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PRE-FEASIBILITY STUDY FOR THE POPA FALLS HYDRO POWER PROJECT

PRELIMINARY ENVIRONMENTAL ASSESSMENT

VOLUME 1: FINAL REPORT

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1 INTRODUCTION

1.1 Background

NamPower (Pty) Ltd is currently investigating the provision of electrical power to meet growing demand in the future. Various options around Namibia have been investigated in the past, including hydro power, wind power, and gas power (refer section 3, below).

A brief study of hydro power potential on the Okavango River was undertaken by the Department of Water Affairs In 1969. A Desk Top Study was also undertaken by the Ministry of Mines and Energy in November, 2000. These studies suggested that a 20 – 30 MW hydro power station was possible at Popa Falls.

In December 2002 NamPower appointed Water Transfer Consultants, through a tender process, to undertake a Pre-feasibility Study for a proposed hydro power project at Popa Falls on the Okavango River near Divundu. Eco.plan (Pty) Ltd was appointed by Water Transfer Consultants to undertake a Preliminary Environmental Assessment of the proposed hydro power project.

The purpose of the Preliminary Environmental Assessment (PEA) was to ensure that environmental considerations were taken into account from the earliest planning stages, along with technical and economic considerations. While WTC was responsible for assessing the technical and economic feasibility of the project, Eco.plan was responsible for undertaking an independent assessment of the environmental feasibility of the project. The process of developing the PEA involved interaction with WTC so that the technical team could respond to environmental concerns in the early stages of project design. The starting point for the Preliminary Environmental Assessment (PEA) was therefore prior to the development of the design or the selection of potential sites.

Should the Pre-feasibility study be favourable - technically, economically and environmentally, then NamPower may proceed to commission the next planning stage – namely a full Feasibility Study and a full Environmental Impact Assessment.

1.2 Scope of Services

The Terms of Reference for the Pre-feasibility Study and Preliminary Environmental Assessment (PEA) were included in the invitation to tender (October 2002). The relevant sections of the TOR (both Technical & Environmental) can be found in **Appendix A** of this report.

The Southern African Institute for Environmental Assessment (SAIEA) provided input to the TOR for the environmental component of the study (refer section 1.3.3).

The Terms of Reference for the Technical and Environmental Studies that comprise the Pre-feasibility Study were endorsed by the Okavango Commission (OKACOM) Popa Falls Steering Committee (OPFSC). OKACOM is a joint commission on water for the Okavango River Basin, and comprises representatives of Angola, Namibia and Botswana.

The Scope of Work that was required from the Environmental Consultant is summarised as follows.

- Public consultation in Namibia and Botswana, (a co-basin consultant was required to assist in Botswana)
- Impacts on functioning of the river ecosystem,
- Consideration of social impacts,
- Wilderness impacts,
- Effects on riparian belt and habitat fragmentation,
- Impacts on land-use issues in the region,
- Compliance with the Environmental Assessment Policy of Namibia,
- Consideration of possible fatal flaws and worst-case scenarios.

Although the study was to be primarily a desktop study, some field investigations were also required. Initial specialist studies were included regarding flora, fauna, aquatic ecology, socio-economic issues, archaeological and grave sites, and implications for land use.

At an early stage in the PEA, it became apparent that the available information on sediment movement in the Okavango River downstream in Botswana would need to be augmented with site-specific data. It was also necessary that this data should be gathered during the high-flow season around March to April. Therefore, the study was extended to include a preliminary investigation of sediment transport at Divundu, which included: -

- Measurement of bedload and "suspended" sediment transport by direct means, and
- Imaging and calculation of bedload transport by means of side-scan sonar and high-resolution bathymetry.

The findings of the sediment study are incorporated in section 6.9.

This report also indicates the need for further investigations that would be required in a full EIA.

1.3 Study Resources

1.3.1 <u>The Environmental Consultancy</u>

Eco.plan (Pty) Ltd is a firm of environmental consultants based in Windhoek, Namibia. It is fully owned by WSP Walmsley, one of the largest independent environmental consultancies in southern Africa. Eco.plan's experience in environmental management covers a wide range of civil engineering projects, mining, and land-use planning in sensitive environments.

1.3.2 <u>Personnel Allocated to the Study</u>

The key personnel in Eco.plan's team were: -

Bryony Walmsley Pr Sci Nat (MA, MSc): Managing Director of WSP Walmsley and of Eco.plan, and responsible for directing, advising, and internal review. Ms Walmsley has over 23 years experience in environmental science in 10 countries – mainly in southern Africa. She founded Walmsley Environmental Consultants in 1990, which became WSP Walmsley in 2001.

Colin Christian Pr Sci Nat (MA in Environmental Science): Manager / Senior Environmental Scientist for Eco.plan and Project Leader for the Preliminary Environmental Assessment. Mr Christian has 16 year's experience in environmental science, including 8 years in consulting in South Africa and Namibia. He spent 5 years as Environmental Scientist with a large engineering firm before taking the leadership of Eco.plan in 2001.

Melle Orford (Masters in Environment & Development): Junior Environmental Scientist and researcher. Ms Orford has experience in rangeland management, health impacts in relation to the Epupa Falls hydro power EA, and has a good knowledge of Namibian environments.

The key specialists who were appointed by Eco.plan as sub-consultants were: -

David Parry (MSc): Director of Ecosurv in Botswana. Mr Parry has 13 years' experience in the management of socio-economic and ecological projects. He was responsible for the public participation programme in Botswana, and fulfilled the role as "co-basin" consultant.

Dr. John Kinahan (PhD): Responsible for an archaeological survey and consideration of cultural issues. Dr Kinahan has vast experience in archaeological investigations in Namibia and other countries – including studies for many dam sites in Africa. He also has many years experience in ecological and cultural matters in Namibia and elsewhere.

Chris Hines (MSc): Botanist and Ecologist – Mr Hines has 16 years experience as an environmental researcher and natural resource planner. His experience includes 9 years experience in north-eastern Namibia. He is an authority on the birds of Namibia and the wider region. Mr Hines was responsible for a survey of flora and avifauna for this project.

Mike Griffin (BSc Hons in Zoology): Senior Conservation Scientist with the Ministry of Environment & Tourism, Namibia. Mr Griffin was responsible for a survey and literature review on fauna (mammals, reptiles & amphibians).

Shirley Bethune (BSc in Zoology & Botany, BSc Hons & MSc in Limnology): Ms Bethune has over 10 years' working experience as a limnologist and aquatic ecologist in Namibia – specifically in the Okavango River System, Caprivi wetlands, and Cunene Rivers. She served as a member of the OKACOM Steering Committee from 1994–2000, and was chairperson of the Wetlands Working Group of Namibia 1996 –2001.

Prof. Terence McCarthy (MSc, PhD): Professor of Geology at the University of the Witwatersrand, South Africa, and leader of a multi-disciplinary team that has researched the physical and ecological functioning of the Okavango Delta for 17 years. Prof. McCarthy has published about 50 research articles on aspects of the Delta. On the Popa Falls hydro power project, he has been responsible for the study of sediment transport and a review of related ecological impacts downstream.

Sven Coles (BSc Hons in Geology): Head of the Marine Geoscience Unit: Council for Geoscience, Cape Town. His team was responsible for a study of sediment transport using sonar side-scan sonar and bathymetry.

1.3.3 <u>External Review</u>

NamPower appointed **Dr Peter Tarr** of the South African Institute for Environmental Assessment (SAIEA) to undertake an independent review of the process of the PEA, and the PEA report. This review is ongoing from the appointment of the consultants throughout the project. Dr Tarr makes use of appropriate specialists from around southern Africa to review the more specialised components of the study.

1.4 Approach to the Preliminary Environmental Assessment (PEA)

Although this is only a Preliminary study, it was caried out in compliance with the requirements of the Environmental Assessment Policy of Namibia. The Department of Environmental Affairs (DEA) within the Ministry of Environment and Tourism was notified at the outset and the proposed scope of work was made available to them. A meeting was also held with Ms C. Claassen to explain the project.

The following approaches were used in the identification of potential environmental impacts: -

- A public participation programme,
- Consultations with authorities,
- Specialist input,
- Literature review,
- Site investigations,
- Use of the RSA Department of Environment & Tourism (1992) Checklist of Environmental Characteristics, in identifying potential impacts,
- Professional experience and discussions with people knowledgeable in the affected region.

Having identified potential environmental impacts, possible mitigation measures were proposed to minimise key adverse impacts. This was an interactive process between Eco.plan and the technical team - Water Transfer Consultants. Thus, at various stages in the pre-feasibility study, environmental issues and information were provided to WTC. This information was fed into the technical design process. WTC endeavoured to address the mitigation of key environmental impacts at the earliest design stages.

Once the technical team had firmed up the technical alternatives, and eliminated those that were clearly not desirable for technical, economic or environmental reasons, then the preferred options for design and operation of the project were subjected to Environmental Assessment. For example, certain weir site alternatives were eliminated at an early stage, and the option of a diversion canal was found, at an early stage, to be uneconomic and undesirable for environmental reasons. The preferred weir site alternatives were then assessed in terms of their environmental impacts.

Each of the key impacts was subjected to an assessment according to specific criteria. These criteria are explained in section 7.1. They are widely adopted in EIAs internationally and are defined in the RSA DEAT Guideline Document (1998) for Implementation of the EIA Regulations in South Africa.

Since the project planning is only at the Pre-feasibility stage, certain components of the project have not yet been planned (e.g. the siting of the switchyard, realignment of roads, and sources of materials). This Preliminary Environmental Assessment therefore cannot make an exhaustive assessment of all the environmental impacts. Its primary purposes are: -

- To identify key environmental issues at the earliest planning stage so that mitigation measures can be incorporated into the design process,

- To identify potential “fatal flaws” – i.e. significant negative impacts that would have to be effectively mitigated before the project could be considered to be environmentally feasible,
- To provide enough information to enable NamPower, the Ministry of Environment & Tourism, and OKACOM, to make an informed decision on whether or not the project should proceed to the Feasibility Study and full Environmental Impact Assessment.
- This PEA is intended to highlight key issues of concern, and thus help to focus the full EIA in the event that NamPower decides to proceed to the next stage of project planning.

2 THE PROPOSED HYDRO POWER PROJECT

2.1 Location

The proposed hydro power project is situated on the Okavango River between Andara (south of the Angolan border) and Popa Falls (which is between Divundu and Bagani). The location is shown in **Figure 1**, while the potential sites for a weir are shown in **Figure 2**. **Figure 3** shows Popa Falls and the area immediately downstream. **Figure 4** is a large scale orthophoto map of the preferred weir sites and impoundment areas. Power transmission would be linked to Mukwe, and from there to Rundu, with a possible extension to Katima Mulilo at a later stage.

2.2 Motivation for the Project

2.2.1 Projected Demand

The current electricity demand in Namibia is approximately 350 MW. After Namibian independence, power demand grew from approximately 225 KW in 1992 to 350 kW in 2002 – representing a growth of over 55% in 10 years. Projected growth at 4% would take demand to approximately 520 kW in the next 10 years. If growth is projected at 6% this figure would be 625 kW in ten years time.

Major developments such as Skorpion Zinc Mine, and Ramatex Textile Factory have had a significant effect on the power demand.

2.2.2 Current & Future Supply Situation

At present Namibia obtains 249 MW from the hydro power plant at Ruacana, which is operated at capacity. The supply is seasonal as the flow in the Cunene River drops during the dry season in Angola. The repair of the Gove and Calueque Dams in Angola, which is expected to be commissioned shortly, will provide an opportunity for better regulation of the flow at Ruacana. Most of the balance of Namibia's supply is made up by imports from South Africa, with some imported from Zambia for Katima Mulilo. At present South Africa exports its surplus power to Namibia and other neighbouring states. However, it is projected that the demand for peak power in the SADC Region will outstrip supply by the year 2006/7. This could result in an electricity price hike for imported power. NamPower therefore has an interest in reducing dependence on imported power.

Various alternative sources of power have been investigated in Namibia, and these are dealt with in section 3 of this report. Popa Falls Hydro Power project is, however, considered to be one of the more economically viable options for Namibia at this stage. Popa Falls has the advantage of being based on a renewable resource, although the flow of the river is rather seasonal. Gas power from the proposed Kudu Gas plant, on the other hand, may be more dependable.

A further motivation for the Popa Falls Hydro Power Project is the regional supply situation – which is explained in the following section.

2.2.3 Popa Falls Supply Area

The Namibian national electricity supply grid currently extends as far north as Rundu. Katima Mulilo is supplied via a 66 kV line from Zambia, or from a 4 MW diesel generator station in Katima Mulilo as a backup.

Due to long transmission lines, the stability of supply to Rundu is sometimes problematic. A generation source in the Kavango Region would help to stabilise power supply and would therefore help to encourage development in the Region. It is therefore proposed to construct a powerline from Popa Falls, via Mukwe to Rundu. At a later stage, the network could be extended to Katima Mulilo if the power demand in the Caprivi Region justifies this expense. At present the cost of power to the consumer in Katima Mulilo is subsidised by the rest of Namibia as the existing supply to the town is more expensive than for the rest of the country.

In future, however, it may become economical to extend the national grid through the Caprivi to Zambia so that power can be traded with Zambia. For this reason, the line from Popa Falls could be constructed at 220 kV capacity, but would only be operated at 132kV for supply from Popa Falls.

Popa Falls Hydro Power Project is therefore intended primarily to supply the Kavango Region. However, surplus power could be made available to neighbouring parts of Angola and NW Botswana. Power could also be used for proposed irrigation projects along the Okavango River.

2.3 Project Components

Full details of the technical options under consideration are provided in the “Technical Report on the Pre-Feasibility Study on the Popa Falls Hydro Power Project (WTC, November 2003). A summary of the project components and technical options is provided in this section below.

2.3.1 A Gated Weir

The Okavango River within Namibia has no large waterfalls that offer the necessary head to drive power generation turbines. It is therefore necessary to construct a weir to provide sufficient head. Popa Falls is a set of rapids with a height of approximately 3,5 metres during low flow conditions, reducing to about 1,5 metres as the water depth below the rapids is increased during high flow periods.

A number of criteria were set in the Terms of Reference for the Pre-feasibility Study, or emerged subsequently, in regard to the location and height of a weir: -

- The impoundment created by the weir may not inundate Angolan territory over and above the Maximum Flood level,
- The weir should not be constructed on Popa Falls due to impacts on tourism and bio-physical impacts,
- Andara Mission station and hospital should not be inundated,
- It was considered environmentally undesirable to affect the flow of water over the falls by diverting water from the main channel,

- Inundation of islands and rocky rapids should be minimised as these islands support natural habitats of special character and unique habitats in Namibia. The communities of plants on these islands are found nowhere else in Namibia or on the Okavango River.
- To optimise power production it was desirable to maximise the weir height, while minimising the relocation of households, businesses and institutions and the area of islands affected.

The selection of weir sites was also constrained by the availability of rock for founding conditions. A number of ridges of sandstone or quartzite across the river influenced the initial selection of site options.

The alternative weir sites considered were as follows: -

- **Site 1** was identified in the Preliminary Feasibility Investigation by the SWA Department of Water Affairs (1969). This site was on the lip of Popa Falls. Refer Photos 1 & 2. This option was rejected early in the pre-feasibility study due to impacts on tourism and bio-physical impacts.

- **Site 1a** is located approximately 1,2 km upstream of Popa Falls. This site was also rejected as being very close to the Popa Falls resort and having no particular advantages over other sites.

- **Site 2** is located approximately 2km upstream of Popa Falls, and downstream of the bridge at Divundu (on the Trans Caprivi Trunk Road). Refer Photos 3 & 4. This site is on a section of river that is about 380m wide, which is much wider than average, and therefore lends itself to the construction of a coffer dam around the weir during construction. A disadvantage of this site is that a number of homesteads and several businesses at Divundu would have to be relocated. This is based on a full supply level of 1007.5 metres above mean sea level. The height of the weir is limited to 7,5 m (from the river bed at approximately 1000.0 m.a.m.s.l.) so as to minimise the property to be relocated, and avoid affecting the bridge approaches or raising the Trans Caprivi Trunk Road. A water level at 1007.5 metres would result in less inundation of islands upstream compared with the proposals for weir sites 4 and 5.

- **Site 3** is located immediately upstream of the Divundu bridge. This site offered no particular advantages over other sites from an engineering perspective. It was rejected as being too close to Divundu bridge and the channel was not wide enough to accommodate the required number of spillway gates. It would also inundate a number of settlements and businesses.

- **Site 4** is located approximately 4,3 km upstream of the Divundu bridge, and approximately 3,8km downstream of the Frans Dimbare Youth Centre. Refer Photos 6 & 8. At a full supply level of 1010 m.a.m.s.l. the upper reaches of the impoundment would not reach the Andara Mission station. The site is in a section of river that has a gradient 10 times greater than at Site 2. It has the engineering advantage that it is possible to construct an auxiliary embankment with a fuse plug in a side channel which can also be used for diverting the river during construction of the weir. It is also possible to construct a higher weir than at Site 2 due to the steeper gradient. It is proposed that a weir at this site could be as high as 9 m (from the bed at 1001.0 m.a.m.s.l.) which significantly increases the power generation potential. However, at a full supply level of 1010.0 m.a.m.s.l., approximately 29% (1,36 km^2) of the wooded islands between Popa Falls and the Angolan border - would be submerged.

- **Site 5** is located approximately 1km downstream of Site 4, but upstream from the Divundu Bridge. Refer Photos 6 & 7. This site is similar to Site 4 with the exception that it does not have a side channel. It has the engineering advantage that the weir height could be increased to 9,75 (from the bed at 1000.25m). The FSL would be at 1010.0 m.a.m.s.l. This alternative increases the power generation potential even further compared to Site 4.

The following table provides details of the preferred weir sites and basin capacities for the various full supply levels. Those in **bold type** are the options that are favoured, technically or economically, at this stage. These are the options assessed in this report.

Weir Site	Full Supply Level (FSL)	Weir Height	Weir Basin Capacity
Site 2	**1007.5 m.a.m.s.l.**	**7,5 m**	**22,5 million m^3**
Site 4	1007.5 m.a.m.s.l.	6,5 m	
Site 4	**1010.0 m.a.m.s.l.**	**9,0 m**	**16,6 million m^3**
Site 4	1012.0 m.a.m.s.l.	11,5 m	
Site 5	**1010.0 m.a.m.s.l.**	**9,75 m**	**24,4 million m^3**

The Pre-feasibility study focussed on weir Site options 2, 4 and 5 as the preferred alternatives from a technical perspective, but having also taken into consideration certain environmental issues.

Site alternatives 1, 1a and 3, on the other hand, were excluded from further analysis in the Pre-feasibility Study and in the Preliminary Environmental Assessment.

At any of the proposed sites, the weir would be flanked by either earth embankments or concrete mass gravity walls to contain the increased water level. Construction materials are discussed in section 2.3.5 below.

The proposed gates, and the operation of the weir are outlined in section 2.4.1 below.

2.3.2 Hydromatrix Turbines, Bulb Turbines and/or Diversion Canal

Various alternatives have been considered for the power generation units.

Hydromatrix turbines are relatively small units that are placed in modules on roller gates in the wall of the weir itself. A large number of turbines is used and each module can be removed individually for servicing. They would be spaced across the weir, alternating with sluice gates.

Some of the advantages of Hydromatrix turbines are: -

- Placement of units across the main channel so that flow is not concentrated to one side of the channel (as in the case of bulb turbines placed in a weir),
- Alternating with sluice gates, to facilitate the sluicing of sediment, and allow floods to pass.
- The costs of civil works are lower.

Bulb turbines are much larger units that could be placed in the weir (to one side of the weir) or could be used in a diversion canal.

Various combinations of the above two types of turbines are under consideration. The various alternatives and combinations are summarised in the table below.

Configuration	Site 2	Site 4	Site 5
Hydromatrix turbines	X	X	X
Bulb turbine without canal to downstream of the Falls	X	X	X
Combined Hydromatrix-Bulb development with canal	X		
Bulb unit – 3m weir with canal to below the Falls.	X		

WTC (November 2003)

The cost of constructing diversion canals was found to be too high to justify the additional power output that could be generated using bulb turbines in conjunction with a diversion canal. Therefore **diversion canals are not favoured by the technical team** and have been only briefly considered in the Preliminary Environmental Assessment.

Placing turbines *in the weir* itself has a number of environmental advantages over the construction of a diversion canal: -

- There would be minimal alteration of the flow regime of the River as the full discharge would remain in the main channel,
- The risks associated with estimating the minimum ecological flow requirements for the main channel would be eliminated.

2.3.3 Switchyard & Control Centre

The switchyard would cover an area of 170 x 170 m and will be situated close to the turbine generators. The switchyard would incorporate a control centre in a building of 45 x 8 metres. The location of the switchyard can only be determined once a weir site has been finally selected. This area would contain the transformers and control equipment. It would receive power by cables from the turbines. The Control and load centre would be operated at 3,3 kV. Four x 10 MVA transformers would step up the output from the switchyard to 132 kV.

The switchyard area needs to be as level as possible. It would have two entrances, and must be easily accessible. The switchyard is normally one of the more unsightly components of a power generation plant and therefore its location would need to be selected with due consideration to visual impacts.

2.3.4 Powerlines

The transmission lines would be routed from the switchyard via Mukwe to Rundu, and at a later stage possibly to Katima Mulilo. Details of the routes of the transmission lines have not been determined at this stage.

2.3.5 Sources of Construction Materials

The nearest existing rock quarry is 50-60 km from Popa Falls towards Rundu. The suitability of the material for the concrete aggregate has not been finally determined. Should it prove necessary to quarry rock from one of the sandstone or quartzite outcrops in the vicinity of the project, the site would need to be selected subject to further environmental assessment.

There is little or no impermeable material in the area suitable for the construction of the core of the embankment. Therefore consideration may be given to utilising a concrete mass gravity wall or an asphaltic core for the embankment.

The river sand was found to be suitable for concrete and could be dredged from the river. Alternatively consideration should be given to using the fine aeolian sand which comprises the dunes in the area. There are many disturbed areas from which sand could be taken with no significant environmental impacts. This possibility will be further investigated during the detailed feasibility phase of the project.

2.3.6 Relocation of Roads, Dwellings, Businesses, and Services

Depending on the selection of weir site and final height of the weir, certain businesses, homesteads, minor roads, and other infrastructure (e.g. telecommunications) may have to be relocated. The sites or route alignments for roads to be rebuilt and buildings to be relocated, have not yet been determined and will be further investigated at the detailed Feasibility stage. These new sites / alignments will need to be included in the full Environmental Impact Assessment.

2.4 Proposed Operation of the Weir

2.4.1 Power Generation at Full Supply Level

As mentioned above, the purpose of the weir is to provide the necessary head to generate power. The weir is not required for storage. The maximum capacity of the preferred weir options is 24,4 million m^3. This represents approximately 0.25% of the mean annual runoff of 9,585 million m^3 / annum, which was determined using the 50 year flow record for Mukwe. Thus the volume of the weir impoundment is very small in relation to the mean annual discharge of the river.

It is proposed that the weir would be operated at "full supply level" (FSL) most of the time – i.e. with the water flowing up to 300mm deep over the top of the weir, and the rest passing through the turbines and sluice gates in the weir. In order to regulate the water level, sluice gates would be placed at intervals across the weir alternating with the Hydromatrix turbines. During low flow conditions the above-mentioned 300mm level may drop, resulting in reduced power generation.

Two types of gates are under consideration - either **conventional radial gates**, or **"TOPS gates"** or a combination of both. The latter are currently in use at Avis Dam, Windhoek. The operation of Tops Gates is based on hydraulic principles and **requires no intervention by operations personnel**. The closing force of the ballast tank plus the weight of the water in the tank, which rises in the tank at the same rate as the water level rises in the weir impoundment, is greater than the upstream force exerted by the water on the gate. This ensures that the gate remains closed. When the water level rises above a preset level above the crest of the gate, the force exerted on the gate by the upstream water increases to a point where the counteracting force, exerted by the gate and the water in the ballast tank, is less than the upstream force of the water. At this point the gates start opening and water is released from the gates. When the flood has passed, and the water level in the weir impoundment starts dropping again, the gates will start to close when the upstream force on the gate is less than the downstream counteracting force.

At no stage will the river be blocked completely. The time required to fill the weir impoundment is calculated for various scenarios (in section 7.2.2) as approximately 5 – 15 days if only 10% of the discharge is held back, while the rest passes through the weir gates. This is based on impoundment volumes ranging from 16,6 million m^3 to 24.4 million m^3.

Filling the impoundment can take place during the high flow period to minimise the impact on the hydrograph. During the high flow season, once filling is complete, the weir will be operated at full supply level (FSL). As the low flow season approaches and the inflow to the impoundment drops, gates will be closed one by one to maintain the water level at FSL. This will result in a slight lag in the hydrograph, but essentially the inflow to the impoundment will equal the outflow through the weir.

2.4.2 The Option of Sluicing of Sediment

The need to ensure that sediment is passed through the weir was identified as a key environmental issue. The reasons for this are explained in section 6.10, 7.2.3 and 7.2.9. The fine sand that comprises about 90% of the river's sediment load will (in the absence of intervention) mostly be deposited within the impoundment as a result of reduced flow velocity created by the weir. This is due to increased cross sectional area, which in turn causes reduced flow velocity. Since the volume of sediment transport is related to velocity^3, a reduction in flow velocity leads to a substantial reduction in sediment transport. Deposition will be most evident at the head of the impoundment. Strong evidence for this comes from Dxherega Lake (McCarthy *et al*. 1993) – refer to **Appendix P** and **Photos 25 & 26**. Without active intervention, this would occur despite the fact that the full discharge of the river is flowing through the weir at all times during operation at full supply level (FSL).

In order to allow sediment to pass through the weir, consideration is being given to the following manner of operation. For 10½ to 11 months of each year the weir would be operated at FSL. Then for 4 to 6 weeks during the high flow period, the gates would be opened fully in order to draw down the level to the natural water level (almost as if the weir was not there). The effect of drawing down the water level would be to reduce the cross sectional area and therefore increase the flow velocity to approximately what it would be in the natural state.

In order to optimise sediment transport through the weir, the ideal time for sluicing would be the peak flow each year. The peak discharge is, however, very variable and in practice it is impossible to predict when the peak will occur. It can only be determined after the event. However, in principle, the aim would be to sluice the impoundment during the highest flow period each year. When ecological impacts of sluicing are taken into account, the ideal time for sluicing may be during the rising or declining limb of the hydrograph – taking into account, for example, ecological factors that cause fish to spawn or migrate. Determining the optimum time for sluicing would therefore require further detailed investigation of both sediment transport and ecological issues.

The environmental impacts of the sluicing option are discussed in section 7.2.2 and 7.2.4.

2.4.3 The Option of Pumping Sediment

An alternative to sluicing would be to construct a sediment trap close to the inflow to the impoundment. This trap would channel the sediment to a pump sump on the right bank of the river. From there it would be pumped to be discharged into the river immediately downstream of the weir. Model testing would determine the size and shape of the sediment trap.

This could have a number of advantages over sluicing: -

- It could be the most reliable way to get sediment through the weir,
- The need for sluicing could be eliminated. Therefore, it should: -
  - reduce the risk of erosion around the perimeter of the impoundment,
  - eliminate the issue of deposition, or erosion below the weir and subsequent problem of redistribution of the sediment downstream,
  - reduce the risk of eroding sandbanks where the African Skimmers breed,
  - reduce the ecological impacts on benthic fauna associated with sluicing of sediment,
  - reduce the potential impacts on water quality that could result from the sluicing of sediments that are enriched with clay and organic matter,
- Power could be generated throughout the year with no "down time" - so the economics and continuity of supply would improve,
- There should be less wear on the turbines as there would be far less sand passing through them.

2.4.4 No Operation to meet Peak Demands

A concern was raised by interested parties about the impacts of water level fluctuations on the Cunene River downstream of Ruacana Hydro Power station. Typical power demand curves for the national grid reflect two peaks per day (morning and evening). At Ruacana Hydro Power station, some water is held back in the reservoir and then released through the turbines to generate extra power during peak demand periods. This has a serious negative impact on invertebrates along the river margins, which are not adapted to these fluctuations in water level – with inevitable secondary impacts up the food chain (Bethune, July 2003 – **Appendix J**). Because this concern was raised in relation to Popa Falls, a brief explanation is offered here.

The reason for the concern about daily fluctuations is that the water level in the Okavango River rises and falls very slowly. Inspection of some of the records show that changes in water level of only 1 or 2 cm/day are typical and a rate of change of 7cm/day is fairly unusual. Therefore daily fluctuation in water levels would carry high ecological risks as organisms in the river are not adapted to high fluctuations. Thus negative ecological impacts would be expected both downstream and around the margins of the impoundment. A daily fluctuation in water level of even as little as 300mm would result in a significant negative impact on water levels, with resultant ecological impacts.

However, by contrast with Ruacana, the Popa Falls Hydro Power Project is a run-of-the-river scheme and operation to meet peak demand is **not possible** (K.Lund, WTC, pers comm). **Therefore unnatural daily fluctuations in water level will not arise.**

3 ALTERNATIVES TO THE PROPOSED HYDRO POWER PROJECT

3.1 Introduction

NamPower has over the past few years been investigating various options for power supply to meet Namibia's growing demand. Options have included hydro power (at Epupa Falls and Baynes on the Cunene Rivers), wind power (at Luderitz), and gas power (Kudu Gas at Oranjemund). Such options are discussed in this chapter as a background to the proposal for the Popa Falls Hydro Power Project.

The development of power supply in southern Africa has mostly followed the traditional engineering and supply approach - building large power generation facilities. Alternative paradigms for power generation or demand reduction have not been implemented. This is also true in Namibia.

Historically, the provision of electrical power supply has focused on a single corporation having responsibility for the generation and/or bulk power supply for the country. The investigations commissioned by NamPower over the past few years have been based on this paradigm, and conventional sources of power. There has been little serious consideration of energy alternatives of a small scale nature (eg. at a household level) that could supplement bulk generation.

In the past decade or so, alternatives to traditional energy supply approaches have proved themselves in real-world applications around the globe. There are many progressive alternatives now being practised in energy supply which can benefit society without undermining the integrity of the ecological systems we depend on (Pottinger 1999).

Therefore, in addition to a summary of the alternatives considered by NamPower so far, this section provides a brief review of alternatives for power generation, supply, and demand management.

3.2 Wind Power

Wind power is in the short term one of the most promising renewable energy sources. Technological advances have caused the price of wind power in favourable locations to drop dramatically. Although wind power cannot produce power 100% of the time and therefore cannot be relied upon for all of a country's power, it could provide a greater proportion of energy production in places with good winds.

In 2000, NamPower completed a feasibility study for a wind park at Grosse Bucht southeast of Lüderitz. In the pilot phase the wind park could generate between 3 and 10MW of power and, if successful, could expand to 20MW. This capacity approaches the capacity of the proposed Popa Falls hydro power project, but it is too far from the area that Popa Falls is intended to supply. Although there was a lot of support for the wind park, plans to develop it have been put on hold due to the project not being economically feasible, i.e. the wind park could not compete with present sources of generation (Langford pers. comm, 2003). Donor funding is being sought by NamPower to develop the project under NamPower's research and development programme.

3.3 Gas Power

The Kudu Gas Field offshore of Oranjemund on Namibia's west coast was discovered in 1973. It is a large deposit by international standards and the gas is of high quality. Natural gas, (almost pure methane) is a clean-burning, efficient energy source, giving off minimal pollution. Levels of sulphur dioxide, carbon dioxide and nitrogen oxides emitted during the combustion process are much lower than for coal-fired power stations and well within international standards (Walmsley 1998). However carbon dioxide is nevertheless produced and is implicated, as a "greenhouse gas", in the process of global warming.

The Kudu Gas power plant is expected to have a power generation capacity of 750MW to 1500MW. The development of Kudu Gas appears to be a preferred option to address the growth in the power demand in Namibia in the short-term. However plans to exploit the Kudu Gas Field have been postponed. According to NamPower (June 2003) new investors, are being sought since the exploitation of the Kudu Gas Fields is still a preferred option for NamPower.

3.4 Hydro Power

Hydro power is currently the world's largest renewable source of electricity, accounting about 15% of the world's electricity. Traditionally thought of as a cheap and clean source of electricity, most large hydro-electric schemes being planned today are coming up against a great deal of opposition from environmental groups and indigenous people.

3.4.1 History of Hydro Power

Early hydro-electric power plants were much more reliable and efficient than the fossil fuel fired plants of the day. This resulted in a proliferation of small to medium sized hydro-electric generating stations. As electricity demand soared in the middle years of the 20th century, and the efficiency of coal and oil fired power plants increased, small hydro plants fell out of favour. Most new hydro-electric development was focused on "mega-projects". The majority of large hydro power plants involved large dams that flooded vast areas of land to provide water storage and thus a constant supply of electricity. In recent years, the environmental impacts of such large dams have resulted in opposition from environmentalists and people living on the land to be flooded. This opposition is based on issues such as: -

- inundation of good agricultural soils,
- ecological impacts on aquatic ecosystems,
- prevention of fish migrations,
- destruction of spawning and feeding habitats for fish,
- loss of forests and other terrestrial habitats,
- disruption of lifestyles and subsistence livelihoods, and
- trapping of silt that is necessary for the fertilisation of floodplains downstream.

One of the trends in hydro power is therefore "run-of-the-river" schemes that do not require storage of water and have lower ecological and social impacts. Popa Falls Hydro Power project was conceived of as a run-of-the-river scheme.

3.4.2 Hydro-electric Power Plants

The amount of electricity which can be generated at a hydro-electric plant is dependant upon two factors; the vertical distance through which the water falls, called the "head", and the flow rate (volume/time). The electricity produced is proportional to the product of the head and the rate of flow.

"High head" power plants are the most common. The added use of a dam to impound water also provides the capability of storing water during rainy periods and releasing it during dry periods. High head plants with storage have the advantage that they can be adjusted quickly to meet the electrical demand.

"Low head" hydro power plants generally utilize heads of only a few meters. Power plants of this type may utilize a low dam or weir to channel water, or no dam and simply use the "run-of-the-river". Run-of-the-river generating stations cannot store water, thus their electric output varies with seasonal flows in a river. A large volume of water must pass through a low head hydro plant's turbines in order to produce a useful amount of power. Popa Falls is a “low head” scheme.

3.4.3 Environmental Impacts of Hydro Power Dams

Dams have many environmental impacts, some of which are just beginning to be understood. These impacts, however, must be weighed against the environmental impacts of alternative sources of electricity. Until recently there was an almost universal belief that hydro power was a clean and environmentally safe method of producing electricity. This was based on the belief that hydro power plants do not emit atmospheric pollutants such as carbon dioxide or sulphur dioxide given off by fossil fuel fired power plants, which contribute to global warming and acid rain. However, recent studies have found that dams do emit greenhouse gases, believed to be the result of decaying organic matter. Hydro-electric power plants do not result in the risks of radioactive contamination associated with nuclear power plants.

The most obvious impact of hydro-electric dams is the flooding of large areas of land, much of it previously forested or used for agriculture. In several cases the dams have flooded the homelands of indigenous peoples, whose way of life has then been destroyed e.g the Gunembe-Tonga people at Kariba. In the case of Popa Falls there will be some displacement of people and subsistence activities, but to a far lesser extent.

Many rare ecosystems are also threatened by dams used for hydro power development. Although the proposed weir at Popa Falls is very much smaller than dams like Kariba, it will also result in the loss of rare habitats – namely, a substantial portion of the rocky rapids, island forests and riverine forests upstream from Popa Falls.

Dams and weirs can have other impacts on a watershed. Damming a river can alter the amount and quality of water in the river downstream of the dam, as well as preventing fish from migrating upstream to spawn. These impacts can be reduced by requiring minimum flows downstream of a dam, and by creating fish bypasses which allow fish to move upstream past the dam. Silt, normally carried downstream to the lower reaches of a river, is trapped by a dam and deposited on the bed of the reservoir. The river downstream of the dam is deprived of silt, which fertilises the river's floodplain during high water periods.

3.4.4 The Future of Hydro-Electric Power

In the past, the World Bank and others have spent billions of foreign aid dollars on large hydro-electric projects in the third world. Opposition to hydro power from environmentalists and indigenous people, and the World Bank requirements for a range of environmental assessments, may restrict the amount of money spent on hydro-electric power construction in developing countries, because of their environmental impacts and the tendency to disadvantage displaced people. The actual effects of dams and reservoirs on various ecosystems are only now becoming understood. The future of hydro-electric power will depend upon future demand for electricity, as well as how societies value the environmental impacts of hydro-electric power compared to the impacts of other sources of electricity.

