nominal list of the people interviewed in the social, economic and hydrologic survey

Attachment 1

Nominal list of the people interviewed in the social, economic and hydrologic survey

No.	Name	Position	Locality
1	Mateus da Costa “Dodó”	Municipal Administrator	Dondo
2	Isabel dos Santos	Head of the ADM Secretariat	Dondo
3	Lino Januário	ADM ‘s SEEP	Dondo
4	Mateus Kizua	Technician of the EKA capturing station	Alto Dondo
5	Gustavo Sores	Odebrecht	Cambambe
6	Cristóvão João	ENE Director	Cambambe
7	Manuel Domingos	Soba	4ª Divisão
8	Domingas Capita	MPLA Coordinator	Dondo
9	João Adão Diogo	MPLA Coordinator	Terra Nova
10	Veríssimo Correia	Community Member	Terra Nova
11	Abelino Vunge	Member	Terra Nova
12	Tito Correia	Member	Terra Nova
13	Carlito Caterça	Member	Terra Nova
14	Felisberto Domingos	Member	Terra Nova
15	Elisa Lucas	Member	Terra Nova
16	Justina Gunge	Member	Terra Nova
17	Teresa Raul	Member	Terra Nova
18	Inês Sumbando	Member	Terra Nova
19	Rosa Caculo	Member	Terra Nova
20	Sousa Domingos	Member	Terra Nova
21	Marcelina Pedro	Member	Terra Nova
22	Fátima Cabassa	Member	Terra Nova
23	Amélia Domingos Direito	Member	Terra Nova
24	Verónica Tomas	Member	Terra Nova
25	Bernardo Januário	Municipal Administrator	Quiçama
26	Filipe	SEEP	Quiçama
27	Domingos Manuel	Commandant	Military Work Yard
28	Filipe Job	Head of operations	Military Work Yard
29	Carol	Odebrecht	Cambambe
30	Alfredo André	President of the Fishermen Association	Ngolome
31	Ângelo David	Member of the Association	Ngolome
32	Sabino Holica	Soba	Mucoso
33	Francisco Manuel	MPLA Coordinator	Massangano
34	André Jamba	Farm Manager	Wakizulo
35	Baptista Afonso	Farm Worker	Wakizulo
36	Simão Teixeira	Administration Inspector	Dondo
37	Domingos Pedro	Soba	Kixingango

No.	Name	Position	Locality
38	Henriques Lourenço	Soba	Cambingo
39	Ângelo David	MPLA Coordinator	Cambingo
40	José Jordão	Member	Cambingo
41	José António Carona	Captainy	Dondo
42	Manuel Sousa	Captainy	Dondo
43	Fernando Silva	Head of the Operation Division	Cambambe
44	Joaquim Valentim	Head of the Observation and Hydrology Sector	Cambambe
45	José Cata Francisco	Technician of the Observation and Hydrology Sector	Cambambe
46	Francisco Miguel João	Responsible for the Pump Station	Cambambe

ATTACHMENT 2

List of the Cambambe Municipality fishermen associations

ATTACHMENT 2 - List of the Cambambe Municipality fishermen associations

ATTACHMENT 2

List of the Cambambe Municipality fishermen associations

No.	Association Name	Members
1	António Agostinho Neto	42
2	Akuento Fishing Association	10
3	Kudiva Fishing Association	20
4	Tumbi Fishing Association	10
5	Bondo Fishing Association	21
6	nzala Nzonji Yetu Fishing Cooperative	35
7	Vida Inicial Fishing Association	14
8	Kiombe Fishing Association	15
9	Nova Vida Cazenga Fishing Association	20
10	Ex-Comandantes das FAPLA Fishing Association	20
11	Saber Andar Fishing Association	10
12	Bernardo e Filho Fishing Association	14
13	Hocha Fishing Association	14
14	Paz Família Fishing Association	10
15	Pires Fishing Association	12
16	Benjamim Fishing Association	10
17	Pai e Filhos Fishing Association	9
18	Jovens Desempregados Fishing Association	7
19	Cazenga Fishing Association	20
20	Watuzemba Fishing Association	14
21	Mãos Largas Fishing Association	20
22	Cazenga Lola Fishing Association	7
Total		**354**

ATTACHMENT 3

Standards for the Water Quality Parameters

ATTACHMENT 3 - Standards for the Water Quality Parameters

Attachment 3

Standards for the Water Quality Parameters (according to the OMS and the European Union).

