

**LOWER CUNENE HYDROPOWER SCHEME
FEASIBILITY STUDY**

FINAL FEASIBILITY REPORT

**PART B 1, TECHNICAL FEASIBILITY - SUMMARY
EPUPA PROJECT**

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Chapter 1: INTRODUCTION

1.1 GENERAL BACKGROUND

1.1.1 The 1969 Agreement

The Governments of Angola and Namibia ratified in 1991 the 1969 Agreement on the Cunene River, initially entered into by the Republic of South Africa and the Republic of Portugal.

In doing so the 1969 Master Plan of the Cunene River was accepted as a general official guideline for the development of the Cunene River.

The 1969 Agreement was based upon earlier extensive studies, carried out by Portuguese and South African Study Groups, responsible for the studies in the Upper and Lower Cunene respectively.

The studies were mainly technical and little focused on the environmental aspects of the development potentials.

With regard to hydropower development, the recommendation of the studies was that Ruacana should be built as the first hydropower project in the Lower Cunene, followed by the Epupa project, at that time envisaged as a two-stage development, Epupa I and II. It was envisaged that the main regulating reservoir in the Lower Cunene would be built at Epupa, and in harmony with the growing electricity demand further projects would follow downstream of Epupa, at Baynes and the Marienfluss sites.

The Agreement of 1969 resulted in the building of the Gove regulation dam in Angola south of Huambo, the Ruacana hydropower scheme located on the border at Ruacana, for the supply of electricity to Namibia, as well as the Calueque Water Scheme for supply of much needed water to the northern parts of Namibia.

1.1.2 The Prefeasibility Study of the Epupa Hydropower Scheme

After the reinstatement of the Permanent Joint Technical Commission for the Cunene River (PJTC) between the Governments of Angola and Namibia, Namibia initiated further studies of a hydropower project in the Epupa region. In 1992 a Pre-Feasibility Study was staged with the objective to assess the Epupa hydropower project from a technical, economic and environmental point of view, and advise on the suitability to embark upon a more detailed feasibility study.

The Pre-Feasibility study focused on three alternative hydropower projects in the Epupa area, based on identified suitable dam sites A, B and C. Alternative A would be located upstream of the Epupa Falls, whilst alternative B and C would be located downstream of the falls. The dam at B would inundate the Epupa Falls and the large colluvial plains upstream the proposed dams, i.e. the Epupa area. The dam at A would enable an artificial preservation of the falls, but the reservoir created by the dam would be equal to

alternative B with regard to inundation upstream. By building a dam at location C, the power potential of A+C would be comparable to alternative B.

The technical and economic studies turned out slightly in favour of alternative B, but it was recommended that further studies should not exclude any of the alternatives.

The preliminary environmental impact assessment done in the Pre-Feasibility Study, however, identified several potential environmental and social consequences that could eventually result from a hydropower development in the Epupa area.

1.2 CONTRACTUAL BACKGROUND FOR THE FEASIBILITY STUDY OF THE LOWER CUNENE HYDROPOWER SCHEME

1.2.1 The Project

The name of the project is the “Feasibility Study for the Lower Cunene Hydropower Scheme”. It is purely a study to investigate and assess the technical feasibility, economic and financial viability and environmental impact of a possible hydropower scheme to be constructed in the Lower Cunene area.

The term Epupa was used through the course of the investigations in different contexts. It has basically been used to describe dam sites in the region of Epupa Falls, i.e. between elevations 510 and 710 m above sea level. It has, however, also been used to describe the overall project, including the Baynes site, down to elevation 380 m above sea level in the Formulation Report Phase of the study.

After the Formulation Report Phase it was decided to complete a full feasibility study and environmental assessment report for both Epupa Scheme B and Baynes in order to provide a complete picture of the advantages and disadvantages of both schemes. It was also decided that Epupa Scheme B should be referred to as Epupa. Consequently, the project names used in this feasibility report are Epupa and Baynes respectively.

Shortly before the deadline for the Draft Feasibility Report it was decided to replace Epupa Hydropower Scheme with Lower Cunene Hydropower Scheme.

The study is financed by NORAD and SIDA and the Governments of Angola and Namibia with NORAD acting as the lead donor agency.

