SECTION 1 : INTRODUCTION

1.1 BACKGROUND

In view of the adverse electricity supply situation in the Kavango and Caprivi Regions in north-eastern Namibia, it has become necessary to investigate various possibilities to improve the power supply to these Regions. One such possibility would be to construct a hydro power plant in the Okavango River in an area where sufficient head is available to justify the construction of such a plant.

As far back as 1969, the Department of Water Affairs of the then South West African Administration, appointed consultants to carry out a preliminary study on the potential of constructing a hydro power plant on the Okavango River and to investigate and report on the technical and economic feasibility of constructing such a plant. Certain reaches in the Okavango River were to be explored at the time, including a reach near Nkurenkuru, which is located some 30km downstream from where the Okavango River first becomes the international boundary. This site was not favoured as it would have involved international negotiations with Portugal (Angola) and the flow in that section of the river is rather variable and storage regulation would have been essential.

Figure 1-1 : Location of Project Area

Downstream of the confluence of the Cuito River, storage regulation would not have been a requisite. However, international negotiations would still have been a requirement in the section of the river between the confluence with the Cuito River and where the Okavango River crosses into the Caprivi Strip. The scope of the 1969 study was therefore limited to the river reach where it flows through the Caprivi Strip.

Since 1990 the Caprivi Region, and in particular the capital, Katima Mulilo, has been supplied with electricity from Zambia via a 66kV line from Livingstone Power Station at the Victoria Falls on the Zambezi River. The electricity demand of the town has recently outstripped the supply capacity of the line, necessitating the consideration of a 132 kV, or preferably a 220 kV line from the Victoria Falls power station to Katima Mulilo. An alternative to this would be to review the old 1969 proposal mentioned above. A very preliminary desk study was carried out which confirmed that this proposal had enough merit to be reappraised.

The recent development of low cost high voltage DC transmission technology by ABB of Sweden has now made it economically feasible to consider the extension of the Namibian power grid from Rundu to Katima Mulilo via Popa Falls, a distance of almost 500km. The joint implementation of this technical solution and the incorporation of a hydro power scheme in the transmission system appear to be an attractive alternative to serve the communities along the Okavango river as well.

Where the Okavango River crosses the Caprivi Strip, it flows for approximately 50 km across Namibian territory before entering into Botswana. The Mean Annual Runoff (**MAR**) in the river at the Popa Falls is approximately 9585 Mm^3 and the natural drop in elevation over the Popa Falls is about 3.5 metres in the low flow season. This available head, plus the drop in elevation between the Namibian/Angolan border and the Falls of approximately 16 m, could be used for a run-of-the-river type of hydro power facility and would require the construction of a diversion system or weir, a headrace waterway, a power station, a return flowpath, switchyard and transmission lines. Such a station was estimated to be rated at between 20 and 30 MW. Further and more detailed studies were consequently considered necessary to establish both the techno/financial feasibility of the proposal, and to investigate its social and environmental values and impacts.

An important technical advantage of the project would be the possibility to connect the Caprivi Region to the Namibian national power grid. The availability of AC generation at the end of NamPower's present AC transmission system will increase the fault level and improve voltage stability and transfer capacity of the 33 kV, 66 kV and 132 kV systems. This would be an added advantage.