Parameters or Indicators	OMS Standards (1993)	European Union Standards (1998)
Turbidity	< 5 NTU	Not indicated
pH	6.5-8.5	Not indicated
Conductivity	250 microS/cm	250 microS/cm
Color	15 mg/l Pt-Co	Not indicated
Dissolved oxygen	< 75%	Not indicated
Hardness	150-500 mg/l	Not indicated
Total of dissolved solids	No standard available	Not indicated
CATIONS		
Aluminum (Al)	0.2 mg/l	0.2 mg/l
Ammonia (NH4)	No guideline	0.50 mg/l
Antimony (Sb)	0.005 mg/l	0.005 mg/l
Arsenic (As)	0.01 mg/l	0.01 mg/l
Barium (Ba)	0.3 mg/l	Not indicated
Boron (B)	0.3 mg/l	1.00 mg/l
Bromide (Br)	Not indicated	0.01 mg/l
Cadmium (Cd)	0.003 mg/l	0.005 mg/l
Chrome (Cr)	0.05 mg/l	0.05 mg/l
Copper (Cu)	2 mg/l	2.0 mg/l
Iron (Fe)	0.3 mg/l	0.2 mg/l
Lead (Pb)	0.01 mg/l	0.01 mg/l
Manganese (Mn)	0.5 mg/l	0.05 mg/l
Mercury (Hg)	0.001 mg/l	0.001 mg/l
Molybdenum (Mo)	0.07 mg/l	Not indicated
Nickel (Ni)	0.02 mg/l	0.02 mg/l
Nitrogen (total N)	50 mg/l	Not indicated
Selenium (Se)	0.01 mg/l	0.01 mg/l
Sodium (Na)	200 mg/l	200 mg/l
Uranium (U)	1.4 mg/l	Not indicated
Zinc (Zn)	3 mg/l	Not indicated
ANIONS		

Parameters or Indicators	OMS Standards (1993)	European Union Standards (1998)
Chloride (Cl)	250 mg/l	250 mg/l
Cyanide (CN)	0.07 mg/l	0.05 mg/l
Fluoride (F)	1.5 mg/l	1.5 mg/l
Sulphate (SO4)	500 mg/l	250 mg/l
Nitrate (NO3)	(See Nitrogen)	50 mg/l
Nitride (NO2)	(See Nitrogen)	0.50 mg/l
MICROBIOLÓGIC PARÂMETERS		
Escherichia coli	Not indicated	0 em 250 ml
Enterococci	Not indicated	0 em 250 ml
aeruginosa	Not indicated	0 em 250 ml
perfringens	Not indicated	0 em 100 ml
Coliform bacteria	Not indicated	0 em 100 ml
Colony count 22oC	Not indicated	100/ml
Colony count 37oC	Not indicated	20/ml
OTHER PARÂMETERS		
Acrylamide	Not indicated	0.0001 mg/l
Benzene (C6H6)	Not indicated	0.001 mg/l
Benzo(a)pyrene	Not indicated	0.00001 mg/l
Chlorine dioxide (ClO2)	0.4 mg/l	
1,2-dichloroethane	Not indicated	0.003 mg/l
Epichlorohydrin	Not indicated	0.0001 mg/l
Pesticides	Not indicated	0.0001 mg/l
Pesticides - Total	Not indicated	0.0005 mg/l
PAHs	Not indicated	0.0001 mg/l
Tetrachloroethene	Not indicated	0.01 mg/l
Trichloroethene	Not indicated	0.01 mg/l
Trihalomethanes	Not indicated	0.1 mg/l
Tritium (H3)	Not indicated	100 Bq/l
Vinyl chloride	Not indicated	0.0005 mg/l

ATTACHMENT 4

Benthos Sampling Journal

ATTACHMENT 4 - Benthos Sampling Journal

ATTACHMENT 4

Benthos Sampling Journal Jornal of Amostragem do Bentos.

SAMPLING CARD 1

Boat: Holísticos.

Área: Cambambe

Project Code: Dam Rehabilitation and Elevation

Station No.: Est CB1

Date: 06.09.09

Position

Latitude Longitude

Weather: Sunny	Wind: Low		
Sampling equipment used (name, area, weight): Dredge			
Animal notes: None			
Sample No.	Depth (m)	No. of vials with sediment	Notes:
MD 1	2 m	1	Sand
MC 2	9,5 m	1	Mud
ME 3	4 m	3	Mud

SAMPLING CARD 2

Boat: Holísticos.

Área: Cambambe

Project Code: Dam Rehabilitation and Elevation

Station No.: Est CB2

Date 06.09.09

Position

Latitude Longitude

Weather: Sunny	Wind: Low		
Sampling equipment used (name, area, weight): Dredge			
Animal notes: None			
Sample No.	Depth (m)	No. of vials with sediment	Notes:
1 MD	4 m	1	Mud
2 MC	4 m	2	Sand
3 ME	2.5 m	2	Sand

SAMPLING CARD 3

Boat: Holísticos.