1.2.2 Client Profile

The Government of the Republic of Angola and the Government of the Republic of Namibia, represented by the Permanent Joint Technical Commission of Angola and Namibia on the Cunene River Basin (PJTC) is the Client for this project.

A sub-committee of the PJTC has been established and is, on behalf of the PJTC, responsible for the day-to-day administration and management of the project.

To ensure the environmental component of the study conforms with the latest international requirements and expectations, the International Union for the Conservation of Nature (IUCN) is assisting the PJTC and advise in this regard.

1.2.3 The Consultant

The name of the Consultant is NAMANG. This is a consortium comprising Norconsult International A.S. (NI) of Norway, SwedPower AB (SP) of Sweden, Burmeister & Partners (BAP) of Namibia and SOAPRO, Lda. (SOA) of Angola. NI is the consortium leader.

The project also includes topographic mapping, geological field works and laboratory analysis. These works have been subcontracted and the contracts have been approved by the Client.

A Consortium Agreement between the four partners was signed in January 1995.

1.2.4 Work Progress

The contract between PJTC and NAMANG was signed in March 1995 and became effective in June the same year.

According to the Terms of Reference the Epupa development should be contained within the river reach between elevations 710 and 510 m above sea level.

The public concern, as expressed at public hearings and in the local and international media about the potential environmental impacts related to hydropower development at Epupa, encouraged PJTC and NAMANG to expand the study with alternative project sites along the Lower Cunene. Sites that, if possible, would reduce the negative environmental and social impacts, but maintaining an acceptable power generation potential.

In the beginning of the Feasibility Study seven different sites, including the A, B and C Epupa schemes of the Pre-Feasibility Study, the Baynes and the Marienfluss sites, were evaluated from both technical and environmental perspectives on a relative scale. A field reconnaissance survey was undertaken in August 1995, to verify general findings of the initial desk studies.

Construction cost estimates were made for the identified scheme alternatives and simplified simulations were carried out of the power generation potential for each specific scheme alternative. A rapid comparative relative environmental screening was made for the different alternatives for the purpose of the Comparative Study.

The result from these initial studies and field inventories were presented to the Supervising Committee of the Feasibility Study (SCFS) and discussed at the SCFS meeting on 31 August 1995. Thereafter further work was undertaken in the Consultant's home office and a report called "Scheme Alternatives in the Lower Cunene-Comparative Study" was presented to PJTC in October 1995. The main conclusion of this study was that Baynes was the best of the new alternatives. Its unit cost of generation compared well with the Epupa B alternative provided the Gove Dam is in operation and the project was considered advantageous with regard to environmental impact. On this basis the Baynes project was recommended for further study. It was later decided by PJTC that the alternatives to be included in the Feasibility Study of the Lower Cunene Hydropower Scheme and compared in the Project Formulation Report would be:

- Epupa scheme A upstream of Epupa Falls in combination with scheme C downstream of Epupa Falls

- Epupa scheme B downstream Epupa Falls
- the Baynes project

The Inception Report, including details on study methodology, topographic mapping and geological field investigations, was also completed in October 1995.

Subcontracts for topographic mapping, geological field investigations and laboratory analysis were awarded after approval of SCFS and these works have been successfully concluded.

The Project Formulation Report was delivered October 1996. The Environmental and Summary portions were revised and reissued along with an addendum to the Technical Report in December 1997.

The Formulation Report presented the results of the technical/economic site assessment and comparative environmental assessment of the various sites in the Epupa region including Baynes. Using this as a basis, the PJTC concluded that Baynes and Epupa should both be carried to the feasibility phase and subject to detailed technical and economic studies as well as a full environmental assessment.

A contract amendment for these additional services was signed between PJTC and NAMANG in February 1997.

NAMANG issued monthly Progress Reports to the SCFS, and PJTC also informed the donors formally by semi-annual Progress Reports.

1.3 THE PROJECT FEASIBILITY STUDY REPORT

1.3.1 Report Objectives

The Contract for the Feasibility Study of the Lower Cunene Hydropower Scheme was carried out in two phases. These were:

1. The Project Formulation Phase
2. The Feasibility Study Phase

Phase 1 commenced as soon as the Contract was effective in June 1995 and terminated with the issue of the revised formulation report and addendum in December 1996.

Phase 2 commenced 1 December 1996 and is completed with the issue of this report.