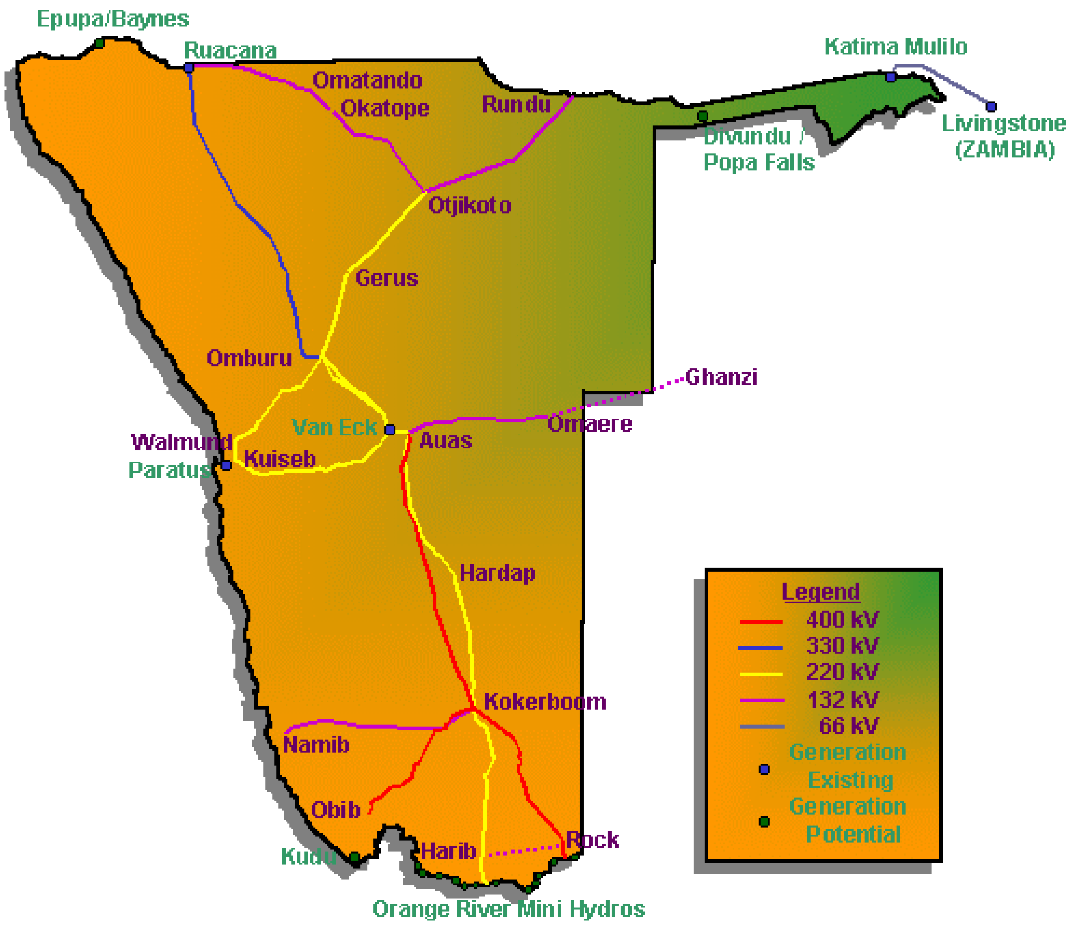

Figure 1-2 : Namibian Power Grid

NamPower consequently decided that the 1969 study should be revisited and that a new study should investigate the viability of the Popa Falls hydro power project by considering its technical, financial, socio and environmental values and impacts at a pre-feasibility level of detail. This study should not limit its investigations to the sites identified in the 1969 study, particularly in view of the fact that a weir on the lip of the Popa Falls would not be acceptable for environmental and other reasons. Consultants were consequently appointed to carry out a pre-feasibility study for the construction of a small run-of-the-river hydro power plant located on the Okavango River in the area of Divundu or further upstream. This study was to take into consideration the latest developments in turbine technology and to include a Preliminary

Environmental Assessment (**PEA**), the findings and results of which would be contained in a separate stand-alone report.

This report therefore describes the procedures followed to identify likely sites for a hydro power plant, discusses alternative turbine options and associated river structures, reports on the findings of the PEA and the identified potential impacts, how these impacts could be mitigated and finally on the economic viability of the selected options.

1.2 SCOPE OF SERVICES

1.2.1 TECHNICAL AND FINANCIAL STUDY

The scope of technical and financial services to be provided by the Consultant were comprehensive and were spelt out in detail in the Terms of Reference provided by NamPower. The scope of work is summarised below:

a) Review of earlier work done, with specific regard to the selection of project alternatives and the preliminary layouts of the more opportune possibilities. (All the options earlier identified, together with further possible alternatives that may be found in the Popa Falls area, should be considered as part of the study)

b) Obtain the best available topographical maps.

c) Preparation of a programme for, and performing of, appropriate site investigations, including preliminary topographical work and geotechnical investigations. This should be done to satisfy the requirements for the preliminary design of the project, economic comparisons of main weir options and associated structures, estimates of reservoir contents and areas that will be inundated, reservoir operation studies, socio and environmental impacts, and preliminary designs. The impact that a weir and future floodlines may have on the approaches of the main road and bridge across the Okavango River at Divundu and solutions thereto should specifically be addressed.

d) Carrying out of further hydrological studies with the emphasis on the verification and enhancement of the long-term stream flow records, the establishment of a flow duration curve for Mukwe, based on updated data from the Rundu, Mukwe and Muhembo gauging stations, the estimation of frequency flows and the probable maximum flood, as well as the determination of associated floodlines. The latter is of specific importance as an input to the design requirements in allowing a safe passage of floodwater past all shoreline developments. The need for environmental releases and the effect thereof on the availability for hydropower generation should be calculated and assessed. The most suitable stream diversion options during the construction phases should also be investigated.

e) Carrying out of baseline and preliminary sedimentological studies.

f) Undertaking of preliminary geological and geotechnical investigations to establish the engineering geological conditions of the project area, availability and qualities of construction materials, and the conditions for weir, waterways and powerhouse construction. This may require in-situ sampling and basic laboratory testing.

g) Investigation into the best possible options for weir types and spillway structures. The area around Popa Falls (Divundu) is already reasonably well developed and it may be important to allow only a marginal head rise between the full supply level of the weir and the maximum flood level, to protect existing concerns. The safe passage of floods should also be a crucial consideration. At the same time the structure should be simple without any complicated mechanical sluice or other control devices. An innovative design solution will be required.

h) Preliminary optimisation of the reservoir size, the weir type, the spillway, the intake structure, the lengths and dimensions of water conduits, the powerhouse and associated structures and sizes of the generating units and the operating head.

i) Carrying out the required electro/mechanical feasibility design for a low head indoor installation from about 5 to 20 kV depending on size and type of installed capacity. The output power to be transported through conductors, disconnectors and circuit-breaker(s) to step-up transformer(s) connected to outdoor distributing busbar(s) in the switchyard. Provision must be made for auxiliary plant transformer(s) and excitation transformer(s). Depending on the design capacity it may be necessary to reduce the mechanical and thermal stresses due to short-circuiting. An air-insulated reactor should then be considered in the branch(es). The plant control philosophy should be based on the Supervisory Control and Data Acquisition system (**SCADA**) principles and the control room should give operating staff a clear view of the power plant, indications of the circuit conditions with voltage and loadings of generator(s) and apparatus. (The equipment in the control room is foreseen to be a programmable logic controller cubicle with auxiliary cubicles hosting instruments, measurement converters, synchronising apparatus, multi function unit protective devices for turbine(s) and generator(s), temperature supervisory equipment, computer bays, station computer(s) etc.) Together with a public communication system for the plant, communication links for transmitting tele-control signals between the plant and a remote control centre will also be required.