In some areas, small-scale hydropower schemes may be the most appropriate energy source. When carefully planned and implemented, small dams producing less than 10 megawatts each can be less harmful to the environment and surrounding communities than large dams. However, scale alone does not determine whether a project will be socially or environmentally harmful. As with planning any hydro power project, small dams should be evaluated individually for their impacts on the catchment and communities, and for their compatibility in an overall catchment management plan. (refer Beyond Big Dams, IRN 1997)

3.4.5 Orange River

The Orange River has been considered as an option for development of a number of small hydro power plants. The combined hydro power potential of such plants is estimated to be 100MW. According to NamPower (May 2003) the development of hydro power plants on the Orange River is complicated by the fact that Namibia's boundary with South Africa lies officially on the north bank of the river. In 1991 the governments of South Africa and Namibia agreed to move the border to the centre of the river, but this has yet to happen (Mendelsohn *et al* , 2002).

3.4.6 Epupa and Baynes Sites (Cunene River)

NamPower estimates the potential of the Lower Cunene River for hydro electric power to be 1600MW. The Cunene River forms the northwestern boundary between Namibia and Angola. In 1991 a joint commission (PJTC) was established between the two countries to investigate a hydro-electric project in the Epupa area. Various concerns were expressed about environmental impacts, and impacts on traditional subsistence lifestyles, particularly those of the Himba people. However, the planning process was halted before proper discussions could be held with these people concerning possible mitigation measures. The issues surrounding the Epupa site led to the investigation of the Baynes Mountains site further downstream. However, the PJTC was concerned that the energy output at this site was only comparable to Epupa if the Gove Dam in Angola was fully operational. This factor could not be assured. Both the Epupa and the Baynes sites were investigated in the Feasibility Study, which was conducted by NAMANG (Corbett 1999).

3.4.7 Ruacana (Cunene River)

NamPower's hydro power plant at Ruacana supplies about half of Namibia's electrical energy at present. However, it is limited by the discharge of the river and can only operate at full capacity during periods when the river is flowing strongly, in summer.

The Angolan government is currently planning to repair the Gove and Calueque Dams, which will help to make a significant improvement (of the order of 20%) in the power output from Ruacana (J. Langford, pers comm).

3.5 Coal & Diesel Power

Namibia does not have reserves of quality coal or oil that could be economically exploited. There are three generation plants using coal or diesel, but these are only on standby in case South Africa is unable to supply for any reason. The cost of using these generation facilities cannot compete with the price of imported power. Namibia's existing facilities are:

Paratus (Walvis Bay)	24 MW	Diesel
Katima Mulilo	4 MW	Diesel
Van Eck (Windhoek)	120 MW	Coal

3.6 Imported Power

A significant proportion (40 to 55%) of Namibia's electricity is imported from South Africa. After Ruacana, this has been the most economical source for many years as South Africa has been exporting its surplus power at reasonable rates. However, the Namibian government has a goal of greater self-sufficiency in energy supply. Furthermore, there is a concern that once South Africa's peak consumption exceeds their current generation capacity (around the year 2006/7) the price of electricity from South Africa can be expected to rise significantly.

However, there is currently no proof that if Namibia became self-sufficient in power generation that the price of this power would be less than or equal to the price of imported power.

The option of buying power from Zambia exists, but one of the problems with power from Zambia has been the reliability of supply (Langford, pers comm).

Recently, NamPower signed a contract for the upgrade of power supply from Victoria Falls to Katima Mulilo, which is not connected to the Namibian national grid. If the grid was extended, then the hydro power plant at Victoria Falls would be an alternative to the Popa Falls project.

3.7 Solar Power

3.7.1 Solar Generation

Solar power is the world's second fastest-growing energy source, increasing on average 16 percent per year since 1990. While solar has its limitations, it is especially appropriate for off-grid applications, where most of the world's 2 billion people who are without power live (Pottinger 1999).

There are a number of ways to convert energy from the sun. The two most common are photovoltaic cells (PV), and solar thermal. Solar thermal has more potential as a large-scale energy source, while PVs are excellent for powering buildings off the energy grid. The price for PVs has dropped more than a hundred-fold in the past 25 years, as their use has grown. Already, new technologies are lowering the cost further, which would make them a competitive source of electricity in many parts of the world.

Photovoltaic cells (PVs)

Kenya has a thriving PV industry, and more households now get their electricity from solar systems than from the national grid. Local people are trained in installing and maintaining solar units. According to the World Watch Institute, approximately 500,000 homes around the world are now generating their own power with PVs. For the more than 2 billion people not connected to a grid, solar power could be the most affordable way to get energy.

In the USA and elsewhere, some utilities have set up “net metering” systems, which allow grid-connected homeowners who have installed solar systems to feed solar energy back into the grid system. Feeding in their own solar power makes the homeowner’s electricity meter run backwards, thereby reducing the household’s energy bill accordingly. This system encourages the installation of solar systems because homeowners get advantages even if they are not at home to use the power they are generating. Currently, 20 states in the United States have such programmes.

One of the objections to PVs is the high capital cost. For most households they are a long term investment. However, if people can sell their surplus power to the national grid, this would make them more attractive. In Namibia, where much of the power demand is for household consumption, PVs offer an excellent supplementary source of power.

In Namibia where the majority of the population are not connected to the grid and are unlikely to be able to afford electricity, PVs would be an affordable way for NamPower to reach these people. The Namibian Energy White Paper sets out an aim for Namibia to be able to produce 100% of peak energy demands and 75% of its total energy demands within its borders by the year 2010. Whether on or off-grid, solar power could be used for domestic energy provision - thus making more energy from the grid available for industrial use, Domestic solar power can also have the benefit of reducing poorer communities’ reliance on wood fuel. NamPower’s Rural Electrification Master Plan indicates that solar power is part of this plan.

3.7.2 Non-electrical Solar Power

A few households in Namibia have taken advantage of the long sunlight hours throughout the year by installing improvised solar water heaters. These require no electricity and no photovoltaic panels. They consist simply of a set of black polythene pipes which are exposed to the sun, and through which water is able to circulate. They can provide sufficient energy to heat a geyser for the average household. These simple systems are cheap to manufacture, and they require a relatively low level of technology. In towns the same geyser can also be connected to the electrical mains for use when solar heating is inadequate. Since water heating is one of the greatest consumers of electricity in the average household, these systems could make a significant contribution to reducing the energy consumption of households – making the bulk power sources more freely available for industrial development.

3.8 Power Demand: Management & Trends

3.8.1 Implications of Policies for Power Demand

Research shows that individual consumers in Namibia are the largest users of electricity, despite the fact that 70% of Namibian's live in rural areas. Mining was once the largest energy consumer, but this industry has stagnated and municipalities supplying individual consumers now account for more than half of the electricity consumed in Namibia. This means that careful demand management is necessary no matter what decision is made regarding hydro power schemes in Namibia (Corbett 1999).

Demand management treats the volume and pattern of power-consumption as variable, and aims to change the behaviour of consumers either voluntarily (prices, education) or involuntarily (regulations, policies). In Namibia per capita energy consumption is low by international standards, however there is potential to improve energy conservation, through awareness, increased rates, and credit schemes to encourage the use of energy efficient appliances. Further research into conservation and demand management is recommended.

Efficiency measures are not free, but they are very cheap compared to new power supply. Utilities in the USA report that the average cost of implementing electricity savings of all kinds has been 2 cents per kilowatt-hour (kWh). In contrast, each kWh generated by an existing power plant costs upwards of 5 cents (and as high as 20 cents), and that does not include the cost of repairing the environmental impacts of energy plants. Experience in the USA suggests that undertaking efficiency measures also brings more jobs than building new power plants, as jobs are created for inspectors and auditors. However, in Namibia, where a substantial proportion of the demand is domestic, the opportunity for demand management may be more limited.

3.8.2 Implications of HIV/AIDS for Power Demand

Projecting energy demand on the basis of historical consumption has its limitations. Namibia saw rapid growth in the first decade following Independence. However, the rate of growth may slow down.

One of the uncertainties in predicting the growth in demand for electricity is the high incidence of HIV/AIDS in Namibia and most southern African countries.

The overall rate of infection in Namibia has increased steadily from 4% in 1992 to 22% in 2000. Currently, about 1 in 4 deaths in Namibia are the AIDS – related (Mendelsohn *et al*, 2002). Furthermore, the majority of deaths from AIDS are in the age group from 25 to 45 which is the most economically productive group (Mendelsohn *et al*, 2002). Not only does AIDS result in adult deaths, but it also leads to reduced fertility, and increased infant mortality (of infected children).

Therefore, HIV/AIDS is expected to have a significant impact on the demographics of Namibia and neighbouring states. It will therefore also impact on the demand for power. The magnitude of that impact needs to be investigated in relation to power demand.

4 LEGAL AND POLICY REQUIREMENTS

4.1 Existing Legislation

A comprehensive review of all legal provisions relating to the proposed hydro power station project has not been undertaken by a specialist legal expert, but some of the most relevant legal and policy documents which may have an influence on the Popa Falls Hydro Power project are mentioned in this chapter.

4.1.1 The Constitution of Namibia

The 1990 Constitution of Namibia is the supreme law of the land. It contains environmental provisions in Chapter 11, which deals with Principles of State Policy. Article 95: "Promotion of the Welfare of the People" provides that: -

> "the State shall actively promote and maintain the welfare of the people by adopting…policies aimed at the following … "Maintenance of ecosystems, essential ecological processes and biological diversity of Namibia and utilisation of living resources on a sustainable basis for the benefit of all Namibians, both present and future…"

The implications for environment and development are seen as follows. Both development and environmental quality are necessary for the "welfare of the people". Therefore the benefits of development should not be attained at the expense of environment or sustainability issues. The benefits of development should also not be attained by one group at the expense of other people. The Constitution creates a framework for consideration of sustainability, equity and sound environmental management.

Article 95 does not create legally enforceable rights but acts as a guide to Government policy regarding the enactment and application of legislation (Article 101 of the Constitution).

4.1.2 The Water Act (Act 54 of 1956)

Section 23 of this Act makes it a criminal offence to: "pollute fresh water or the sea in a way that makes the water less fit for any purpose for which it is or could ordinarily be used by people, including use for the propagation of fish or other aquatic life, or use for recreational or other legitimate purposes". This Act would therefore be relevant to the proposed project with regard to any activity that makes the water less fit for fish or other aquatic life.

Water legislation is curently under review in Namibia – refer to sections 4.2.3 and 4.2.4 below.

4.1.3 The Forest Act. No. 12 of 2001

The Forestry Act No.12 of 2002 explicitly protects riparian vegetation, and legislates against soil erosion and resultant siltation. A section of this act that is particularly relevant to the hydro power project is Part IV: -

> "Protection of natural vegetation. No.22 (1) b) No person shall on any land which is not part of a surveyed erven of a local authority (without a license)…cut, destroy or remove – any living tree, bush or shrub growing within 100 metres of a river, stream or watercourse."

> "Control over deforestation. No. 23 (1)…no person shall (b) clear the vegetation on more than 15 hectares on any piece of land….which has predominantly woody vegetation; or (c) cut or remove more than 500 cubic metres of forest produce from any piece of land in a period of one year."

NamPower will need to comply with the necessary licencing requirements for the destruction of forest areas.

4.1.4 Nature Conservation Ordinance, 1975 (No.4 Of 1975)

Currently fish in inland waters are regulated under the Nature Conservation Ordinance, 1975 (No.4 of 1975) Chapter Five.

Explosives, poisons and intoxicating materials are not allowed to be placed in any inland waters. This may have implications for blasting during construction of the weir.

4.1.5 Inland Fisheries Resources Act (Act No.1 of 2003)

This Act has the objective of ensuring sustainable utilisation of freshwater resources. It favours subsistence fishing over commercialisation – recognising the importance of subsistence fishing in the livelihood of many riparian communities. It encourages cooperation with neighbouring countries regarding the management and conservation of shared waterways. It also prohibits the use of destructive fishing methods, and the introduction of non-indigenous fish species.

This Act also requires that the construction of weirs and dams must first be approved by the Minister of Fisheries.

4.2 Future Legislation

4.2.1 The Environmental Management Bill

Although this is not yet law, a final draft of the Environmental Management Bill has been prepared by the Ministry of Environment & Tourism. It is intended, amongst other things to: -

- Give effect to the provisions in the Constitution,
- Regulate Environmental Assessments,
- Contain provisions on environmental rights and duties of Namibians,
- Establish binding environmental principles.

4.2.2 Pollution Control and Waste Management Bill

This Bill has also not yet been enacted, but it anticipates the following provisions: -

- Provision for Integrated Pollution Control (IPC) Licences
- Regulation of the storage, transport, management and disposal of waste.

The controls that do exist are contained in the Public Health Act, and Section 23 of the Water Act, which prohibit the pollution of water including groundwater.

4.2.3 White Paper on National Water Policy for Namibia (May 2000)

This White Paper was drawn up by the Namibian Water Resources Management Review (NWRMR). It sets out the policy framework for equitable, efficient and sustainable water resource management and water services in Namibia. Chapter 2 of this document sets out the policy for Namibian Government with regard to water resource development, utilisation, management and protection. The policy is based on 12 basic principles, which reflect the principles set out in the Constitution of Namibia and those agreed at the Earth Summit of 1992. Of these principles, two are especially relevant to the current project. Principle No.8 states that the management of water resources needs to harmonise human and environmental needs and protect water quality, whilst acknowledging the role of water in supporting eco-systems. Principle No.12 states that Namibia shall strive to promote equitable and beneficial use of international watercourses, based on generally accepted principles and practices of international law.

4.2.4 Water Resources Management Bill (MAWRD 2001)

This bill will provide for the fundamental reform of the law relating to water resources management and is guided by the White Paper on National Water Policy for Namibia (May 2000).

The Water Resources Management Bill also makes provision for *inter alia* Basin Management Committees, and Licences for water abstraction.

Chapter 8 deals with Shared International Water Resources, committing Namibia to comply with “any international treaty, convention or agreement to which the Republic of Namibia is a signatory”. It sets out the powers and responsibilities of the Minister with regard to promoting institutional relationships, joint management and planning, data bases, stakeholder participation, and dispute resolution.

Chapter 9 deals with Pollution Control and permitting requirement for effluent discharge.

Chapter 10 makes provision for Water Management Areas to be proclaimed, which would place certain restrictions on the abstraction or use of water in the designated areas.

Chapter 12 deals with Dam Safety and Flood Management. It sets out certain requirements for information that must be provided to the Minister, and certain factors that must be considered in relating to dam safety, including socio-economic impacts if the dam fails. The Minister may also prohibit the construction of dams or other structures that may cause increased flooding.

4.3 National Policy & Guideline Documents

4.3.1 Namibia's Environmental Assessment Policy

Namibia's Environmental Assessment Policy was approved in August 1994 by Cabinet Resolution 16.8.94/002. This Policy provides guidelines for Environmental Assessments (EA's) and is being widely used to encourage sound environmental management throughout the country. Furthermore, the Draft Environmental Management Bill anticipates that requirements for EA's will become law in the near future. Included in the aims of the EA Policy are the following: -

> "Maintaining ecosystems and related ecological processes, in particular those important for water supply, food production, health, tourism and sustainable development;
>
> "Maintaining maximum ecological diversity by ensuring the survival and promoting the conservation in their natural habitat of all species of flora and fauna, in particular those which are endemic, threatened, endangered, and of high economic, cultural, educational, scientific and conservation interest." (p.2)

The EA procedure sets out to (*inter alia)*: -

- "Better inform decision makers and promote accountability for decisions taken,
- "Consider a broad range of options and alternatives when addressing specific policies, programmes and projects,
- "Strive for a high degree of public participation and involvement by all sectors of the Namibian community in the EA process,
- "Take into account the environmental costs and benefits of proposed policies, programmes and projects,
- "Take into account the secondary and cumulative environmental impacts of policies, programmes and projects,
- "Promote sustainable development in Namibia, and especially ensure that a reasonable attempt is made to minimise anticipated negative impacts and maximise the benefits of all developments." (P.3-4)

4.3.2 Draft Wetlands Policy

The Draft Wetlands Policy (May 2003) is intended to promote the conservation and wise use of wetlands, thus promoting inter-generational equity regarding wetland resource utilisation. It facilitates Namibia's efforts to meet its commitments as a signatory to the International Convention on Wetlands (Ramsar Convention) and other multinational environmental agreements.

The Policy recognises the importance and scarcity of wetlands in Namibia, existing threats to wetlands (including alien invasive weeds and agricultural development). It also recognises that water concerns extend beyond human needs for health and survival – that water is essential to maintain natural ecosystems and that, in a country as dry as Namibia, all social and economic activity depends on healthy aquatic ecosystems.

The Policy mentions the fact that Namibia has designated four wetlands as Ramsar sites but several others also qualify for Ramsar status - including the lower Okavango River (downstream from Mukwe). It also states that certain of these wetlands or components of these wetlands demand absolute protection, **specifically including the rocky rapid habitat sections of the perennial rivers, e.g. between Mukwe and Popa Falls on the Okavango River.**

Amongst others, the Policy emphasises: -

- The need for a Basin-wide Management Approach,
- The need to expand the protected areas network in Namibia (specifically including the Okavango river downstream of Mukwe),
- Any decisions concerning the use of wetland resources shall be made in acordance with the *Precautionary Principle* and the *Polluter Pays Principle,*
- Strategic Environmental Assessments are encourged,
- A conservative approach to allocation of water resources is recommended until more detailed information on the entire water resource is available,
- The threat of alien aquatic weeds and other alien organisms that threaten wetland functioning,
- Sites that are the only known habitat for certain endemic fish species, and endemic and rare amphibians, birds and mammals should be given special protection,
- The need extend CBNRM activities into all areas associated with wetlands that have potential for ecotourism,

This document also lists many other policy documents that are relevant to wetlands in some way. For example: -

- The policy on "*Land-use planning: towards sustainable development*" of May 1994 includes a section on wetland systems.

  This states the policy of the Ministry of Environment and Tourism as follows: -

  > "to encourage the rational and integrated planning of wetland systems, in accordance with the philosophies of the Ramsar Convention on wetlands, based on the ecological principles of preservation of biotic diversity, maintenance of life support systems and sustainable use".

- The policy on "*Conservation of biotic diversity and habitat protection*" of May 1994 also makes it the policy of the Ministry of Environment and Tourism to ensure adequate protection of ecosystems, including wetlands.

4.3.3 Namibia's Biodiversity Strategy and Action Plan (2002)

This document has as its fifth objective, Sustainable Wetland Management, which aims to: -

- Protect and maintain essential ecological functions and the biological diversity of Namibia's wetland ecosystems,
- Create additional conservation areas for wetlands,
- Promote integrated land and water management,
- Raise awareness of wetland values and threats.

4.4 Regional and International Law, Policy and Guidelines Documents

4.4.1 The SADC Protocol on Shared Watercourse Systems

The Protocol on Shared Watercourse Systems in the Southern African Development Community Region was signed and ratified in 1995.

The issue of sovereignty is the first to be addressed. Article 1 provides that SADC states are entitled to use water resources in their territory "without prejudice to their sovereign rights". Despite the "equitable use" and "significant harm" principles being applied, the approach of the Protocol is that of limited or qualified territorial sovereignty as opposed to co-governance and the recognition of the holistic nature of water and water resources. Therefore, the SADC Protocol provides for river basin management organisations in which states have a forum for negotiation and information sharing, rather than for strategic planning and decision making for the basin as a whole. The Protocol does make provision for management institutions for shared watercourses, and sets out five components that limit the use of international watercourses. They are as follows: -

- Balancing development with conservation,
- Inter-state co-operation,
- Equitable sharing of water resources,
- Developing compatible national systems,
- Notification of emergencies.

Since "territorial sovereignty" remains the primary concern in international water resource agreements, the principles of equitable use, information sharing and significant harm will remain theoretical, and dispute resolution, requiring practical application of these principles will remain difficult to achieve. The Protocol's provisions for trans-boundary management institutions offer some opportunity for conflict resolution - the current understanding of effective trans-boundary management is a more flexible view of the concept of sovereignty, in that inter-state collaboration over regional resources "reinforces rather than diminishes the sovereignty of each state" (GCI 1999:5). This could carry through to newly established management institutions provided for in the SADC legal framework" (Tompkins 2003).

4.4.2 UN Convention on the Non-navigational Use of International Watercourses

The United Nations General Assembly adopted the UN Convention in 1997. It represents the "codification" of the rules of customary international law as regards shared watercourses. It establishes three critical principles in the use of shared watercourses. They are: -

- The principle of equitable and reasonable utilisation according to a number of factors including social and environmental factors. The principle states that these must be considered on a case-by-case basis (Article 6)
- The principle of obligation not to cause significant harm (Article 7), which protects downstream users of the watercourse from upstream development or utilisation. This principle introduces the possibility of compensation in the event that serious harm is caused
- The principle of prior notification in the event of planned measures that may "have a significant adverse effect upon other watercourse states" (Article 12)

The UN Convention is not yet in force and therefore not legally binding, but Namibia, Angola and Botswana have ratified this Convention.

4.4.3 The International Convention on Biological Diversity

The Convention on Biological Diversity was ratified by the Namibian Government in 1992. Thus Namibia has an obligation under international law to protect its endemic species (i.e. species - for which most of the world population - lives or breeds in Namibia). This Convention can be expected to give rise to regulations in future.

Namibia therefore has an obligation to conserve any endemic species in the study area.

4.4.4 The Ramsar Convention on Wetlands

Namibia is a signatory to the Ramsar Convention on Wetlands. This Convention, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty, which provides the framework for national action and international co-operation for the conservation and wise use of wetlands and their resources.

The Okavango Swamps is a Ramsar site, a fact which places obligations on countries upstream to manage the Okavango River is a manner that is not detrimental to the Swamps.

In Namibia, the stretch of the Okavango River **from Mukwe through the Mahango Game Park to Mohembo** was proposed by MET as a Ramsar site, but this was not approved by Cabinet – despite the fact that it **meets the criteria for Ramsar status**. The Ramsar criteria that are relevant to this section of the Okavango River are as follows: -

Criterion # 2: "A wetland should be considered internationally important if it supports vulnerable, endangered or critically endangered species or threatened ecological communities",

Criterion # 4: "A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions",

Criterion # 6: "A wetland should be considered internationally important if it regularly supports 1% or more of the individuals in a population of one species or subspecies of waterbird".

Both the section of river from Mukwe to Popa Falls, and the section from the falls down to Mohembo, satisfy these three criteria with respect to birds, and the upper section with regard to certain species of fish as well.

Birdlife International (2002) and Fishpool and Evans (2001) recognise the above-mentioned section of river as an "Important Bird Area" (IBA), which satisfies the Ramsar criteria and the Birdlife International criteria for IBA's.

4.4.5 OKACOM

The following is an easy reference analysis of the Trans-boundary Okavango River Basin Agreement (OKACOM**)**.

BASIN	OKAVANGO RIVER
Basin states	Angola, Namibia, Botswana
International, regional agreements, other basin agreements (Signed and ratified)	**SADC Protocol (1995 Revised 2000)**[1]
Institutional Agreement	**Okavango River Basin Commission (OKACOM)**
States involved in agreement	**Angola, Botswana and Namibia**
Date of agreement	**1994**
Legal Basis for agreement	**SADC Protocol, national acts**
Background	**Formulated as a result of increasing demand in Namibia and Angola, coupled with the ecological importance of the Okavango Delta and its significance for Botswana**[2]
General approach	**Collaborative process in management and implementation, not in formulation**
Representation of communities/ local users (left to state or in agreement)	**Left to state – stakeholder representation through regional steering committees. Environmental NGOs have increased the level of community involvement but mostly in Botswana**
Extent of public participation (PP) in formulation of agreement	**None – state level**
PP in agreement implementation	**Relatively good – through Environmental Impact Assessment and Transboundary Diagnostic Analysis**
Provision for environmental needs	**Relatively good, but Angola's political problems have kept her out of many of the processes of OKACOM, a situation which may test the provisions of the agreement as the country pays more attention to social and economic development than the civil war has previously allowed**
Management focus: • **Allocation** • **Management** • **Development**	**All – environmental assessment is included, regional steering committees for technical processes, currently undertaking an Integrated Basin Management Plan – funded through Global Environment Facility & IUCN**
Management Style	**Relatively collaborative through regional committees and through the draft Transboundary Diagnostic Assessment (baseline data)**
Monitoring: quantity, quality, supply, and allocation	**Monitoring is ineffective at the moment, but current plans should improve. The agreement "provides a useful framework for collaboration"**
Regulation and enforcement of provisions of agreement	**To date, there has been little enforcement, but the low population density of the river and lack of industrial use and water infrastructure has assisted**
Current projects in the basin with transboundary water management effects	**'Every River' Project, attempting to balance local user needs in Namibia, Botswana and Angola from a social, economic and environmental perspective**[3]
Member perceptions of allocation equity	**Possibility that Namibia will seek litigation in the International Court of Justice over its (currently postponed) plans for a pipeline to Windhoek, which Botswana opposes. Angola's involvement has been hampered by its political problems**
Conflicts and disputes	**War in Angola and lack of development in Namibia, has resulted in less conflict on the Okavango than other major rivers. Increased demand in Namibia has resulted in increased abstraction from the Okavango. The plan to pipe water to Windhoek raised a considerable protest, and the possibility of international litigation over water issues. OKACOM does not have the mechanisms to deal with such disputes, and despite its environmental focus, needs adjustment for issues such as this, as well as increasing water requirements in Angola**
Extent of marginalised users	**NGO activity has promoted the users of Botswana communities, and the war in Angola has largely kept the focus off integrated water management, but given the condition of the rural poor in Africa generally, it is likely that most users of the Okavango basin are unrepresented**
Effect on state and local user relations	**State relations are under pressure from Namibia's threat of international litigation. The Okavango Liaison Committee is separated from the OKACOM process and could create potential conflict**

[1] Mohammed-Katerere, J. 2001. *Review of the Legal and Policy Framework for Transboundary Natural Resources Management in Southern Africa*. Paper 3: IUCN-Regional Office of Southern Africa Series on Transboundary Natural Resource Management in Southern Africa [Online]. Available at: http://www.iucnrosa.org.zw/tbnrm/publications.html. [Accessed: 12 August 2002] at 47.
[2] Anon. 2002. *Sharing Water: Towards a Transboundary Consensus on the Management of the Okavango Delta*. Unpublished Proposal by The Natural Heritage Institute and the World Conservation Union (IUCN): Regional Office for Southern Africa (ROSA) at 2.
[3] *Every River* Project Team. 2001. *Every River has its People: Stakeholder Workshop Report.* Kalahari Conservation Society. Maun. Botswana at 3.

BASIN	OKAVANGO RIVER
Comment	**Potential conflicts resulting from unplanned abstraction in Angola and development in Namibia will put pressure on OKACOM. The agreement highlights "the need to redress the respective rights of state and citizens"**

Source: Tomkins 2003

4.4.6 World Commission on Dams

The World Commission on Dams (WCD) was set up in 1997 with support from the World Bank and the IUCN to review the development effectiveness of large dams, assess alternatives for water resources and energy development, and to develop internationally acceptable criteria, guidelines and standards, for the planning, design, appraisal, construction, operation, monitoring and decommissioning of dams. The output of the Commission was a set of research reports on case studies, rather than a convention.

Classification and Ecological Impacts

According to the International Commission on Large Dams, a large dam is defined as having**:**

- **a height of 15 m or more (from the foundation), or**
- **a height of 5-15 metres and have a reservoir volume of more than 3 million m^3.**

The same definition was also used by the WCD. According to this classification, the proposed weir for the Popa Falls Hydro Power Project would be a large dam (height 7.5 – 9.75m and volume 16.7 – 24.4 million m^3).

Many of the findings of the WCD are relevant to Popa Falls. The WCD found that the impacts of large dams included: -

- the loss of forests and wildlife habitat,
- the loss of species and the degradation of upstream catchment areas due to inundation of the reservoir area,
- the loss of aquatic biodiversity, of upstream and downstream fisheries, and of the services of downstream floodplains, wetlands, and riverine ecosystems,
- cumulative impacts on water quality, natural flooding and species composition where a number of dams are sited on the same river.

On balance, the ecosystem impacts are more negative than positive and they have led, in many cases, to significant and irreversible loss of species and ecosystems. In some cases, however, enhancement of ecosystem values does occur, through the creation of new wetland habitat and recreational opportunities provided by new reservoirs.

Measures to mitigate these ecosystem impacts have so far met with limited success. For example: -

- It is not possible to mitigate many of the impacts of reservoir creation on terrestrial and aquatic ecosystems and biodiversity,
- Fish by-passes to mitigate the blockage of migratory fish has had little success,

Socio-economic Impacts

The Commission also found a number of social impacts of dams, including: -

- People living downstream from dams have suffered serious harm to their livelihoods and resources on which they depend, such as fish,
- Adverse health impacts of dams are common,
- Compensation was often inadequate, and did not address the need for social development of the displaced people to replace subsistence livelihoods that had been affected,
- The poor, disadvantaged groups, and future generations often bear a disproportionate share of the social and environmental costs of large dams without gaining a commensurate share of the economic benefits,
- The social and environmental costs of large dams were often not weighed up against the benefits, giving a false impression of the net benefits of the projects.

In **summary**, the Commission found that: -

- The benefits of large dams were frequently overestimated at the planning stage,
- The environmental impacts of dams were usually underestimated and many impacts were not anticipated,
- Measures to mitigate adverse environmental impacts were seldom adequate.

5 THE PUBLIC PARTICIPATION PROGRAMME

5.1 Description of the Public Participation Programme (PPP)

A comprehensive Public Participation Programme (PPP) was carried out at an early stage in the Preliminary Environmental Assessment process in order that the concerns of interested parties, authorities, and the wider public could be established. The main purposes of the PPP were to: -

- introduce the project proposal,
- explain the PPP and environmental assessment processes,
- hear and record public issues and concerns,
- provide opportunities for public input and gathering of local knowledge.

By eliciting the concerns of Interested & Affected Parties (I&APs) the study aimed to address these concerns in the environmental assessment process – along with issues raised by the environmental specialist team.

Eco.plan undertook the PPP in Namibia, while an independent environmental consultant, Ecosurv, who are based in Botswana, undertook a parallel programme in that country.

The following activities were carried out as part of the PPP.

- The project was advertised in the Namibian press - The Namibian, The Republikein, and the Algemeine Zeitung on 24 January 2003. In Botswana, the meetings were advertised in The Ngami Times two 2 weeks prior to the meetings.

  These advertisements invited people to the public meetings, and to register as Interested & Affected Parties (I&APs).

  An earlier press release by NamPower was published in a national newspaper on 12 December 2002, also helped to draw public attention to the project and the PEA.

- The meetings at Divundu and Rundu were also advertised on NBC radio, and A4-sized adverts were also put up in public places in and near Divundu.

- Known individuals and groups / organisations were also contacted directly by letter, fax or email to draw attention to the project and the PEA study.

- Public meetings were held in Namibia and Botswana to introduce the project, and to hear and record public concerns. These meetings took place as follows: -

  - Windhoek, NamPower Convention Centre, 04 February 2003,
  - Xaxanaka, a campsite in the Okavango Delta, 10 February 2003. This meeting was held with a group of scientists at the invitation of Conservation International. The scientists were conducting an “Aquarap” – a rapid assessment of ecological conditions in the Delta as part of a long term monitoring programme.
  - Maun, 11 February 2003. Two meetings were held in parallel. One was conducted in English at the Sedia Hotel, and another was conducted in Setswana at the Kgotla.
  - Divundu, Frans Dimbare Youth Centre, 12 February 2003,

- Rundu, Namibian Development Corporation, 13 February 2003. Rundu is the seat of the Kavango Regional Council – the region in which the project site is situated

- Short information sheets were distributed at all the meetings. Contact details were also provided for written responses.

- Minutes of the public meetings were circulated to those who attended, and to any other parties who had registered as I&APs.

- Letters were also sent to various authorities in Namibia and Botswana, providing them with an opportunity to express their view or concerns. In some cases these were followed up with meetings to gather information or hear issues and concerns: Ministry of Environment & Tourism, Ministry of Agriculture, Water & Rural Development (in Namibia). These consultations included government and tribal authorities in Botswana (refer to **Appendix F and G**).

- Informal consultations with specialists outside of the project team were also held in order to gather information, and to assist in assessing potential environmental impacts. Thus, in cases where there was some doubt about the magnitude or significance of impacts, input from a wider body of knowledgeable people was sought.

- A Summary of Issues & Concerns was also circulated with the minutes. I&APs were invited to respond if they felt that their issues or concerns were not adequately reflected in the summary.

Supporting documents on the Public Participation Process are contained in the Appendices as follows: -

- the advertisements in the Namibian press are contained in **Appendix B**,
- meeting presentations are contained in **Appendix C**,
- minutes for Namibia are contained in **Appendix D**,
- correspondence is contained in **Appendix F**,
- a list of Namibian participants is contained in **Appendix E**,
- A comprehensive report on the PPP activities in Botswana is contained in **Appendix G.** This includes a list of participants in Botswana. It also provides certain **recommendations** regarding the environmental assessment process.

The results of the public participation programme are contained in the following section.

5.2 Results of the PPP / Issues & Concerns

5.2.1 Preface

In this section, the outcomes of the Public Participation Programme are presented. This section serves as a record of issues and concerns that were raised by I&APs. It must be emphasised **that the issues and concerns are presented as they were raised by participants** and do **not** constitute an assessment of these issues. The assessment of these issues is provided in section 7.

The purpose of presenting the issues raised by participants in this section is simply to: -

(a) ensure transparency regarding the concerns that have been expressed,
(b) provide a list of issues that needed to be considered during the Preliminary Environmental Assessment (or full EIA).

Further issues were also raised during the specialist studies, literature reviews and professional investigations. All of these concerns are addressed in this report at a level of detail that is appropriate to a Preliminary Environmental Assessment. Those issues that require more in-depth assessment will be further investigated during the full Environmental Assessment during the full Feasibility Study, if the project proceeds to that stage.

For convenience the issues and concerns raised are divided into **bio-physical issues**, **socio-economic issues** and **issues related to the planning and decision-making process**. This distinction is somewhat arbitrary and a degree of overlap between these categories is acknowledged. For example, many of the potential socio-economic impacts are secondary impacts that could result from ecological impacts (e.g. if ecological degradation occurred, it could result in impacts on subsistence fishing or tourism).

5.2.2 Bio-physical Issues

Water

- Extent of the impoundment?
- Backing up of river upstream – during normal operation and floods?
- Altered hydrograph: pulses or dampening of the hydrograph.
- Will river flows be regulated? What implications will there be to the hydrograph?
- Will the gates in the weir be closed at any stage– thus stopping the flow downstream?
- How much water is needed to fill the weir?
- How long will it take to fill the impoundment?
- For how long will flow be restricted in the river while the impoundment is filled?
- Can a simple flow-of-the-river power plant be installed that does not interrupt natural flow and sediments?
- Any reduction in flow or flow rate at Mohembo would be of concern.
- Loss of delta water due to groundwater seepage and evaporation in the impoundment.
- Will the project affect water quality or cause pollution (e.g. by lubricants in the machinery)
- Will water temperature be affected?
- Abstraction of water for irrigation could reduce the water available for power generation.
- Will secondary developments that have impacts occur once the dam is developed? e.g. irrigation, extraction of water

Sediment

- Sediment supply is vital to the functioning of the Okavango Swamps and the wetlands from Popa Falls downstream. If that supply was reduced or interrupted there could be severe ecological impacts on these ecosystems.
- Bedload sediment transport will be interrupted. Sediment is known to be a critical process in maintaining the Delta ecosystem.
- Sluicing could result in a “plug” of sediment going through that may block the channel below the falls or even form a “mini-delta”.
- The process of flooding and sediment transport is important for development of sandbars and the breeding of certain animal and bird species.

- Are there any examples of weirs designed that allow for successful transport of sediments? Concern that the Okavango system should not be used for experimentation, as it is such an important wetland.
- Increase in sediment from construction and erosion could be deposited downstream.
- There is currently little understanding of sediment flow through the Popa Falls system.

Erosion

- To the extent that sediments are trapped behind the weir, there would be net erosion downstream.
- Removal of sandbanks and deepening of the channel downstream could make the channel more efficient and therefore reduce the extent of flooding of the seasonal wetlands on either side.
- Destruction of the sand-forest islands in the weir impoundment as a result of raised water level.

Flora & Fauna

- Impacts on birds breeding on sandbanks – e.g. African Skimmers
- Impacts on birds such as Rock Pratincoles at the Falls and other rapids upstream that could be drowned out.
- Are any important fish breeding areas affected?
- Will a change from flowing shallow water to stiller, deeper water have any ecological impacts?
- Sediments are home to aquatic invertebrates. These could be adversely affected by alterations in sediment flow – e.g. regular smothering.
- Biodiversity issues need to be investigated.
- Diversion of water during construction or operation may affect the movement of aquatic or terrestrial animals.
- Won't the flow-current affect the living organisms (such as amphibians and fish) and their breeding areas?
- Any reduced flooding in the wetlands (Mohembo and downstream) could have impacts on birds, fish & animals that use the wetlands.
- Even minor alterations to the natural flow regime could have significant ecological impacts.
- How will fish etc get past the weir?
- The islands upstream are unique habitat in Namibia.