1.3.2 Report Layout

Overall philosophy is to provide documentation that will allow PJTC to compare the Epupa and Baynes alternatives, make decisions as to which project to proceed with and thereafter have a stand alone Environmental Assessment and Feasibility Report without extra information that has outlived its usefulness. In order to achieve this, the matrix of report volumes shown in Figure 1.1 was developed.

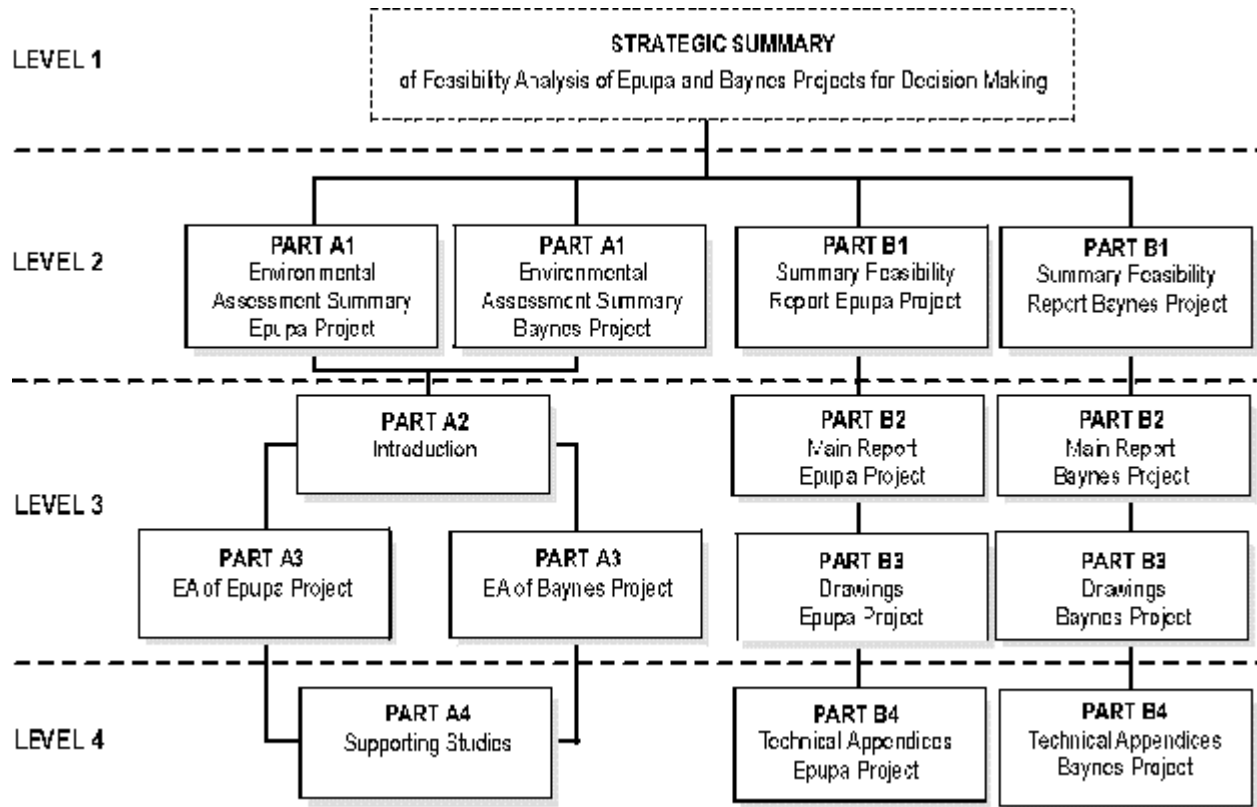


Figure 1.1 Structure for the Feasibility Report

Level 1 Strategic Summary

The strategic summary contains comparative information of both sites and combines environmental and economic/technical consideration. The information presented in this volume gives an overview for the PJTC to aid in choice of which project site to develop further. After the decision is made which site is to be developed, the strategic summary will have only historic significance.

Level 2 Summary

This level and all levels below this are divided into four independent volumes:

- Epupa Environmental Assessment
- Baynes Environmental Assessment
- Epupa Feasibility
- Baynes Feasibility

A broad interest exists for the project and many would like a copy of the results of the Environmental Assessment and the Feasibility Report without needing the full details. This summary enables the documents to be provided to broader public and large distribution.