j) Preparation of pre-feasibility level designs and drawings of the recommended project components. These are to include the required infrastructure and site establishment for the purposes of project construction and eventual scheme operation. Although a single site-specific recommendation would be a preferred choice, it will be accepted that a final refinement will need to be done as part of a more detailed investigation phase.

k) Preparation of a cost estimate for the project components and other items including professional services, land acquisition, and physical contingencies.

l) Investigation of the benefits of the scheme with regard to its value as a power generating unit and its viability for supplying electricity to the region.

m) Preparation of a preliminary implementation schedule covering in general terms all further phases of the works.

n) Analysing the economic and financial implications and prospects of the Popa Falls (Divundu) scheme, including sensitivity analyses of the results to changes of main parameters and assumptions.

o) The option of preparing a detailed terms of reference for the feasibility study of the project.

1.2.2 PRELIMINARY ENVIRONMENTAL ASSESSMENT

A PEA Study was to be undertaken in compliance with the Environmental Assessment (**EA**) Policy of Namibia. The primary purpose was to address Steps 1 to 4 of the official Namibian

Environmental Assessment Procedure (**NEAP**), to determine the significance of the social and environmental impact of the project and subsequent requirement for a full EA. A complete PEA assessment thus had to be made, so that the various alternatives within the project are adequately understood, and so that these could be compared with the no-project alternative.

a) **Submission of Project (Step 1)** : The Consultant was required, on behalf of the Client and as part of the scope of work for this PEA:

- to compile and submit a project proposal to the Directorate of Environmental Affairs (**DEA**).

- to identify the environmental implications of the proposed project across the national boundary with both Angola and Botswana and to consult with interested parties and ministries in these countries, as well as in Namibia.

(b) **Registration (Step 2)** : To arrange for the official registration of the project proposal with the DEA.

c) **Proposal Development (Step 3)** : To perform the following:

- notify interested and affected parties and plan in consultation with the Client, a one day public participation meeting in Windhoek, Maun, Popa Falls and Rundu,
- collect, evaluate and present baseline data at a level necessary for initial decision making on relevant social and environmental characteristics of the project area, including the reservoirs, the various project sites and downstream reaches;
- identify and assess the potential impacts on the culture, lifestyles and livelihoods of the people in the area of the scheme, graves and other archaeological sites, potential health hazards, land tenure and use, relocation of people, and benefits and disadvantages of the changes;
- appraise the functioning of the river ecosystem with emphasis on the project area;
- appraise the impact of the scheme on the lower river and swamp ecosystem;
- assess the effect of the scheme on the wilderness value of the region, the flora and fauna and on ecotourism;
- value the impact of the scheme on the broader land-use options in the region,

considering both primary and secondary effects;

- assess the impact of the scheme on water quality, including chemical and physical attributes.

On the basis of the above evaluation, and in close collaboration with the technical and financial feasibility, consider provisional management plan options together with possible mitigation measures for dealing with the major effects.

- Consider probable fatal flaw and worst-case scenarios.

d) **Classification of Proposal (Step 4)** : The Consultant was to determine the requirements or otherwise for a full environmental assessment together with the DEA. The Consultant may be retained to develop the terms of reference for such a study. This will, however, be the subject of a separate contract at the time and in the event of the full EA being required.

e) **Reporting (Step 5) :** On completion of the PEA the Consultant was required to compile a report to a standard acceptable to the DEA and major international financial funding institutions. The report was to provide documentation on the work done with the further purpose to obtain interim approval to proceed with a next phase of the study.

f) **Terms of Reference (Optional)** : The optional preparation of a Terms of Reference for a EA study to be carried out as part of the feasibility study phase of the project. This option was priced in the Consultant's Financial Proposal.

1.3 STUDY TEAM

1.3.1 THE LEAD CONSULTANT : WATER TRANSFER CONSULTANTS

WTC - Water Transfer Consultants was established in 1996 as a partnership practice constituted as a joint venture between three Namibian consulting engineering firms, **Bicon Namibia** (Pty) Ltd, **Lund Consulting Engineers** (**LCE**) and Parkman Namibia (Pty) Ltd. Parkman Namibia have since closed their offices in Namibia and have left the country. Bicon Namibia and Lund Consulting Engineers have decided to continue providing services in the field of large water engineering projects under the banner of **WTC**.

WTC was the lead consultant in the project team and was supported by specialist sub-consultants and specialists. The specialist sub-consultants were **Fichtner GmbH & Co KG** of Stuttgart in Germany, who provided services for the hydro power component of the study, and **Eco.Plan** in Windhoek, who carried out the Preliminary Environmental Assessment Study (**PEA**).

WTC was responsible for the preliminary design of the alternative river structures including spillway gates and sediment transport and bypass installations in association with specialist consultants.

1.3.2 SUB-CONSULTANTS

Fichtner GMBH & Co KG is a well known German Consulting Engineering company with offices in 27 countries with about 1200 employees all over the world, of which 850 are engineers, scientists, economists and information scientists who on average have more than 15 years professional experience. Fichtner has been responsible for the design of 32 hydro power plants worldwide.

Fichtner was responsible for the preliminary design of alternative hydro power plants and generating set configurations, determination of operating heads and active storage volume requirements. They were also responsible for the financial and economic analysis.

Their Study Team was headed by Mr B. Somdalen who has over 30 years professional experience in the water technology and hydro power sector.