Área: Cambambe

Project Code: Dam Rehabilitation and Elevation

Station No.:

Date

Position

Latitude Longitude

Est CB3

06.09.09

Weather: Sunny	Wind: Low		
Sampling equipment used (name, area, weight): Dredge			
Animal notes: None			
Sample No.	Depth (m)	No. of vials with sediment	Notes:
1 MD	4 m	3	Sand
2 MC	4.5 m	2	Sand
3 ME	2 m	1	Mud, fine sand

ATTACHMENT 5

Reports of Analyses Carried Out in Namibia

ATTACHMENT 5 - Reports of Analyses Carried Out in Namibia

Attachment 5

Reports of Analyses Carried Out in Namibia

ANALYTICAL LABORATORY SERVICES cc
P.O. Box 86782 Eros, Windhoek, Namibia
Tel (061) 210132 Fax (061) 210058 e-mail analab@mweb.com.na

TEST REPORT

To: **Holisticos**

Urbanizaçâo Harmonia
Rua 8, Casa 410, Benfica
Luanda

Attn: Ms. P. Roque

e-mail: holisticos@gmail.com

Date received: **22-Sep-09**
Date required:
Date completed: **29-Sep-09**

Your Reference: Water analysis
Lab Reference: I090905

Sample details CmB2
Location of sampling point:
Description of sampling point:
Date of sampling:
Time of sampling:
Test item number I090905/1

Parameter	Value	Units
Iron as Fe	0.2	mg/l
Zinc as Zn	0.03	mg/l
Nickel as Ni	<0.01	mg/l
Chromium as Cr	<0.01	mg/l
Cadmium as Cd	<0.01	mg/l
Lead as Pb	0.01	mg/l
Mercury as Hg	<0.01	mg/l

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e-mail: holisticos@gmail.com

Date received: **22-Sep-09**
Date required:
Date completed: **29-Sep-09**

Your Reference: Water analysis
Lab Reference: I090905

Sample details CmC2
Location of sampling point:
Description of sampling point:
Date of sampling:
Time of sampling:
Test item number I090905/2

Parameter	Value	Units
Iron as Fe	0.08	mg/l
Zinc as Zn	<0.01	mg/l
Nickel as Ni	<0.01	mg/l
Chromium as Cr	<0.01	mg/l
Cadmium as Cd	<0.01	mg/l
Lead as Pb	<0.01	mg/l
Mercury as Hg	<0.01	mg/l

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Attn: Ms. P. Roque

e-mail: holisticos@gmail.com

Date received: **22-Sep-09**
Date required:
Date completed: **29-Sep-09**

Your Reference: Water analysis
Lab Reference: I090905

Sample details CmD2
Location of sampling point:
Description of sampling point:
Date of sampling:
Time of sampling:
Test item number I090905/3

Parameter	Value	Units
Iron as Fe	0.4	mg/l
Zinc as Zn	0.01	mg/l
Nickel as Ni	<0.01	mg/l
Chromium as Cr	<0.01	mg/l
Cadmium as Cd	<0.01	mg/l
Lead as Pb	<0.01	mg/l
Mercury as Hg	<0.01	mg/l

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Luanda

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e-mail: holisticos@gmail.com

Date received: **22-Sep-09**
Date required:
Date completed: **29-Sep-09**

Your Reference: Water analysis
Lab Reference: I090905

Sample details CmD3
Location of sampling point:
Description of sampling point:
Date of sampling:
Time of sampling:
Test item number I090905/4

Parameter	Value	Units
Iron as Fe	0.3	mg/l
Zinc as Zn	<0.01	mg/l
Nickel as Ni	<0.01	mg/l
Chromium as Cr	<0.01	mg/l
Cadmium as Cd	<0.01	mg/l
Lead as Pb	<0.01	mg/l
Mercury as Hg	<0.01	mg/l

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Luanda

Attn: Ms. P. Roque

e-mail: holisticos@gmail.com

Date received: **22-Sep-09**
Date required:
Date completed: **29-Sep-09**

Your Reference: Water analysis
Lab Reference: I090905

Sample details CmE3
Location of sampling point:
Description of sampling point:
Date of sampling:
Time of sampling:
Test item number I090905/5

Parameter	Value	Units
Iron as Fe	0.2	mg/l
Zinc as Zn	<0.01	mg/l
Nickel as Ni	<0.01	mg/l
Chromium as Cr	<0.01	mg/l
Cadmium as Cd	<0.01	mg/l
Lead as Pb	<0.01	mg/l
Mercury as Hg	<0.01	mg/l

ATTACHMENT 6

Maps

ATTACHMENT 6 – Maps