Sustainability

- If the river level falls due to developments in the catchment of Angola or Namibia, will this affect the viability/ sustainability of the project in future?
- Degradation in the catchment could threaten the water resources and thus the long term viability of the project.
- The impacts may not be apparent today but may happen gradually over time.

Other

- Powerline routes – visual impacts and birds.
- Borrow pits for building materials could destroy important vegetation.

5.2.3 Socio-economic Issues

Livelihood & Local Economics

- Compensation for resettled people. How will people be consulted, and compensated?
- To what extent will the youth be involved in the project, e.g. through provision of employment opportunities?
- Will the local people benefit from employment opportunities, rather than imported labour?
- Will the project affect grazing of livestock, fish resources and croplands?
- Rural livelihoods of people downstream, particularly the poor, would be most affected by any changes in flow regime.
- All livelihood activities in the area are dependent on the Okavango, of which any disturbances to the system may affect the activities. This is a primary concern for people living downstream – both those who make a subsistence livelihood from the river, and those who are dependent on tourism.
- Seasonally flooded floodplains within the impoundment, if permanently flooded, will affect livelihoods.

Tourism

- Visual impacts affecting tourist facilities: e.g. Suclabo Lodge, Popa Falls Resort and N//goabaca Community Run Campsite.
- All aspects of tourism should be taken into account: walking, boating, birding etc.
- Vibrations and noise from the turbines.
- Secondary impacts as a result of ecological degradation.

Cultural

- Inundation of graves, cultural or archaeological sites
- Effects on people living next to and using the river.
- Social disruption and altered lifestyle if people are removed.

Health & Safety

- Influx of workers and implications for the spread of HIV / AIDS
- Any increased bilharzia or malaria?
- Construction staff could be vulnerable to attacks by crocodiles or hippos.
- There are also landmines in the area that may affect off-duty staff who are unaware of this risk.
- Socio-political issues between the San people who run the campsite and the Mubukush people.

Equity (distribution of costs and benefits)

- Studies should consider the number of people to benefit from the power and those detrimentally affected by the development of the project.
- Net benefit analysis will not fairly include impacts to the Delta system.
- Concern that Namibia, would receive all the benefits while Botswana, downstream, would absorb all the impacts.
- How could the local people afford electricity?

Other

- MFMR are building a Fisheries Research Institute in the same area. Is there a possible conflict?
- Would the project bring down electricity prices?

5.2.4 Issues related to the Planning & Decision-making Process

- Further details of the project should have been made available before the meetings. [It was explained that this was not possible as the project proposals were still being developed.]
- Would alternative power sources be studied as part of this pre-feasibility study?
- Wind power (e.g. at Lüderitz) would have fewer environmental impacts.
- Have other alternatives such as wind power been considered?
- Have alternatives such as solar power been considered?
- The cost-benefits of this scheme vs the cost benefits of wind power.
- The cost of alternative "low impact" power generation vs the cost of Popa Falls Project.
- What would be the impact on the national electricity supply grid?
- Is it proposed to sell power to neighbouring countries, or use it only for Namibian consumption?
- Is there sufficient justification for building the dam?
- Have there been any considerations to use other rivers such as the Zambezi?
- NamPower could explore possible use of the coastal water rather than the Okavango.
- "Engineering solutions are never able to fully alleviate impacts to natural processes such as sediment transport".
- At a "key stakeholder meeting" at the National Conservation Strategy Co-ordinating Agency (NCSA) in Gabarone (20 March 2003) it was stated that the Botswana delegation at OKACOM (July 2002) had asked that Namibia undertake a detailed assessment of alternatives to the Popa Falls project. There was concern that this had not happened except on a simple cost per unit basis – which did not take into account environmental costs.
- With Popa Falls being able to produce at most only 30 Megawatts, what justification is there for constructing the station upstream of a wetland of international importance?
- There may be other more acceptable options that would not have an impact on the Ramsar site. There is a need to seriously consider alternatives.
- Ramsar should be involved in the process of reviewing the PEA.
- Can the powerline from RSA provide all the foreseeable Namibian power requirements?
- The potential cost of impacts to the Okavango Delta (that cannot be accurately quantified in the EIA) may make the Popa Falls scheme non-viable compared to other options.
- How will future developments be taken into account?
- Secondary impacts such as availability of power leading to other developments – e.g. irrigation.
- Cumulative impacts with other developments. Some new activities may start as a result of the power supply.
- Additional spin-off developments that become possible indirectly due to the project development (e.g., irrigation) need to come into the EIA.
- Which proposed developments should be brought to the attention of the project team?
- How will the people be notified if they are to be displaced by the weir impoundment?
- Impact on the Game Park east of the Divundu-Popa Falls area? What is the policy re developments like this in Game Parks?

- Does the electricity output from the scheme justify the environmental impacts and risks?
- Consultation with local people who are directly affected is needed.
- The manner of compensation for adversely affected parties needs to be negotiated.
- When does an issue become a fatal flaw? How are issues weighed against each other? One needs the evaluation criteria to be transparent.
- What criteria will be used to make the final decision?
- Liability for impacts needs to be made clear in the PEA documentation.
- The decision making process for acceptance of the PEA to proceed to the feasibility and design stage is not clear, and appears to lie entirely within Namibia. The decision to proceed should lie with OKACOM.
- What is the sustainability of the project in terms of the lifespan of the weir, and other installations?
- How could water transfer from rivers to the north (e.g. the Congo River) affect the Okavango River and the Popa Falls project?
- Has the bigger basin potential being considered? We need an Okavango basin plan and Strategic Environmental Assessment (SEA). The OKACOM initiated Global Environmental Fund (GEF) funded Okavango Basin Study is only partially complete. Why is Namibia not willing to wait for its outcome before proceeding with unilateral planning.
- Have Angola's requirements been considered?
- Where does SADC feature in the planning?
- What process will be used to incorporate environmental impacts and costs felt in a downstream country?
- If there is a need to increase the height of the weir later, will another EIA be commissioned?
- The EIA appears to be focused on Namibia. Okavango Delta impacts should be included in the full EIA.
- There is a need to study the whole Okavango system and understand it before planning any developments on the system.
- Why is the consultation limited to Maun, whereas the most affected are the people in Mohembo and Shakawe
- Concern for transparency in the EA process.
- Where has this type of development worked? Is it not unwise to experiment with a very fragile system like the Okavango?
- Concern that the Okavango Swamps may be drying up naturally. If this is true then Nampower may be throwing away their money.
- The consulting team (for the next stages of the investigations) should have representatives from Botswana and Angola, to ensure a consideration of all the concerns.
- Does the PEA study extend to Botswana?
- Will the concerns identified here at this meeting be addressed in the PEA and full EIA?
- There is a need for a risk assessment on the environmental impacts of possible failure of the weir to transport bedload sediments.
- Will the concerns of Ramsar and the Government of Botswana be fully taken into account?
- Timeframe of the PEA and proposed EIA is too short to bring in the scale of the problem. Comprehensive identification of impacts on the delta may take longer.
- Insufficient time for the PEA and EIA to address all concerns.
- Cumulative impacts from other (secondary and spin-off) developments relating to the hydro power scheme need to be considered.
- Would the Namibian government proceed with the project even if NamPower advises against it?

- Concern that there may be pressure on Botswana (from South Africa) to accept the hydro power development at Popa Falls.
- Need to include Botswana proposed developments and their impacts on the Delta if considered as cumulative impacts (these include proposed village water supply proposals by Dept. of Water Affairs, Botswana).
- Some of the participants expressed scepticism about the EIA process and their ability to influence the outcome.
- NamPower is in the business of sale of electricity; can we believe their commitment to stopping the project if there are unacceptable environmental impacts?
- If there are impacts in the future, that were not identified, how will we deal with these and associated costs? Are these costs brought into the decision making process and will NamPower be willing to accept liability for these impacts?
- Concern that Namibia may go ahead regardless of Botswana's concerns.
- Will NamPower please get back to the participants to inform them of the results before the pre-feasibility decisions are finalised?
- Will the concerns identified in this (Maun) meeting be addressed in the PEA?
- Will the environmental and social costs felt by Botswana be included in the EIA analysis?
- Botswana should have an opportunity to comment on the TOR for the full EIA.
- A decision to accept the findings of the PEA and to proceed should be done through inter governmental discussions at a country-to-country level.

5.2.5 Requests and Comments arising from the Public Participation Process in Botswana

A number of requests and concerns were expressed to Ecosurv during the public participation in Botswana. These gave rise to the following summary by Ecosurv (Appendix G).

- ♦ At the Feasibility stage a strategic assessment of the Okavango Basin is requested. This assessment would need to take in cumulative impacts of other water-related developments.
- ♦ Alternatives do exist for power supply; e.g. the upgrade of the Livingstone line and a link to the Namibian grid. With such alternatives available it will be difficult for an EIA to accept any significant environmental impacts to a wetland of international importance. It is requested that greater attention should be given to green alternatives. Britain has just committed itself to providing 20% of its total electrical power from green alternatives.
- ♦ The burden of proof, that the hydropower facility will not interrupt sediment flow, will lie with NamPower: examples of sediment transport mechanisms that work, guarantees of success, and commitment to decommissioning if the approach is shown to cause unacceptable impacts is requested.
- ♦ Commitment to a full and fairer (from a Botswana viewpoint) EIA is requested. The EIA would need to include a cost-benefit analysis that takes into account a scenario in which sediment transport is interrupted.
- ♦ It may be necessary to suggest that an external audit of the EIA is carried out by the Harry Oppenheimer Okavango Research Centre (HOORC).
- ♦ The public requested an additional public meeting in Maun to outline the results of the PEA.
- ♦ Regardless of the quality of the PEA, if it comes out with a positive conclusion, it is unlikely to be accepted. The public and government are very possessive over the Okavango Delta and will strongly oppose developments that may impact on it.
- ♦ There is a strong feeling in Botswana that Namibia is jumping the gun by not awaiting the output of the basin studies commissioned by OKACOM.

As mentioned in the preface to this section 5.2.1, the contents of this section (above) represent the issues and concerns expressed by I&APs. These views have been presented as a record of the Public Participation Process – preceding any assessment of these issues and concerns.

It should also be noted that, at the time of the public meetings, the project proposals were still being developed, and options for mitigation of potential impacts were still under consideration. During the public participation for the full EA it will be possible to provide more details on the project alternatives, impacts and mitigation – based on this PEA report.

6 THE PROJECT ENVIRONMENT

Photos of the study area are shown at the back of this report.

6.1 Climate

6.1.1 Sunshine, Radiation & Temperatures

Intense solar radiation, erratic low rainfall, little cloud cover, and high temperatures are characteristic of the climate of Namibia throughout the year but especially in the summer months.

The Popa Falls area is situated at about 18° South latitude and is thus well within the tropics.

Over Namibia as a whole, the average values for solar radiation range from 5.4 to 6.4 kWh/m^2/day. In the Popa Falls area, this figure is 6.0 to 6.2 kWh/m^2/day. Except along a narrow coastal margin, Namibia receives an annual average of 8 to 11 hours of sunshine per day. For the Popa Falls area, the average is 8 to 9 hours per day. This has relevance for solar power potential.

The annual average temperature in the Popa Falls area is more than 22^o Celcius. The average maximum temperature during the hottest month (October), is between 32^o and 34^o C. The average minimum temperature during the coldest month (July) is between 4^o and 6^o C. Frost is unusual with an average occurrence of 1 to 5 days per year. (Mendelsohn *et al,* 2002)

6.1.2 Rainfall, Humidity and Evaporation

The northeastern regions of Namibia receive, on average, the highest rainfall. However, rainfall is unreliable and unpredictable. Agriculture is therefore limited without irrigation. In the Popa Falls area, the median (i.e. the most frequent) and average annual rainfall is between 550 and 600 mm/year.

The average humidity in the Popa Falls area is between 10 and 20% in the least humid month (September). In February, the most humid month, the humidity rises to 80 or 90%.

Evaporation rates are high, and highest during the summer months before the rains begin. The average evaporation rates (for open water evaporation) in the Popa Falls area are from 1,820 to 1,960 mm/year.

Tyson identified an 18 year oscillation in rainfall over the summer rainfall regions of southern Africa (cited in McCarthy *et al,* 2000). This means that 9 years are drier than average, followed by 9 years that are wetter than average. The 1960's saw below average rainfall, the 1970's above, the 1980's below average etc. The significance of an oscillating rainfall and runoff regime is that the assessment of environmental impacts based on short term measurements (e.g. sediment transport) need to be interpreted with caution.

6.1.3 Winds

No site-specific data are available for wind speed and direction. The nearest available data is for Rundu. The following information has therefore been based on data for Rundu, but also taking into account data for Katima Mulilo (from Mendelsohn *et al,* 2002).

Wind directions are very variable, but winds from the north-east, east, or south-east are experienced most often. Calm conditions are frequent – probably about 45 - 50% of the time. Wind speeds are generally low. The lowest wind speeds are usually experienced during the evenings and early mornings. Wind speeds typically rise to their maximum daily level around 14h00. The average speeds for this time of day range from about 10 – 14 km / hour throughout the year, with the averages being at the higher end of this range in summer.

6.2 Geology, Soils & Topography

The catchment of the Okavango River is composed mainly of deep Kalahari sands of aeolian (wind-blown) origin. These fine sands accumulated during earlier climatic conditions when the desert extended far further north into Angola and Zambia. The wind-blown sand was well sorted by wind and consists of particles mainly in the size range 0.2 – 0.4 mm. These fine sands cover 80 – 90% of the catchment, right up into the central areas of Angola.

Soils along the Namibian portion of the Okavango River are broadly classified as Ferralic Arenosols – i.e. having high contents of combined oxides of iron and aluminium, and being of wind-blown origin (Mendelsohn *et al,* 2002). However this broad classification covers many local variations. The most fertile soils tend to be close to the river, where the increased percentage of finer particles improves the water retention and fertility of the soils. Most agricultural activities are therefore situated close to the river.

The topography of the northeastern Kavango Region reflects the wind-blown origins of these deposits and comprises dunes that have been stabilised by vegetation. Within the Kavango Region, the soils on these dunes are poorly developed. The fertility of these soils is maintained by nutrient recycling by plants and is susceptible to disturbance by removal of the natural vegetation.

Where the Okavango River follows the Angolan border, and along the Cuito River in Angola there are extensive floodplains in parts, which provide temporary “storage” of water during the annual flood periods – releasing water slowly back into the main channel. However, in the section from the Angolan border (north of Mukwe) to Popa Falls, the Okavango River has incised into the aeolian dunes. Ridges of quartzitic rock have been exposed as a result. The most prominent of these forms Popa Falls, but many other outcrops form riffles and rapids between Mukwe and Popa Falls. Notwithstanding these rapids, the river gradient is very low. The top of Popa Falls is at 1,000 m.a.m.s.l. The steepest section which may be affected by the proposed scheme is from the Angolan border to just upstream of the Divundu bridge. This has a gradient of the order of 1: 1,000 (or 0,09337% - K.Lund, WTC, pers comm). From the Divundu bridge to Popa Falls the gradient is much less as the falls act rather like a natural “weir”. The gradient in this section is of the order of 1: 10,000 (or 0,00961%).

In the section from Mukwe to Popa Falls, and particularly upstream from Divundu, the main channel splits into smaller channels – forming a number of islands. The splitting up of the channels appears to be controlled by the existence of ridges of rock (quartzitic sandstone). Some of the islands are composed of Kalahari dune sand, and in some cases they also have a base of rock. The islands are believed to be residual aeolian dunes – having been left behind as the River incised its course (Kinahan, pers comm, and Hines (April, 2003)). Other islands, with quartzite bases, appear to have been formed through the slow accumulation of alluvial deposits, and contain more clay material mixed with sand.

From Mukwe to Divundu there are no extensive wetlands. Below Popa Falls, the topography changes. The gradient becomes flatter and extensive floodplains occur. The start of extensive floodplains near Bagani marks the topographic transition to the "Panhandle" of the Okavango Delta.

6.3 Tectonic Activity and Seismicity

Information on tectonic activity and seismicity comes mainly from the Okavango Delta, which lies within a fault-bounded trough. McCarthy *et al* (2002) have described the relationship between faulting and sedimentation in the Delta and Panhandle areas. The Panhandle also occupies a minor fault zone that may represent a graben structure, with its apex at Popa Falls.

McCarthy *et al* (2002, Figure 2C, p.182) shows the distribution of seismicity in southern Africa. A distinct cluster of seismic records is evident in and around the Okavango Delta. Local seismicity may be caused by sediment loading and/or regional tectonic activity.

McCarthy *et al* (1993) analysed available seismic data for the area between 22°E and 24°E, and from 18°S to 20.5°S for the period 1951 to 1992. A total of 109 seismic events exceeding a magnitude of 2.7 were recorded during that period. The highest magnitude on record for that period was 6.7 on the Richter Scale. Popa Falls is approximately 50km from this zone.

Seismicity may be of relevance to the proposed hydro power project in two ways.

Firstly, a risk assessment would be necessary to confirm that the structural integrity of a weir would not be affected. Kikjo (Council for Geoscience, Pretoria – pers comm) has recommended that a seismic risk assessment would be necessary for the construction of a weir in the Popa Falls area. The Council for Geoscience is also able to provide input concerning design requirements for a weir in relation to seismic risks.

Secondly, the distribution of water in the Okavango Delta has varied enormously over recent decades. Various hypotheses have been put forward to account for this. One hypothesis is that seasonal water-loading could result in seismic events. However, McCarthy *et al* (1993) found that there was no correlation between seismic events and seasonal water loading. They also cited studies of dams that indicated that water depth was a factor in seismic events in dams – however, the water depth in the Delta generally varies within a range of only one metre. So this hypothesis must be discounted. A second hypothesis is that tectonic movements related to regional faulting or warping could cause shifts in the distribution of water over time (Wilson, 1973 and McCarthy, 1993). A third hypotheses is that the deposition of sediment in channels results in channel beds being raised until they are above the surrounding swamps. Channel failure then results in redistribution of water (McCarthy *et al,* 1993) There is a large body of evidence that supports the latter hypothesis. The Okavango Research Group at the University of the Witwatersrand has produced a number of research papers from 1986 to 1993. While regional tectonics may have some influence on water distribution over time, the evidence points to the role of sediment accumulation in channels as the dominant factor in changing the distribution of water across the delta. This process is explained by McCarthy in the specialist report produced for this PEA study (McCarthy, July 2003 – which is contained in **Appendix L** to this report.)

6.4 Flora (Terrestrial)

A brief field survey of flora was undertaken by C.Hines, for Eco.plan from 7-9 March 2003. This survey was supplemented by available published material and the personal experience of the author in this area over many years. The contents of this section follow the report by Hines (April, 2003). Detailed orthophoto maps were used to assist in the characterisation of vegetation types, but no mapping of vegetation could be undertaken at this preliminary investigation level. Likewise it was not possible to produce an exhaustive inventory of the plants in the area. The south bank of the river and some of the islands were accessed by boat, vehicle and on foot. The area north of the Trans Caprivi trunk road and east of the river could not be accessed due to the presence of landmines.

The study area comprised 2 distinct sections: -

- The areas to be inundated by the weir site alternatives between Mukwe and Popa Falls.
- The areas downstream from Popa Falls to the Botswana border.

The vegetation of the study area is characterised by species common to a wide area of southern Africa, associated with the Kalahari sands of Namibia, Botswana, Zimbabwe, Zambia and Angola. However, along the river the vegetation comprises more tropical species and the riparian habitats are regarded as unique within a Namibian context, even though the majority of species have extensive African distributions. The islands in the Mukwe to Divundu area are regarded as being the most interesting and important in terms of unusual species in Namibia and a number of threatened species are found in this area.

The vegetation of the study area has not been particularly well researched with the only published work being that of Hines (1996) from the Mahango Game Park area. The wetland habitats in the downstream section are typical of the Okavango system as a whole.

6.4.1 Vegetation types impacted by the impoundment

Terminalia sandy islands

In the Mukwe to Divundu section of the river there are numerous islands of different sizes characterised by a cover of large trees normally associated with the Kalahari sands on either side of the river. Refer Photo 15. It is thought that these islands represent remnants of Kalahari dune sands, which have not been reworked by alluvial action. The characteristic species are *Terminalia sericea*, *Guibortia coleosperma*, *Burkea africana*, some small examples of *Pterocarpus angolensis* and shrub species such as *Bauhinina petersiana*, *Acacia fleckii*, *Baphia massaiensis* and *Croton grattissimus*. All of these species are typical of the extensive Kalahari woodlands in the area. There are few species of conservation concern, with the exception of *Pterocarpus angolensis* (Vulnerable) which is sparsely distributed on these islands. The islands are however, regarded as unique in the Namibian context and as such have a high conservation value.

These islands will undergo major changes if they are inundated by the weir. It is likely that many of the large woody specimens will drown and die off. There will probably be severe erosion of the sand deposits on the islands, particularly if the water level is allowed to fluctuate, and particularly during above-average peak flow events. The islands will probably be colonised in time by species such as *Syzygium guineense* and reeds once inundation has taken place. The likelihood of this happening is high and the resulting change will be long term.

Depositional islands

Refer Photo 16. This vegetation type is noticeably different from the Terminalia sandy islands discussed above. These islands are based on the quartzites of the area but have been formed through the slow accumulation of alluvial deposits. The soils are generally clays with a high fraction of sand. Some saline accumulation is noticeable on some of these islands. The formation of these islands is thought to take place in much the same manner as the wooded islands in the lower sections of the Okavango which is well described in Ellery, McCarthy and others (Okavango Research Group Volumes 1-5 (1986 – 1998)).

The vegetation is dominated by species often found in the riparian fringe forests and as such are floristically most closely related to this type. The wettest margin of the islands is characterised by species such as *Syzygium guineense*, the palm *Phoenix reclinata*, *Rhus quartiniana* and *Myrica serrata*, with patches of reeds and hydrophytic grasses being common on shallower soils. The main forested sections are dominated by species such as *Parinaria curatellifolia*, *Piliostigma thonningii*, *Garcinia livingstoneii, Acacia nigrescens*, usually with an understorey characterised by *Friesodielsia obovata*, *Combretum mossambicense* and other scandent climbers.

This vegetation type is thought to be particularly species rich and contains a number of restricted range species in Namibia, including several orchid species (*Bonatea steudneri* – Critically endangered, and *Habenaria epipactidea* – Vulnerable). These islands are not common in the inundation area and if flooded will represent a significant loss of biodiversity in a Namibian context.

These islands, representing unique habitats on the Okavango River and in Namibia, are important for biodiversity in a Namibian context. Most of the species on the islands will die as few are tolerant of prolonged inundation. Replacement of woody elements will probably be by species such as *Syzygium guineense* and *Phragmites* reed beds. Change will be permanent and the likelihood of recolonisation by the current species assemblage will be unlikely. These islands will probably be eroded by wave wash and slumping if inundated.

Riparian fringing forests

Refer Photos 5 & 9. The Riparian fringing forests are very similar to the Depositional Islands described above, but tend to be dominated by a different set of species such as *Acacia nigrescens*, *Diospyros mespiliformis*, *Combretum imberbe*, *Terminalia prunioides*, *Kigelia africana* and shrub species such as *Pavetta zeyherii*, *Combretum* spp. and *Grewia* spp. The sites are slightly drier than the Depositional Islands and this may explain the species changes. In some areas, where there are saline deposits the vegetation is dominated by the palm, *Hyphaene ventricosa*, but this type is commonest in the lower sections of the river near the Botswana border, well outside the inundation zone.

Much of the fringing forests, on the west bank, are severely degraded through cutting and clearing for subsistence agriculture (e.g. Photos 7 & 8) but there are still mature tracts of woodland left in the area near Andara (Photo 12).

Inundation will undoubtedly kill most of the species present here with the consequent replacement by flood tolerant species such as *Syzygium guineense*. The few remaining patches of riparian forests in reasonable condition would be a loss in terms of biodiversity as this habitat is regarded as species rich in a Namibian context. The protea *Protea gauguedi* was recorded in this area in the past, but is now thought to be extinct in Namibia.

Dry quartzite ridges

This vegetation type is common along the margin of the river where the main quartzitic "dykes" lie across the river and up the adjoining slopes. Soils are generally shallow sands lying between the bands of quartzite. These sites may not be directly influenced by water levels in the river and are considerably drier than the adjacent riparian fringing forests.

The vegetation is characterised by species such as *Lannea discolor*, *Crossopteryx febrifuga*, a number of *Grewia* species, *Tinnea rhodesiana*, *Combretum celastroides*, *Terminalia prunioides* and the rare *Terminalia stuhlmannia*. Large baobabs, *Adansonia digitata* are associated with this vegetation type as are isolated examples of *Sclerocarya birrea*, *Berchemia discolor* and the python vine *Fockea multiflora*.

The inundation of this habitat will be limited as only a small percentage of the total extent will be flooded by the projected flood levels. There are some species of conservation concern within this type (*Eulophia* orchids) but as such a small percentage will be lost to inundation, this is not thought to be of any significance.

Upslope Kalahari sands

The Upslope Kalahari sand vegetation type is widespread and dominates the landscape away from the immediate influence of the river. In some limited areas along the river margin this vegetation type comes down to the river's edge and will be inundated following the construction of the impoundment. Soils are deep, dystrophic Kalahari sands, which have not undergone any major reworking by alluvial action, except perhaps on the margins of the river.

Characteristic species include *Baikiaea plurijuga*, *Burkea africana*, *Erythrophleum africanum* and *Terminalia sericea*. The shrub layer often contains species such as *Bauhinia petersiana*, *Baphia massaiensis* and the suffrutex *Diospyros chamaethamnus*. These are widespread, common species throughout the region and are of little conservation concern.

Very little of this habitat type is likely to be flooded and any loss to inundation is not considered to be significant.

6.4.2 Vegetation types in the downstream areas

Figure 3 shows the extensive wetlands that begin near Bagani and broaden out downstream. Refer Photo 19. Vegetative communities are considered here as there is potential for the project to impact upon them. In the event that sediment was trapped behind the weir, or the hydrograph was affected, e.g. during sluicing operations, these areas downstream could be affected in one of two ways. Firstly, existing sandbars and vegetated islands could be lost through erosion. Secondly, potential deepening of the river channel would result in a reduction of the extent and/or duration of seasonal flooding of the floodplains and seasonal grasslands.

Sandbars and Islands

This vegetation type is characterised by alluvial sand deposits covered by *Phragmites* sp. reeds with isolated patches of woody species such as *Rhus quartiniana* and *Myrica serrata*. There are no plant species of any conservation concern on these islands, but they represent important breeding habitat for birds and reptiles.

Seasonally inundated grasslands/wetlands

The seasonally inundated grasslands and wetlands associated with the Okavango River are particularly common and well developed in the Mahango Game Park where the floodplain of the river is at its widest in Namibia. Refer Photo 19. There are a number of different types of inundated grasslands and wetlands in the area. These include:

- *Cyperus papyrus* is the characteristic dominant of this association and is generally found together with the fern *Thylypteris interrupta* and *Ipomoea rubens*. Certain floating leafed macrophytes such as *Najas pectinata, Nymphaea caerulea, Ottelia ulvifolia, Rotala* sp. and *Trapa natans* often form dense mats around the papyrus beds, but are generally rooted in the substrate below the papyrus.
- *Echinochloa stagnina* and *Vossia cuspidate,* which form tall, dense floating grassmats, are typical of the seasonally flooded areas of the floodplain and are most extensive between the mouth of the Mahango Omuramba and the Giant Baobab. This vegetation type is restricted to those areas with relatively heavy alluvium, which dries out and floods annually. It is absent where the frequency of flooding is irregular.
- Extensive areas of sedge-dominated (Cyperaceae) seasonal swamps occur throughout the park, but are best developed in the lower reaches of the Mahango Omuramba and in certain backwater areas in the Buffalo Section, near the Botswana border. This association is dominated by two species, *Cyperus articulatis* and *Scirpus inanis.*

There are few plant species of conservation concern within this vegetation type. However, these seasonally inundated floodplains represent some of the most important grazing and home-range habitats for numerous species of mammals (e.g. Red Lechwe, Common Reedbuck, Sitatunga, Shortridge's Mouse) and birds (e.g. Slaty Egret, Wattled Crane, Rufous-bellied Heron). Any loss of these habitats through reduced periods of inundation and drying out would result in major changes in the ecological functioning of the Mahango Game Park and the areas within the West Caprivi on the opposite bank.

6.4.3 Red Data species and species of concern

The Red Data species listed below are those listed by the NBRI (Windhoek) data base and have been classified according to the conventions of the IUCN. Many species occurring in the area are listed as *Data Deficient* or *Lowest Risk* and these are not given here as insufficient information is available on these species.

The following Red Data Species have been recorded within the study area:

Ansellia africana Leopard Orchid **Vulnerable**
Rare on the Mukwe-Divundu islands. These would be threatened to the extent that host trees are threatened. They are widespread in southern and central Africa, but generally rare in Namibia.

Baikiaea plurijuga Zambezi Teak **Vulnerable**
A common constituent species of the Kalahari woodlands on both sides of the river. The impact of any impoundment on this species will be minimal as few examples occur within the inundation zone.

Bonatea steudneri Ground Orchid **Critically Endangered**
Collected on the islands near Andara and only known from this area in Namibia (and southern Africa). Loss of this habitat would lead to local extinction of this species in Namibia.

Eulophia species Orchids.
A number of orchids have been recorded on the islands between Divundu and Mukwe but no flowering material has been observed here and so the identification of the actual species is not known. Two species may occur here:

- *Eulophia leachii* Ground Orchid **Vulnerable**
- *Eulophia livingstoniana* Ground Orchid **Endangered**

Both these species occur further east in the Caprivi, but have relatively wide distributions (*E. leachii*, very rare in South Africa: *E. livingstoniana* widespread in tropical Africa) in the sub-Region. Namibian populations may be significantly impacted by loss of island habitats.

Habenaria armatissima Ground Orchid **Lowest Risk**
Although this species is reasonably common in Namibia, it is the only population known in southern Africa. It is included here because the Namibian population of this species is centred on the islands within the study area. To the extent that their island habitat is lost through inundation or erosion, this population will also be lost.

Habenaria epipactidea Ground Orchid **Vulnerable**
This species is widespread in southern Africa. However, the Namibian population is limited to the Mukwe-Divundu area and is likely to be significantly impacted by loss of the island habitats through inundation.

Protea gaguedi African Protea **Data Deficient**
In Namibia, this species of protea has an extremely limited range and has been severely impacted by overutilisation for traditional medicine. It has not been recorded since about 1986 and is thought to be extinct in Namibia. It may survive on the islands between Mukwe and Divundu where it was recorded in the past. The existence of this species in the area of inundation needs to be established, as any loss of suitable habitat would severely impact its local population if it does still exist. This species is, however, widespread and common through Africa as far north as Ethiopia.

Pterocarpus angolensis Kiaat **Vulnerable**
A common constituent species of the Kalahari woodlands on both sides of the river. The impact of any impoundment on this species will be minimal as few examples occur within the inundation zone.

6.5 Fauna (Mammals, Reptiles & Amphibians)

This section follows the specialist report by M. Griffin (May, 2003 – **Appendix I**) undertaken for this preliminary environmental assessment. His report was based on a desk top study of the relevant fauna in the area and a five-day field trip (3-8 April 2003). A draft annotated checklist of the relevant fauna was generated through the desktop study using available literature sources. This was followed by the site investigation. The purpose of the site investigation was to survey for potentially sensitive habitats, and to conduct opportunistic inventory surveys. Inventory methods included opportunistic grab-sampling (primarily), pitfall trapping (with drift fences), and electronic bat detection (ANABAT).

The draft checklist was finalised after the field inspection, and is provided in **Appendix I**.

6.5.1 Species

The array of amphibians, reptiles and mammals which occur (or are expected) in the area can be divided into 2 primary groups: -

- Those species not dependent specifically on this wetland system for their survival. These species usually have broad ranges within the region and are not characteristically associated with wetlands or dependent on them, and,
- Those local species which are dependent on the wetland habitats provided by the Okavango River.

This report deals specifically with only those species dependent on the river and associated wetland habitats. However all species in the area are covered in the annotated checklist, and those considered to be wetland-dependent species are noted.

The checklist itemizes 38 species of frogs, 75 reptiles and 124 mammals, all known or expected to occur within the project area. Of these fauna, **10 species of frogs, 8 reptiles and 18 mammals are regarded as dependent on the current array of wetland habitats provided by the Okavango River. These species have no other local alternatives.**

Although only 15% of the local fauna are wetland-dependent, **over 90% of these species are of national conservation concern; this high incidence reflects the high vulnerability of wetlands and associated species, as well as the relative rarity of this habitat within Namibia.**

The Spottednecked Otter (*Lutra macucollis*) is a shy species that requires near-pristine river conditions (Barnes (ed) 1998) and is found in the study area.

6.5.2 Special habitats

The study area has special significance for Namibia as it is characterized by **wetlands** and wetland-associated fauna and flora. As Namibia is primarily an arid country -wetlands making up only approximately 3-4% of it’s surface area, (Simmons, et al. 1991) **these habitats are very rare**. In addition, because of Namibia’s arid character, people are naturally drawn to wetlands. The human–induced degradation of wetland habitats in the Kavango Region is particularly noticeable (Simmons, et al. 1991; Curtis et al. 1998) and this can be expected to continue to the extent that human populations increase and compete for a continuously dwindling resource base.

The **rock outcrops** in the area are also considered to be of **special importance due to their scarcity** in a “sea of Kalahari sand”, and because they produce the **falls and rapids** in the area. Potential terrestrial rupicolous (rocky) habitats are unique in the area; they are disjunct from any other rocky habitats and are very limited and localized in extent. Although previous surveys of these rocky habitats by zoologists have not yet identified any new, special taxa, this habitat must still be regarded as potentially high in endemic taxa due to their isolated nature. Rupicolous substrates, in general, are habitats of high endemism in Namibia (Simmons et al. 1998), and this possibility must be kept in mind regarding areas to be inundated or affected by flooding.

6.6 Avifauna

This section is based mainly on the specialist report by Hines (April, 2003) undertaken for this preliminary environmental assessment.

The area from Andara through Popa Falls and the Mahango Game Park supports more species of birds than any other similar sized area in the whole of Namibia (NABAP data, Barnard 1999). It is also recognised as being one of Namibia's most important avifaunal biodiversity hotspots (Robinson, et al 1999) with over 450 species recorded in the past (NABAP data, personal observations).

Barnes (ed), (1998) classifies the area from Andara to Mohembo as an important bird area, and provides further information on the important bird species found along this section of the Okavango River.

The discussion of the potential impacts of the proposed hydro-power scheme is based on personal observations by Hines (April, 2003) over a 20 year period, and published materials. These have been supplemented to a limited extent by a 3 day field investigation during which incidental bird observations were made while assessing the vegetation of the project area. No specific and directed field survey work was undertaken during this pre-feasibility study. This study aims at providing information which would provide insights into the potential impacts of the proposed hydro-power scheme on avifauna. A full assessment of impacts can only be carried out once the precise area to be impacted has been identified.

The avifauna of the project area is relatively well known (Hines, 1987; Brown & Jones, 1994; Penry, 1994; Hines, 1996; Allen, 1997). The references cited here are, generally, annotated lists, and the principal short-fall in information is population data for the Red Data Species which occur here.

6.6.1 <u>Red Data Species and Species of Concern</u>

Four categories of Red Data Species are given according to Brown (1993) and Brown (1997) and are listed below.

- *Amber* species are those requiring regular monitoring because of low numbers, restricted distribution (including endemics), specialised requirements, or they are so classified because insufficient information is available to place them in one of the other categories. These are not dealt with in this report.
- *Rare* species are defined as those with small or localised populations.
- *Vulnerable* species are those species believed likely to move into the endangered category in the near future if the causal factors continue to operate.
- *Endangered* species are those species in danger of extinction in Namibia if the causal factors continue to operate.
- *Critically Endangered* (not defined in Brown 1993 or in Brown 1997).

The following Red Data Species (as per Brown 1993 & 1997) have been recorded in the area and may be impacted by the developments associated with a hydropower scheme:

- Great White Pelican *Pelecanus onocrotalus* **Vulnerable**

Scarce non-breeding visitor. Small groups have been recorded along the river, most often during the period when the floodplains are drying up and fish are trapped in channels and ponds. There is no suitable breeding habitat for this species. It may benefit from the construction of an impoundment.

- Pinkbacked Pelican *Pelecanus rufescens* **Vulnerable**

Rare non-breeding visitor. Solitary individuals have been recorded in most months along the river, seldom staying for more than a few days. There is no suitable breeding habitat. It may benefit from the construction of an impoundment.