Eco.Plan (Pty) Ltd is a Namibian registered environmental consultancy that is a subsidiary of WSP Walmsley in South Africa. The WSP Group is an international company based in the United Kingdom. **Eco.Plan** is therefore able to draw on a large body of experience where required.

Eco.Plan's responsibility was to carry out the PEA and assemble a team of environmental experts in the fields of fauna and flora, archaeology, sediment transport and aquatic ecology, covering the significant environmental issues that were anticipated on the project. **Eco.Plan** was also responsible for arranging and facilitating public participation meetings in Windhoek, Maun (Botswana), Divundu and Rundu.

In view of the importance of potential environmental impacts, co-basin partners with a knowledge of the Okavango system, were included in the team. Obstruction to the flow of sediment in the river and its impact on the Delta was a key issue that needed to be addressed.

1.3.3 PROJECT TEAM

In addition to the sub-consultants, specialists were appointed to undertake various components of the work. The study team members, their affiliations and their areas of expertise are listed below.

a) <u>Technical Team</u>

- T.P.M. Young : Independent Specialist : Project Manager
- K. Lund : WTC : Dam Engineer
- F. Jeske : WTC : Electrical Engineer
- R. Stoldt : WTC : Civil Engineer
- F. Kuchling : WTC : Civil Engineer
- C. Hundsdörfer : WTC : Draughtsperson
- R. Kloppers : WTC : Draughtsperson
- B. Somdalen : Fichtner GmbH : Hydro Power Specialist
- Dr. K. Peissner : Fichtner GmbH : Hydraulics Engineer
- K. Richardt : Fichtner GmbH : Turbine Specialist
- H-J. Zahn : Fichtner GmbH : Electrical Engineer
- Dr. P. Pintz : Fichtner GmbH : Senior Economist
- Dr. S. Palt : Fichtner GmbH : Hydro Power Engineer
- Prof. A. Rooseboom : Sigma Beta : Sediment Transport
- W. van Wyk : BKS : Dam Engineer
- Dr. J. Lourens : BKS : Geotechnical Specialist
- C. Langhout : BKS : Hydrologist
- P. Townshend : Flowgate Projects : Spillway gates

b) <u>Socio-Environmental Team</u>

- B. Walmsley : Eco.Plan : PEA Project Advisor
- C. Christian : Eco.Plan : Environmental Scientist
- M. Orford : Eco.Plan : PEA Assistant
- K. Mvula : Eco.Plan : PEA Assistant
- Chris Hines : Independent Specialist : Flora and Birds
- Dr. John Kinahan : Independent Specialist : Archaeologist

- Mike Griffin : Independent Specialist : Fauna
- David Parry : Independent Specialist : Public Cons. -Botswana
- Shirley Bethune : Independent Specialist : Aquatic Ecologist
- Prof. Terrence McCarthy : Independent Specialist : Sediment Transport

1.4 METHODOLOGY

1.4.1 OVERALL APPROACH

A skeleton outline of the approach followed in the preparation of the pre-feasibility study, is given below:

- Field visit which took place from 21st to 24th January 2003. The purpose of the field trip was to visit previously identified dam sites and potential new weir sites. Geological conditions were assessed and construction material sampled;

- Revision of hydrological analyses to verify and enhance long-term stream flow records. Frequency and duration of low flow events were determined and a flood frequency analysis carried out;

- Sedimentological studies were carried out to quantify sediment transport and to identify methods of ensuring the continued movement of sediment down the river;

- A Preliminary Environmental Assessment was undertaken to determine the significance of the social and environmental impacts of the project. The following overall approach was adopted:

    - Step 1 in terms of the EA Policy was to submit a project proposal to the DEA and to notify the respective ministries in Angola and Botswana;

    - Step 2 was to register the project with the DEA;

    - Step 3 was to carry out the PEA in accordance with the requirements of the EA Policy of Namibia;

- Selection and analysis of alternative weir sites;

- Critical review of alternative weir types and design consideration;

- Investigate alternative spillway options and the incorporation of fish ladders/bypasses;

- Carry out a detailed analysis of hydro power plant and turbine alternatives including the option of utilising the fall across the Popa Falls;
- Development of power scheme concepts;
- Energy production optimisation;
- Mitigation and management of environmental impacts;
- Preparation of construction cost estimates;
- Carry out a financial and economic analysis, and
- Preparation of an implementation programme.

1.4.2 SITE VISITS AND INVESTIGATIONS

First Visit

A number of site visits took place before and during the study. The first visit, which was the site inspection arranged by NamPower on 17th October 2002 for the benefit of the tendering parties, gave the Consultants the opportunity to become familiar with the project area. This visit covered the area from just downstream of the Popa Falls to approximately 13 km upstream of the falls to the Frans Dimbare Youth Centre. A number of potential sites, including those identified during the 1969 study, were visited.

A considerable amount of valuable information was obtained from discussions with NamPower officials, both during the field visit and during the subsequent briefing meeting.

Second Visit

The second field visit took place a week after the commencement of the study. This visit, which included the Consultant's sub-consultants and specialists, gave those that had not seen the site before the opportunity to familiarise themselves with the project area and the conditions on site. This visit took place from 21st January to 24th January 2003.

The main purpose of this visit was to identify alternative dam sites and to carry out a geotechnical/geological reconnaissance of the area. As part of this activity samples were collected from various potential sources of construction material, including embankment fill material, embankment clay core material and river sand. Sites for opening quarries for concrete and filter aggregate were also identified.