Level 3

Level 3 is the main body of the studies. According to the Terms of Reference the technical/economic and environmental components should be carried out concurrently but presented in separate reports. The environmental study was carried out independently from the technical/economic study with regard to all professional matters. There was, however, interaction and co-ordination between the environmental and technical teams. Technical layout and cost estimates considered environmental protection and mitigation and the environmental report incorporates modifications and improvement to layout and design of project facilities.

The environmental and economic/technical sections differ in presentation approach in that the environmental report is divided into two parts, having a common introduction section that covers both Epupa and Baynes areas followed by a site specific environmental assessment. The common introduction is structured such that it holds together logically and is complete with either site follow-up.

The economic/technical section is presented in two independent volumes. Information and studies common to both areas are repeated. This duplication of information is deemed necessary in order to preserve the logical progression of subjects in the report and maintain independence between sites.

Level 4 Supporting Documents and Appendices

The environmental supporting studies present the documents prepared by local and foreign experts that provide background for the environmental assessment.

Technical appendices are divided according to chapter such that the appendix numbering reflects the chapter to which the appendix relates.

Some chapters in the main reports contain information that references annexes, which differ from appendices in that they are contained at the end of the appropriate chapter.

1.4 FEASIBILITY TECHNICAL/ECONOMIC REPORT METHODOLOGY

1.4.1 Terms of Reference

An overall Work Program and Detailed Terms of Reference for the study as worked out by PJTC is given in Appendix 1.1 (Part B4, Vol. 1).

1.4.2 Methodology Overview

The methodology for preparation of the feasibility report can be described as coming from four broad categories:

- Desk Studies
- Field Studies
- Analyses
- Reports

In general, the process begins with the desk studies where available information is assembled. Field studies are planned based on what is missing or out of date from the existing information base. Analysis proceeds after information is in place and the entire process is presented in the report.

Many if not most of the subjects described below have elements of entire process, yet they are classified below in only one or two of the categories based on where the majority of the effort is focused. Hydrology for example has elements of desk and field studies in that it assembles existing records and collects any additional information required, however it is classified as analysis since the end product is the result of an analysis and processing the information to provide a flow record for the project sites.

The majority of desk studies and field investigations were completed prior to completion of the formulation report.

1.4.3 Desk Studies

Power System Study - provides background on the existing supply and transmission systems. Information was provided by Nampower in Namibia and Empresa Nacional de Electricidade (ENE) in Angola describing the organisation of the power suppliers, generation facilities, and condition and capacity of existing transmission systems.

Power Market Survey - analyses present consumption and models future electricity demand. Characteristics of the market are assembled, including past and present electricity consumption by consumer categories. Based on the historic trends identified, national development plans and energy needs of large development projects in mining and water supply, electricity demand projections are established. The survey results in multiple future power usage scenarios that are used in generation simulations and economic and financial analyses.

Geology - desk studies include surveys and summaries of existing studies in Angola and Namibia and a general description of geological history and the types of rock formations found in the project area. This information is background for the more site specific geology investigations described in the field investigation section below. As geology relates directly to many of the major capital costs in hydropower development (dam foundation, tunnels and underground powerhouse), significant resources have been used to define and characterise the geology to the extent possible.

Seismology - defines the probability and magnitude of major seismic events occurring in the project area. Major seismic events are those of importance in design, and seismic stations throughout the world record these events. This information was processed and used to determine statistical probabilities of earthquake events occurring in the project area and the expected bedrock seismic acceleration for use in design of project features.

Alternative Water Uses - considers social, political and industrial influences in order to simulate water use alternatives. Water use agreements between Angola and Namibia, population projections, plans and purpose for water resource projects and future industrial and agriculture development all contribute to determination of the future water use. The final result is a series of scenarios that are used in the generation simulation.

1.4.4 Field Studies

Mapping - is of special interest for dam and powerhouse and reservoir locations. Aerial mapping with some ground control areas was performed of these critical areas. Detailed mapping was performed for feasibility design of dam, powerhouse, tunnels and intake and outlet areas. Reservoir area mapping was used to determine storage volume and for

environmental studies, but at a larger scale. Roads and transmission line layout were performed using existing maps.