- Slaty Egret *Egretta vinaceigula* **Vulnerable**

Scarce (non-breeding) resident. Recorded throughout the year in small numbers (generally fewer than 3 birds together). Numbers increase markedly during periods of declining floods, when birds are most often seen in areas with floating mats of *Echinochloa* and *Vossia.* This species would be significantly impacted if there was any floodplain habitat loss through scouring and deepening of the main river channel downstream of the project.

- Whitebacked Nightheron *Gorsachius leuconotus* **Endangered**

Rare resident. Recorded most often in dense wooded thickets overhanging the main river, between Buffalo and Picapau on the east bank. This species is probably commonest in the Mukwe-Divundu area where it occurs in dense *Syzygium guineense* thickets. Very young birds have been recorded in March/April and the species may breed in the area. The impact of an impoundment would probably benefit this species in the long term if the current forests are replaced by *Syzygium* thickets, but populations in the area affected by the impoundment will undergo marked declines before these thickets can become established.

- Saddlebilled Stork *Ephippiorhynchus senegalensis* **Endangered**

Scarce visitor. Recorded throughout the year in Mahango Game Park in very small numbers (< 5 birds). It is generally found feeding in wet floodplain habitats, along the edge of the river channels and in ephemeral pans. Any loss of floodplain habitats and wetlands will severely impact the small population occurring here. Unlikely to benefit from the construction of the impoundment.

- Marabou Stork *Leptoptilos crumeniferus* **Rare**

Uncommon to common visitor. Recorded in all months of the year, this species is found throughout the area in wooded as well as open floodplain and riverine habitats. Can be abundant. No suitable breeding habitat exists. Unlikely to be severely impacted by changes in flood levels in the river or by the construction of the impoundment.

- Yellowbilled Stork *Mycteria ibis* **Vulnerable**

Scarce to uncommon visitor. Recorded in small numbers throughout the year. This species favours riverine habitats, lagoon margins, flooded grasslands, swamps and marshes. Any loss of islands, wetlands and seasonally inundated floodplains will significantly impact the occurrence of this species in the area.

- Sacred Ibis *Threskiornis aethiopicus* **Rare**

Scarce (non-breeding) resident. Formerly common in floodplain habitats, this species has become scarce since the destruction of its main breeding sites by Elephant and fire. Now only seen irregularly in small numbers. Common in Shakawe in Botswana. Any further loss of islands, wetlands and seasonally inundated floodplains will significantly affect the occurrence of this species in the area.

- Glossy Ibis *Plegadis falcinellus* **Vulnerable**

Uncommon to scarce visitor. Recorded in small numbers in the summer months, but is most common during periods of declining floods from April to July. No suitable breeding habitat exists. Any loss of islands, wetlands and seasonally inundated floodplains will significantly impact the occurrence of this species in the area.

- Hadeda Ibis *Bostrychia hagedash* **Vulnerable**

Rare visitor. There are isolated records of this species from the study area. It is common at Shakawe and the reasons for its not becoming established in Namibia are unclear, as suitable breeding and feeding habitats exist especially on the islands in the Mukwe-Divundu area.

- African Marsh Harrier *Circus ranivorus* **Vulnerable**

Uncommon to rare resident, subject to considerable fluctuations in numbers. During the late dry season few birds recorded as most of the floodplain is dry. With the onset of the rains and floods numbers increase markedly. Probably breeds in the floodplain areas of the Mahango Game Park. Any loss of islands, wetlands and seasonally inundated floodplains will significantly impact the occurrence of this species in the area.

- African Fish Eagle *Haliaeetus vocifer* **Vulnerable**

Uncommon resident. Only occurs along the river and associated floodplain habitats. Numbers are lower during the breeding season when territories are aggressively defended. Some local movement must occur with the local population being supplemented considerably during the late dry season (October), when up to 63 birds were counted along the northern floodplain in the Mahango Game Park (Hines 1997). This species will probably benefit from impoundment construction in that new breeding and feeding habitat may be created. However, any loss of wetlands and seasonally inundated floodplains will significantly impact the occurrence of this species in the area.

- Western Banded Snake-Eagle *Circaetus cinerascens* **Critically Endangered**

Scarce resident. This species is restricted to the densely wooded riverine strip and it occurs throughout the year. Recorded breeding (Brown & Hines, 1987). This species was at one time commonly recorded in the Mahango Game Park south of Kwetche. This area has been severely altered by Elephant and may have resulted in the birds leaving the area as few birds are recorded in this area currently. A small population occurs in the Mukwe-Divundu area with the birds known to breed on some of the islands here. Any loss of riparian habitats, wooded islands or any dense stands of vegetation through inundation will signficantly impact the local population occurring here.

- Wattled Crane *Grus carunculata* **Critically Endangered**

Scarce resident. Four pairs occupy distinct territories on the floodplains on both sides of the river in the Mahango Game Park-Buffalo area. Usually seen in pairs or family groups of three. Breed soon after high-water in May/June. Any loss of wetlands and seasonally inundated floodplains will significantly impact the occurrence of this species in the area. This species is considered globally threatened.

- African Finfoot *Podica senegalensis* **Critically Endangered**

Not conclusively recorded in the study area although suitable habitat exists in the Mukwe-Divundu area as part of the riverine fringing forest and island forest. These birds require river margins with dense overhanging vegetation. The inundation of this area would significantly impact any existing small population if they are present.

- Red-winged Prantincole *Glareola pratincola* **Vulnerable**

Common resident. Found in large flocks (>500 birds) on sandbanks and short grass habitats on the main floodplains. Breeds in extensive colonies from September to December during periods of low water. Any loss of wetlands and seasonally inundated floodplains will significantly impact the occurrence of this species in the area.

- Rock Pratincole *Glareola nuchalis* **Vulnerable**

Common breeding intra-African migrant. Occurs from June to March/April on rocky outcrops with fast flowing water from the Mukwe to Divundu and downstream to the northern border of the Mahango Section. Breeds December to March. Most nests are found within a metre or two of the water-level, with the lower rock outcrops of rapids being utilised. The population on the Zambezi River has been reduced through the building of the Kariba Dam and flooding of the Gwembe Valley. "Further dam building will reduce the population further, because there are no alternative breeding sites; existing sites are unlikely to be able to absorb more pairs of Rock Pratincoles." (A.J. Tree in Barnes (ed), 1998, p.453). The flooding of any of the rocky islands and outcrops would signficantly impact the breeding population of this species in the area. The study area is a regional stronghold of this species in southern Africa.

- African Skimmer *Rhynchops flavirostris* **Endangered**

Uncommon breeding intra-African migrant. Present in the study area as soon as sandbanks become exposed enough to allow roosting July to February when sandbanks are once again inundated. Breeds in extended colonies on sandbanks from late August/September to October. Any loss of sandbars and sandy islands in the main channel of the river through scouring and sediment loss would significantly impact this regionally important population. This species may benefit to a degree with the construction of an impoundment as it may provide additional still-surface feeding grounds. This will, however, not compensate for the loss of their breeding habitat in the area.

- Coppery-tailed Coucal *Centropus cupreicaudatus* **Vulnerable**

Common resident. Recorded in all months of the year. Restricted to floodplain and riverine habitats, seldom venturing into riparian woodlands. Any loss of wetlands and seasonally inundated floodplains will significantly impact the occurrence of this species in the area.

- Pel's Fishing Owl *Scotopelia peli* **Critically Endangered**

Scarce resident. Recorded in all months of the year. Most often recorded in riparian woodland and tall trees along the main river course, but may be found roosting up to 200 m from the river. Formerly regularly recorded south of Kwetche, but now absent from the area probably as a result of elephant damage to the riparian woodland here. Several territories are known from the Mukwe-Divundu islands. Any loss of the large trees within the riparian habitats (through inundation) will lead to a significant reduction in the local population.

- Greater Swamp Warbler *Acrocephalus rufescens* **Vulnerable**

Common resident. Only occurs in dense stands of Papyrus and other tall aquatic grasses and reeds. Any loss of perennial wetland habitats supporting Papyrus will result in the loss of this species from the area. The impoundment may, however, support new growth of Papyrus in the future.

In reviewing this list of Red Data Species, it should be borne in mind that this list is specific to the status of each species in Namibia only. Several species could be regarded as peripheral to Namibia rather than threatened as a population – this includes species such as Sacred, Glossy and Hadeda Ibis. African Finfoot has not been confirmed as occurring within the study

area, even though there has been an influx of observers into the area in recent years and the habitat (with trees overhanging the water) appears to be very suitable for this species.
Collar *et al.* (1994) lists two species found within the study area as being globally threatened. These are Slaty Egret and Wattled Crane. For both these species the study area is part of their major global stronghold and they have to be considered to be of the highest conservation concern (Allen, 1997). The local populations of both these species are likely to be significantly impacted if the flood regime relating to the floodplains in the downstream areas is altered through channel deepening and reduced inundation periods.

Two other species, Whitebacked Night Heron and Saddle-billed Stork, are regarded by Collar & Stuart (1985) as being continentally threatened. It is uncertain as to how significantly any impoundment will impact the populations of the heron. However, the small population of the stork occurring here is dependent on the floodplains for its existence and any changes will probably affect this species negatively.

6.7 Aquatic Ecosystems

This section is based on the specialist report by Bethune (July, 2003) which is found in **Appendix J** of this report. The study was based on a review of the relevant available literature on the Okavango River and similar seasonal perennial systems, on Bethune's personal knowledge of the river in Namibia, and a brief site visit. The site visit was undertaken from 6 – 10 March 2003, just before the peak flood level for the year. The visit included a helicopter survey of the potential weir sites and the river from Mukwe to the floodplains below the Popa Falls, a reconnaissance by boat of some of the islands between Mukwe and Andara and the stretch of river from Frans Dimbare Youth Centre to the Divundu Bridge. Several sites on the southwestern bank including Andara and the Popa Falls eastern bank were further investigated.

6.7.1 Ecological Water Requirements

The Okavango River is a tropical perennial river driven by seasonal flood events. The types and distribution of vegetation and animals, and the long and short term dynamics of essential ecological processes are largely determined by the extent, duration and timing of these floods. This is true for the river itself, the associated floodplain and the Delta ecosystems. Therefore, maintaining a natural flood regime is essential to the functioning of this system. A hydrological report on the surface water resources of the Okavango River, prepared for OKACOM (Hatutale 1994) states that although it is difficult to quantify, it is important to ensure that river flows remain sufficient to sustain the river biota and maintain the seasonal flood regime that is essential to the productivity of floodplain plants and animals.

In the 1997 reports to OKACOM, Bekker (1997) and Hines (1997) confirm that no attempt has been made to quantify the environmental water demand for the Namibian section of the Okavango River. They emphasised the need to clarify how much and when water is needed to support the plants, animals and essential ecological processes of the river system.

That same year, working on the Initial Environmental Evaluation of the feasibility study on the Grootfontein – Rundu pipeline, (Ellery 1997, Murray 1997, Water Transfer Consultants 1997) did in fact attempt the challenge. Ellery provided a rough estimate that some 15,120 m^3/km/day was necessary to support the floodplain system in Namibia. He further recommended that the specialist workshop approach, the Building Block Methodology (King *et* *al* 2000) should be used as a first step towards a more accurate determination of the ecological water requirements for the Okavango River.

6.7.2 Aquatic Macro-invertebrates

Aquatic macro-invertebrates are processors of organic matter, vital in the self-purification processes of rivers, and contributing a valuable food source for larger fauna. Each river system or section within a river, has its particular aquatic invertebrate communities that serve particular functions. Any reduction or increase in water flows, sediment or nutrient inputs will change the structure and effectiveness of these communities and cause some species to be lost and others to increase. The abundance and diversity of aquatic macro-invertebrates can be used as an indication of the ecological health of a river. Changes can help track water quality and general environmental degradation. According to the OKACOM report, Water Transfer Consultant 1997, Curtis 1997, little research has been done on the ecology and habitat requirements of the aquatic invertebrates of the Okavango River and there are no detailed systematic surveys of the aquatic invertebrate fauna.

Based on Museum records Curtis (1990a) lists some 256 species of aquatic macro-invertebrates (mainly insects) from the Okavango River system. There are at least 27 snail species, 6 crustacean species, and 203 insect species found in the Okavango River (Curtis *et al* 1998). Forty of the insect species have been recorded only for the Okavango River. According to Piney (reported in Water Transfer Consultants 1997), the Okavango Delta in Botswana is one of the richest and most interesting areas in southern Africa in terms of dragonflies (Odonata). This is confirmed by Curtis *et al* (1991) who found high species richness for the Odonata recorded from the Namibian section.

de Moor *et al* (2000) reported on a series of detailed surveys by the Department of Water Affairs and the Albany Museum on the macro-invertebrates of the Cunene River. Prior to these surveys, only 58 aquatic invertebrate species had been recorded from the Cunene River (Curtis 1991), this more detailed work has increased the number to over 216 species. It can be assumed that the situation in the Okavango system is similar and that a similar investigation should be undertaken to look more closely at the true diversity of aquatic invertebrates.

More attention has been given to the snails of the Okavango River, particularly those of medical or veterinary importance and this is well documented (Curtis 1990a, 1990b, 1997, Curtis and Appleton 1987, Curtis *et al* 1998, Brown *et al* 1992). These confirm the diversity of snail species in the Okavango and that bilharzia is prevalent in the area. The hosts of both species of *Schistosoma* that infect man occur in the Okavango River, namely *Biomphalaria pfeifferi,* the intermediate host of *Schistosoma mansoni* that causes intestinal bilharzia and *Bulinus (Physopsis) globosus*, the intermediate host of *Schistosoma haematobium* that causes urinary bilharzia. Of veterinary importance are the carriers of livestock fascioliasis, *Lymnaea natalensis, Bulinus tropicus* and the host of paramphistomiasis *Bulinus forskali.*

The only other diseases, in the Okavango area that are carried by invertebrates are malaria, horse sickness and ngana. There are no records of sleeping sickness, river blindness (Onchoceriasis) nor filariasis recorded for Namibia (Curtis 1997).

One of the snails found, *Bellamya monardi*, is thought to be endemic to the Okavango River and has been found only at Andara and Popa Falls (Curtis 1990). Some of the other snails are endemic to the northern river systems. *Bellamya monardi* occurs only in the Okavango and Cunene rivers, *Pila occidentalis*, a large edible apple snail is found only in the northern Namibian rivers and pans.

The freshwater mussel *Caelatura kunenensis* is limited to the Cunene, Okavango and Cuvelai, and *Aspatharia pfeifferiana* to the Cunene, Okavango and upper Zambezi rivers (Appleton 1996).

6.7.3 Fishes

The fish fauna in the Okavango River system is diverse and abundant as the river provides a wide habitat diversity. Some 83 species have been recorded from the river, including 71 species in Namibia. There is a wealth of literature on the fishes of the Okavango River System pertinent to this assessment (Bethune and Roberts 1991, Bethune and Skelton 1984, Hay 1995, Hay *et al* 1996, Holtzhausen 1991, Skelton 1897, 1993, Skelton and Merron 1984, 1985 1987, Skelton *et al*1985 and Van der Waal 1990). Some of the species are sufficiently generalized to survive impoundment and to flourish there, whilst others with more specific habitat requirements e.g. flowing water, or particular substrates such as vegetation or rocks, would die out.

Fish distribution in the Okavango River, is mainly determined by the duration and timing of floods, habitat preferences and food supplies. The seasonal flood cycle has a major influence on fish breeding and has been shown to directly stimulate spawning. The seasonally inundated shallow waters provide safe, well-vegetated nesting and nursery areas for fish. Migration is also triggered by these floods.

Essentially the ichthyofaunal dynamics are driven by the seasonal flooding of the system. Three fairly distinct fish communities can be distinguished: -

- a resident component made up of species that are found in the river throughout the year,
- a longitudinal component consisting of the fish that migrate downstream with rising water levels and return upstream when water levels recede,
- and a lateral component that move into the floodplains to breed and feed when these are inundated, returning to the mainstream as these dry out (Skelton & Merron 1984, Hines 1997).

Hay (1995) found a decline in fish resources in the river, which he attributes to habitat destruction and over-fishing. His results show a steady decline in catch per unit effort over the last decade, and fewer large specimens are being caught in most areas. The only exceptions were within the protected area afforded by the Mahango Game Park. The most vulnerable species are the specialised feeders, the habitat specialists and those species dependent on the annual flood for successful reproduction.

Of importance to this assessment, are the **habitat specialists** or specific rheophilic species living in the **rocky rapids habitats** (Photos 13, 14 & 2) **that extend from Mukwe to Popa Falls**. These are mainly small clarids or catfish adapted to rocky habitats and fast flowing water. They include species such as *Clarias stappersii, Clarias dumerilli,* the rare, solitary bagrid species *Parauchenoglanis ngamensis*, the common stargazer mountain catfish, *Amphilius uranoscopus,* the long-tailed spiny eel, *Aethiomastacembelus frenatus,* the Okavango suckermouth or rock catlet *Chiloglanis fasciatus,* the slender stonebasher, *Hippopotamyrus ansorgii*, the red-eye labeo *Labeo cylindricus,* as well as two red-data species considered rare, the broad-head catfish, *Clariallabes platyprosopos* and the oscillated spiny eel, *Aethiomastacembelus vanderwaali* (Skelton 1987, Hay 1995).

The designation of "rare" is given to species with small or restricted populations, which are not at present endangered or vulnerable but which are at risk. In the Red Data book on Fishes, Skelton (1987) warns that the **broad-head catfish and the oscillated spiny eel are particularly vulnerable to the construction of dams and weirs, as are the migratory species that rely on flowing water and a free passage along the river**. *A. vanderwaali*, the oscillated spiny eel, is rare because of its very restricted habitat preferences. It lives in holes and crevices in rocks and needs well-oxygenated flowing water – conditions that are found only in a few localities in the Okavango and upper Zambezi Rivers. Changes in water level and flow velocities would potentially destroy the specialist niche occupied by this species. The broad-head catfish, *C. platyprosopos* is similarly rare and adapted to living in rocky rapids. Hay considers a third rheophilic species, *C. fasciatius,* to be "vulnerable" in the Okavango River in Namibia and a possible candidate for Red Data status. These small rock catlets are seldom found, occurring only in the Okavango and Kwando rivers and would be threatened by an impoundment. Another Red Data species that could be affected, if the shallow marginal waters east of the Cuito confluence are inundated, is the rare *Ctenopoma intermedium.* (Hay 1995).

Several of the Okavango fish species are known to migrate in response to seasonal flood cycles in the river in order to breed, or feed. These migrations often occur by night and may be triggered by the first rains, by a rising water level or by flood pulses. They would be effectively stopped by any barrier across the river such as a weir. The rare barred minnow *Opsaridium zambezense* occurs in clear rapidly flowing water in the pools below rapids and is known to migrate. In South Africa the construction of weirs and dams has led to their disappearance from several rivers (Skelton 1987).

Several of the fish species, particularly the larger predatory fish regularly migrate up and downstream as well as in and out of the floodplain areas. The proposed weir would effectively cut off these migrations, which are so essential to breeding success. An effective fish by-pass should therefore be incorporated and designed with the assistance of fish specialists with expert knowledge of the fish in this river.

6.8 The Okavango River

In this section, information on the characteristics of the Okavango River are presented as background to an understanding of the environmental impacts of the proposed hydro power project. WTC (November 2003) has provided more detailed information on the hydrology of the river as part of the Pre-feasibility Study.

6.8.1 The Okavango & Cuito Rivers

Catchments

The Okavango River is joined by its major tributary, the Cuito River, about 80km upstream from Mukwe, and about 150km downstream from Rundu.

The Cuito and Okavango Rivers drain catchments of 70,000 and 115,000 km^2 respectively situated in central Angola. These catchments receive rainfall of 876 and 983 mm / year respectively (McCarthy *et al*, 2000). Rain falls in the Angolan parts of the catchment between December and March. Peak discharge occurs in the Popa Falls section most often around April. The peak in the hydrograph thus takes some time to travel downstream.

Rainfall in the Namibian reach of the Okavango River is only about 550 – 600 mm, and Namibia contributes almost no runoff to the Okavango River (el Obeid and Mendelsohn, 2001).

Discharge & Flood Peaks

The mean annual discharge of the Okavango River at Mukwe (based on 50-year records) is about 9,585 million m^3 / year. It is, however, quite variable ranging from a low of 6,000 million m^3 to a high of 16,400 million m^3 over the past 60 years (McCarthy *et al,* 2000).

The Okavango River contributes about 55% and the Cuito about 45% of the total discharge at Mukwe (el Obeid and Mendelsohn, 2001). Although they rise in similar rainfall areas, the hydrological characteristics of these two rivers are very different. The Cuito River passes through extensive swamps, which act like sponges, absorbing water and then releasing it slowly. As a result the Cuito River has a higher baseflow but a lower peak than the Okavango River above the confluence of these two tributaries.

Overbank flooding in sections of the Okavango River, where it is flanked by wetlands, is more or less an annual event. The term “floods” in this context therefore refers to a regular event and not an extreme event.

In the Mukwe – Mohembo reach of the river, the peak discharge occurs anytime from March (or even February) to May, but most often in April. The annual flood varies enormously in magnitude and duration, and it is difficult to characterise a “typical” flood. When the peak discharges of the Okavango and Cuito Rivers coincide, then the peak is likely to be higher and of shorter duration. In other years, the peaks on the two tributaries are staggered such that as one rises the other declines. This may result in a lower peak of longer duration, or two separate peaks. **Figure 5** shows the hydrographs for six of the 50 years on record at Mukwe. These were selected in order to show the considerable variation in the flood hydrographs.

Baseflow at Mukwe, on the other hand, which occurs from about the end of May until December, is very much more consistent.

Rate of fluctuation in river level

The rate of rise and fall of the water level has a number of implications:-

- small aquatic organisms that inhabit the river margins are adapted to slow rise and fall of the water levels in this river,
- larger organisms, including many fish species feed off the aquatic invertebrates mentioned above,
- increased rate of fluctuation may impact on the erosion of sandy banks and islands.

Observations on site during March and April 2003, showed that water levels rose by only about 1 cm / day. Analysis of data supplied by Water Affairs, from 16 February – 01 April 2003 during the rising flood, showed that the water level rose at a maximum rate of about 7,4 cm / day (late February). While the peak flow for the 2003 flood season was modest, the above figures indicate that the rate of change of water level was very slow indeed.

The rate of change is a function of many factors. The very flat longitudinal profile, and the large distance downstream from the source of the water in Angola, tend to flatten out the flood hydrograph. In addition, extensive wetlands on the Okavango and Cuito Rivers absorb flood waters and release them slowly.

Further analysis of the maximum rates of change of river levels over longer periods would be desirable to determine the maximum rates of fluctuation that occur.

Flow velocities

Water Affairs has a cable across the river just below the bridge at Divundu, where they have established a relationship between measured flow velocities and water levels on a guage plate under the bridge. The flow velocities are averaged over a cross sectional profile of the river. Maximum velocities are on average 60% higher than the average velocities. However, it is the mean velocities across the profile that are of significance for sediment transport.

Data on flow velocities are available for this station from 1968/69 to 1997/98. The velocity data are summarised in table below. The highest mean monthly maximum velocity for this period was 1.41 m/s (recorded in both April 1969 and April 1979).

Flow velocity data for the Okavango River at Divundu Bridge (m/s)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mean	0.33	0.33	0.40	0.50	0.65	0.79	0.89	0.76	0.56	0.47	0.41	0.37
Med.	0.33	0.33	0.40	0.50	0.62	0.72	0.81	0.77	0.57	0.47	0.41	0.36
Max	0.40	0.45	0.57	0.72	**1.18**	**1.26**	**1.41**	**1.09**	0.75	0.59	0.52	0.45
Min	**0.24**	**0.23**	**0.27**	0.35	0.38	0.48	0.58	0.49	0.36	0.33	0.32	**0.28**

Bold type shows highest and lowest flow periods

Human Impacts in the Catchment

The upper catchment of the Okavango River in Angola has been altered very little by human activity such as dams or agricultural chemicals (Mendelsohn et al, 2002). Within Namibia, destruction of much of the riverine forest for slash and burn agriculture or commercial irrigation projects has led to some increase in turbidity in recent years. However there are currently no major impacts of human activities on the river flow or water quality. This is true for the river within Namibia and Botswana.

6.8.2 Water Quality

The most detailed determination of water quality was during a three year study by the Ecological Research section of the Department of Water Affairs from 1984 – 1986 (Bethune, 1987, 1990, 1992). The ten sites surveyed seasonally included Mukwe, Andara and Popa Falls. The waters of the Okavango River in Namibia are described as good quality, clear, well-mixed, well oxygenated, typically soft with very low conductivity (30 – 45 µSiemens/cm and TDS values between 25 and 42 mg/l). Chemical concentrations and nutrient concentrations were low - typical of an unenriched system.

The range of chemical concentrations measured at the mainstream sites during the 1984 surveys is given below:

Na+	1-3 mg/l	SiO_2	8 – 15 mg/l	Org P sol	0.01 – 0.1
K+	1-2 mg/l	Cl^-	0,5 – 1 mg/l	Total P	0.01 – 0.15
Ca ++	6 – 16 mg/l	Total N	0.1 – 1.5		
Mg ++	3 – 8 mg/l	PO_4 -P	0.01 – 0.07		

Hay (1995) found very similar water quality measurements when determining his index of biotic integrity on the river ten years later. Trewby (2002) reported that the chemistry remained much as determined in 1984 with the possible exception of reduced water clarity. She describes the river water as oligotrophic, low in nutrients, of low turbidity, with low total dissolved solids (TDS) and with conductivity values below 45 µS/cm.

Silt loads measured by the Hydrology Division at Rundu from 1973 to 1980, (Hatutale 1994) were never above 0.01% which is low when one considers that typical silt loads measured in the ephemeral rivers are usually between 1 and 3%. Actual measurements for the Okavango river were: 1973 -16.4 mg/l; August 1976 - 59mg/l; October 1977 – 39 mg/l; June 1978 - 37 mg/l; March 1979 – 32 mg/l and in February 1980 – 24 mg/l.

6.8.3 Channel Characteristics

The characteristics of the river channel vary from place to place. In the upper reaches of the study area (from Mukwe/Andara to Divundu) the banks and bed of the river are mostly sandy, interspersed with rocky “dykes” across the river. These rocky outcrops appear to have been responsible for the breaking up of river channels, resulting in a number of islands both large and small. These islands are either unconsolidated aeolian sand, or sand with a clay fraction. The islands and banks are vegetated down to the water’s edge with forests, or with patches of reeds. In places the forest has been cleared from the banks for human habitation or subsistence farming. However the islands are mainly undisturbed.

Below the bridge at Divundu, the channel widens considerably as a result of the restriction caused by the rocky ridge forming Popa Falls. Here fewer islands occur and the bed of the river is predominantly sandy but having a number of rocky outcrops. The channel tends to be lined with reeds or trees except where these have been cleared on the west bank. A few patches of Papyrus occur on the north bank upstream from the falls.

From Popa Falls down to Mohembo extensive sand banks become exposed during the low flow season. There are some islands that are covered in reeds, or trees. The banks are either forested or covered by reeds and extensive beds of Papyrus occur. However these banks are still earth banks – a factor that changes in the Panhandle of the Okavango Swamps.

Within Botswana the channels become lined with vegetation such as Papyrus and these channels leak water continually into the back swamps – so that the channels become more numerous but narrower with distance downstream. The significance of this fact in relation to sediment transport will be explained in section 6.10.

6.9 Sediment Transport Investigations

6.9.1 Introduction

At an early stage in the study, the transport of sediment was identified as a key issue for the environmental impact assessment of a weir. The importance of sediment transport for the wetlands in the Mahango area and the Okavango Swamps is explained in the section 6.10. This section provides an introduction to previous studies, and a brief account of field investigations that were undertaken for this project. These investigations have provided site-specific data in order to improve understanding of the manner, and volume of sediment transport at Divundu / Popa Falls.

The importance of sediment transport for the ecological functioning of the Okavango Swamps has been recognised for many years. Ellery *et al* (1993) described the role of vegetation, hydrology and sedimentation processes as determinants of channel form and dynamics in part of the Okavango Delta.

Possible interruption of the transport of fine sand was identified in the feasibility study for water abstraction from the Okavango River and supply to the Eastern National Water Carrier (Water Transfer Consultants 1997). This report points out how essential the fine sand, carried as bed load, is to the dynamics and renewal of the Delta ecosystem downstream. McCarthy (1997) emphasized this issue in the Initial Environmental Evaluation on the downstream impacts of the above-mentioned study warning that bedload movement should not be disrupted, especially by construction of impoundments such as weirs. A good review of the processes involved in sediment transport has been given by McCarthy (1992).

A large body of research has been undertaken over a period of 17 years by the Okavango Research Group, based at the University of the Witwatersrand. This is a multidisciplinary team of scientists. Their studies cover geology, tectonic activity, hydrology, sedimentation, geomorphology and the role of plants in the lower Okavango River and Delta. All of these factors interact in a complex and dynamic manner to influence the ecology of the Okavango Swamps. Essentially, the deposition of sediment plays a major role in maintaining the ecological diversity of the Okavango Swamps by keeping the system in a state of constant change and renewal, thus preventing the Swamps from becoming salinised. A collection of the research papers produced by the Okavango Research Group is available in five Volumes (1986 – 1998).

The importance of sediment transport for the Okavango Swamps is explained in some detail by McCarthy (July 1993) for this PEA Study. The full report is contained in **Appendix L** and a summary is provided in section 6.10 below.

In order to acquire site-specific data on the manner and volumes of sediment transport, a further study was proposed at Divundu. The ultimate objective of these studies was to devise and evaluate potential mitigation measures that could be implemented through the siting, design, and operation of the project – to ensure that sediment was not trapped behind the proposed weir.

The rationale for undertaking these investigations at the pre-feasibility stage, was as follows.

- Firstly, there are certain differences between the channel characteristics in the Divundu area versus the Okavango Swamps. Channels near Divundu are contained by earth banks, whereas the channels in the latter are lined with reeds and Papyrus and continually leak water into the backswamps.

- Secondly the gradients in the Divundu area are steeper than in the Delta, especially near weir sites 4 and 5 (upstream of the bridge).
- Thirdly, it is notoriously difficult to accurately measure bedload transport (Yuqian, 1989 and Rooseboom, pers comm). It was therefore considered important that more than one method should be used, so that the results could be compared and verified in some way.
- Fourthly, sediment transport is greatest during high flow periods. It was therefore necessary to undertake measurements during the high flow period.

April was the month chosen in which to measure sediment transport, as it is normally the month with the highest flow. Two study teams were mobilised on site at Divundu from 24-27 April 2003. Eco.plan co-ordinated and assisted in these investigations. A representative from WTC also assisted.

The first team, led by Prof. T. McCarthy from the University of the Witwatersrand, undertook direct measurement of suspended and bedload sediment transport. He used the same methods as he had previously used in Botswana. A detailed account is provided by McCarthy (June, 2003) as **Appendix K** to this report.

The second team, led by S. Coles from the Marine Geoscience Unit (Council for Geoscience, RSA) undertook a separate study using side scan sonar imagery in conjunction with highly accurate bathymetry of the river bed. A detailed report is provided by Coles (May, 2003) as **Appendix M** to this report.

A site was chosen for both teams some 300m downstream from the Divundu bridge. Here the channel is relatively straight and of fairly uniform depth. The co-ordinates of the western end of the transect were approximately S 18° 06' 10" and E 21° 33' 20". This section of river was selected for a number of reasons: -

- It was close to the Water Affairs cable, a site from which historical and recent data on river levels and flow velocities could be obtained,
- The river course is fairly straight so that the flow profile across the river would be relatively uncomplicated,
- An attempt was made to avoid navigational hazards such as rocks,
- It was necessary to find clearly discernible bedforms that were identifiable in repeated sonar scans.

The channel width, depth, flow velocity and the nature of the bed (rock or sand) were first determined. Some characteristics of the channel and flow rate during 24-27 April 2003 were as follows: -

- Active channel width was measured as 152m, with reed beds on the river margins beyond that,
- Mean channel depth was measured as 3.4m (about 0.45m below the highest water level for the season),
- Channel cross sectional area was calculated from a sounding depth profile as $522m^2$,
- Width of active bedload movement was approximately 140 m,
- Average flow velocity was calculated from a measured flow velocity profile as 0.60m/s,
- The discharge was calculated as 313 m^3/s,
- The water level on a guage plate under the Divundu bridge was 3.54 m,

The methods used and the results obtained are summarised as follows.

6.9.2 Measurement of Suspended Sediment

The methods used are explained by McCarthy (June 2003 – **Appendix K**). The samples were found to be remarkably clean and visibility was in the order of 2 to 3 m depth. They contained very small amounts of organic matter such as particles of algae, but very little sand and no discernable clay or silt-sized particles. Okavango River water contains very little silt and clay due to the fact that most of the catchment is underlain by wind-blown sand (McCarthy and Ellery, 1998).

Due to difficulty in obtaining accurate measurement at such low concentrations, a further sampling programme was undertaken by WTC from 4-5 June 2003, with samples of 100 litres each. The results, after burning off organic matter in an oven at 500°C, are shown in the table below

Depth: measured from the River Bed	Concentration (grams / litre)				Suspended Sediment Load (m^3 / day)
	35 m chainage	70 m chainage	105 m chainage	Average	
2,0m	0.000368	0.000302	0.000175	0.0003	0.85
1,5m	0.000648	0.000238	0.000284	0.0004	1.17
1,0m	0.000739	0.000266	0.000673	0.0006	1.69
0,5m	0.000996	0.000727	0.001915	0.0012	3.66
0,2m	0.002871	0.004389	0.009469	0.0056	16.84

WTC (November 2003)

Based on these figures, the average transport of suspended sediments over the full river depth was calculated by WTC (November, 2003) as **24.21m^3/day** on the day of sampling.

In interpreting the above figure for total suspended sediment load, it is important to note the following: -

- This "suspended" sediment load is comprised mainly of fine sand, the movement of which is best described as "saltation". Saltation refers to the hopping and bouncing of particles, which is the typical manner of transport of sand particles in the size range encountered under the normal range of flow velocities in the study area. It is therefore debatable whether the "suspended" sediment load should be regarded as being additional to bedload transport or included in bedload transport (G. van Langenhoven, pers comm).
- The measurements in the table were made more than two months after the peak discharge for the season. Depending on the method proposed to ensure sediment transport past the weir, and depending on how "suspended" load is treated in relation to total sediment transport, it may be necessary to undertake further measurements of "suspended" sediment.

6.9.3 Measurement of Bedload Sediment Transport using the Helley-Smith Sampler

The Helley-Smith bedload sampler is an instrument designed for the direct measurement of bedload transport. The method is explained by McCarthy (June 2003 - **Appendix K**).

The average flow velocity was measured at 0.60 m/s. Total discharge of the river at the time of measurement was calculated at 313 m^3/s.

Individual bedload samples are very variable as they are influenced by the position on the dunes. Therefore a large number of readings are required to ensure a reliable average. In this case, 134 samples were taken on a grid system over a period of two and a half days.

The volume of sand transported across the active channel width was calculated to be **197 m^3/day at the time of measurement**. As the density of the sand is 1.66 g/cm^3, this volume corresponds to 327 tonnes/day (or 0.027 kg/m/s).

McCarthy *et al* (1991; 1992), through studies in the Okavango Delta, had previously established a relationship between flow velocity and bedload discharge. These studies covered a range of average flow velocities from 0.27 to 0.74 m/s. The results from the Divundu site lie on the same flow velocity - bedload discharge relationship as the channels of the Okavango Delta. The equation of the line of best fit to these data is:

$$Q = 0.154\ U^{3.4}$$

where Q is bedload discharge in kg/m/s and U is average flow velocity in m/s.

Based on historical records of monthly flow velocities for the Divundu sampling site, provided by Water Affairs, it was possible to estimate that the average monthly bedload discharge as shown in the table below.

Calculated average monthly bedload sediment discharge at the Divundu bridge for the period 1968 to 1998.			
Month	**Velocity (m/s)**	**Bedload (tons)**	**Bedload (m^3)**
Oct	0.33	1,206	727
Nov	0.33	1,206	727
Dec	0.40	2,320	1,398
Jan	0.50	4,954	2,989
Feb	0.65	12,087	7,281
Mar	0.79	23,462	14,134
Apr	0.89	35,184	21,195
May	0.76	20,568	12,390
Jun	0.56	7,282	4,387
Jul	0.47	4,014	2,418
Aug	0.41	2,523	1,520
Sept	0.37	1,780	1,072
Total		**116,586**	**70,232**

Thus the annual bedload sediment discharge through the Divundu bridge site amounts to approximately 117,000 tonnes, or **70,000 m^3/year**.