Detailed inspections were held at Sites 2, 3 and 4. Site 2 coincides approximately with Site C, identified in the 1969 study. Site 3 is located just upstream of the Divundu bridge and Site 4 approximately 4,5 km upstream of the bridge.

Third Site Visit

The purpose of this and the following two visits was to attend a public participation meeting held at the Frans Dimbare Youth Centre and to participate in sediment sampling activities. However, these visits did afford the Consultant the opportunity to re-visit weir sites for the purpose of firming up on previously gathered information and to better understand the mode of sediment transport.

Fourth & Fifth Site Visit

The purpose of both these site visits was to undertake sediment sampling in the Okavango River at Divundu, a point in the river approximately 300 m downstream of the Divundu bridge. The results of these sediment sampling field trips are reported on in **Section 5.4** of this report.

1.4.3 MAPPING

NamPower had arranged for aerial mapping to be undertaken prior to the commencement of the study. A subsidiary of Eskom, which carries out airborne laser surveys, was appointed through Wouter Viljoen & Associates, a Windhoek based aerial, engineering, topographical and industrial surveys company, to undertake an airborne laser survey of the reach of the Okavango River between a point where the river crosses into the Caprivi Strip, to a point just below the Popa Falls. Mapping produced from this survey contained orthophoto colour images and contours at half metre intervals. Although the preparation of the maps was very time consuming due to the large amount of data to be processed, they proved to be invaluable to both the technical and environmental teams on account of the large amount of information that is shown on the maps.

Maps at scales of 1:2000, 1:4000 and 1:10000 were produced by the Consultant, which were used to select potential weir sites, to identify areas of flooding during the seasonal peak floods, and to identify the number of households, businesses, institutions, churches and service stations that would need to be relocated if they were to be flooded as a result of the construction of a weir across the river. The maps also proved to be of value for the selection of suitable routes for relocating sections of district road D3402, telephone lines and the NamPower 33kV powerline where these would fall below the high flood levels.

1.5 PROJECT AREA

1.5.1 THE OKAVANGO RIVER BASIN

The headwaters of the Okavango River are contained in two main tributaries, the Cubango River, as the Okavango River is known in Angola, and the Cuito River in the Angolan Highlands as shown in **Figure 1-3**[9)] on the following page. The Cubango River has a reported catchment area of approximately 115 000 km² with an annual rainfall of 605 to 1 125 mm, averaging 983 mm, while the Cuito River has a catchment area of approximately 73 000 km² and an annual rainfall ranging from 476 to 1100 mm, averaging 876 mm[14)]. The combined catchment area at the Popa Falls site is approximately 203 000 km². Both rivers originate in the same area as the Cunene River, which explains the similar hydrological regime; the annual flows were used in earlier studies undertaken in 1989[7)] to determine the hydro power potential of the Cunene River. Section 3 determines the method of analysis for deriving flow duration relationships and flood peaks.

The combination of the two mentioned tributaries produces a Mean Annual Runoff (**MAR**) of approximately 9 585 Mm³/a in the Okavango River, which is almost ten times more than the internal ephemeral rivers of Namibia together, and which also equals the combined runoff of the Orange River and the Cunene River.

The Okavango River flows for a distance of 415 km along the border between Angola and Namibia in the north-east[9)]. In this reach of the river the average gradient is low and the water flows in a two to six kilometre wide valley between 30 m and 70 m below the surrounding shrub savannah and woodland, which is one of the most densely populated area in Namibia[3)]. Where the Caprivi Strip starts, the river turns southwards into Botswana and towards the Okavango Delta and swamps.