Geology - field studies can be categorised as either defining subsurface material properties for design and construction or for determining sources for construction materials. Major geological field investigations on this project included:

- Core hole drilling - defined rock characteristics in the area of dam, tunnels, and powerhouse. It also correlated and confirmed the results of geophysical surveys
- Test pits - allowed large scale observations and laboratory testing of soil samples not available from drill cores, mainly for potential material sources
- Geophysics-seismic refraction survey together with test pit and drill hole information defined extent and properties of subsurface features
- Local Geologic mapping described surface deposits and integrated information from desk studies, drilling, and geophysics. In addition it addressed tracing and assessment of rock intrusions, joints, weathering patterns, weak zones and other similar features.

1.4.5

Analysis

Hydrology - existing flow record plus the results of correlation between the Cunene and other similar water basins allowed determination of a reliable record of the historical flow patterns in the river prior to development. This information was used in the generation simulation model along with the reservoir storage and generation capacities of existing and planned projects along the river.

Sediment - information used to determine a likely range of sediment to be expected at the project sites included experience from Ruacana, and general information on the drainage basin.

Project Layout - is a very large category that incorporates multiple design disciplines and project features. This section goes hand in hand with the Simulation and Optimisation section described below.

The results of the previous information gathering process are utilised. The example of dam design illustrates how the base information is interconnected; mapping is used to find the dam axis with minimum material volume and calculate reservoir volume; hydrology yields flood flows, normal and maximum water level and spillway capacity; drillhole information, geological mapping and geophysical data defines dam foundation level and foundation treatment; test pit information influences the type of dam material used and; results of simulations and optimisations find the optimised dam height. The dam is analysed using loading cases with flood and seismic load cases derived from hydrology and seismic studies. The process is similar for other components, including the following major items:

- Dam
- Powerhouse,
- Tunnels
- Electrical Equipment
- Mechanical Equipment
- Access Roads
- Power Transmission

The final results are drawings of the alternative projects, layout, quantities and costs of the projects.

Simulations and Optimisations - describe a system analysis where the entire water resource is examined to determine optimal use of the resource combined with other sources of generation in the Namibian power system. Basic input included hydrological record of the river without development and information on the reservoirs located along the entire river basin and alternative generation within the power system. The criterion for the best scheme is the overall least cost of power to the entire Namibian power system from 1999 to 2020.

During the design process, several features including installed capacity, tunnel diameter, dam height, and reservoir drawdown were optimised using the criteria mentioned above. Sensitivity analyses were then performed to examine the influence of some of the assumptions. The analyses resulted in calculation of energy production for the system and cost of power production.

Transmission System - interrelates with the project layout and simulation process. The present and proposed additions to the transmission system provides the means by which the energy is transmitted to market. Existing power system information along with characteristics of new system alternatives was analysed in transmission system stability. Topographic information and environmental considerations were used in preparation of transmission line layout and costs.

Economic and financial analyses - two types of economic analysis of the projects are carried out. The first, the economic viability test, seeks to establish that the allocation of scarce resources for the projects can compete with other investments in Namibia. The other seeks to verify that the selected project is a least cost option of supplying energy to meet the projected electricity demand of Namibia. The financial analysis provides the pre-tax cash flow of the project as a first indication of the financial viability of the project. Resource efficient prices (shadow prices) are used in the economic analysis while market prices including a future tariff scenario are applied in the financial analysis.

Alternative Energy - information was assembled on alternative energy sources to the projects including thermal power, additional imports, solar and wind generation. The alternatives' energy costs were established in order to evaluate their possible future role in a system context based on system costs and various other criteria.

Environment - has been considered throughout the project. The project design has been co-ordinated with the team preparing the environmental assessment, leading to integration of environmental considerations into the project features and costs. Examples of this co-ordination are the environmental guidelines used in transmission line routing and the intake tower design to allow water to be drawn from multiple water levels to reduce temperature and dissolved oxygen problems.

1.4.6

Reports

For this feasibility study, two major phases are described above; Phase 1 (formulation) and Phase 2 (feasibility). The formulation phase was further broken down into inception and formulation reports as well as multiple progress reports and meetings. At each report and presentation of information at different phases of the process, the information

available at the time has been presented to the client, examined, commented on and further refined.

Three main reports were delivered during the process:

- Inception - define process, scope and basic procedures
- Formulation - compare alternatives and preliminary optimise projects
- Feasibility - in depth analysis of most promising projects, i.e. Epupa and Baynes

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