It should be noted that this estimated annual bedload discharge is less than previously reported for the upper Panhandle of the Okavango Delta (170,000 tonnes - McCarthy and Ellery, 1998). The reason for this is that the present results are based on velocities averaged over a period of 30 years, more than half of which were relatively dry years, whereas McCarthy and Ellery (1998) based their calculations on flow velocities acquired during the relatively wet years of the early 1970s. A bedload discharge of 170,000 tonnes would equate to approximately 100,000 m^3/year.

The figures in the table above illustrate the rapid increase in sediment discharge during the period of the peak seasonal flood. The variability of sediment discharge from month to month, year to year, and even from one decade to another needs to be borne in mind in any attempts to extrapolate from historical data.

Analysis of the particle size of bedload sediments indicates that it consists almost entirely of fine sand, which is extremely well sorted. Samples taken from the bed at random by McCarthy were found to contain average grain sizes ranging from 0.25 mm to 0.39 mm.

A separate particle size analysis by NamWater indicates the following size distribution.

>0.43 mm	0.0%
0.25mm - 0.43mm	89.6%
0.13mm - 0.25mm	1.4%
0.11mm - 0.13mm	0.8%

Clearly over 90% of the sediment load is fine sand. This is comprised of quartzite, and the particles are fairly well rounded.

6.9.4 Measurement of Bedload sediment using Side-scan Sonar & Bathymetry

A team, from the Marine Geoscience Unit (MGU) of the Council for Geoscience, undertook a survey of the riverbed near Divundu. The purpose was to determine the rate of bedload sediment transport using a combination of side-scan sonar, high-resolution bathymetry and highly accurate positioning techniques. The study would also reveal the manner and morphology of bedload transport under the flow conditions at the time.

The use of this technology for this purpose in a river was a new application for the MGU, who had extensive experience at sea but not in rivers. Yuqian, (1989) however, recommended that sonar imaging was one of the more accurate ways of determining bedload transport in rivers. Given that bedload transport is difficult to measure accurately, it was considered valuable to make use of an independent method and compare the results with the Helley-Smith measurements. The survey was undertaken during the same period as the Helley-Smith measurements (26-27 April 2003). A detailed report by Coles (May, 2003) is provided in **Appendix M**.

Six gridlines, at 5m intervals across the river were surveyed repeatedly. Four surveys were run over a period of 28 hours on the same gridlines – thus providing four “snapshots” of the river bed morphology covering an area 400m in length by 30m in width (cross channel). The time spacing ensured that individual bedforms would be recognisable from one scan to the next. A portion of this area measuring 100m by 30m was analysed in detail to determine the bedload transport rates. This section was selected due to the presence of well developed bedforms that were easily recognisable in successive scans.

Various techniques were then used to compare the four successive scans, particularly the first and last scans – indicating the maximum movement of the dune forms over the 28 hour period.

The survey found that it was possible to image the bedforms at high resolution (a 60mm pipe in the bank of the river was clearly discernable in the side-scan images). The side-scan imagery was less accurate than the bathymetry. However the bathymetric survey achieved an accuracy of better than 2cm, and this was used for the calculation of bedload transport.

The sonar side-scanning was able to resolve bedforms at two scales (first and second order bedforms), while even smaller ripples of a few milimetres in height were evident by eye in shallow water, being superimposed on the second order bedforms.

The first order bedforms were the focus of the analysis. These were lobe-shaped transverse dunes across the main channel as shown in Photos 17 and 18. Within the detailed study area, the maximum dune height was 1.07m and the minimum was 0.11m. As expected the dunes tended to be highest near the middle of the deepest channel – tapering off towards the sides of the channel.

The distance between dune troughs (wavelength) was of the order of 10 to 17 metres.

The rates of movement of individual dune troughs varied widely across the width of the bedforms. Over a 28 hour period the high-resolution bathymetric data shows advance of the troughs ranging from 1.35m to 8.61m with an average of 3.98m (n =28). This equates to rates of migration in the range: 4.842 cm/hour to 30.879 cm/hour with an average of 14.307 cm/hour. The potential errors are small due to the better than 2cm accuracy in X, Y and Z axes.

Calculation of the **volumes** of sediment transport per day (24 hours) The results are provided as follows.

Dune	Volume of transport m^3/m/day
A	0.2935
B	0.4553
C	1.5049
D	0.4939

These figures are based on accurate bathymetric data along dune fronts. They relate to a 22m cross section of the river within the 30m width scanned. (In some cases the dune front did not extend to the full 30m scanned width - thus the figures only relate to a 22m cross section).

In order to interpolate the results to a wider cross section, the side-scan data was used because the side-scan can "see" a wider cross-section than the bathymetry. In the table below, the length of each dune front that was visible on the side-scan was multiplied by the volume of transport for that dune to give the total volume of transport for each dune. The total for each dune was then averaged for the four dunes.

Dune	*Length of active dune front (curved lines) metres	Volume of transport m^3/m/day	Volume of transport per dune m^3/day
A	67.18	0.2935	19.72
B	65.67	0.4553	29.90
C	69.79	1.5049	105.03
D	67.08	0.4939	33.13
Total			187.77
Average (n=4)			**46.94**

Thus the average **measured** volume of transport per dune was **46.94 m^3 per day**. The figures in the second column* are the actual lengths of the individual dune fronts (curved lines). However these curved fronts are passing through a cross-sectional channel width (measured in a straight line) ranging from 54.77m to 60.87m (average of 57.82m). Thus the 46.94 m^3 / day is the bedload transport over a 57.82m wide section of the river channel.

The overall width of open channel (i.e. excluding reedbeds) was approximately 140m. If one assumes that the rate of transport is the same across the entire channel, then the **transport across the whole channel can be estimated as follows: -**

140/57.82 x 46.94 = **113.66 m^3 /day** at the time of measurement (April, 2003).

It must be emphasised, however, that the rate of transport is **not** constant across the channel. The dunes are basically lobed – and move faster in the middle of the channel (or where the flow velocity is greatest) and slower towards the sides of the channel. Therefore interpolating to the full channel width is difficult, and inaccuracies are introduced. The figure of **113.66 m^3 /day is likely to be an overestimate** as the real data was measured in the cross-section where the flow was greatest. Any calculations based on interpolated data should thus be interpreted with great caution, and this figure is not considered adequate for design purposes.

A limitation of the sonar method to determine bedload transport is that it can only be used where there are well defined dunes, which is usually not across the entire width of the river. Where the bedload movement is in the form of small ripples, e.g. near the banks, the sonar would not be effective. Observations on site, however have indicated that dunes occur in the thalweg (i.e. where the most rapid flow occurs) where the greatest transport of sediment will also occur.

Further sonar surveys may be necessary at different times of the year to obtain more complete data, and data at different stages of the annual hydrological cycle. Future surveys would also need to cover the full width of the river if possible within the navigational constraints such as rocks and the need to survey in straight lines. Where no large dunes occur, a reliable method would need to be devised to interpolate across the full channel width.

Concerning the present survey, volumes of sediment transport should only be regarded as an indication of the total transport during the survey period and should not be used for design purposes without further data collection. It would be desirable to establish a mathematical relationship between the sediment transport measured by sonar methods and flow velocity. This would make it possible to estimate the sediment transport for historical periods from flow velocity data – in the same manner as for the Helley-Smith sampler (section 6.9.3).

While the current sonar survey was limited in terms of the measurement of total sediment transport, it nevertheless made a considerable contribution to the study on sediment transport:

- The survey confirmed the nature of the bedforms – both from the very accurate bathymetric data and the side-scan images,
- It was demonstrated that volumes of sediment transport can be measured accurately, especially from the bathymetric data where dunes are clearly evident. Provided that future surveys are made across the full width of the channel, or a reliable method is devised for interpolating across sections of the channel where there are no large dunes, sonar surveys should yield reliable estimates of bedload transport.

6.9.5 Summary and Conclusions Concerning Sediment Transport

Sediment transport rates

The table below provides a summary of the data on sediment transport rates. The results of the investigations undertaken specifically for this project are presented first i.e. daily rates of transport, followed by estimates of annual transport based on earlier and current studies.

Measurements of daily sediment transport at Divundu 2003		
Period	**Method & Source of Data**	**Value**
4-5 June 2003	WTC (November 2003) calculated the total **suspended sediment** load for the full river depth. The samples were taken with a pump. Whether this transport of saltating sand particles should be considered as part of bedload or additional to it is open to debate.	24 m^3/day.
24-27 April 2003	McCarthy (June 2003) measured **bedload transport with the Helley-Smith bedload sampler**. Total bedload transport was calculated as the average of 134 samples taken from a grid across the channel.	197 m^3/day
26-27 April 2003	Coles (May, 2003) measured **bedload transport using accurate bathymetry and side-scan sonar** on the section of the channel with prominent dunes in the thalweg (highest flow velocity). He then interpolated across the entire channel, based on the assumption that the rate of movement is the same. Coles considers this an overestimate as the rate of transport would in fact be less near the banks.	113 m^3/day

The surveys were planned for April with the intention of coinciding with the peak flood for the season. In fact the hydrograph peaked in mid-March, rather earlier than usual, and the peak in 2003 was rather low. Moreover, at the time of bedload sampling, the water level was about 0.45m lower than at the peak. Flow velocity was therefore well below what might be anticipated during a large seasonal peak flow. When the suspended sediment samples were taken in June, the flow had dropped even further. These issues need to be borne in mind in interpreting the results of the above data.

Estimates of annual sediment transport based on current and earlier studies		
Period	Method & Source of Data	Value
	McCarthy and Ellery (1998) reported bedload transport in the Panhandle of the Okavango Delta. The estimates were based on measured bedload transport and flow velocities established during the relatively wet years of the early 1970s. This estimate is thus much higher than that of McCarthy (June 2003) below.	100,000 m^3 / year.
1968-1998	McCarthy (June 2003) calculated the **annual bedload transport** based on a previously established relationship between bedload transport and average flow velocity, in the Okavango Delta. The previous and current studies made use of the same equipment and methodology. Data for transport and velocity from the 2003 study conformed to the same relationship as previously established. This made it possible to use the existing flow velocity data for Divundu to calculate average sediment transport per month for the 30-year period. The sum of the monthly averages gives the mean annual transport for the 30 year period.	70,000 m^3 / year.

General Conclusions about the Nature and Measurement of Sediment Transport

The on-site investigations have confirmed earlier studies concerning the manner of sediment transport, and have provided further insight into the nature of bedforms and their movement. The following general conclusions can be made.

- The sediment load of the river consists almost entirely of fine sand – approximately 90% of which ranges from 0.25mm - 0.43mm in size.

- There is strong evidence that particles in this size range are not truly suspended at the velocities normally encountered. They are moved along the bottom by saltation and traction, rather than truly in suspension. Settling time, following disturbance (e.g. around rocks) is very rapid – as evidenced in **Photo 18**. In the absence of active intervention, these particles can be expected to settle in the impoundment in the form of sandbars, starting from the head of the impoundment. Evidence for this is derived from the fact that bedload transport is related to the third power of the flow velocity, and flow velocity will drop as a function of increased cross sectional area in the impoundment. Further evidence is derived from Dxherega Lake in the Okavango Delta, where sediment has been shown to be accumulating forming a sandbar at the inflow over many years (McCarthy *et al*. 1993) and **Appendix P**.

- Samples taken from fast-moving water in Popa Falls also contained very little suspended sediment (sand), which suggests that concentrations of this material will be low at all times, even during the average annual peak flow. However, the possibility that greater volumes of sand may go into suspension during well above-average peak flows cannot be ruled out.

- This sand is transported primarily as bedload, in the form of dunes as shown in **Photos 17 and 18**. The dune bedforms were identified at three scales; the primary dunes had amplitudes of about 1m, with secondary dunes of the order of 0.1m and tertiary “ripples”. Bedforms migrate by sand moving up the backs and falling over the slip face of the dunes. The migration of the primary dunes can be measured using high-accuracy bathymetry with RTK differential GPS. The secondary and tertiary bedform movements are assumed to be taken into account in the movement of the primary dunes. The size and form of the dunes can be expected to change in response to changing flow velocities.

- Whether saltating sand particles (measured as “suspended” load) should be regarded as additional to bedload or part of it, is open to debate (van Langenhoven, per comm).

- Bedload transport rates are very sensitive to flow velocity. As a result, the calculated bedload transport figures per month (section 6.9.3 above) indicate large differences in transport rates per month (even when averaged over 30 years). The differences between the rates for individual months, or days, would be even higher. This needs to be taken into account in all design considerations.

- The sonar side-scan and bathymmetry produce accurate results where substantial dunes are evident. However, the application of this method is limited to such dunes, which makes it difficult to apply this method across the entire channel (Photos 17 and 18 show that large dunes typically do not extend across the whole channel). Therefore, either a method must be established to reliably interpolate from a portion of the channel with dunes to the rest of the channel with no conspicuous dunes, or other methods (e.g. the Helley-Smith sampler) must be used in conjunction with the sonar methods. A combination of both methods is recommended.

- The water contains little silt or clay-sized particles - too little to measure accurately. Nevertheless, this material is evident amongst reeds and pools along the banks where small volumes have been filtered out over long periods from large volumes of water. Although low in concentration, some of this material can be expected to settle within the impoundment due to reduced flow velocities. The ecological implications in the impoundment are currently unknown, while the role of fine material in the Okavango Delta is explained in section 6.10, below.

- The water contains small volumes of organic matter including algae, decomposing leaf litter and other detritus. This material, although suspended, settles fairly quickly in standing water, and it may have ecological implications as it accumulates in the impoundment, also depriving the Delta downstream of this organic material.

- Variability in rainfall in the catchments tends to be cyclical with resultant oscillation in discharge. This variability would have a direct influence on sediment discharge. Therefore, for design purposes (a) estimates of sediment movement need to be extremely conservative, and (b) design parameters for the weir in relation to sediment transport should take into account extreme events and not only average flow conditions. Moreover, given the difficulty of obtaining acurate sediment transport measurements, it is better to overestimate than to underestimate the daily or annual transport figures.

- The nature of further data collection should be influenced by the proposed method for ensuring sediment transport. If sluicing is proposed, then it will be necessary to know the range of total volume of sediment entering the impoundment per year – because this is the volume that will need to be sluiced out. If sediment pumping is proposed, then design criteria should probably be determined by considering the maximum rate of transport of sediment per day – because the sediment trap and pumping system will need to be designed to effectively accommodate the maximum daily transport.

6.10 The Ecological Importance of Sediment Accumulation in the Okavango Delta.

This section provides a summary of the report by McCarthy (July 2003) that was prepared for this PEA. The full report is contained in **Appendix L.**

6.10.1 <u>Introduction</u>

The Okavango Delta and its catchment form a closed hydrological system, with no outlet to the ocean. The Delta is located in a semi-arid area, where evaporation is about four times the annual rainfall. Most (98%) of the water discharged into the Delta each year by the Okavango River is ultimately lost to the atmosphere by evapotranspiration. The ground provides some temporary storage, but no substantial outflow of groundwater beneath the swamps has been determined. The entire region, both catchment and Delta, is underlain by Kalahari sand. There are several implications arising from this unusual setting: -

- Okavango River water is very low in nutrients,
- the input of sediment is dominated by eroded Kalahari sand, with very little silt or mud,
- the concentration of solutes in Okavango River water is very low,

- the Delta wetland, has evolved around these unusual environmental conditions, and notwithstanding the high evaporation loss, saline surface water is rare in the Delta. Moreover, the Delta exhibits immense habitat and biological diversity. Sediment transported to the Delta plays a pivotal role in maintaining this diversity and reducing the impact of the high evaporative loss. This brief review outlines the importance of sediment in maintaining the diversity and well-being of the Okavango ecosystem, and examines the possible consequences of upstream sediment impoundment.

A few aerial views of the Panhandle and Delta are shown in Photos 20 – 22, which show some of the many habitats types that comprise the Delta.

6.10.2 Nature of the Sediment

Sediment transport in the Okavango River can be divided into three categories: bedload, (consisting of sand), suspended load, and the solute load (dissolved in the water).

The bedload sand is well sorted, with an average grain size of about 0.35mm. This is transported along the bed of the river in the form of ripples and dunes. McCarthy and Metcalfe (1990) estimated that some 170,000 tonnes of bedload is transported past Mohembo into Botswana each year. Recent estimates, based on a longer discharge record of the Okavango River indicate that this estimate is probably too high, and is more likely to be in the region of 120,000 tonnes. The density of bedload is 1.66 gm/cm3, so this corresponds to about 70,000 m^3 per annum.

The suspended load consists of silt, mud and organic material, which is sufficiently fine grained to be held in suspension in the water. The concentration of this type of suspended material has been measured to be about 8 mg/l. The total amount of suspended material carried past Mohembo each year has been estimated to be 39,000 tonnes (McCarthy and Ellery, 1998).

The concentration of dissolved solutes in the Okavango River water is low, about 40 mg/l, but the annual discharge is large and therefore also the total solute load. It has been estimated that about 380,000 tonnes of solutes are delivered to the Delta each year (McCarthy and Ellery, 1998). Of this, about 24,000 tonnes leaves the Delta as surface flow, and the remainder accumulates in the Delta. This consists of 139,000 t of silica, 110,000 t of calcium carbonate, 17,500 t of magnesium carbonate, 61,500 t of sodium bicarbonate and 30,000 t of potassium bicarbonate.

6.10.3 The Nature of the Okavango Delta

The Okavango Delta has developed in a depression formed by rifting. In this depression, sedimentation has formed a large alluvial fan with an area of about 40,000 km^2. The wetlands area (permanently inundated) is considerably smaller than the fan. The Delta surface is remarkably smooth, with relief seldom exceeding two metres (Gumbricht *et al*., 2001). The Okavango River meanders down the Panhandle, and supplies water to the wetlands which flank the river. At the southern end of the Panhandle, the river divides into a number of channels which distribute water across the fan surface. Channel banks are made primarily of aquatic plants growing on a substrate of peat. The channel margins therefore leak water continually into the surrounding wetlands. This leakage sustains the permanent wetlands in the Panhandle and upper fan.

Discharge in the Okavango River is seasonal, peaking at Mohembo in April. As the seasonal flood level rises, water leaks from the channels. The area of inundation thus expands, and may attain as much as 12 000 km^2. Passage of the flood wave across the Delta is very slow, taking about 4 month to cover the 250 km from Mohembo to Maun. Peak flooding of the Delta therefore occurs in July or August. About 2% of the inflowing surface water, plus rain which falls on the Delta, flows out as surface water via the Boteti River. Studies on the flood plains of the fan have indicated that between 80% and 90% of the flood water infiltrates the ground, temporarily, and replenishes a near-surface aquifer (Dincer *et al*., 1976; Ramberg *et al*., 2003). During the months following peak flood, the area of inundation steadily declines as surface water infiltrates or evaporates. The very low gradient and the gently undulating nature of the fan surface results in maximum dispersal of water, and the average depth of water in the seasonal wetland is in the region of 30 cm. Although the local topographic relief is small, the gently undulating nature of the topography combined with the shallow depth of the water, results in numerous islands across the wetland, particularly in the seasonally flooded areas. Average water depth in the permanent wetlands is somewhat greater (about 1.5 m), so islands are less common.

6.10.4 <u>Sediment Dispersal and Deposition, and its Importance in Ecosystem Functioning.</u>

Since there is little outflow from the Delta system, all of the particulate sediment and the bulk of the solute load is deposited in the Delta. Deposition of the three forms of sediment is discussed separately.

Solute Load

The solute load accumulates in the permanent and especially the seasonal wetlands. The high water deficit creates the possibility for the formation of saline pans, but these are rare in the Delta. As discussed above, the seasonal flood raises the ground water table beneath both flood plains and islands. The bulk of the seasonal flood is stored temporarily in this way. In the ensuing months, this water is lost to the atmosphere by transpiration from wetland plants and vegetation on the islands.

However, as water is lost by transpiration, the dissolved ions remain and their concentration in the groundwater steadily increases. At the same time, the water table falls. Trees on the islands are particularly powerful “transpirative pumps” and they lower the water table beneath islands compared to that beneath the surrounding flood plains. Consequently, there is a net flow of groundwater towards islands.

Rise in the salinity of the groundwater results in saturation of dissolved substances, first silica and subsequently calcite. The precipitation of these salts in the soil causes expansion and hence island growth. This process is believed to be largely responsible for the undulating topography of the Delta. As the salinity rises, the water becomes toxic to plants, and island interiors are therefore frequently devoid of vegetation. Numerical modelling indicates that the groundwater beneath the interior of an island would become salinized in about 100 to 200 years.

The saline groundwater thus produced is more dense than normal, and cascades downwards by density-driven flow, to reach deep saline groundwater which underlies the fresh, near surface groundwater. Notwithstanding this removal of saline water from the near surface environment, field observations indicate that over time, the salinized, barren interiors of islands expand, and eventually islands become completely salinized, and all trees die. This situation does not commonly occur, however, because of a second form of sedimentation which is discussed below.

Suspended Load

Suspended load (silt, mud and organic material) is a relatively minor component of the total sediment load. Suspended sediment is transported into the permanent wetlands, and it accumulates along with organic material, thus forming a component of the peat which underlies the aquatic vegetation. The ecological importance of this accumulation is discussed further below.

Bedload

Bedload is transported in channels. The channels leak water, and become progressively narrower downstream. Their ability to transport the bedload therefore declines, and bedload accumulates on the channel beds, causing shallowing of the channels. This shallowing increases water loss, which in turn stimulates vegetation growth in the surrounding wetlands (McCarthy et al., 1992). The reason for this stimulation is the low nutrient status of the water. In wetland environments with very slow water flow, nutrients are stripped from the water, and plant growth rate is slow. Where water flow is rapid, and especially if the water is sourced from outside the wetland, such as from primary distributary channels, nutrient status is higher and there is continual replenishment, so plant growth is stimulated. Thus, accumulation of bedload on channel beds is accompanied by upward growth of the flanking vegetation, and channel depth remains unchanged. In effect, the entire channel and its flanking wetland is slowly elevated by bedload accumulation. Down-stream channel gradient declines as channels aggrade, and plants begin to encroach the channel. This culminates in runaway aggradation and the channel fails. Water diverts elsewhere to form new channels, usually along hippo trails.

Failure of a distributary channel and the consequent diversion of flow into new channels has important secondary effects. Regions that previously did not receive water may now become inundated and are converted to wetland. This process can produce radical shifts in wetland distribution. For example, the failure of the Thaoge distributary channel caused a shift in water distribution from the western to the eastern side of the Delta, a change which took place in the late 1800s. Areas deprived of water also undergo important changes – wetlands begin to desiccate. The peat catches fire and slowly burns down.

This destruction of accumulated peat has important ecological consequences. Nutrients and fine material, especially clays, are in short supply in the Delta, for reasons discussed above. Both are essential for terrestrial plants. The burning of peat releases accumulated nutrients, especially phosphorus, and also clays, which were derived from the suspend load. Soils resulting from peat burning are therefore very fertile, and support nutritious grasslands. Areas where peat has recently burned therefore tend to have high game populations. Over time though, the nutrients are dissipated, the clays become mixed into the normally sandy soils, and the nutritional quality of the grasslands declines.

Channel aggradation and failure is an extremely important process in the ecology of the Delta, for it results in constant change in water distribution. This constant change means that vegetation communities are constantly being disturbed, and thus can never achieve climax status. It is this constant change which is responsible for the immense biological diversity of the Okavango Delta.

Channel failure has another important consequence, related to toxic salt accumulation on islands. The life of a distributary channel is about 100 to 150 years, of the same order as the time required to salinize islands. As a consequence of channel failure, islands in the affected region are deprived of water. The water table beneath these islands falls. Rain flushes sodium bicarbonate from the soils, and the toxicity is removed. The precipitated silica and calcite remain, however, so the islands retain their form. In this way, channel failure results in the restoration of areas affected by toxic salt accumulation.

In the Panhandle region of the Delta, bedload sedimentation also plays an important role. Here, salt accumulation is not prominent. The Okavango River in the Panhandle meanders strongly, and the region is a mosaic of old, abandoned channels and other meander-related features. A large proportion of the introduced bedload appears to be accumulating in the Panhandle, and its primary effect is to induce channel aggradation. As these channels aggrade, water is diverted to form new channels, usually via hippo trials. Whilst such hippo trails frequently initiate new channels, the water invariably comes to occupy previously abandoned river courses, usually old meanders. In this way, the Okavango River constantly changes its course across the width of the Panhandle, but at all times maintains its meandering form. At present, there are at least two such channel changes underway in the Panhandle. Although detailed modelling is still underway, it is possible that channel switching in the Panhandle is very rapid, which is why salt accumulation does not occur on the islands in this region.

The Delta thus operates as a superbly integrated system to minimize the potential negative impacts of the high water deficit in the region and to maximize the utilization of the limited nutrients available. In all of this, sedimentation, especially of bedload, plays a pivotal role.

The consequences of sediment impoundment are dealt with in section 7.2.

6.11 Socio-economic and Political Environment

6.11.1 The Local People

Namibia has a comparatively small population, but most of the people are concentrated in the wetter areas of the north. The population of the Kavango Region in 2001 was about 201,000 – making this the fourth most populated region in Namibia. Well over 100,000 of these people are rural dwellers, comprising approximately 11% of the rural population of Namibia.

The uneven population distribution is closely related to the availability of natural resources. In the Kavango Region population is concentrated along the Okavango River. Along this river, and including the area of the proposed hydro power scheme, population densities are the third highest in Namibia, i.e. between 25 – 50 people/km^2.

Fertility rates are high - 4.7 children per woman in 2000 – and the population in this area is anticipated to reach approximately 250,000 by the year 2021. The structure of this population is skewed towards young people in the age group 0 – 15 years. Life expectancy in 2000 in this region was 40 years.

Over 20% of rural households have from 4 to 5 members per household. Fifty two percent of these members are dependents, and more than 50% of these households have no cash or wage incomes. Some surveys treat people who have no income as unemployed, however in Kavango most people are occupied with subsistence tasks such as collecting wood, crop growing, collecting water, fishing etc – i.e. lifestyle occupations.

6.11.2 Ethnicity, Politics and Land Tenure

There are two main ethnic groups in the study area. The majority language group is the Kavango – Mbukushu people, and the minority San – Khwedam group. The Mbukushu migrated from the eastern Caprivi and colonised the area along the Okavango River, in particular around Andara, in the early 1800's. However, the San people are believed to have been the first occupants of the area around the Okavango River.

There is evidence that the ethnic minority of the Caprivi i.e. the San/Bushman (Khwedam) people are subject to discrimination by the Mbukushu people. Throughout Namibia San/Bushman have historically been marginalised. Their lifestyle and livelihoods are constantly under threat from more powerful groups of people. It has been suggested that, if the San/Bushman are displaced from the Popa Falls area by the project, this could be seen as a victory by the Mbukushu people and result in further marginalisation of the San/Bushman (Odendaal 2003, pers. comm)

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.

These leaders play an important role in the allocation of land and grazing and in settling disputes. Land in Mukwe is communal land (formally owned by the state), and National Parks which are state owned. On communal land, people share access to common property resources. However, some of the land is exclusive, consisting of fenced farms around rural homesteads, and many larger areas are allocated for the exclusive use of certain people. Small areas of communal land may be allocated for special purposes by way of a permit, often called 'permission to occupy'. The tourist lodges (e.g. Suclaba Lodge) on the Okavango River are usually located on PTO's.

It is evident that a variety of people and bodies exert control over the land that will be affected by the proposed hydro power scheme. This will have certain implications for resettling people whose livelihoods would be affected or who will be displaced by the proposed weir. Issues such as resettlement and compensation are likely to be complicated by the diverse nature of controls over land tenure in the affected area.

6.11.3 Health and Wellbeing

Five diseases accounted for 46% of deaths in government hospitals between 1995 and 1999. The main causes of death in the Kavango Region are AIDS, malaria, gastroenteritis, acute respiratory infections and tuberculosis. Many deaths attributed to tuberculosis and malaria are now associated with AIDS, which makes people more susceptible to other diseases. After AIDS, malaria is the biggest killer disease in the Kavango. The incidence of malaria in the area of the proposed hydro power scheme is on average 400 per 1,000 people.

In 1992, AIDS accounted for less than 2% of deaths. This rose to 28% in 2000. One out of every four deaths in Namibia is now due to AIDS (Mendelsohn, 2003). The effect of AIDS on the structure of the population is related to three demographic aspects i.e. the increased death rate, reduced fertility, and the absence of children who would otherwise have been born to women that have died. With over 20% of Namibians aged 15 to 49 infected with the virus in

2000, at least one in five people who are now in that age group are expected to die from AIDS before 2010.

6.11.4 Subsistence Activities

Photos 23 & 24 provide an overview of the subsistence lifestyle of most of the people in the study area, and indicate their reliance on natural resources.

The economy of the Mukwe- Bagani area is based mainly on subsistence activities, particularly agriculture, and other natural resources. The cash component for many households is also supplemented to some extent by government pensions.

Most of the infrastructure in the Kavango region, schools, clinics, churches, mission stations, tourist lodges, telephone and power lines, a good gravel road and most of the villages are found in a narrow strip a few kilometres wide along the Okavango River. Most of the people living there are to some extent dependent on the living natural resources of the area. Houses are traditional wood and mud structures. People obtain fish and reeds from the river, and they garden and plant crops in a narow strip alongside the river and the floodplains. (Bethune 1991, el Obeid and Mendelsohn 2001).

In 1997, the natural resources of the river were estimated to support some 100,000 Namibians downstream of Rundu and a further 80,000 people in Botswana (Water Transfer Consultants 1997). Intense human pressure, particularly in the narrow strip on the western bank of the river in Namibia, is reflected in the degradation of vegetation alongside the river. Much of the riparian vegetation has been removed from the western bank, making the remnant woodlands, including islands, very important in terms of remaining biodiversity in the region.

Although, natural resource use plays a large role in the economy of communities living alongside the Okavango River (Cassidy 1997), there has been little effort to place an economic value on these natural resources - either in Namibia or Botswana. The best comparison is the study by Turpie *et al* (1999) that examines the economic value of the Zambezi Basin wetlands and includes an assessment of wetlands in Caprivi. They assign values to those resources that can be directly harvested, such as fish and reeds, those that support agriculture such as dry-season grazing provided by floodplains and fertile soils, and those that provide an income from tourism.

Agriculture

In the Kavango Region the most important livelihood activity is subsistence agriculture, based on livestock and crop farming. This is predominantly close to the river. Cultivation practices involve low input (e.g. no fertilising, no irrigation) and low output (low yields). Draught power is used to cultivate fields. Labour is the most valuable input to crop growing, and most of the labour is provided within the family. However, some hiring of casual labour occurs during busy periods and payment is often made in agricultural products rather than cash.

The majority of crops are grown on dry land fields (i.e. without irrigation). This means that crop cultivation is entirely dependent on rainfall. Planting is usually done after the first rains, generally in November and December. Crops are planted in batches at different times in order to spread the risk of crop failure due to unpredictable periods of hot dry weather without rain. Insect pests and certain bird species are also a threat to cereal crops.

Some farmers sell excess production in good years, but domestic production is often too low to meet all the cereal needs of households. Many households store grain from one year to the next in case of drought.

Soil fertility, which is never high anywhere in the region, is markedly higher alongside the river, on river terraces and floodplains. Mendelsohn and Roberts (1997) confirm Eco.plan's observations of agricultural practices on site – viz. that the limited good soils are mainly to be found along the rivers. Simmonds (1997) describes the soils alongside the Okavango River as "infertile aeolian Kalahari sand" low in organic material. He mentions that the river terraces are enriched by clays and silts deposited by seasonal floodwaters. Although these soils are mostly unfavourable to irrigation agriculture, the small patches of soil that have been enriched by the river are vital to subsistence agriculture in the study area.

The most important crops are cereals, mainly mahangu, sorghum and maize. According to Mendelsohn and Roberts 1997, mahangu dominates in 47% of the cultivated fields, followed by sorghum (27%) and maize (26%). Maize is grown mostly in the more moist eastern areas, while mahangu and sorghum are cultivated in the drier areas.

Vegetables and fruit are in demand from tourists staying in the Mukwe area. According to available sources (MAWRD 1997, 1999; Hishweka 1995; Gali 2000; Namibia Development Consultants 2000) the potential for irrigated horticultural production is currently largely under-utilised. Most of the products to supply the tourist industry are imported from South Africa. However, there are some vegetable gardens producing mainly cabbage, tomatoes, carrots, green mealies, sweet potatoes, onions and beetroot.

Livestock

Cattle farming is the most important agricultural activity in the Mukwe constituency and has increased dramatically during the past 15 years. In winter, cattle are concentrated along the Okavango River, where the floodplains and reedbeds provide grazing. However, despite a slight increase in off-take after the introduction of prices equal to those south of the Veterinary Cordon Fence in the mid-90s, off-take is well below what is recommended. This is partly because of the high cost of marketing, which requires quarantining, and high transport costs. Even more important, however, is the fact that cattle have a high social value.

The large increase of cattle over the last century is a matter of environmental concern. Increasing grazing pressure is causing changes to the natural habitat (e.g. decrease in perennial grass species abundance). These changes are reducing the ability of the environment to support cattle farming. Alternative incomes such as employment through tourism are important in sustaining livelihoods in this area.

In contrast to cattle, goats and poultry as well as the few pigs are only valued in terms of food. They are, however, mainly used for the farmers' own supply and to a limited extent sold on local markets.

Fishing

Fishing plays an important role in the lifestyle, diet and economy of the local people in Namibia and Botswana. Along the Namibian section of the Okavango River, there are some 20,000 to 30,000 active fishermen and 35 – 55% of households catch fish. They use mainly traditional fishing gear and most of the fish caught are consumed at home (Mendlesohn and

Roberts 1997, el Obeid and Mendlesohn 2001). However, some of the fish is sold or bartered locally.

Information on fish yields of this system is out-dated. Hay (1995) found that fish resources were declining. However, fish still play an important role in livelihood security for the people of this region. Government policy discourages commercialisation of fishing in rivers as commercialisation would jeopardise subsistence fishing which is vital to some of the poorest people in the area. This policy underlines the importance of fish to subsistence livelihoods.

Crafts & Building

Reeds from the riverbanks, timber from the woodlands and thatching grass from floodplains are important as building materials, for making household items such as baskets and sleeping mats, and for making tools and fishing gear.

Wood is an extremely important resource to the households in this region. It is used for building most houses, heating and cooking. Despite the potential for electrification in rural areas, electricity will remain unaffordable for most people.

Traditional Wild Products

Several other wild products are not only of traditional importance, but could also gain increasing importance with tourism development. This includes material for building and souvenirs such as roots, palm leaves, reeds and grasses. Roots (*Combretum sp.*) and palm leaves are used for baskets. Reeds are used for mats and building. Grasses are used for roofing. No information has been found on the rates of harvesting, or the rates of regeneration, but superficial comparison of the area around the settlements with less populated areas further afield indicates that these resources are diminishing. Harvesting of traditional wild fruits, berries and mushrooms, although small in volume, probably plays an important role in meeting nutritional and even medicinal requirements as well as being valued lifestyle activities.

As resources diminish, people have to travel further and further. Thus the state of the environment has a direct bearing on the wellbeing of local people.

6.11.5 Commercial Activities

Tourism

Tourism is the fastest growing economic sector in the world, a trend that holds true for Namibia as well. Tourism is Namibia’s third largest industry and second largest earner of foreign exchange. The value of tourism has increased by 8-10% each year over the past decade. There are several reasons why tourism is so important to Namibia. Primarily it has the potential for generating jobs, including rural areas. In 1998, the estimated 25,000 jobs in the tourism sector represent 15% of all private sector employment.

The Ministers of Tourism of the SADC Countries stated in a meeting on 1 July 2002 in Kasane, that tourism has been the fastest growing industry for the past two decades, and the sector is recognised as the economic driver of SADC's national economies by increased growth in GDP's, poverty reduction, employment, and management of sustainable economies through the involvement of communities.

One of the most important regional growth centres is the multi-country area of the Caprivi with the unique attractions of Victoria Falls in the east and the Okavango Delta to the south and the National Parks and wetlands of Namibia to the west. While development in Zimbabwe, and Zambia, has so far been mainly based on the Victoria Falls, Botswana has recognised tourism as a preferred land use option in the region, based on its unique natural environment.

Namibia's tourism sector is also based on its unique natural environments, large areas of unspoiled wilderness, the diversity of interesting wildlife, and majestic scenery. These are natural resources that have substantial economic potential as well.

Tourism in the northeast of Namibia was restricted for decades by the civil war in Angola and unrest in the north-eastern regions. This makes it difficult to place a value on tourism as the potential of this area is still highly underutilised. However, tourism in the Kavango and Caprivi regions is integral to the rest of Namibia, and from the mid-1990's growth rates were above the national average. Then there was a rapid shut down in tourism in 2000 due to political unrest and the murder of tourists in this area. Tourism has only recently begun to pick up again in this area.