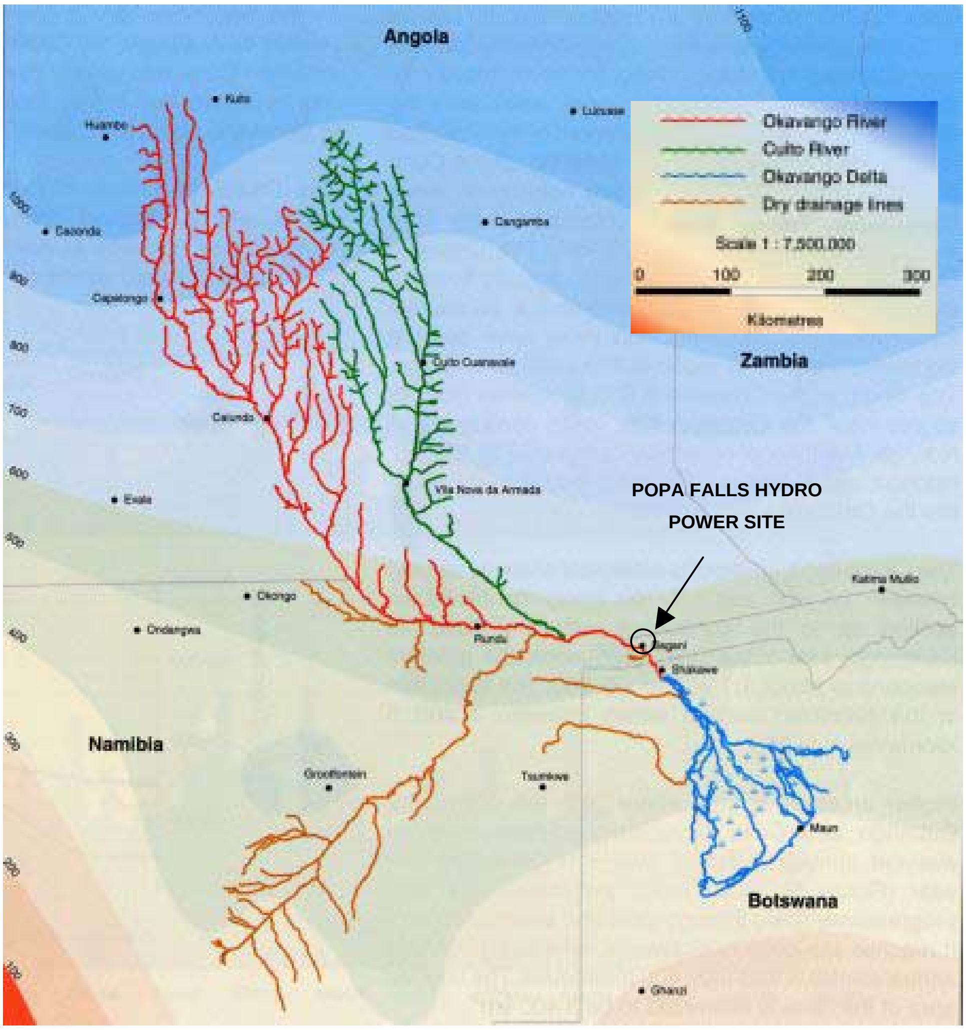

Figure 1-3 : The Okavango River Basin

The Okavango River enters Botswana at the village of Mohembo, where the "panhandle" starts with its 15 km wide floodplain. The river then splits to form the permanent delta and the seasonal swamp. The Okavango Delta has at its seasonal maximum, a total surface area of approximately 14 000 km² of which 6 000 km² are perennial channels and swamps and 8 000 km² are seasonal swamps[11)]. The Okavango Delta is situated in the north-western part of Botswana on the fringes of the semi-arid Kalahari Basin in the central southern African plateau. The delta and swamps owe their origin to the south-westerly extension of the East African Rift system which has produced a large rift valley transecting the course of the Okavango River[12)]. The swamp lies between the Gumare Fault in the north-west, and the Thamalakane fault and the Kunyere fault in the south-east.

The evaporation and the evapotranspiration in the swamps is very high, constituting more than 95% of the water balance of the system, and, on average, only 2% of the total inflow into the swamps is measured as occasional outflow into the Boteti River which flows south-eastwards towards Lake Xau[14)].

1.5.2 THE PROJECT AREA

The project area extends from approximately one kilometre downstream of the Popa Falls to the Andara Mission Station located some 19 km upstream of Popa Falls. The width of the project area, measured from the centreline of the main stream, varies between 0,5 km and 1,0 km depending on the impoundment width of the weir lake and the extent of the area affected by the relocation of households, businesses, institutions, churches and service stations. The area includes all identified weir sites as well as the Frans Dimbare Youth Centre and the Andara Mission Station. A partial view is given of the Project Area in **Figure 1-4**. For a more complete map of the project area covering the area from just downstream of the Popa Falls to the Angolan border, refer to **Figure B1-1** of **Appendix B**.

Figure 1-4 : The Project Area

Figure B2-1 of **Appendix B** shows the extent of the project area from where the Okavango River crosses into the Caprivi Strip to a short distance below the Popa falls.

1.5.3 PREVIOUS STUDIES

The study that was undertaken by Hydroconsults in 1969 identified three alternative dam sites of which the preferred site was located on the lip of the Popa Falls (Site A), and two further sites located approximately 2 km (Site B) and 4 km (Site C) upstream of the Falls. The study, however, limited its analyses to Sites A and B as these were considered to be the sites that would provide hydro power potential at acceptable costs. Site C was located too far upstream of the falls which would require a very long headrace canal. Each of the two sites (A and B) were analysed for dam heights (FSL) of 1006,0m, 1008,0m, 1009,5m, 1014,5m and 1018,0 metres above mean sea level (**m.a.m.s.l.**).

The hydrological analyses carried out at the time using the flow records of the Mukwe gauging station which were synthetically extended to 21 years. The **MAR** was assessed at roughly 11 500 Mm³/a. A frequency analysis of all monthly flows showed that at the 95% level, a flow of approximately 420 Mm³/m which equates to 160 m³/s, could be relied on.

It was proposed that the dam would consist of a concrete spillway section with free overflow for dam heights up to elevation 1009,5 m.a.m.s.l. and with spillway gates for the higher levels. The spillway section, which varied in length between 700 m and 900 m, would be flanked by earth embankments.

The salient points resulting from the hydro power analysis carried out for Site A are given in **Table 2-1**. This table shows that the most economical option would have been a dam with a full supply level (**FSL**) elevation of 1009,5 m.a.m.s.l., which would have an average power output of 123 GWh/a and an energy cost of R 0,515 c/kWh (1969 values).

Table 2-1 : Salient Parameters of the Preferred Option (Site A)
for Various Full Supply Options

Alternative	Units	1	2	3	4	5
Full Supply Level (FSL)	m.a.m.s.l.	1006.0	1008.0	1009.5	1014.5	1018
Gross Storage	Mm³	16	36	57	170	290
Usable Storage	Mm³	10	19	30	85	150
Design Flow	m³/s	162	164	166	177	189
Gross Head	m	7.5	9.5	11.0	16.0	19.5
Effective Head	m	6.9	8.7	10.1	14.7	17.9
Average Power	MW	9.3	12.0	14.0	21.7	28.2
Installed Capacity	MW	18.6	24.0	28.0	43.4	56.4
Firm Energy	GWh/a	81	105	123	190	250
Capital Costs (1969)	Mil Rand	4.73	5.83	6.67	10.50	13.0
Energy Cost (1969)	c/kWh	0.54	0.52	0.515	0.535	0.55

The above table shows that the most economical option would be a dam with a FSL of 1009.5 m.a.m.s.l, which would have an average power output of 123Wh/a and an energy cost of 0.515C/kWh (1969 values).