Tourism data for Namibia, especially at a local level, are relatively limited. It is mainly based on arrival statistics at border posts which are compiled by the Ministry of Home Affairs (MHA), accommodation statistics for Ministry of Environment and Tourism accommodation establishments (MET); and accommodation statistics of the Hospitality Association of Namibia (HAN). These statistics do not distinguish between tourists and business people, and the arrival statistics do not consider the national movement of tourists. Most of the data are only available as global summaries.

Over the last few years community based tourism, sponsored by MET and several NGO's, has developed in this area in the form of campsites, which are normally connected to conservancies. In registered conservancies, communities are given more rights and responsibilities with regard to managing natural resources. In the area of the proposed hydro power project, on the northern end of Popa Falls there are two community campsites known as N//goabaca and White Sands. The former has been in operation since 1997 and is managed by the Kyaramashan Community Trust. The latter is proposed for redevelopment as a lodge.

The arrival of foreign visitors to Namibia has increased steadily (by an annual average of 10%) over the last 5 years. MET (2002) estimates that 84% of these arrivals are classified as tourists, resulting in absolute terms to about 723,000 tourists in 2001. Foreign arrivals to the Kavango and Caprivi Regions have developed quite differently from the rest of Namibia. The number of tourists in the Caprivi Region is estimated at about 30,000 -40,000 tourist arrivals per year. Most tourists are just in transit to and from neighbouring countries. Before the political unrest, tourists were staying on average, 3 days in Caprivi (MET 1997) while the average length of stay in Namibia was 11.8 days, with holiday visitors staying 12.5 days on average (Deloitte & Touche 1997).

Information for Caprivi is that the most important visitors to north-eastern Namibia with respect to spending power are overseas tourists. Peak arrivals are in July and August. However, over the last few years the former low season for overseas tourists (at the end of the year) no longer prevails. The number of arrivals is only lower in November and February.

Currently, tourists from RSA, dominate the tourism market in the Caprivi. These tourists often bring their own camping equipment and provisions, i.e. the majority belong to the low end segment of the market. They make use of community and MET campsites. The same applies to "overlanders" and "backpackers" from overseas who are playing an increasing role in Namibia and Caprivi. These tourists presumably want to experience natural beauty, wilderness, wildlife, eco-tourism and active holidays.

The number of guests at the Popa Falls Resort Campsite has increased from 2,912 in 2001, to 3,437 in 2002 (data supplied by MET). Suclaba Lodge, just below Popa Falls, is frequented by overseas tourists with occupancy rates of 50% to 60%. Other tourist facilities downstream from Popa Falls include Mahango Safari Lodge, Ndlovu Safari Lodge, and Ngepi Camp. Near Divundu there is also the Divundu Guest House B&B.

The attractiveness of the area lies in a combination of wildlife, rivers, wetland systems and riverine forests, as well as the cultural heritage of traditional livestyles. Birding is also an increasing tourist activity.

Riverine habitat forms the most valuable area for tourism in the Kavango and Caprivi regions. This habitat supports a high diversity of flora and fauna. This is particularly true for the wetland/swamp systems of the Kwando and Okavango Rivers. The Kwando River supports extensive permanent swamp vegetation in its many backwaters and former river channels. Game is attracted to these floodplains for water, grazing and browsing. A special advantage along the Okavango River is the good viewing points due to the open nature of the vegetation and high points in comparison to the uniform terrain of the surrounding Kalahari Sand Woodlands.

Not only is the Popa Falls – Andara area attractive in its own right, but it is also well situated on an important international tourist route. The area upstream from the Frans Dimbare Youth Centre is still largely unspoiled, particularly the islands. The potential of this area for tourism is, however, still undeveloped.

Protected Areas

There are four protected areas located in the region of the proposed hydro-electric power station, namely the Popa Game Park, the Caprivi Game Park, Khaudum Game Park and Mahango Game Park. According to a Cabinet Resolution the Mahango and Caprivi Game Parks will be merged to form the Bwabwata National Park (Mendelsohn *et al*, 2002). To effectively protect the wildlife and to avoid the spread of foot and mouth disease to Botswana, no cattle will be allowed in the park. The MET shall, however, give communities (neighbouring or living) in the Bwabwata National Park conditional tourism rights in the park such that they can establish, either on their own or in a joint venture, community based tourism and hunting facilities.

There is an emerging conservancy, namely Muto'iku-Bwabwata, which is in the area of the Popa Falls.

Commercial Agriculture

Despite the overriding importance of subsistence farming, the commercial sector is growing in two different ways. On the one hand subsistence farmers dispose of some of their surplus crops and livestock in barter trade, in the villages. On the other hand a few farms produce cereals, vegetables etc. only for sale. For example, some maize is sold to the mill in Katima

Mulilo and cattle are sold to MeatCo. Local sales of cattle in so-called “bush markets” amounts to about another 2% of the total cattle herd per year (Mendelsohn and Roberts 1997).

Commercial cereal farming is - with a few exceptions – still based on rainfed production, whilst commercial horticultural farming is mainly irrigated. The poor transport infrastructure, and large distances to markets are some of the problems facing commercial agriculture.

Nevertheless, the Ministry of Agriculture has plans to develop a number of irrigation projects along the river between Rundu and Divundu. The long term plans include thirteen irrigation projects with a total area of 8,563 ha. Seven of these projects are already in operation, with a total area of approximately 770 ha. When fully developed, the 13 projects will have a combined water demand of 128,445,000 m^3/annum. This amounts to approximately 1.34% of the average discharge that flows to Botswana every year. The combined average rate of demand will be 15.45 m^3/second, but this is not spread evenly throughout the year.

The nearest of these irrigation projects to the proposed hydro power scheme is the Mukwe Irrigation Project. This would cover an area of 4,900 ha on the east side of the River, stretching from the Angolan border to the Trans Caprivi Trunk Road at Divundu. Thus it would destroy much of the remaining riverine woodland on this – the less disturbed side of the river. No independent, detailed Environmental Assessment has been undertaken for this project.

Forestry

Productive forests in Namibia are almost exclusively in the Kavango and Caprivi Regions. The Ministry of Environment and Tourism together with the “Namibia-Finland Forestry Programme” undertook a forest inventory of Caprivi in 1997 and 1998. They concluded that, of the 57 species enumerated, there was potential for sustainable utilisation of two species - *Baikaea plurijuga* (Zambezi Teak or Mukusi) and *Pterocarpus angolensis* (Mukwa or Dolf). With rotation periods of about 100 years these two species could be sustainably harvested.

In the project area, the use of timber is currently not organised, and there appears to be no active protection of timber resources at present.

Sport Fishing

In addition to subsistence fishing, sport fishing is part of the tourist attraction in the Okavango Swamps and upstream in the Popa Falls area. Species such as Tiger fish and Nemwe are popular with fisherman from far afield. A number of commercial enterprises offer fishing safaris to the Okavango Swamps.

Manufacturing

With the exception of some service and light industries in Rundu and Katima Mulilo (e.g. brick making), the Kavango and Caprivi Regions are devoid of any manufacturing. The Region imports all its manufactured goods from centres accessible by road, such as Windhoek and from industries in Zambia, Zimbabwe and South Africa (NPC 2000). In addition to the formal enterprises several micro-manufacturers are working in the Region. They include: woodwork/furniture producers, maize mills and bakeries.

Other than crafts, there is no manufacturing industry in the project study area. In the Region as a whole, the production of home crafts plays a much larger role than manufacturing. Most of the producers are specialised in one type of craft, often even in one product only, particularly regarding carving. Generally home crafts could have an excellent market with tourism and would bring direct benefit to the most disadvantaged villagers. Various NGOs are assisting this sector at the community level.

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 due to marginal soils, but forestry, based on natural resources offers some potential for sustainable production.

7 PRELIMINARY ASSESSMENT OF ENVIRONMENTAL IMPACTS

7.1 Introduction and Assessment Criteria

In sections 7.2 to 7.4 a preliminary assessment is made regarding the environmental impacts of the proposed hydro power project and related infrastructure. It should be noted that this is a Preliminary Environmental Assessment, and the project alternatives have not yet been finalised. Therefore further investigation and a more detailed assessment will be required for a full Environmental Assessment at the Feasibility Study stage.

The early project planning and preliminary design process has taken into account the key environmental issues along with technical and economic considerations. Certain project alternatives have already been rejected, and design options have been influenced as a result of the interaction between the technical and environmental teams. This preliminary assessment is made on the basis of the current proposals. These may change or be refined in response to further environmental investigation or economic and technical analysis.

Both the impacts of the environment on the development, and the impacts of the development on the environment have been considered. Possible mitigation of negative impacts (or enhancement of positive impacts) has also been considered in the assessment, where appropriate.

In sections 7.2 and 7.3, each of the potentially significant impacts are assessed in terms of the following **criteria**: -

- The **nature** of the impact (an explanation of how the environment will be affected and by what activities),

- The geographical **extent** of the impact,

- The **duration** :-

  - Short term 0-5 years,
  - Medium term 5-15 years,
  - Long term – lifespan of the project,
  - Permanent.

- The **intensity (or magnitude)** of the impact :-

  - Low (natural, social and cultural functions are not significantly affected)
  - Medium (natural, social and cultural functions continue but are modified)
  - High (natural, social and cultural functions become altered to the degree that they become dysfunctional).

- The **probability** of the impact actually occurring: -

  - Improbable (a low probability that the impact will occur)
  - Probable (a distinct probability that the impact will occur)
  - Highly probable (it is most likely that the impact will occur)

- Definite (where the impact will occur regardless of prevention measures).

- The **level of confidence** that can be placed on this preliminary assessment before further investigation : -

  - Low (would indicate that further investigation is required if the impact could be significant)
  - Medium (further investigation may be required if the impact could be significant)
  - High (the impact is well understood. However further investigation may be required to determine the effectiveness of possible mitigation measures).

- The **Significance** of the impact is determined as a synthesis of the above assessment criteria where: -

  - Low significance means that the assessed impact would not have an effect on the decision to approve the project or the particular project alternative,
  - Medium significance – the assessed impact should have an effect on the decision unless it is effectively mitigated,
  - High significance – the decision would be influenced regardless of any mitigation.

Where various alternatives are available for the design or operation of the project, these alternatives are assessed separately as far as possible. For example, alternative sites for the weir, alternatives for passing sediment through the weir, etc.

As far as possible, for each impact a table is provided with an assessment before mitigation of the impact. In many cases it is not yet possible to assess the impacts after mitigation, as further investigations into possible mitigation measures are required. Recommendations for further investigation are also made.

Consideration has been given to the project stage at which the impact could occur: -

- Design,
- Construction,
- Operation,
- Decomissioning.

However, the emphasis is on the more significant issues that can be influenced at the planning and design phases. Further details, for example relating to the construction phase, will need to be assessed and addressed in the full EA and an Environmental Management Plan for construction and operation.

In spatial terms, four broad impact zones have been identified as a framework for consideration of impacts: -

- The weir impoundment,
- Downstream impacts in the river and wetlands in Namibia and Botswana,
- Land-based installations and infrastructure,
- Upstream impacts on fish migration.

Sections 7.2 and 7.3 deal with bio-physical impacts, and socio-economic issues respectively. Section 7.4 deals with cumulative or synergistic impacts, or issues relating to the planning process.

7.2 Assessment of Bio-Physical Impacts

7.2.1 Impact on Water Resources / River Discharge

Zero water abstraction

The project would **not** involve any abstraction of water.

Water may be abstracted for irrigation e.g. for the Mukwe Project, but this project is not dependent on the Popa Falls project (refer to section 7.4).

Evaporation

The average annual evaporation rate is in the range 1820–1960 mm / year (Mendelsohn *et al*, 2002). This figure refers to open water evaporation. Net evaporation (after deducting rainfall, which, on open water would reduce the net loss) would be in the order of 1200mm/year (G.van Langenhoven, Hydrological Services, Directorate of Water Affairs, pers comm). A rough estimate of the mean annual evaporation was calculated as shown in the table below.

Weir Site	Area of original channels (m^2)	Area of Impoundment* (m^2)	Therefore increased surface area (m^2)	Annual loss due to evaporation at 1,2m/year (m^3)	% of Mean annual discharge at Mukwe (9585 Mm^3/a)
2	2,930,000	8,124,000	5,194,000	6,232,800	0.065 %
4	2,260,000	6,287,000	4,027,000	4,832,400	0.050 %
5	2,910,000	8,184,000	5,274,000	6,328,800	0.066 %

* impoundment areas provided by K.Lund, WTC

These figures provide a good indication of the order of magnitude of evaporation, but it is recommended that the original and new surface areas should be digitized, and the increased volume of evaporation more accurately determined.

It must be borne in mind that evaporation is not equally spread throughout the year. The impact of evaporation (in relation to ambient discharge of the river) would be greatest in about October or November, when the river is at its lowest and temperatures and evaporation are close to their highest rates for the year.

In the context of the mean annual discharge of the river, the water lost through evaporation would be a very small percentage. For this reason, the significance is rated as “low”.

For comparison with the annual evaporation loss, NamWater supplied 11,0 million m^3 of water to the City of Windhoek for the 12-month period September 2002 to August 2003 (L.H. Andreas, NamWater, pers comm). This figure excludes the variable abstraction from boreholes and the reclamation works by the City of Windhoek directly.

The impact of evaporation should be assessed further in the context of cumulative losses of water from the river system (refer section 7.4).

Seepage

The ground conditions are predominantly fine Kalahari sand, which is expected to be highly permeable, underlain by sound quartzite rock. It is possible that seepage into the ground may be increased due to the increased area submerged, and the increased pressure due to water depth. The depth of the sand at the weir sites is not known at present. The greater the depth of the sand to bedrock, the greater is the likelihood of increased seepage. The magnitude of this impact has not yet been investigated.

The volume of increased seepage is not expected to be significant on its own. However, the cumulative impacts of water loss from evaporation, seepage and abstraction for irrigation and urban water supply in the long term need further investigation (refer to section 7.4).

The water loss through seepage needs to be determined through measurement of the permeability and modelling of seepage under actual conditions within the impoundment. A conservative approach should be taken as water loss as a result of seepage has been greatly underestimated on dams in arid areas in the past (e.g. the Aswan Dam).

Water loss due to increased evaporation and seepage	
Nature of Impact	Increased surface area will lead to increased **evaporation** from the impoundment. **Seepage** may also increase due to increased pressure, increased area of inundation, and the permeable nature of the Kalahari sands where bedrock is deep.
Mitigation	No mitigation is possible for evaporation or seepage
Extent	Impoundment area, affecting the river flow downstream to the Okavango Swamps. Any water lost as a result of the impoundment is also lost to the Swamps, however insignificant.
Duration	Long term
Intensity	Low
Probability	Definite for evaporation. Probable for Seepage
Confidence	Medium for evaporation. Low for seepage
Significance	**Low** for this project on its own
Further investigation required	• Determine more accurately the increased surface area and the volume of evaporation. • Determine the permeability of the ground and model the seepage rate from the impoundment. • Assess the cumulative water losses in the context of all other losses to the river system (from irrigation, municipal supply, seepage and evaporation). • Any further assessment of the impacts of evaporation and seepage should consider the **increased** loss in relation to the ambient runoff in the river.

7.2.2 Impacts on the Hydrograph / Fluctuating Water Levels

Operation at full supply level after one-off filling of impoundment (Scenario A)

As explained in section 2.4.1, the weir will be operated at full supply level most of the time. At no stage will the flow of the river be completely interrupted.

The proposal to use Hydromatrix and/or bulb turbines **in the weir itself**, as opposed to constructing a diversion canal, will help to minimise the effect on the hydrograph during normal operation as there will be no diversion of water from the main channel. (A possible exception to this may occur during construction – if weir site 4 is selected. In that case a short section of river will be deprived of water during construction, but there will still be no significant effect on the hydrograph below the weir site.)

During operation at full supply level, the entire flow of the river will pass through or over the weir. Therefore there will be no significant effect on the hydrograph at all. However, as the flood period declines to a level where the water would drop below the top of the weir, gates will be closed one by one to maintain the full supply level (FSL) – in order that the head can be maintained and power be generated. This will result in a slight lag in the hydrograph for a short period. However, because the volume of the impoundment is small in relation to the total flow, the impact on the flood hydrograph would be small. Even when all the gates are closed, the full flow of the river will still be going through the turbines in the weir.

During filling of the impoundment after construction of the weir, it will take a certain amount of time for the weir to fill up. To minimise the impacts on the hydrograph, it is recommended to fill the impoundment during the highflow season. However, the best timing for filling should be determined by the results of further ecological assessment. The calculations below are intended to illustrate that the impact, on the hydrograph, of filling the weir impoundment would be very small.

Firstly, the table below shows percentage of the year for which the discharge of the river exceeds a particular flow rate.

Flow (m^3 / s)	% Exceedance (approximate)
100	95+%
200	65%
300	40%
400	23%

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Secondly, the table below considers the weir impoundments with the smallest and largest volumes respectively (i.e. the best case and worst case scenarios in terms of filling time). If it is assumed that only 10% of the flow is held back to fill the impoundment, while the rest is allowed to pass through the gates, the time taken to fill the weir is then calculated for each flow rate. 10% is an arbitrary figure, but it represents an assumed "worst case", in terms of filling time but a relatively low impact on the hydrograph. It is recommended that only a very small percentage of the flow should be held back so as to minimise the influence on the hydrograph. Estimates of filling time range from about 5 – 15 days.

Note that the low flow scenario (100 m^3/s) or less is not considered, as there is no need to fill the impoundment during such a low flow period.

Weir Site	Capacity (m^3)	Flow Rate (m^3 / s)	% of flow held back	Time to fill weir impoundment (seconds)	Time (days)
(Smallest) Site 4: FSL at 1010.0 m.a.m.s.l.	16,600,000	200	10%	830,000	9.6
		300		553,333	6.4
		400		415,000	**4.8** min
(Largest) Site 5: FSL at 1010.0 m.a.m.s.l.	24,400,000	200	10%	1,220,000	**14.1** max
		300		813,333	9.4
		400		610,000	7.1

The figures below are taken from the 50 year records available from Mukwe, just upstream of the proposed weir sites. They are provided here for comparison with the flow rates used in the table above.

Discharge of the Okavango River at Mukwe: 1949/50 – 1998/99		
Lowest instant minimum discharge ever recorded	80.5 m^3/s (Nov'49 & Nov'96)	Occurrences below 100 m^3/s occurred in only 13 months in 50 years.
Highest instant maximum discharge ever recorded	1,473.0 m^3/s (Feb 1967)	Occurrences above 1100 m^3/s occurred in only 8 months in 50 years.
Lowest mean annual discharge (based on daily records)	200.8 m^3/s actual (1992/93) 178.1 m^3/s estimate (1995/96)	
Highest mean annual discharge (based on daily records)	485.5 m^3/s (1967/68)	

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A selection of a few historical hydrographs is shown in **Figure 5** indicating the natural variability of the annual hydrograph.

The volume of the impoundment is small in relation to the discharge of the river. The smallest and largest volumes of the impoundment represent only 0.17% and 0.25% respectively of the mean annual runoff of the river (9,585 million m^3/annum).

Furthermore the variability of the annual flow hydrograph is considerable. It is therefore concluded that the effect on the hydrograph of a one-off filling of the weir would be insignificant, provided that it takes place during the high flow season. **The rate of change in the water level should not be allowed to exceed the natural rate of change in water level**. Abnormal peaks or troughs in the hydrograph should be avoided.

Based on the scenario that the weir is filled once and then operated at full supply level thereafter, it is concluded it is possible to fill and operate the weir in such a way that there would be very little impact on the hydrograph. This conclusion is based on the following: -

- The natural variability of the hydrograph is great,
- The weir can be filled during the high flow period,
- A low percentage of the flow can be held back to fill the weir, and even so the filling time would be only about 5 – 15 days.

The ecological implications of the timing of filling operations, however, need to be investigated further.

Impacts on the hydrograph under the scenario of one filling and then operation at full supply level.	
Nature of Impact	Filling the weir will cause a perturbation in the hydrograph. When the flow drops below the weir level – necessitating the closing of gates, a lag in the hydrograph will occur. These activities will result in a slightly altered hydrograph downstream.
Mitigation	• Fill the dam during the high flow period, and at a low percentage of the ambient discharge. • Ensure that operation of gates leads to alterations in the hydrograph that are within the natural variability with no sudden peaks or dips. • The rate of change in water level should not be permitted to exceed the natural rate of change of several cm /day.
Extent	Downstream of the weir, possibly as far as the Okavango Swamps
Duration	Short term: 5 – 15 days during one-off filling, or as little as 5 - 7 days if filled during high flow conditions. Fluctuations during normal operation would be very gradual.
Intensity	Medium, reducing to low if filled during the high flow period.
Probability	Definite
Confidence	Medium
Significance	**Medium,** reducing to **low** if filled during the high flow period**.**
Further investigation required	Further details of design and operation, and their implications for the hydrograph, are needed at the Feasibility stage.

The above assessment is based on one-off filling and thereafter operation at full supply level. However other methods of operation may have greater impacts and should be considered with great caution. These are evaluated as follows.

Annual Sluicing of the impoundment to remove sediment (Scenario B)

If the weir is sluiced annually in order to remove sediment from the impoundment, then the rate of draw down and refilling would lead to greater impacts on the hydrograph than those discussed above, and would need careful consideration. Firstly, instead of a one-off impact during filling, there would be a significant impact annually during filling and emptying of the impoundment. Secondly, the rate of fluctuation of water level would be far greater than in the natural conditions. This is illustrated as follows.

The object of sluicing, is to lower the water level (during the high flow period) by opening the gates fully for a proposed period of 4-6 weeks. By lowering the level, the flow velocities and the rate of sediment transport are increased. During sluicing no power can be generated. Therefore, for power generation, it would be necessary to lower the water level as fast as possible and raise it again as fast as possible after sluicing is completed. It is expected that the duration of filling or emptying would be a week or less. To draw down the water level from 9m (weir height) to say, 3m water depth, in 7 days, the rate of change in water level would be about 85cm/day in the impoundment. However, the natural rate of fluctuation is normally less than 7cm /day and typically only 1 or 2 cm per day. Therefore sluicing will result in a rate of change in water level of the order of 10 times greater than the normal maximum rate of change. Downstream, the rate of change may be even greater due to the channel being narower than the impoundment.

This simple analysis, although requiring refinement, suggests that it will not be possible to undertake sluicing within the natural rate of change in water levels.

The reason this is important is that changes in the flow conditions trigger certain ecological events. For example, the rising limb of the hydrograph triggers fish to move out into the wetlands outside of the main channel to spawn. An unseasonal or unnatural peak followed by a drop in water level could potentially leave fish stranded in the wetlands – with serious consequences for reproduction. Therefore the optimum timing of sluicing events needs further consideration and careful management. Any manipulation of water levels that leads to unnatural changes in water levels or flow regime would carry serious ecological risks. If the period of draw-down or refilling was lenthened to reduce the rate of change, it would be detrimental to the economics of power generation.

Impacts on the hydrograph / water levels due to annual sluicing operations	
Nature of Impact	Perturbation in the hydrograph as for scenario A, but annual (instead of one-off) and of greater intensity as the filling and emptying time would need to be more rapid.
Mitigation	Sluicing can only be effective during the high flow period, but this will not provide adequate mitigation.
Extent	The hydrograph could potentially be affected as far as the Okavango Swamps.
Duration	Long term: annually for about a week during lowering and a week during filling (4-6 weeks for sluicing overall) but more accurate determination is required.
Intensity	Medium to high
Probability	Definite
Confidence	Medium
Significance	**High**
Further investigation required	A substantial amount of investigation on the hydrological (and ecological impacts) would be required in order to determine the acceptability of sluicing operations, and to determine when sluicing should be conducted, and at what rates of draw-down and refilling.

Pumping of Sediment (Scenario C)

An alternative to sluicing is to catch sand as it enters the impoundment, pump it continuously via a pipeline or conduit, and release it below the weir. Since during normal operation the inflow to the impoundment equals the outflow, there will be no impact on the hydrograph as a result of pumping operations. The impact **on the hydrograph** of Senario C is therefore the same as for Scenario A.

7.2.3 Impacts on Sediment Transport

Deposition in the Weir Impoundment

The nature of the sediment in the Okavango River, and its manner of transport, was described in section 6.9. In summary, the sediment in the river is predominantly fine sand, which is transported mainly as bedload in the form of migrating dunes.

As the river enters the impoundment, it will encounter a deeper cross sectional profile (say double the depth). Since the same discharge now flows through a greater cross sectional area, the velocity of flow drops (say by half). The volume of transport of this sand is proportional to the flow velocity^3. If the flow velocity is halved, the transport will be reduced by a factor of eight. From this illustration it is apparent that a small increase in depth leads to a large reduction in the carrying capacity of the water. Thus the fine sand is deposited in the impoundment. This deposition begins at the head of the impoundment in the form of a sand bar, which advances slowly downstream towards the weir. This process has been demonstrated over a period of many years in a natural system in the Okavango Swamps – viz. Dxherega Lake (McCarthy *et al,* 1986 and McCarthy *et al*, 1993). Refer also to **Appendix P** and **Photos 25 & 26**.

In the absence of active intervention to get sediment to move through the weir, bedload will accumulate in the form of a sand delta, which will build forward from the inlet of the impoundment. This will gradually advance until an equilibrium state is reached and the depth of the river is close to its "natural" depth. The equilibrium would occur because, as sediment is deposited, the depth decreases. This leads to an increase in flow velocity again, until the river is transporting sand as before. The equilibrium state may be reached when the weir is, say, two thirds full of sand, and the delta has reached the weir. Thereafter, sand will pass through the weir at its equilibrium rate. Estimates of the time taken for this equilibrium state to be reached are provided in the table below. The annual volumes of sediment transport are taken from McCarthy's older and recent estimates (McCarthy, June 2003 and section 6.9.5 above).

Weir site	Capacity (million m^3)	Two-thirds capacity (million m^3)	Years to fill impoundment at 100,000 m^3/ annum	Years to fill impoundment at 70,000 m^3/ annum
Site 2: FSL at 1007.5 m.a.m.s.l.	22.5	15.0	150	214
Site 4: FSL at 1010.0 m.a.m.s.l.	16.6	11.1	111	158
Site 5: FSL at 1010.0 m.a.m.s.l.	24.4	16.3	163	232

Unless steps are taken to prevent this bedload accumulation, it will have several negative consequences downstream. The magnitude of the impact will depend mainly on the effectiveness of mitigation measures to reduce sediment accumulation, and to a minor extent, on the volume of the impoundment as well.

Potential Erosion of the River Bed Downstream

Impoundment of sediment would result in downstream scour as the river re-establishes its equilibrium sediment load. Very simply, sediment will continue to be moved in the downstream direction without being replaced. Thus, for as long as sediment is accumulating in the weir impoundment, downstream scour will occur. How this scour will be distributed along the length of the channel cannot be predicted easily, but it could result in significant lowering of the channel bed.

Since the depth and extent of scouring is not known at this stage, the assessment of this impact has been approached by outlining a range of scenarios and then determining the effects of each. The analysis below is based on the following assumptions: -

- the scoured volume would be equivalent to the volume of sand deposited within the weir impoundment,
- scour will mainly affect the river bed, rather than the banks, which are partially stabilised by vegetation,

- the volume of the scoured portion of the river is conceptualised as a triangular prism with its greatest depth at the upstream end, tapering to zero at the downstream end. This is based on the premise that scour would be greatest just below Popa Falls and would reduce in depth downstream as the river picks up its load from the bed. The end of the scoured section would occur where the river is carrying its full load once more.

While these assumptions are open to debate, the following simplified scenarios will nevertheless serve to illustrate that the issue of downstream scour is important and must be investigated in greater depth. It must be noted that these tables relate only to a situation in which there was no mitigation to prevent sediment accumulation in the impoundment.

Distance downstream affected by scour = 2V / (ht x w) where: -

V = volume of sediment per annum
w = width of channel
d = distance of the scour effect downstream
ht = depth of scour.

Scen-ario	Annual Volume of Sediment Transport (highest estimate) (m^3/annum) = V	Assumed maximum depth of scour below Popa Falls (metres) = ht	Typical width of channel below Bagani (metres) = w	Calculated distance of scour effect downstream per annum (metres) = d	Total extent of impact over 100 years if no intervention (km)
A	100,000	0.2	150	6,667	1,000*****
B		0.5		2,667	400*****
C		1.0		1,333	200
D		2.0		667	100

Scen-ario	Annual Volume of Sediment Transport (lowest estimate) (m^3/annum) = V	Assumed maximum depth of scour below the Falls (metres) = ht	Typical width of channel below Bagani (metres) = w	Calculated distance of scour effect downstream per annum (metres) = d	Total extent of impact over 100 years if no intervention (km)
A	70,000	0.2	150	4,667	700*****
B		0.5		1,867	280
C		1.0		933	140
D		2.0		467	70

*Note that Maun is only about 300km from Popa Falls, and the basin topography would limit erosion beyond Maun. Therefore some of these theoretical distances are not practically possible.

The channel width of 150m used is conservative as the channel actually narrows downstream, particularly in the Panhandle where the channel becomes lined with vegetation and leaks water to the backswamps. Actual channel width is closer to 100m near Mohembo (Botswana border), reducing to about 50m near the lower end of the Panhandle. The calculated distances of the scour downstream may therefore be very much underestimated. Depths of scour of 0.5 to 1.0m are considered to be realistic as the heights of the dune bedforms are in this range. However, these rough estimates serve only as an indication that the impact of scour could be far reaching and must be further investigated.

The consequences of channel deepening, if this was allowed to happen, would be serious. Deeper channels would be hydraulically more efficient with the result that there would be less overbank flooding through the **Mahango area in Namibia**. Overbank flooding would not only be less frequent, but also less extensive. The result would be drying out of the floodplains, with severe impacts for certain species of mammals, fish, birds, and amphibians.

Within the **Panhandle of the Delta**, deepened channels could prevent channel switching for several hundred years. Lowering of the bed of the channel in this way would result in less water leakage from the river and consequently the area of seasonally inundated wetland flanking the Panhandle would decline. Reduction in the rate of channel switching would probably allow climax communities to develop, and the habitat diversity could be reduced. Salinization of islands in the Panhandle may also occur.

The **Delta** itself may become deprived of bedload sediment. Here too, channel entrenchment could occur, and the duration of the life of distributary channels could be extended. It is likely that permanent wetland would be lost around the upper distributary channels, although this may be compensated for by a downstream increase in permanent swamp, as more water is conveyed through the system. The present structure of the ecosystem is thus likely to be affected. Prolonging channel life would result in a reduction of habitat diversity in the wetlands of the fan as communities attain climax status. In addition, toxic salt accumulation would continue for longer, and many islands would consequently become completely salinized, thus impairing their function as toxic salt accumulators. Salinization of surface water could possibly result.

At this stage of Okavango research, quantification of these impacts is not possible, and in fact it will probably be several decades before numerical models of the Okavango Delta ecosystem become possible. In the interim, only qualitative assessments of impact can be made, which could be augmented by field observations to assess specific impacts, such as loss of wetland due to channel incision, for example. The assessment of probable impacts is based on existing knowledge of ecosystem functioning. Whilst there is a fairly good overall understanding of the ecosystem available, there are still many unknowns, and therefore there are likely to be impacts other than those identified above which are completely unanticipated.

The duration of the impact on channels could be as much as double the time taken to fill the weir with sediment. This is because, once the weir is full, the deepened channels would start filling up from the Popa Falls end.

Impacts of the weir on sediment transport	
Nature of Impact	Sediment accumulation resulting in scour downstream. Drying out of wetlands in Namibia and Botswana, possible prevention of channel switching in the Delta, and consequent serious ecological impacts.
Mitigation	Refer to sections 2.4.2 and 2.4.3
Extent	70 km to hundreds of km (possibly throughout the Delta). The extent would be reduced or eliminated depending on the effectiveness of mitigation measures.
Duration	Long term: double the time that it takes to fill the impoundment with sediment to equilibrium level (est. 200 – 460 years). Reduced or eliminated depending on the effectiveness of mitigation measures.
Intensity	High, possibly reducing to low or even eliminated with good mitigation
Probability	Definite without mitigation. To be determined with mitigation.
Confidence	High if no mitigation.
Significance	In the absence of *effective* mitigation, the significance of this impact can only be regarded as **high.** However, since mitigation measures are proposed, and at this the significance is considered to be **medium**, possibly reducing to **low** if mitigation can be implemented to a very high level of efficiency.

Further investigation required	Determine the effectiveness of possible mitigation measures.

Thus the impact of sediment accumulation is a **potential fatal flaw**. However a number of possible mitigation measures have been proposed. These mitigation measures cause certain adverse impacts as well, which are explained in the next section.

7.2.4 Impacts of Alternative Methods to Prevent Sediment Accumulation

Impacts of Sluicing

Sluicing involves opening all the weir gates and thus drawing down the water level to the "natural" level (almost as though the weir were not present). This would be done during the high flow period each year. The object is to increase flow velocities and therefore pick up deposited sediment and transport it through the weir. The **effectiveness** of this method is discussed below, followed by a discussion of the adverse **impacts** of sluicing.

Experience from rivers and dams around the world has shown that sediment can be moved through impoundments by sluicing, provided that the volume of the impoundment is less than 2% of the mean annual discharge of the river (Rooseboom, pers comm). The proposal in favour of sluicing is based on experience elsewhere. It is also based on the fact that most rivers transport much of their load in suspension. In the Okavango River, however, the silt and clay-sized particles that are normal in most rivers are present only in small quantities. The fine sand that comprises over 90% of the river's load is transported as bedload in the form of migrating dunes. Furthermore, the very low gradients on the Okavango River result in fairly low flow velocities. While it is possible that the sand may become truly suspended (as opposed to saltating) for short periods in extreme flood events, there is no evidence for this at present.

For a number of reasons, it is doubtful that sluicing can be adequately effective in this case.

Firstly, the rate of advance of dunes was measured by means of sonar bathymetry in April 2003 (Coles, May 2003). Under the flow conditions at that time, the rate of advance of dunes averaged about 3.4m/day. If sluicing were practiced for 45 days under such conditions, a dune would advance by only 153 metres. These measurements were made a month after a fairly low annual peak. However, considerably greater rates of dune movement would be required to get all the sand through the weir as the impoundments are about 8 to 10km in length and much of the sediment will be deposited at the inlet first.

Secondly, it would not be possible to increase the flow rates above the natural flow rates. Thus it would not be possible to move sand faster than the natural rate of movement. For 46 – 48 weeks sand will be accumulating in the impoundment. To move this through the entire length of the impoundment in only the remaining 4 – 6 weeks of the year, without increasing the flow velocity above the natural level, would be unlikely. This would be true even accepting the fact that sediment transport is not equal throughout the year.

Thirdly, even if the sediment were artificially agitated, the settling time has been shown to be very rapid. This is clearly demostrated in **Photo 18**.

In order to determine the effectiveness of sluicing, scale modelling at the University of Stellenbosch is proposed by WTC for the next phase of the feasibility study.

If we turn now from the effectiveness of sluicing, and assume that a very high proportion of the sediment could be removed by sluicing, then the following impacts can be expected to arise. To determine the magnitude and significance of these impacts, further investigation would be required.

- The impact on the hydrograph/water levels was assessed in section 7.2.2 above.
- A rapid draw down of the water level in the impoundment, of the order of 10 times greater than normal, is expected to cause erosion around the perimeter of the impoundment. It is possible that the hydrostatic pressure in the sandy banks and islands would lead to erosion of the margins as water trickles out from this unconsolidated sand. The risk of erosion needs to be further modelled and assessed.
- For 46 to 48 weeks of the year sediment will be accumulating in the impoundment. During the period of sediment accumulation, sand banks some distance below Popa Falls can be expected to be eroded. These sandbanks are known to be the breeding grounds of the African Skimmer, which would be directly affected by any scouring effect.
- Assuming that sluicing is highly effective, this would mean that most of the years' supply of sediment would be moved through the weir in 4 – 6 weeks. However, once through the weir, there is no control on how this sediment will be redistributed. Most of the sluiced sediment would probably be deposited below the weir, or perhaps below Popa Falls. **Photo 1** shows the formation of a sandbar below Popa Falls during the low flow period, and the same process was apparent during the field investigations in March and April 2003. This deposition is due to the rapid settling time of the fine sand. How this sand would be redistributed down the length of the eroded channel is not yet known and would require further investigation. However, it was demonstrated above, that erosion of the channel bed could extend for several kilometres downstream in a year. It is likely that the channel immediately below Popa Falls would become clogged with sand for a time, while sandbanks further downstream were eroded away.
- The sand on the river bed is inhabited by a variety of invertebrates, bacteria etc. These benthic fauna fulfill a variety of ecological functions. Some break down detritus, while others are food for higher organisms such as fish. These benthic fauna may be smothered by the release of sediment from the impoundment.
- Certain biological processes occur in benthic sediments. The field investigations found that small but significant amounts of organic matter were carried in suspension and were also evident in dune troughs on the river bed. Some of this organic matter will accumulate on the bed of the impoundment, where it will decompose. Chemical processes often lead to the depletion of oxygen in benthic sediments, and the production of gases such as CO_2, H_2S, and methane. When the sediments are sluiced out of the impoundment, fish and other aquatic organisms are likely to be exposed to water with altered chemistry, possibly including raised levels of the above-mentioned gases, and reduced oxygen. Fish kills may result.
- While the concentrations of clay-sized particles are very low by world standards, it is likely that some of this material will settle in the impoundment. During sluicing the fine particles will therefore be released into the water at higher concentrations than normal – with further negative impacts on water quality. Clay particles also have chemical implications as they are transporters of chemicals and ions which adhere to their surfaces.
- The release of clays and organic matter that has been concentrated in the impoundment will result in an increase in turbidity downstream for the duration of sluicing.
- To the extent that sluicing affects the hydrograph there may be negative ecological impacts. For example, many biological processes, such as fish breeding, are triggered by hydrological factors, changes in water temperature or chemistry. These factors are not well understood, or at best are only understood for certain species. Therefore, sluicing

could involve significant ecological risks in river ecosystems that are not adapted to rapid changes.

- Sluicing would have to be continued after decommissioning of the power plant, unless the weir was removed.

Impacts of sluicing	
Nature of Impact	Initial scour downstream during sediment accumulation. Slow redistribution of sand downstream, possibly temporary clogging of channels. Smothering of benthic fauna, with secondary impacts up the food chain. Negative impacts of altered water chemistry and turbidity. Draw down of the water level may cause erosion of the islands and river banks in the impoundment.
Mitigation	Sluicing during the high flow will help to reduce the impacts of sediment clogging channels. It will also dilute the impacts on water chemistry. The impacts on fish breeding and other ecological functions, however, is not known. Mitigation may not be adequate.
Extent	Unknown. Sluicing during the peak flow may reduce the extent, and intensity of impacts, but the best time for sluicing in terms of hydrological and ecological impacts needs to be better understood.
Duration	Direct impact over 4-6 weeks, but continuing longer in the event of die-off of certain species. It is not known whether impacts would be reversed within the annual sluicing cycle.
Intensity	Potentially high, but requiring quantification in relation to sediment movement.
Probability	Highly probable
Confidence	Low – further research required
Significance	**High,** but requiring quantification.
Further investigation required	• Modelling of physical and chemical impacts is needed in order to quantify these impacts if sluicing is proposed. • Modelling and assessment of the erosion risk around the banks and island margins. • Physical impacts relating to sediment movement can probably be quantified. However, it will be impossible to quantify all ecological impacts, and there are likely to be some ecological impacts that cannot be predicted.

Once the operational procedure of the hydro power project has been determined, the acceptable limits to variation in flow need to be further established. The manner and timing of the annual sluicing event (if applicable) needs to be investigated in terms of its ecological impacts. The impacts downstream also need to be investigated particularly on the floodplains in the Muhango National Park, and Okavango Swamps.

However, regardless of its effectiveness, sluicing will carry significant ecological risks that will be difficult to quantify or even to predict. The option of **sluicing is therefore not recommended**.

Impacts of Pumping Sediment

The fact that sand moves predominantly as bedload creates the opportunity for sediment pumping. The feasibility of this method has not yet been investigated in detail, but the concept was explained in section 2.4.3. The sediment would be captured as it enters the weir impoundment and pumped to the downstream side of the weir, where it will be released. Model testing would determine the size and shape of the sediment trap and the effeciency of pumping.

Assuming that it is possible to capture and pump almost all of the sediment reaching the impoundment, this method would have a number of advantages: -

- The need for sluicing should be eliminated, which would reduce or eliminate the negative impacts of sluicing as follows: -
  - reduce the risk of erosion around the perimeter of the impoundment due to rapid draw-down during sluicing,
  - eliminate the issue of deposition, or erosion below the weir and subsequent problem of redistribution of the sediment downstream,
  - reduce the risk of eroding sandbanks where the African Skimmers breed,
  - reduce the ecological impacts on benthic fauna associated with sluicing of sediment,
  - reduce the potential impacts on water quality that could result from the sluicing of sediments that are enriched with clay and organic matter,
  - reduce the impact on turbidity.

- Sand, with its small content of organic matter would be pumped past the weir on a continuous basis. Less organic matter and clay particles would be deposited in the impoundment,
- Pumping should be the most reliable way to get sediment through the weir,
- The need for costly modelling of the sluicing option and the question of redistribution of sediment downstream, would be eliminated. Such modelling could involve the risk of error.
- Power could be generated throughout the year with no "down time" - so the economics and continuity of supply would improve.
- There should be less wear on the turbines as there would be far less sand passing through them.
- From a scientific viewpoint, the pumping of sediment would make it possible to determine the volumes of transport with greater accuracy on an ongoing basis. This would make a useful contribution to science and possibly to future projects on the Okavango River.

The disadvantages of the pumping option are: -

- A heavy onus on NamPower to ensure faultless management to avoid any interruption in the sediment pumping system. A back-up system for pumping would therefore be required.
- Sediment pumping would need to continue forever after decomissioning, unless the weir was removed.

Impacts of pumping sediment	
Nature of Impact	Disturbance to benthic fauna.
Mitigation	Demolition and removal of the weir after decommissioning of the project.
Extent	From the head of the impoundment to a few hundred metres downstream of the weir.
Duration	Long term – lifespan of the weir (or permanent if the weir is not removed)
Intensity	Low
Probability	Probable
Confidence	Medium

Significance	**Low**
Further investigation required	The effectiveness of pumping needs to be established, beyond reasonable doubt, based on tried and proven technology.

Pumping of sediment is considered to have far less impact than sluicing and is the prefered option for environmental reasons.

7.2.5 Impacts within the Impoundment: Islands, River Margins & Vegetation

Inundation of Islands and Riverine Forests

A rough estimate of the surface area of each impoundment is shown in the table below. In addition to the areas normally occupied by channels, some 4,0km^2 to 5,3km^2 will become permanently inundated.

Weir Site	Area of original channels (m^2)	Area of Impoundment (m^2)	Therefore increased surface area (m^2)
2	2,930,000	8,124,000	5,194,000
4	2,260,000	6,287,000	4,027,000
5	2,910,000	8,184,000	5,274,000

The areas inundated comprise some extremely important habitat: riverine forests, island forest, and rocky riverbed habitat.

For weir sites 4 and 5, WTC (November 2003) calculated the areas of islands that will be inundated between the weir and the Angolan border. For weir sites 4 and 5 the proposed full supply level is the 1010.0 m contour. In the case of weir site 4, approximately 29% (1,36km^2) of the islands would be submerged. In the case of weir site 5, a slightly greater area would be affected, approximately 30%.

Erosion

The impacts on islands and riverbanks are expected to be far more extensive than the area of inundation for a number of reasons: -

- Water levels during above-average flood events will increase, which will expose the islands and riverbanks to greater risk of erosion,
- The roots of trees are very important in stabilising the unconsolidated sands, and even in creating little eddies that lead to deposition of sand. Die off of trees along the margins would therefore result in greater erosion,
- Water levels fluctuate very slowly in the Okavango River. In the event of fluctuations in river level above the normal rates, it is very likely that erosion will occur along the margins. This would be applicable in the event of sluicing of the impoundment, and is explained in more detail in section 7.2.4.

At this stage it is very difficult to predict the extent of erosion. Further investigation is required to assess the magnitude of this impact, but it is safe to say that it will be greater than the extent of the full supply level.

Impacts on Vegetation: Impoundment and Upstream Areas

Hines (April 2003) identified five categories of vegetation that would potentially be affected by the weir impoundment. These vegetation communities were described in section 6.4.1. The impacts on each vegetation community are stated briefly below.

- **Terminalia sandy Islands:** A major negative impact will occur in relation to the islands that are inundated or partially inundated. It is likely that most of the large woody species will die off where significantly increased water levels are encountered. The islands will probably be colonised by species such as *Syzygium guineense* and reeds once inundation has taken place. The likelihood of this happening is high and the resulting change will be long term.

- **Depositional islands:** These islands are not common in the inundation area and if flooded will represent a significant loss of biodiversity in a Namibian context. In the event of flooding, most of the species on these islands will die as few are tolerant of prolonged inundation. Replacement of woody elements will probably be by species such as *Syzygium guineense*, and *Phragmites* reeds. Change will be permanent and the likelihood of recolonisation by the current species assemblage will be unlikely. These islands will probably be eroded by wave wash and slumping if inundated.

- **Riparian fringing forests:** There is very little of this habitat left along the Okavango River as most of it has already been cut down for subsistence or commercial agriculture. The few remaining patches of riparian forests in reasonable condition would be a loss in terms of biodiversity. Moreover, this habitat is regarded as species rich in a Namibian context. Inundation will undoubtedly kill most of the species present here with the consequent replacement by flood tolerant species such as *Syzygium guineense*.

- **Dry quartzite ridges:** The inundation of this habitat will be limited as only a small percentage of the total extent will be flooded by the projected flood levels. There are some species of conservation concern within this type (*Eulophia* orchids) but as such a small percentage will be lost to flooding this is not thought to be of any significance.

- **Upslope Kalahari sands:** Very little of this habitat type is likely to be flooded and any loss to inundation is not considered to be significant.

In addition to the island woodlands, a substantial amount of riverine forest will be destroyed. This riverine forest occurs in a narrow band along the riverbanks, so that it is very susceptible to a rise in water levels. The area of riverine forest that will be affected has not been quantified. The length of the impoundment margins is of the order of 11 - 13km. On the southwest bank much of the forest has been cleared although many large trees remain. On the northeast bank, much more of the forest is intact.

In summary, the critical habitats that will suffer a major impact will be the **island woodlands, and riverine fringe forests.** These are **unique plant communities** in Namibia. These plant communities provide **valuable habitat, most of which has already been destroyed in Namibia, and which is under threat.** The loss of these plant communities is considered to be a major negative impact.

While these island- and riverine- plant communities are considered to be more important than individual species, the following **Red Data species** that occur in the affected area, are also of concern: -

- *Ansellia africana* Leopard Orchid (Vulnerable): these are rare on the Mukwe-Divundu islands. These would be threatened to the extent that host trees are threatened. They are widespread in southern and central Africa, but generally rare in Namibia.

- *Bonatea steudneri* Ground Orchid (Critically Endangered): this species has been collected on the islands near Andara and is only known from this area in Namibia (and southern Africa). If their habitat was lost, it would lead to local extinction of this species in Namibia.

- *Eulophia* species Orchids: a number of orchids have been recorded on the islands between Divundu and Mukwe but no flowering material has been observed here and so the identification of the actual species is not known. Two species may occur here:
  - *Eulophia leachii* Ground Orchid (Vulnerable)
  - *Eulophia livingstoniana* Ground Orchid (Endangered)

  Both the above species occur further east in the Caprivi, but have relatively wide distributions (*E. leachii* is very rare in South Africa; *E. livingstoniana* widespread in tropical Africa) in the sub-Region. Namibian populations may be significantly impacted by loss of island habitats.

- *Habenaria armatissima* Ground Orchid (Lowest Risk): although this species is reasonably common in Namibia, it is included here as the northern Namibian population (centred on the islands within the study area) is the only population known in southern Africa. To the extent that their island habitat is lost, this population will also be lost.

- *Habenaria epipactidea* Ground Orchid (Vulnerable): the Namibian population of this species (widespread in southern Africa) is limited to the Mukwe-Divundu area and is likely to be significantly impacted by loss of the island habitats through inundation.

- *Protea gaguedi* African Protea (Data Deficient): in Namibia, this species has an extremely limited range and has been severely impacted by overutilisation for traditional medicine. It has not been recorded since about 1986 and is thought to be extinct in Namibia. However, it may survive on the islands between Mukwe and Divundu where it was recorded in the past. Although this species is widespread and common through Africa as far north as Ethiopia, any loss of suitable habitat would severely impact this population if it does in fact still exist in Namibia.

The distribution of the above species within the affected area will require further investigation in order to determine the magnitude of the impacts on these species. However, it must be emphasised that the local loss of a rare species is not the only issue. Rare species contribute little to ecosystem functioning. It is the loss of habitats (plant communities) that is of greatest significance in this case.

Impacts on plant communities and species within the impoundment	
Nature of Impact	Loss of substantial portions of rare and threatened habitat that is unique in Namibia - both island- and riverine fringe forests. Potential loss of red data species – i.e. rare or endangered in Namibia. This impact will be further aggravated by above-average flood events.
Mitigation	The only possible mitigation is to select weir site 2, or reduce the heights of weirs 4 or 5 – to reduce the area of inundation.
Extent	The impoundment area (islands and river margins) as far upstream as is impacted by the FSL and aggravated flooding. Extent could be reduced by reducing the height of the weir.

Duration	Permanent
Intensity	High (up to 30% of the key plant communities affected by the FSL, and a greater area affected by extreme floods and/or erosion of margins). Needs to be determined for particular species (depends on their actual distribution in relation to the impoundment area).
Probability	Definite for island and riverine forest communities. Needs to be determined for certain red data species.
Confidence	High for habitat loss. Medium for red data species.
Significance	**High**
Further investigation required	• The detailed species composition, distribution and extent of the major vegetation communities needs to be determined in relation to the full supply level, • The occurrence, distribution, and population sizes of the Red Data Species occurring within these communities needs to be established, • The importance of the vegetation units to other taxonomic groups (that are not yet recorded in the area) and to rural livelihoods in the area. Once the exact site and height of the weir has been decided, and the area of inundation has been determined, an inventory of the woodland, islands, river fringes, and agricultural land that will be inundated needs to be carried out and the environmental, social and economic cost of this loss calculated.

The loss of island habitats and riverine forest in this section of the river is regarded as highly significant. This is not only because of the occurrence of several Red Data species of plants, but also because the affected area supports some of the last areas of true forest along the Okavango River in Namibia. Furthermore, the island habitats are unique within the Okavango River system.

Potential Introduction and Spread of Alien Aquatic Weeds, or Reeds and Papyrus

Following the disturbances caused by the initial inundation of new impoundments, most take several years to a decade to stabilize. This period of instability is caused by the change from the flowing water system to a quiet water one, and the decomposition of organic matter in the soil. The resultant increase in nutrient concentrations may manifest as pest problems, algal blooms or **aquatic weed infestations**. Although alien invasive floating plants have not been a problem in the upper reaches of the Okavango River in the past, a quiet water body is often the focus of aquatic weed infestations. The potential that weeds such as water hyacinth *Eichornia crassipes* (Kariba weed), *Salvinia molesta* or water lettuce, *Pistia stratiodes* may be translocated from infested areas in Caprivi, Moremi or Kafue floodplains, exists (Bethune, July, 2003 – **Appendix J**). The potential impact on nutrient loading is mitigated to some extent by the fact that the impoundment is small in relation to the volume of throughflow.

Any construction project creates an opportunity for the establishment of alien invasive plants. Alien weeds have infested many dams in southern Africa in the past, resulting in the need for extremely costly maintenance and eradication programmes. While the Okavango River has remained fairly free of alien invasive water plants such as *Salvinia molesta,* there is the potential for this to be introduced on boats, trailers and vehicles used during construction or boating in the impoundment thereafter. If introduced, the opportunity exists for excessive plant growth in the impoundment. This could be aggravated if there is additional nutrient loading from fertilisers as a result of agriculture along the river. These alien weeds could then spread to the Okavango Swamps, where they present a significant ecological threat and would be very expensive to eradicate.

If sediment were allowed to accumulate in the impoundment, over time the system would get shallower. This factor, together with low flow velocities, creates the potential for **Papyrus and Phragmites** to become established around the margins (as it has in the still water above Popa Falls). Papyrus forms floating “rafts” of dense vegetation. Although normally rooted, these rafts sometimes break away during floods. This issue may become a problem for the turbines in the long term.

If **pumping of sediment** is implemented, a **sediment trap** would be constructed in the riverbed across the impoundment just below the inflow. Upstream of the sediment trap the water will probably become shallower due to sediment deposition. Depending on the channel characteristics sand may accumulate. In that case, sand would need to be dredged to maintain sufficient water depth to ensure that sediment settles and does not skip over the sediment trap. If the water becomes too shallow and slow flowing (e.g. along the margins) reeds or papyrus are likely to become established. *Phragmites* reeds can establish very quickly, and this may have consequences for the maintenance of the sediment trap – requiring regular dredging and clearing of reeds.

Impacts of potential alien weed infestation, or growth of reeds or papyrus in the impoundment	
Nature of Impact	(a) Potential introduction and spread of alien invasive weeds. (b) Alteration of nutrient balances, resulting in conditions favourable for the growth of alien weeds and/or reeds and papyrus. (c) Growth of reeds or papyrus in shallowing water between the inflow and the sediment trap as a result of sediment deposition.
Mitigation	(a) Control the use of boats, ensure that boats, trailers, vehicles are free of weeds. This includes the construction and operations phases. (c) Implement a regular maintenance programme to prevent reeds encroaching on the sediment pumping system.
Extent	(a) The impoundment, or even as far as the Okavango Swamps. (c) The impoundment, between the inflow and the sediment trap.
Duration	Long term controls to prevent aquatic weed infestation. Long term maintenance for sediment and reed encoachment.
Intensity	Unknown
Probability	Improbable for introduction of alien aquatic weeds, provided that controls are implemented. Probable for growth of Phragmites or Papyrus.
Confidence	Low for introduction of aliens. Medium for encroachment of reeds or papyrus.
Significance	**Medium** for introduction of aliens. **Low** for encroachment of reeds or papyrus.
Further investigation required	• Institute controls as part of an Environmental Management Plan • Institute a programme of regular maintenance.

7.2.6 Impacts of Flooding / Probable Maximum Flood (Over and Above the FSL)

The weir will influence the lateral extent of the Probable Maximum Flood (PMF), and also the water depth and flow velocities. The impact of above-average floods should be considered in terms of both the lateral extent of flooding above the full supply level, and the effects of elevated water levels affecting riverbanks and islands that were previously above flood levels.

The water level during the PMF would be 0.75m above the top of the weir gates if the gates were fully closed (K.Lund pers comm). By comparison, the normal water level during operation will be 0.30m above the top of the weir, dropping below that when the river level is very low.

WTC (November 2003) calculated the flood peaks and return periods for the Okavango River at Popa Falls as shown in the table below. The return period indicates the statistical frequency of a flood of the corresponding magnitude. The upper limit for a 1,000-year return period was 2,955, which is comparable to the estimate for a 1:10,000-year period (approx. 3000 m^3/s).

Return Period (years)	Flood Peak (m^3/s)
2	640
5	870
10	1030
20	1195
50	1420
100	1595
200	1780
500	2040
1000	2955
Maximum	3000

WTC (November) 2003

WTC drew the floodlines for the PMF before and after the construction of the weirs at a scale of 1:4,000. On the smaller scale map, Figure 4 (1:25,000), attached to this report, the upstream limits of the maximum flood have been shown, but the lateral extent is too small to be represented at this scale. A brief description of the influence of the weirs on the PMF is provided as follows.

PMF for Weir Site 2 (full supply level at 1007.5 m.a.m.s.l.)

When the extent of the PMF is compared with the full supply level (FSL), from weir site 2 to the Divundu bridge, the inundation resulting from the PMF would extend only slightly beyond the full supply level.

From the Divundu Bridge to Frans Dimbare Youth Centre, there could be a significant increase in the impacts of intermediate floods, and the forest margins could be exposed to substantially increased erosion. However, the PMF would lead to catastrophic impacts regardless of the weir. Note that the highest discharge on record was 1,473m^3/s (Feb 1967) which is similar to the calculated 50-year return flood of 1420 m^3/s. This is less than half the discharge of the PMF.

The FSL of the impoundment for weir site 2 ends at a point about 1,6km above Frans Dimbare Youth Centre. Upstream from there, there is very little difference between the lateral extent of the PMF before and after construction of weir 2. The limit of the influence of weir site 2 is shown on **Figure 4**.

PMF for Weir Sites 4 & 5 (full supply level at 1010.0 m.a.m.s.l.)

For weir site 4 or 5, there is a significant but not a major difference in lateral extent between the FSL and the PMF. Buildings that are part of the Frans Dimbare Youth Centre would, however be inundated and would require protection.

From the Frans Dimbare Youth Centre upstream, there is very little effect of the weir on the extent of the PMF. **Figure 4** shows the limit of the new PMF level – just downstream of Andara. However, as stated above, increased flow velocities may have a significant impact on the trees along island margins and riverbanks.

In the assessment table below, it is the difference between the full supply level and the PMF that is assessed.

Impacts on probable maximum flood level over and above the full supply level	
Nature of Impact	Increased lateral extent of flooding, and increased water depth leading to increased erosion of trees and vegetation along the river banks and island margins.
Mitigation	The only possible mitigation is to reduce the height of the weir.
Extent	Weir site 2 – to about 1,6km upstream from the Frans Dimbare Centre. Weir sites 4&5 – to just below Andara Mission Hospital. The extent of the new PMF could be decreased by reducing the height of the weir.
Duration	A permanent increase in the flood risk, but a flood would be of short duration.
Intensity	Medium to High
Probability	Low – as per the return periods in the table above
Confidence	Medium
Significance	**Low** for the PMF and low magnitude floods, but **Unknown** for intermediate to large floods
Further investigation required	• The difference in area between the PMF before and after weir construction needs to be calculated. • Consideration should be given to the minimum weir height that would be economically feasible.

The significance of the PMF, in relation to the FSL, is considered to be low, but floods of intermediate to large magnitude could result in increased erosion as a result of the weir. This would need to be modelled in the next phase.

7.2.7 Impacts of Possible River Diversion

Possible Permanent Diversion for Operation of the Project

The possibility of diverting a portion of the river was considered in the pre-feasibility study and route options are considered in that report (WTC, November 2003). Weir sites 2, 4 and 5 were considered in this regard. However, it was found that a diversion canal was not economically optimal. The diversion option has therefore not been assessed in detail in this PEA report.

If the diversion option was to be revisited, then the following issues would need to be addressed: -

- The in-stream flow requirements of the section of river channel that suffered a reduced flow would need to be determined to a high level of confidence,
- Additional destruction of riverine woodland habitat for a diversion canal, would need to be quantified and assessed,
- Potential additional impacts on rural homesteads, and croplands, would need to be assessed,

- Impacts on tourism potential would need to be assessed – particularly in relation to the community campsites on the east bank at weir site 2,
- Impacts on archaeological sites and gravesites would need to be further investigated.

Diversion and canalisation would inevitably increase the environmental impacts of the projects, both on land and in the river. However, a **diversion is not proposed**.

Possible River Diversion During Construction

Weir site 4 lends itself to a temporary diversion, to facilitate construction, due to the presence of a normally dry channel running parallel to the main channel.

The use of a diversion channel could have a negative impact on terrestrial habitats, particularly riverine forest.

Further investigation and assessment of this option is recommended in the full EA.

7.2.8 Impacts on Vegetation Downstream of the Weir & Popa Falls

Two types of vegetative communities were identified in the areas downstream of Popa Falls as far as the Botswana border.

- **Sandbars and Islands:** There are no plant species of any conservation concern on the islands downstream of the falls, but they represent important breeding habitat for birds and reptiles.

- **Seasonally inundated grasslands/wetlands:** There are few plant species of conservation concern within this vegetation type. However, these seasonally inundated floodplains represent some of the most important grazing and home-range habitats for numerous species of mammals (e.g. Red Lechwe, Common Reedbuck, Sitatunga, Shortridge's Mouse) and birds (e.g. Slaty Egret, Wattled Crane, Rufous-bellied Heron).

Both the above habitats have the potential to be affected if sediment is deposited behind the weir, resulting in deepening of the river course and drying out of the floodplains (refer to section 7.2.3). Any loss of these habitats through reduced extent or duration of inundation could result in major changes in the ecological functioning of the Mahango Game Park and the areas within the West Caprivi on the opposite bank.

If channel deepening did occur, and flood duration on the floodplains is decreased, this will have a major impact on the species composition, productivity and structure of the vegetation types on the floodplains. This in turn will have a significant impact on numerous reptiles, birds and mammals, many of which are Red Data Species.

Very small concentrations of clays and organic material, which are normally present in the river, will be partially deposited behind the weir. This material may be important for the wetlands – given the fact that the Okavango River carries very low nutrient loadings. Therefore, to the extent that wetlands downstream of the weir are deprived of this material and associated nutrients, there could be an impact on the wetlands. However this issue needs to be further investigated before a proper assessment can be made on the magnitude or significance thereof.

Impacts on plant communities on floodplains downstream from Popa Falls	
Nature of Impact	Sediment deposition in the impoundment, if not adequately mitigated, would lead to channel deepening, reduced overbank flooding and drying out of wetlands, or part thereof.
Mitigation	As for sediment transport (section 7.2.3)
Extent	Needs to be determined, but probably including most of the Mahango Game Park and Buffalo Conservation Area. However, assuming that mitigation of sediment impoundment is highly effective (close to 100%) and continuous, there would no significant impact on these wetlands. However, if such mitigation fails or is inefficient, then it would not be possible to mitigate the impact of channel deepening.
Duration	Long term (in the worst-case scenario) Annual and cyclical in the case of sluicing.
Intensity	Needs to be determined.
Probability	Highly probable without mitigation
Confidence	High
Significance	This impact would be of **high** significance if not effectively mitigated. But in view of the probability of sediment pumping being effective, this is reduced to **medium** significance at this stage. If mitigation can be shown to be highly efficient based on tried and proven technology, then this may be reduced to **low** significance.
Further investigation required	As for sediment transport (section 7.2.3)

The significance of the potential impact on wetlands in Namibia is rated as "medium", because there is a strong possibility that the sediment problem can be solved. In that case the risk to wetlands would be decreased substantially.

7.2.9 Okavango Swamps

McCarthy (July, 2003) has provided a good summary of the potential impacts of the project on the Okavango Swamps (**Appendix L** and section 6.10). The role of sediment transport is central to the environmental impacts of the project on the Okavango Swamps. In the event that sediment was trapped behind the weir, or that mitigation measures failed or were inefficient, the following impacts could be expected in the Okavango Swamps: -

- Channels would become deeper instead of aggrading as a result of the accumulation of fine sand on the channel beds,
- Channels would therefore remain operating for longer, and channel failure would decrease,
- Since channel failure leads to redistribution of water across the swamps, this redistribution would be arrested,
- Normally toxic levels of salts on the islands are reached with roughly the same periodicity as channel failure. If this system is disrupted so that stabilisation of plant communities occurs, then areas of the swamps will become salinised to toxic levels and die off.

In summary, constant change is the key to the bio-diversity and ecosystem renewal in the Swamps. The change is driven by the supply of sediment. It is therefore of critical importance that the sediment supply should not be interrupted.

Thus a solution to the efficient and continuous transport of sediment past the weir is central to an assessment of the impacts on the Swamps.

Two other issues also need to be better understood.

- Certain species of fish migrate up the Okavango River. To the extent that the weir and its impoundment is an obstacle to migration, the Swamps could be adversely affected. The Namibian Directorate of Inland Fisheries is currently undertaking a study on fish migrations in the Okavango River, which is not yet published (Oelofsen, pers comm).
- Secondly, the deposition of some of the very small amounts of clay and somewhat greater amounts of organic matter (e.g. algae and detritus) in the impoundment, may also lead to further deprivation of nutrients in this nutrient-poor system. This issue may be offset to some extent by the increased use of agricultural fertilisers in the catchment, and by increased human activities affecting the river upstream of the project.

The Okavango Swamps support large numbers of people whose livelihoods are based on subsistence activities (fishing, crafts etc) and a vast tourism industry, which is important to Botswana's economy and foreign exchange earnings. Any significant adverse impacts on the Swamps would have corresponding secondary impacts on the economy – both at the subsistence and commercial levels. It is not possible to assess these impacts at this stage.

A full assessment of impacts on the Okavango Swamps can only be undertaken once the issues of sediment transport, and the design of a fish by-pass has been further investigated. The significance of impacts in Botswana should be regarded as **potentially highly significant**, until it can be shown, beyond doubt, that the impacts on sediment transport, water quality, and fish migrations can be mitigated effectively.

7.2.10 Impacts on Fauna (Mammals, Reptiles & Amphibians)

Affected habitats and species

There are four types of habitat that will be affected by the project: -

- The weir impoundment will change from a shallow water, fast flowing environment to a deep water still environment. The many rocky areas of riverbed can be expected to become covered in sediment to a greater or lesser degree (depending on the mitigation used for the transport of sediment).
- Rocky koppies may be affected by quarrying for stone, and to a minor extent by inundation.
- Downstream of the weir the river course may become deepened and rocky sections more exposed (again depending on sediment transport issues).
- Through the Mahango Game Park, channel deepening, if it occurs, would lead to drying out of the floodplains.

At this stage it is not possible to make a comprehensive assessment of all the fauna that will be affected by the project. With regards to the species listed in **Appendix I**, which can be affected by the alteration of the river flow, there are two categories of fauna: -

- Species that inhabit the running water and only use the terrestrial habitat incidentally eg. crocodiles, terrapins and otters.

- Nearly all the other species are dependent on the aquatic/terrestrial interface. Even primarily aquatic species, though, may depend on the interface at some time during their life-cycle.

Changes in the flow conditions can be expected to benefit some species while penalising others. Creating a relatively still impoundment, with associated impoundment flats may benefit Hippo, Cape Clawless Otter and Terrapins, which prefer backwaters.

The vulnerable Spottednecked Otter (*Lutra macucollis*) which requires pristine habitat is found in the area that will be affected by the impoundment. To the extent that the rocky sections of river course are inundated and consequently silted up, the habitat for these creatures would be adversely affected. Thus the impoundment is expected to have a direct impact on this species as crucial habitat will be inundated.

Downstream of the weir, conditions may become more suitable for species requiring swift, clear water if scouring occurs eg, Spottednecked Otter and some Terrapins.

However, the current situation is characterised by a matrix of habitat types – so that it is possible that some suitable habitats may be replaced by others. Thus the specific location of these specialised habitats which may change.

The only new habitat created will be the impoundment, and this will be at the expense of primarily terrestrial habitats, including vegetated islands, and rocky rapid sections with fast flowing water.

If erosion and channel deepening occurred downstream of the weir as a result of impoundment of the sediment, then significant negative impacts could arise. Vegetated islands, reedbeds, and sandbanks could be threatened. A loss of reedbeds in the Mahango Game Park, could for instance, mean the reduction or loss of Situtunga (a species of very high conservation concern). The population of Situtunga in the Mahango Game Reserve represents a significant proportion of the entire Namibian population of that species. Most other wetland-dependent species in the Reserve would also be affected to a greater or lesser extent.

Mitigation

With regards to the local fauna (amphibians, reptiles and mammals), damage, alteration and elimination of the **river and wetland-interface** must be kept to a minimum. A simple guideline would be to choose the weir site option, which ultimately results in the least amount of: -

- Inundation of vegetated islands,
- Flooding of riverbanks – specifically riverine forests,
- Flooding and/or inundation of terrestrial rupicolous (rocky) habitats,
- Ensure that sediment management practices do not lead to erosion of vegetated islands, reedbeds, and sandbanks in the Mahango Game Park.

The natural seasonal flood regime of the river must be maintained at all times (including the period taken to fill the impoundment) ie. floodplains and backwaters must cycle naturally, spatially and temporally.

If bulk stone is required for construction, surface stone should not be used. A quarry, of limited surface extent should be considered, preferably from a site already degraded. The selection of the site for quarying must be subjected to prior assessment in terms of flora and fauna.

The concept of the river as a “linear oasis” should be maintained (including the primary stream as well as strips of riverine vegetation). The fauna of the Mahango Game Park for instance is a product of migrations, along the river between Angola and Botswana. It is important that these avenues be sustained (although they are already partially interrupted by human settlement). In particular, aquatic species and species dependent on riverine vegetation should be able to continue to pass through the weir area, and surrounding infrastructure (vegetated riverine strips).

Future Investigations

If a decision is made which will lead to the disturbance or destruction of significant amounts of natural riverine or island vegetation (e.g. from the weir, roads, infrastructure construction, inundation or flooding), then full-scale inventories of those specific habitats must be conducted. This is to document, with voucher specimens, the species which did occur before the original habitat was permanently lost. This is particularly important in the case of islands which will be entirely inundated.

The three-toed sengi (*Petrodromus tetradactylus*) is a species of national as well as global conservation-concern (Nicoll & Rathbun, 1990; IUCN website), but has not been recently confirmed as occurring in Namibia. In Namibia, this species would likely be dependent on natural riverine vegetation/forests. It is not likely to occur on the western bank of the Okavango River because of the extensive habitat alteration which has already taken place there. However, this species may be present in patches of natural vegetation on the eastern bank of the river or on the islands – areas where natural riverine vegetation/forest is still relatively abundant. The presence of this species within areas to be flooded could be considered to be a fatal flaw in some options of this development.

There is insufficient information available at this preliminary stage for a proper assessment of the impacts on fauna to be made. Therefore, a further detailed assessment will be required during the full EA.

7.2.11 Impacts on Avifauna (Birds)

Hines (April, 2003) (**Appendix H**) has provided an analysis of the impacts on important bird species. The status of the river between Mukwe and Mohembo as an Important Bird Area and potential Ramsar site was referred to in sections 4.3.2 and 4.4.4. The following Red Data Species (Brown 1993 & 1997) have been recorded in the area and may be impacted by the developments associated with a hydropower scheme. Although the emphasis in this section is on Red Data Species, it must be emphasised that there are hundreds of other species that could also be affected by the project since this part of Namibia has the highest diversity of bird species (refer section 6.6.)

The following species may benefit from an impoundment: -

- Great White Pelican *Pelecanus onocrotalus* (Vulnerable): scarce non-breeding visitor.
- Pinkbacked Pelican *Pelecanus rufescens* (Vulnerable): rare non-breeding visitor.
- African Fish Eagle *Haliaeetus vocifer* (Vulnerable): uncommon resident.

The following species would be negatively affected by the loss of woodlands on islands and river margins, or rocky habitat in the impoundment areas: -

- Whitebacked Nightheron *Gorsachius leuconotus* (Endangered): rare resident. The impact of an impoundment would probably benefit this species in the long term if the current forests are replaced by *Syzygium guineense* thickets, but populations will undergo marked declines before these thickets can become established.
- Hadeda Ibis *Bostrychia hagedash* (Vulnerable): rare visitor.
- Western Banded Snake-Eagle *Circaetus cinerascens* (Critically Endangered): scarce resident. This species is restricted to the densely wooded riverine strip and has been recorded breeding on some of the islands in the Mukwe-Divundu area.
- African Finfoot *Podica senegalensis* (Critically Endangered): not confirmed in the Mukwe-Divundu area, but suitable habitat exists as part of the riverine and island forests.
- Rock Pratincole *Glareola nuchalis* (Vulnerable): common breeding intra-African migrant. Occurs from June to March/April on rocky outcrops with fast flowing water from Mukwe to Divundu and downstream to the northern border of the Mahango Section. Breeds December to March. Most nests are found within a metre or two of the water-level, with the lower rock outcrops of rapids being utilised. The population on the Zambezi River has been reduced through the building of the Kariba Dam and flooding of the Gwembe Valley. "Further dam building will reduce the population further, because there are no alternative breeding sites; existing sites are unlikely to be able to absorb more pairs of Rock Pratincoles." (A.J. Tree in Barnes (ed), 1998, p.453). The flooding of any of the rocky islands, rapids and outcrops would signficantly impact the breeding population of this species in the area. The study area is a regional stronghold of this species.
- Pel's Fishing Owl *Scotopelia peli* (Critically Endangered): scarce resident. Several territories are known from the Mukwe-Divundu islands. Any loss of the large trees within the riparian habitats (through inundation) will lead to a significant reduction in the local population.

The following species would be negatively affected by any loss of wetlands/ floodplains, or moist grasslands and islands or sandbanks in the downstream areas: -

- Slaty Egret *Egretta vinaceigula* (Vulnerable): scarce (non-breeding) resident.
- Saddle-billed Stork *Ephippiorhynchus senegalensis* (Endangered): scarce visitor.
- Yellow-billed Stork *Mycteria ibis* (Vulnerable): scarce to uncommon visitor.
- Sacred Ibis *Threskiornis aethiopicus* (Rare): scarce (non-breeding) resident.
- Glossy Ibis *Plegadis falcinellus* (Vulnerable): uncommon to scarce visitor.
- African Marsh Harrier *Circus ranivorus* (Vulnerable): uncommon to rare resident.
- African Fish Eagle *Haliaeetus vocifer* (Vulnerable): uncommon resident.
- Wattled Crane *Grus carunculata* (Critically Endangered & globally threatened): scarce resident.
- Red-winged Prantincole *Glareola pratincola* (Vulnerable): common resident.
- African Skimmer *Rhynchops flavirostris* (Endangered): uncommon breeding intra-African migrant. Present in the study area as soon as sandbanks become exposed enough to allow roosting from July to February when sandbanks are once again inundated. Breeds in extended colonies on sandbanks from late August/September to October. Any loss of sandbars and sandy islands in the main channel of the river through scouring and sediment loss would significantly impact this regionally important population.
- Coppery-tailed Coucal *Centropus cupreicaudatus* (Vulnerable): common resident.
- Greater Swamp Warbler *Acrocephalus rufescens* (Vulnerable): common resident.