1.6 ENVIRONMENTAL OVERVIEW

1.6.1 LAND OWNERSHIP AND TENURE

The Kavango Region (48,483km^2) is headed by a Regional Governor who chairs a Regional Council. The Region is divided into 7 political constituencies, each represented by a Regional Councillor. The proposed hydro power project falls within the Mukwe constituency. Within this constituency there are various traditional leadership systems. The various leaders play an important role in the allocation of land and grazing rights, and settling disputes. Much of the land is state-owned, being either communal or a protected area, but some is privately owned. Since authority structures and land tenure systems are complex, issues such as resettlement and compensation may be complicated.

1.6.2 CLIMATE

The Popa Falls area has a warm tropical climate with summer rainfall. The rainfall averages 550 to 600 mm/year but is highly variable and unreliable. Evaporation rates are high - 1,820 to 1,960 mm/year. Climatic variation tends to be cyclical, with an 18 year oscillation in rainfall. This must be considered in the assessment of environmental impacts and project design. Measurements and predictions based on short term studies must be interpreted with caution.

1.6.3 GEOLOGY, TOPOGRAPHY AND SOILS

The catchment of the Okavango River is composed mainly of deep Kalahari sands, extending far into Angola. Soils along the river in Namibia are classified as Ferralic Arenosols - derived from these sands. The most fertile soils tend to be close to the river, where the increased percentage of clay particles improves water retention and fertility. A detailed description of the geology of the project area is provided in **Section 4.**

The topography of the Popa Falls area is relatively flat and comprises low, ancient dunes that have been stabilised by vegetation. Extensive floodplains are common on the Okavango and Cuito Rivers, but the section from the Angolan border to Popa Falls is an exception. Here the

Okavango River has incised into the dunes and as a result, ridges of quartzitic rock have been exposed causing many rapids and pools including Popa Falls itself. A large number of islands occur in this reach.

1.6.4 HYDROLOGY

A detailed description of the hydrology of the river is provided in **Section 3.**

1.6.5 WATER QUALITY

Due to the fact that the catchment of the Okavango River in Angola has been altered very little by human activities and due to the geology of the catchment (largely Kalahari sands), the waters of the Okavango River are good quality, clear, well-mixed, well-oxygenated, typically soft with very low conductivity and low total dissolved salts. Chemical concentrations and nutrient concentrations are low. In Namibia, much of the riverine forest has been destroyed for slash and burn agriculture or commercial irrigation projects, leading to some increase in turbidity in recent years. Although there are currently no major human-induced impacts on the river, it is anticipated that with the cessation of hostilities in Angola, agricultural and water resources development may increase in the Cubango and Cuito catchments in the future.

1.6.6 FAUNA

The area is rich in mammals, reptiles and amphibians: 38 species of frogs, 75 reptiles and 124 mammals, are known or expected to occur within the project area. Of these fauna, 10 species of frogs, 8 reptiles and 18 mammals are dependent on the current array of wetland habitats on the Okavango River. These species have no other local alternatives. Over 90% of these species are of national conservation concern. This figure reflects the high vulnerability of wetlands, as well as the rarity of this habitat in Namibia.

The rock outcrops, both terrestrial and aquatic, are especially important due to their scarcity in this otherwise sandy region. Since rupicolous substrates in general, are habitats of high endemism in Namibia, the rocky outcrops in the study area must be regarded as having a high endemic taxa due to their isolated nature.

The area from Mukwe to the Mahango Game Park supports more species of birds than any similar sized area in Namibia - over 450 species. It is recognised as one of Namibia's most important biodiversity hotspots for birds.

Fish species in the Okavango River are diverse and abundant as the river provides a wide habitat diversity. Some 71 species have been recorded in the Namibian reach of the river. The seasonal flood cycle has a major influence on fish breeding and is known to directly stimulate spawning. Of particular importance to this study, are the rocky habitat specialists living from Mukwe to Popa Falls - mainly small clarids or catfish. Ten such species occur in this area, including two Red Data species that are considered rare, while a third species is considered vulnerable because of its habitat specialisation and the scarcity of such habitat.

Several of the Okavango fish species are known to migrate in response to seasonal flood cycles in order to breed, or feed. The weir would obstruct these migrations. An effective fish by-pass must therefore be incorporated and designed with the assistance of specialists with expert knowledge of the fish in this river.

The aquatic invertebrates of the Okavango River and their ecological requirements are not well known but at least forty are thought to be endemic to the river.

1.6.7 FLORA

While many of the species in the Mukwe – Mohembo area are common to a wide area of southern Africa, the particular plant communities associated with the riverine habitats are unique within a Namibian context. The islands in the Mukwe to Divundu area are particularly important for conservation and a number of Red Data species occur here.

1.6.8 ARCHAEOLOGY

Kinahan (1986) found that archaeological sites were clustered almost entirely within 500m of the river – a pattern that is still reflected in settlement patterns today. There is also a concentration of sites upstream of Mahango Game Reserve, with very low frequencies south of that point.

The area around Popa Falls has not been extensively surveyed and it is possible that archaeological sites may be discovered there. The right bank within the study area has been disturbed by settlement to a degree that makes further significant finds unlikely (Kinahan, 2003). The left bank has not been surveyed due to its military history and the presence of landmines to this day. The islands also need to be surveyed in the next phase to check for the presence of burial sites.

There is a Portugese Fort at Mucusso, east of the river, almost opposite Andara. Its elevation in relation to the river is not yet known, but it is unlikely to be affected by the weir impoundments.

1.6.9 SOCIO-ECONOMIC STRUCTURE

There are two main ethnic groups in the study area: the majority language group is the Kavango – Mbukushu people, and the minority is formed by the San – Khwedam group. About half of the 201,000 people in the Kavango Region are rural dwellers. Most live along the Okavango River where population densities are 25 – 50 people/km^2. Most rural people live in traditional wood and mud houses. Over 50% of households have no cash or wage incomes. The dependency ratio is high (52%) due to a high proportion of young people. The local people are mostly occupied with subsistence activities, so their livelihood is very dependent on natural resources.

There is a high incidence of disease in the Kavango Region – the biggest killers being AIDS, malaria, gastroenteritis, acute respiratory infections and tuberculosis. These five diseases account for nearly half of deaths.

The economy of the Mukwe - Bagani area is based mainly on subsistence agriculture, and other natural resources. The cash component for many households is supplemented by government pensions. Cattle farming is the most important agricultural activity in the Mukwe constituency, where the floodplains and reedbeds provide grazing. Cattle have a high social value, while goats, poultry and a few pigs are valued for food. Fishing plays an important role in the lifestyle and diet of the local people in Namibia and Botswana. Along the Namibian section of the Okavango River, some 35 – 55% of households catch fish. Some is sold or bartered locally, but most is consumed on a subsistence basis. Reeds, timber and thatching grass are important as building materials, and for household items. Wood is extremely important for building, heating and cooking. Roots, palm leaves, and grasses are also used for household items and souvenirs. Wild fruits, berries and mushrooms are collected for food even medicinal requirements.

Despite the potential for electrification in rural areas, electricity will remain unaffordable for most people in the vicinity of Popa Falls.

Alternative incomes such as employment through tourism are potentially important in sustaining livelihoods in this area. Tourism is Namibia’s third largest industry and second largest earner of foreign exchange. In 1998, tourism provided jobs equating to 15% of all private sector employment. Namibia's tourism sector is based on its unique natural environments, large areas of unspoiled wilderness, the diversity of interesting wildlife, and majestic scenery. Since the civil war in Angola ended, tourism in the Kavango and Caprivi regions has increased markedly and has great potential, including community-based tourist ventures. There are currently six tourism establishments between Divundu and Mohembo, and two campsites.

The attractiveness of the area lies in a combination of wildlife, rivers, wetland systems and riverine forests, as well as the cultural heritage. Birding is also an increasing tourist activity. The Mahango-Popa Falls–Andara area is attractive in its own right, and well situated on an important international tourist route (Trans Caprivi Highway). The area near Andara is still largely unspoiled, particularly the islands, and has considerable potential.

There are four protected areas located near Popa Falls, which are proposed to be merged to form the Bwabwata National Park. There will be scope for communities and joint ventures to establish community based tourism and hunting facilities in this Park.

Some rainfed commercial agriculture exists but is limited by poor soils, unreliable rainfall, and large distances to markets. Nevertheless, the Ministry of Agriculture plans to develop a number of irrigation projects along the river between Rundu and Divundu – ultimately totalling an area of 8,563 ha. Seven projects (770 ha) are already in operation. When fully developed, the combined water demand will be 128,445,000 m^3/annum (1,34% of the average discharge to Botswana every year). The nearest of these irrigation projects to the proposed hydro power scheme is the Mukwe Irrigation Project, on the left side of the river.

With a few exceptions, the Kavango and Caprivi Regions are almost devoid of manufacturing. A few exceptions include woodwork/furniture products, maize mills and bakeries. Carving and home crafts have a potentially good market with tourism. The development of industry, however, faces a number of obstacles. The area is far from markets and sources of raw materials. Agricultural potential is limited, but forestry products could be worked in this area. Tourism probably offers the greatest potential for sustainable development in this area. The availability of power locally from the Popa Falls project could be of benefit to current and future tourism, industrial and agricultural development in this region of Namibia.

1.7 REPORT STRUCTURE

This report is structured in the following way:

Sections 1 to 4 of the report provide an overview of the baseline conditions present in the project area. Section 1 provides an introduction and a brief description of the Okavango River catchment and the baseline environmental conditions. Sections 2 to 4 provide more detail on the key environmental aspects most relevant to this project, namely: hydrology, engineering geology and sediment transport.

The proposed project is described in Sections 5-10. Section 5 provides a brief overview, while the various project components, i.e. weir sites, hydropower units, sediment removal, weir gates and the proposed transmission system, are described in Sections 6-10 respectively. At the end of each of these sections, the alternatives are evaluated in terms of their technical/financial, social and environmental implications. An integrated summary of the potential impacts and mitigation measures is provided in Section 11.

Section 12 includes recommendations for further work arising out of this pre-feasibility study, while Sections 13 and 14 provide cost estimates and financial analyses based on the preferred configuration. Section 15 presents a possible implementation schedule whist the conclusions of this pre-feasibility study are presented in Section 16.