In reviewing this list of Red Data Species, it should be borne in mind that the status of each species applies to Namibia only. Several species could be regarded as peripheral to Namibia rather than threatened as a population – this includes species such as Sacred, Glossy and Hadeda Ibis.

Collar *et al.* (1994) lists two species found within the study area as being globally threatened. These are Slaty Egret and Wattled Crane. For both these species the study area is part of their major global stronghold and they have to be considered to be of the highest conservation concern (Allen, 1997). The local populations of both these species are likely to be significantly impacted if the flood regime relating to the floodplains in the downstream areas is altered through channel deepening and reduced inundation periods.

Two other species, White-backed Night Heron and Saddle-billed Stork, are regarded by Collar & Stuart (1985) as being continentally threatened. It is uncertain as to how significantly any impoundment will impact the populations of the heron. However, the small population of the stork occurring here is dependent on the floodplains for its existence and any changes will probably affect this species negatively.

Impacts on birds in the impoundment areas (Red Data species only)	
Nature of Impact	Only Red Data species have been considered in detail, but hundreds of other species could be locally affected. These critical habitats will be negatively affected for a number of species that breed and/or feed here:- • Wooded areas destroyed by the impoundment, • Rocky rapid sections drowned out by the impoundment.
Mitigation	Reduce the height of the weir, or select weir site 2.
Extent	Over 30% of the available island habitat between the Angolan border and weir site 4 or 5. Reduced if weir height lowered.
Duration	Long term to permanent
Intensity	High
Probability	Definite within the impoundment areas. Probable beyond the full supply level due to erosion, high floods etc
Confidence	High
Significance	**High** for the impoundment areas.
Further investigation required	• Population estimates for species of concern, and their distribution relative to the main vegetation units and/or habitats. • Impacts of proposed impoundment developments on species of concern

The loss of island habitats and riverine forests in the impoundment section of the river is regarded as highly significant because of the occurrence of several Red Data species of birds in the habitats associated with the islands and riparian fringe. The drowning of rocky rapids will also significantly reduce the available habitat for breding and feeding, particularly in the case of the Rock pratincole.

Impacts on birds in the downstream areas (Red data species only)	
Nature of Impact	The potential impact on the wetlands, moist grasslands, sandbanks, and islands downstream is a secondary impact of potential failure to transport sediment through the weir. The result would be loss of breeding and home range habitat for Red Data species and many others.

Mitigation	• Ensure sediment transport through the weir. • Refer also to section 7.2.3 Assuming that mitigation of sediment impoundment is highly effective (close to 100%) and continuous, there would be no significant impact on these wetlands. However, if such mitigation fails or is inefficient, then it would be likely that the floodplains will be adversely affected, with serious consequences.
Extent	Needs to be determined, but probably including most of the Mahango Game Park and into the Delta
Duration	Long term
Intensity	Needs to be determined.
Probability	Probable, if mitigation fails
Confidence	High
Significance	This impact would be **highly** significant unless sediment transport is ensured. Since such mitigation appears likely at this stage, the significance is considered to be **medium**, or possibly even **low**.
Further investigation required	• Population estimates for species of concern, and their distribution relative to the main vegetation units and/or habitats. • Impacts of proposed impoundment developments on species of concern • Impacts of changes in sedimentation rates in the downstream reaches on species of concern • Refer also to section 7.2.3

The significance of this impact on birds is rated high for the impoundment area as a substantial portion of available habitat will be lost, and there is no mitigation possible – except to reduce the height of the weir.

In the downstream areas the impacts will depend on the solution to the sediment transport issue. Since a solution seems likely at this stage, the significance is rated as medium. The potential exists, however for major impacts on Red Data species such as Wattled Crane and Slaty Egret, and many others, if sediment transport fails. However, if the sediment transport issue can be resolved at a high level of efficiency and reliability, then there should be no significant impact on the floodplain species.

7.2.12 Impacts on Water Quality

Construction

During construction, there is the potential for pollution in a variety of forms: -

- Effluent and fuel spills often occur on construction sites / camps and can be detrimental to the local biota and for some distance downstream. Hydrocarbons (fuels, oils, hydraulic fluids etc) are highly toxic to aquatic organisms and must be kept out of the river at all times. The Okavango water is poorly buffered and small increases in nutrient levels could also cause localised eutrophication problems. This sort of unnecessary pollution can be managed through effective implementation of an Environmental Management Programme (EMP) for construction, including Environmental Specifications included in Contracts.
- If toxic materials, such as bituminous products are used for sealing and reducing permeability, the use of these products would need to be managed.

- Disturbance of the riverbanks and bed, and the destruction of riverbank reedbeds and forests will disturb large volumes of sediment. Sand particles will settle out very quickly, but finer silt, clay and organic particles, which have accumulated over time in the reed beds, will be released to the river. This will increase turbidity and may have certain short term impacts on water chemistry for some distance downstream.
- Drowning of vegetation in the impoundment area leads to decomposition with associated high oxygen demand. This would have negative impacts on aquatic organisms if not mitigated. Therefore it is normal practice to remove all vegetation from the impoundment area before the impoundment is filled. A few large trees e.g. leadwood (*Combretum imberbe*) could, however be left standing to provide nesting and roosting sites for birds.

The impacts of pollution from toxic substances can and must be managed through an EMP and strict enforcement of environmental specifications on site. The impacts of disturbance of sediment would be impossible to prevent. In any event, the impacts of pollution during construction would be short term. Furthermore, provided that pollution risks are properly managed, there should be no significant pollution.

Operation

Various impacts on water quality are normally associated with impoundments. These may potentially include: -

- Pollution by chemicals, fuels and lubricants,
- Anaerobic decomposition of organic matter in sediments,
- Reduction in oxygen levels,
- Changes in water temperature,
- Changes in nutrient balances.

There is little chance of pollution from the hydro power turbines or other installations during operation. However there is always a risk of pollution by fuel and oils from vehicles, boats or accidents at storage facilities, and these risks need to be controlled by means of an Environmental Management Plan.

Small volumes of clay and organic material will be deposited and concentrated in the impoundment due to reduced flow velocities, and this normally leads to changes in water quality. These changes may include anaerobic decomposition in sediments, reduced oxygen levels – due to the high oxygen demand associated with decomposition.

Nutrient levels may increase due to decomposition as well. Phosphates and nitrates lead to algal blooms or excessive growth of aquatic weeds in the impoundment and/or downstream. This may be aggravated by the proposed agricultural projects along the river (e.g. at Mukwe).

Impoundments also frequently result in stratification of water temperature. Particularly in the summer months, the impounded surface waters (in the epilimnion) tend to be warmer, less turbid and to have higher concentrations of dissolved oxygen than the bottom or hypolimnetic waters that tend to be colder, less well oxygenated and often more turbid and nutrient rich. Stratification, if it occurs, can be expected to be greatest during the early summer months when the discharge of the river is low, and solar heating and air temperatures are high. As the flood stage rises from January onwards, the amount of water flowing over the top of the weir should increase – reducing the accumulation of warm surface water. Thus, water released from the impoundment may differ from the water in the river and could change the water chemistry and water temperatures for a short distance downstream. For some fish species water temperature acts as a stimulus to start spawning. Disruptions to aquatic organism's life cycles can result from release of warmed epilimnetic or cold hypolimnetic water into the river below the reservoir. The high volume of throughflow through the impoundment should reduce the risk of stratification. However, this issue needs to be considered in more detail.

The accumulated clays and organic substances in the impoundment can also be expected to reduce the nutrient levels available to the floodplains downstream.

The potential impact mentioned above may be mitigated to a degree as a result of the following factors: -

- The volume of the impoundment is small in relation to the throughput of water. Therefore retention time is low,
- Water will be released continually through the bottom of the weir, which will help to prevent a build-up of water with raised nutrient levels or depleted oxygen levels.
- If water is continually allowed to flow over the top of the weir, as well, then the opportunity for stratification will be reduced.

The manner of operation of the scheme may be critical to mitigating the impacts on water quality caused by the impoundment. If sluicing is practised to remove sediments, this is probably the greatest threat to water quality (for the duration of sluicing). Fine clays, organic matter and products of decomposition would be released in the sediments discharged. Products of anaerobic decomposition are likely to be released, oxygen demand will increase, nutrients will be released at concentrations higher than normal, and turbidity will be increased. Since sluicing would have to occur during the high flow period, there would be some mitigation as a result of dilution. However, on the other hand, this period is important for fish breeding. There is a risk of fish kills downstream and in the impoundment, and/or the possibility that small changes in water chemistry and temperature may interfere with fish breeding. These risks need to be further investigated and quantified if the sluicing option is considered.

The option of pumping sediment past the weir, thus eliminating the need for sluicing, would therefore help to reduce some of the impacts on water chemistry.

A more detailed assessment of water quality issues will be needed in response to further details on the operation of the weir.

Monitoring

Recent studies indicate little change in water quality since the 1984/86 baseline study by the Department of Water Affairs. However, it will be important to include a detailed limnological investigation during the full EIA to enable sound monitoring programmes to be devised and carried out against a good set of baseline data. In particular, the impacts of any changes during construction, filling and operation of the project - particularly during annual flushing and refilling (if applicable), will need to be monitored.

7.2.13 Impacts on Aquatic Ecosystems

The project will have the potential for significant adverse impacts on the aquatic ecosystems in the river. In broad terms, these impacts could result from: -

- Perturbations to the flow hydrograph,

- The change from fast flowing shallow water to slow flowing deep water environments,
- Loss of particular riverine habitats, due to drowning out within the impoundment zone, or erosion of sandbanks, loss of overhanging vegetation etc,
- Disruption of fish migrations due to the weir and the habitat barrier created by the impoundment itself,
- Changes in water chemistry, or possibly temperature.

Understanding of biological processes is, at this stage, not sufficient to properly assess these potential impacts. However an explanation of some of the key issues is made in this section.

Impacts on aquatic habitats

The main alteration to habitats will be the change from seasonally fluctuating, shallow, flowing water or lentic ecosystem to a deeper still water or lacustrine ecosystem, more akin to the lagoon areas found downstream in the panhandle and delta. The variety of riverine habitats, which allow for the great diversity of plants and animals in this river will be reduced. The weir will form a large, 6-10m deep impoundment, causing the permanent loss of extensive areas of certain habitats (e.g. those associated with rocky rapids, islands, island fringes, riverbank reed-beds, papyrus fringes, riparian woodlands, riffles and a variety of river microhabitats. This reduction in habitat diversity will cause a reduction in biodiversity. Generally this will cause a reduction in species richness, where only those species that can adapt to quiet waters will survive. The fish fauna typical of the large lagoons in the Delta are adapted to fairly shallow waters with well vegetated margins, which may not be the case in the new impoundment particularly if water levels fluctuate depending on operation of the scheme.

Changes in water chemistry, temperature, oxygen content and nutrients, (see section 7.2.12 above) as well as a reduction in habitat diversity, are expected to result in a change in the invertebrate and fish fauna.

One of the most important habitats that will be partially lost is the **rocky rapid** sections that exist between the Angolan border and Divundu. Depending on the weir site chosen, about half of this habitat will be directly impacted by the weir impoundment. Changes in the vegetation along the river margins, and loss of rocky habitats will affect ecological functioning of the river. For example, aeration resulting from the rapids will be reduced. Nutrient and sediment transfers will be altered. Initially there may be increased nutrients supplied to the impoundment, but once the system has stabilised, the nutrient and food input to the system can be expected to decrease due to reduced vegetation along the river margins. Depending on the sediment management methods used, sedimentation may gradually smoothen and finally cover all the submerged rocky habitats within the basin. The rate of this process and the type of sediment will depend on the mitigation measures to ensure sediment transport. Riffles and river microhabitats will be lost and will reduce overall habitat diversity. As the diversity of habitats is decreased, the diversity of insect and food fauna will decrease and consequently the diversity of fish will also be reduced.

The loss of substantial portions of the existing **island habitats, and riverine forests** will also be detrimental to the aquatic systems. Nutrient processes will be affected, and erosion of margins can be expected. The supply of food species e.g. insects from overhanging vegetation, will also be affected.

Even under ideal conditions of operating at full supply level and not allowing fluctuations in water level, it will take time for vegetation to establish around the margins of the impoundment. However, should the water levels fluctuate at a rate greater than the natural rate of change, a denuded draw-down zone typical of most impoundments, may prevent the re-establishment of marginal vegetation.

Impacts on species

Hay (1995) points out that the species most vulnerable to altered flow conditions are the specialised feeders, habitat specialists, and those species dependent on the annual flood for successful reproduction, whilst the more tolerant species with a wider range of habitats and feeding requirements would adapt well.

The loss of habitat diversity will lead inevitably to a loss in diversity of fish species, at least within the impoundment zone. Of particular concern in the swift-flowing rocky rapid sections of the river, are the two rare species found only in rocky rapids: the broad-head catfish, *Clariallabes platyprosopos* and the oscillated spiny eel *Aethiomastacembalus vander-waali*. It is expected that these two species will not be able to survive in the impoundment and their population may be at risk in this part of the river due to the loss of a substantial portion of the favourable rocky habitat. Selection of weir site 2, or lowering of the height of the weir, would reduce the area of rocky habitat that is destroyed.

The food chain in regard to river fish is dominated by tiger fish, a visual predator. By day most of the other fish tend to "hide" in the shallows, in reed-beds, amongst rocks and in the shadows of overhanging branches of riverine trees, typically only venturing out at night. Should these sheltering habitats be reduced, a resultant decline in the diversity and number of fish in the river is expected.

Of particular concern in the shallow margins of the river below the confluence with the Cuito River is the rare habitat specialist, *Ctenopoma intermedium,* a species dependent on dense marginal vegetation and considered threatened by habitat destruction (Hay 1995). It is found only in this section of the Okavango River. A related, less scarce species, *Ctenopoma multispine* would also be vulnerable to the loss of shallow riparian waters.

Not only will fish species diversity be reduced, but also the diversity of aquatic invertebrates. A recent investigation of the aquatic macro-invertebrates of the Kunene River (de Moor *et al* 2000) warns about the potential impacts of converting from a lotic (flowing water) to a lentic (still water) ecosystem. The creation of an impoundment will destroy riparian vegetation that provides refuge for both the aquatic larval stages and the adults. The numbers and diversity of species would decrease, with the ephemeroptera (mayflies), tricoptera (caddisflies), coleoptera (beetles) and diptera, particulary the chironomids and simulids, being most affected. Experience elsewhere has shown that impoundments detrimentally influence riverine aquatic macro-invertebrates and impair the overall biological functioning of the riverine ecosystem.

If sluicing is practised, there is an added risk that benthic macro-invertebrates could be smothered by the silt released from the weir. This could also result in reduced species diversity.

Impacts on migration of fish – upstream and downstream

Weirs are often an effective barrier cutting off or restricting fish migration and have caused drastic declines in populations of migratory species and often the local extinction of those species. An example is the disappearance of the barred minnow, *Opsaridium zambezense* from much of its former range in South Africa. This migratory fish is found in the pools below the rapids in the Okavango and would be particularly vulnerable to the building of a weir near the Popa Falls.

The annual catfish migrations are well-known in the Okavango System, with species such as *Clarias gariepinus* and *Clarius ngamensis*, moving to the shallows to spawn. Several researchers have noted that, at certain times of the year, tiger-fish, *Hydrocynus vittatus* densities shift from one area in the river to another confirming that they migrate up and downstream with rising and falling floods (Skelton & Merron 1984, 1987, 1898, Hay 1995). Other migratory species in the river are *Brycinus lateralis, Labeo cylindricus* and *Micralestis acutidens.*

The weir will be a potential barrier to fish migration both upstream and downstream and as migration is often a response to breeding requirements, this could lead to reduced reproduction in the floodplains downstream with subsequent impacts on the system as a whole. The provision of a fish by-pass could mitigate this impact, but this would need to be approached with caution. Not all fish by-passes have been successful in the past. It will be necessary to design an effective fish bypass to ensure that all migratory species of fish are able to bypass the weir. This bypass cannot be modelled on those used in Europe or North America, since the fish in the Okavango River are not all highly energetic fish like salmon, which can make use of “fish ladders”. In this case, the system will need to take into consideration also the sluggish species. The conditions in the by-pass need to be similar to the natural pools and riffles in the rocky sections of the river.

Further investigation will be required to determine the necessary design requirements for a fish by-pass, and the effectiveness of proposals will need to be assessed for each particular migratory species.

Ecological impacts of fluctuations in the hydrograph

The habitats and ecosystems of the Okavango River and its floodplains fluctuate in rhythm with the hydrological and seasonal cycles in the river. The biota are adapted to these changes and equipped to handle this cyclical environmental stress. On the other hand, additional, unseasonal changes brought about by the operation of the hydro power scheme could prove too stressful with serious affects on the fauna of the system.

Pallett (1997) warns that seasonal floods play an important ecological role. If the timing of changes to the hydrograph, or the volume of overbank flooding is significantly affected, then this can have ecological consequences. Decreases in sediment and nutrient transfer, could also have adverse impacts in Namibia and throughout the Delta. The results could include a reduction in the diversity of fish species and macro-invertebrates, and even loss of floodplain habitats. However, for the most part, it should be possible to manage these impacts through careful design and operation of the project. Of concern though is the proposed annual sluicing and refilling to allow sediment transport.

In addition to the impacts on water quality mentioned in section 7.2.12, the perturbation in the hydrograph, if changes are too rapid, may trigger unseasonal fish migration that could lead to impaired breeding if for example the conditions in the floodplains are not yet optimal for breeding. Another effect of sluicing already mentioned, could be reduced macro-invertebrate diversity due to smothering of benthos. It could also cause unseasonal floodplain inundation, which may be detrimental to the dry season biota of these floodplains. For example in the Mahango Game Park warthogs and other burrowing animals may have their burrows and young in the floodplain, or it may drown important grasses that the grazers in the park need.

This aspect of dry season floodplain use, particularly in the park should be more carefully investigated during the full EIA.

In the Botswana section of the river, the most important factor determining fish productivity is thought to be the nutrient pulse that results from the seasonal floods. These nutrients together with the creation of shallow breeding, feeding and nesting areas as the floodplains of the seasonal swamps are inundated, determine the productivity of the system (Murray 1997). This nutrient pulse would be substantially disrupted by sluicing. If sediment pumping is practiced, this impact will be reduced but not eliminated as the impoundment will still retain some of the clays and organic matter.

If the project was used to meet diurnal fluctuations in electricity demand, additional impacts would arise. Experience at Ruacana since the 1970s has shown that the hydro power scheme has a major impact on the aquatic biota downstream particularly on the aquatic invertebrate fauna (Moor *et al,* 2000). This is due to daily diurnal pulses of water that are released – having a "tidal" effect downstream. This daily wetting and drying out of floodplain and river margins has a serious impact on marginal vegetation, erosion of banks and the invertebrate fauna of the river, as well as on the breeding areas of some fish. The long-term impacts include the reduction of the self-cleansing function of the river and a serious loss of macro-invertebrate biodiversity, and may interfere with fish breeding, particularly of species that make "nests" in shallow water. The issue of daily fluctuations is mentioned here as a concern at this preliminary planning stage. However, since daily fluctuations are not part of the current proposal, this impact would not arise.

During the construction phase, certain additional impacts could arise. These would include: -

- Diversion of water around the construction site and working in the river, could interfere with fish migration, increase silt load and turbidity, and smother benthic organisms.
- Blasting kills fish as they are very susceptible to pressure changes and their swim-bladders are easily ruptured. Any blasting during construction activities would cause local fish kills. Care should be taken to avoid breeding seasons or migration times. Further investigation would be necessary to determine these.

In summary, the potential impacts of the proposed hydro power project and weir will be most severe in the impoundment area. Depending on the design and operation of the scheme, there may also be downstream impacts. Should fish migration be affected, these impacts will extend upstream too. Any changes to the magnitude, timing and duration of seasonal floods, or significant changes in water quality parameters will have an impact on river ecosystems, productivity and biodiversity.

The impacts on aquatic ecosystems have the potential to be significant and far-reaching. Although many of the impacts can be mitigated through careful design and operation of the scheme, the project will always carry significant risks in terms of ecological impacts as the available knowledge of these systems is not comprehensive.

A key impact in the impoundment area will be the loss of rocky habitat, and this should be minimised through the choice of weir site and height of the weir. In the downstream areas, key impacts will depend on the success of operation within the natural variation of the hydrograph.

Daily fluctuations in water level (due to generation for peak demand) should not be permitted.

Greater understanding of the ecological impacts is required, particularly with regard to the natural occurrences in the river that trigger certain biological events - such as migrations and breeding. This information needs to feed into the design of the operation of the project. Recommendations for further investigations are made as follows: -

- If sluicing is proposed, the appropriate timing needs to be determined in relation to ecological processes in the river (e.g. migrations and breeding of fish), and the impacts need to be further investigated,
- Include a detailed investigation of the macro-invertebrate fauna of the Okavango River similar to the recent study by the Dept of Water Affairs and the Albany Museum on the Cunene River. Other than the snails, little is known of this component of the river biota, and the information would be important in planning a sound operational procedure for the scheme and for the determination of the ecological water requirements and future monitoring of water quality changes,
- Investigate the possibility of temperature stratification in the impoundment,
- Potential impacts of changes in water and sediment chemistry also need to be better understood.

7.2.14 Quarrying of Construction Material, and Disposal of Waste

There are no quarries in the near vicinity of the project for construction stone. Therefore it is likely that rock will have to be excavated from small hills (koppies) near the river, or from the area to be inundated (below the full supply level). The koppies are important for certain species of plants, and they may also be important for certain species of reptiles. The rocky rapids are important for certain species of fish, birds, and even otters. Therefore, more detailed environmental evaluation is required as part of the site selection process for quarrying of stone.

The same will apply to the location of a site for the disposal of construction waste, and vegetation that is cleared from the weir impoundment.

7.2.15 Provision of Renewable Energy versus Negative Impacts.

Hydro power has a major advantage over other sources of power such as those based on fossil fuels as it is based on a renewable resource. It is also relatively “clean” power as it does not generate greenhouses gases to the extent that coal- or oil-fired power stations do. Furthermore, it does not pose the risks and problems of waste disposal that are associated with nuclear power plants.

However, while hydro power has many benefits in terms of relatively “clean” power based on renewable resources, the benefits need to be weighed up against the negative impacts of impoundments. The World Commission on Dams has cited many case studies revealing that:

- the benefits of dams are often overestimated at the design stage,
- the environmental and social impacts are normally underestimated,
- and the measures proposed for mitigation are seldom as effective as predicted (WCD 2000) (and section 4.4.6 above). In terms of the WCD criteria, the proposed weir is classified as a large dam.

Attempts at mitigation of the ecological impacts of large dams have met with limited success due to the failure to anticipate and avoid some impacts, the poor quality and uncertainty of predictions, the difficulty of coping with all impacts, and the only partial implementation and success of mitigation measures. More specifically: -

- It is not possible to mitigate many of the impacts of reservoir creation on terrestrial ecosystems and biodiversity,
- The use of fish by-passes to mitigate the blockage of migratory fish has had little success, as the technology has often not been tailored to specific sites and species,
- Good mitigation results from a good information base, early co-operation between ecologists, the dam design team and affected people, and regular monitoring and feedback on the effectiveness of mitigation measures,
- Environmental flow requirements (which include managed flood releases) are increasingly used to reduce the impacts of changed streamflow regimes on aquatic, and floodplain ecosystems downstream.
- One of the modern approaches is to offset the losses resulting from habitat destruction by proclaiming special protection measures for the remaining habitat. For example, the islands, forests and rocky riverine habitats near Andara, need further protection, and have considerable tourist potential.

7.3 Assessment of Socio-Economic Impacts

7.3.1 Impacts on Subsistence Livelihoods

The local people rely heavily on the natural resources provided by the river, and the small plots of fertile soil close to the river. Subsistence activities are not just a means of survival, they are also a way of life. Although the people are poor, they enjoy a certain quality of life that can be threatened by the need for relocation.

No detailed assessment has yet been carried out on the social impacts of the project as the areas affected have not been finalised. A full socio-economic assessment is necessary as part of the full Environmental Assessment in due course.

The World Commission on Dams (2000) has provided a number of insights arising from the analysis of the socio-economic impacts of dams in the past. These include: -

- People living downstream have suffered serious harm to their livelihoods due to impacts on natural floodplain function and river fisheries,
- Many of the displaced people were not identified or enumerated, and therefore were not resettled or compensated,
- Where compensation was provided it was often inadequate to enable people to establish a new lifestyle,
- Those who were resettled rarely had their livelihoods restored, as resettlement programmes have focused on physical relocation rather than the economic and social development of the displaced,
- The further the people are moved, the less likely it is that their livelihoods can be restored,
- The poor, other vulnerable groups, and future generations often bear a disproportionate share of the social and environmental costs of large dam projects without gaining a commensurate share of the economic benefits:
- Affected populations living near reservoirs have often faced adverse health conditions as a result of environmental change and social disruption,
- Gender gaps have widened and women have frequently borne a disproportionate share of the social costs and reaped few of the benefits,
- With regard to the distribution of the costs and benefits, the WCD emphasises that the

'balance-sheet' approach to adding up the costs and benefits is increasingly seen, on equity grounds, as a poor means of choosing the 'best' projects. The true economic profitability of large dam projects remains elusive, as the environmental and social costs of large dams were poorly accounted for in economic terms.

The above list of potential issues is provided as a background and guide for a more detailed socio-economic assessment in the full Environmental Assessment.

More specific to the Popa Falls area, the main impacts could relate to the reliance of the local people on fishing, subsistence agriculture, materials for crafts, potential for diseases, and social and cultural disruption. These will be explained in more detail below.

Subsistence Agriculture

The impoundment will have a significant negative impact on the availability of suitable soils for some 12 km of the river course. This is because the best soils are restricted to a narrow margin along the river, where there is a higher percentage of clay and organic matter in the soil. Thus many displaced families may lose an important means of production of food. It may not be possible to provide alternative lands as the soils further from the river are less fertile and less suitable for dry land farming.

There is the potential for partial mitigation in regard to soil fertility through introduction of the concept of trench cultivation. This is a system of deep mulching using only readily available natural materials. However there is little experience available in Namibia and the system would need active promotion and training for it to become acceptable in this cultural context.

Livestock

Currently, livestock graze on the fertile riverbanks and reeds on the floodplains. The productive area of available grasslands near the river would be reduced as a result of the impoundment. Some displaced families would be disadvantaged as a result of lost accessibility to grazing. However, reedbeds may increase in time along the margins of the impoundment.

Fishing

About a third to half of the households (section 6.11.4) along the river catch fish, and fish are an important source of protein in the diet of the people. The impacts of the project on fish resources cannot be quantified at this stage. However, to the extent that fish resources are adversely affected by the project, this would represent a direct economic impact on local communities, not only those close to the impoundment, but possibly also upstream and downstream as far as Botswana.

Moreover, it is almost impossible to predict how fish will or will not adapt to the deep water, still conditions created by the impoundment. In the case of Kariba Dam, there was no Zambezi species that could fill the vacant niche created by the dam. Exotic species, suitable for human consumption, were introduced. However, the introduction of new species would not be acceptable in the Okavango River, given the unique nature of the Okavango Swamps.

If the project has a negative impact on fish resources and migrations of fish, this impact will be suffered not only in the vicinity of the project, but also potentially far afield upstream, and downstream into the Okavango Swamps (refer section 7.3.11)

Crafts and building

Materials for use in crafts and building are harvested from the reedbeds along the river, and from forests (both riverine and Kalahari woodlands). The inundation of forests, may result in a reduction of the materials locally available. Reedbeds, on the other hand, are likely to become established along the new margins of the impoundment within a few years if the water level does not fluctuate significantly.

Wood is used not only for crafts and household implements, but also for firewood. The hydro power project will result in a reduction in available trees for wood for these purposes in the impoundment area. The electricity provided by the project will probably not benefit the people who are thus disadvantaged, as electricity will not be affordable to most of these people.

Traditional wild products

The forests also provide wild fruits, and medicinal plants for the local people. Although the quantities involved are very small, the nutritional contribution of wild fruits may be significant.

Impacts on subsistence livelihoods	
Nature of Impact	The impoundment will flood areas that are important to the local resource base – grazing, forests – for crafts and firewood, agricultural fields, wild products and possibly reduce fish resources.
Mitigation	Displaced people may need to be assisted to find alternative livelihoods.
Extent	Weir impoundment area and surrounding land
Duration	Long term to permanent
Intensity	High
Probability	Definite
Confidence	Medium
Significance	**Medium**
Further investigation required	• Full socio-economic assessment

7.3.2 Impacts of Relocation

A number of homesteads will be displaced within the area to be inundated by the weir impoundment. The number of households affected was provided by WTC (May 2003).

Weir site	Households to be relocated
2	260
4	80
5	100

It is normal practice in Namibia to compensate people by means of a cash payment. However, the impact of relocation of communities is far greater than a one-off financial consideration. Lifestyles and livelihoods may be seriously disrupted for many of the people who are displaced. Compensation does not enable people to gain the skills required to manage their sudden increase in cash, or to find a new livelihood to replace the old. Loss of small agricultural lands, and possibly reduction in fish resources, may therefore lead to impoverishment of displaced people. As mentioned in section 6.11.2, land tenure systems in this area are complex. Therefore a detailed socio-economic study would need to be conducted and options for mitigation of these impacts would need to be worked out in consultation with the affected communities.

Certain other structures may also have to be relocated, e.g. a clinic, a church, a service station etc. However, these can be re-established without undue impact on the people, provided that they remain as accessible as before.

The impacts of relocation is considered to be of **medium** significance as it should be possible to mitigate the impacts to some degree.

7.3.3 Potential Diseases

The construction of dams elsewhere has often resulted in an increase in the incidence of certain diseases. In a normal healthy ecosystem, pest species that are responsible for the spread of certain diseases are kept under control by predators. For example, mosquito larvae are eaten by fish, frogs etc. However, when an ecosystem is disturbed, the result is sometimes disproportionate growth in pest species due to a breakdown in the ecological balance. Since malaria is already prevalent in the Popa Falls area, there is a distinct possibility that mosquitoes, and hence malaria, could increase – to the detriment of the local people.

Similarly, the change in habitat from fast flowing water to a still water habitat has the potential to increase the incidence of bilharzia. This has happened elsewhere, e.g. in the Aswan Dam in Egypt. This impact may not be immediate, but as suitable snail habitat (reedbeds) become established around the margins, conditions are created for the increased spread of the disease. In Rundu, the incidence of bilharzia is extremely high in sectors of the community. This is partly due to small pockets of infestation on parts of the floodplain that are inadequately flushed by the river (Fudge, LuxDev, pers comm).

The incidence of HIV/AIDS is already high in Namibia and in the Divundu area. The introduction of a large workforce from outside of the area, without their spouses and families, creates an opportunity for the further spread of HIV/AIDS, both to and from this area of the country.

The potential for increased disease would be difficult to mitigate, but because the intensity of the impact is difficult to predict, the significance of this issue is rated as **medium**.

7.3.4 Impacts on Tourism in Namibia

Community Campsite

The N//goabaca Campsite is situated at the north end of Popa Falls and is run by the Kyaramashan Community Trust, who expressed concern about weir site option 1 or a canal or pipeline from weir site 2 to below the falls. These options would have had an impact on this campsite and the proposed lodge at the old hunters' camp known as White Sands - directly downstream of the campsite. However, weir site 1 has been rejected by WTC. Weir site 2 is still an option, but a canal or pipeline is not currently proposed. The weir at this position would not be visible from the campsite or the White Sands site due to a bend in the river and the tall woodlands along the river.

A weir at site 2 could, however, have an impact on boating above the falls, and there is potential for the channel to become clogged by sediment if the sluicing option is implemented. During construction, noise is also likely to affect the tourist establishments.

The impoundment itself could be part of the tourist attraction as it would facilitate boating at all times of the year. However boating would need to be controlled to prevent importation of aquatic weeds. It should be restricted to eco-tourist activities and noisy water sports should be excluded.

Popa Falls Resort

The Namibian Wildlife Resort campsite and bungalows are situated at the south end of Popa Falls in tall riverine forest. A view of weir site 2 is obscured by the forest and by wooded islands. Depending on the operation of the weir, especially in relation to sediment transport, these islands could be susceptible to erosion. However, if sediment is pumped instead of sluiced, then it should be possible to design the outflow from the weir such that the islands do not become eroded. The weir may, however, be visible from boats on the river near the resort.

Suclabo Lodge & Other Lodges Downstream

Suclabo Lodge is situated immediately below Popa Falls (marked “Ho” in **Figure 3**). Weir site 2 would not be visible from the lodge, but noise during construction may reach the lodge if the wind is in the right direction. The attractions of the lodge include boat rides up the river to the falls, and a magnificent view from the lodge of forest across a deep river channel. If sluicing is practised, it is likely that sediment will reduce the depth of water, for at least part of every year, to the extent that navigation on the river will be impeded. This would obviously be detrimental to the lodge. However, if sediment is pumped instead, then there should be no significant impact of the project on the lodge. Other lodges downstream would probably be affected in the same way to a similar or lesser degree - Mahango Safari Lodge, Ndlovu Safari Lodge, and Ngepi Camp.

In the upstream areas near Andara, the quality of the natural environment, and the low density of settlement, presents an opportunity for a number of tourist developments. These could be developed along the lines of Namibia’s Community Based Natural Resource Management Programme (CBNRM) where communities register conservancies, which then enter into joint venture partnerships with lodge developers.

The impact on existing tourist establishments could be significant if sediment is sluiced as turbidity in the normally clear water will increase, and sandbanks may obstruct navigation even in relatively small craft, for part of the year.

The upstream areas near Andara have considerable potential for tourism, especially community based tourist ventures. However, it is difficult to predict how the presence of a hydro power station would affect the perceptions tourists. Many eco-tourists to the northeast of Namibia are looking for “wild” natural areas.

7.3.5 Impacts on Local Trade, Commerce and Industry

The project can be expected to have a short term positive impact on trade and commerce in the Divundu area as it will bring a large workforce into the area during construction. However, once construction is complete, only a handful of people will be required to stay and operate the project. Thus there will be little or no direct sustainable benefit to trade and commerce.

The availability of power may create opportunities for small industries and the further development of home crafts in the area. Power can also be made available for irrigation. However, as stated in section 6.11.5 the area suffers from other obstacles to industrial development, and probably the greatest economic potential for the area lies in tourism.

7.3.6 Employment Opportunities

Short term employment opportunities will be provided during construction. Employment of unskilled labourers is likely to occur, while the more skilled workforce will probably need to be sourced outside the area.

Once construction is completed, the project will provide permanent employment for only a few people – most of whom are likely to be sourced from outside the area. Therefore the project will provide very few sustainable employment opportunities. The provision of power to the area, may, however have some positive spin-offs in this regard as suggested in section 7.3.5 above.

7.3.7 Aesthetic Impacts / Sense of Place

Weir

Three weir sites are currently under consideration (sites 2, 4 & 5).

Site 2 would be highly conspicuous from the district road (D3403), which would have to be re-aligned due to the inundation. From the Divundu bridge on the Trans Caprivi Trunk Road (B8) however, the wall itself 2,5 km away would not be conspicuous as it would be operated at full supply level. Only in the event of sluicing, or emptying of the impoundment for any other reason, would the wall become conspicuous. At full supply level, the large expanse of water would dominate the view from the bridge, which would be an attractive feature, providing increased visual amenity to passing traffic, albeit at the expense of forest.

Weir sites 4 and 5 would be conspicuous from the district road (D3402), short sections of which may have to be re-aligned. The weir itself (downstream face) would be more conspicuous from the Trans Caprivi Trunk Road (B8) than in the case of weir site 2. Weir sites 4 and 5 are about 2km and 1km from that road respectively.

Switchyard

The switchyard is potentially the most unsightly component of the proposed project. It is difficult to mitigate this impact, but the aesthetic issue needs to be taken into account in the decision regarding its location. In the case of weir site 2, it may be possible to screen the switchyard behind existing forest if it located near the prison agricultural project. However, no layout plan has yet been proposed.

Powerlines

No alignments for powerlines have yet been proposed. Powerlines generally have three significant impacts: -

- Potentially high visual impacts,
- They are hazardous for large species of birds, including rare and endangered species such as cranes. They should therefore be routed as far away as possible from watercourses and wetlands. This is probably the most serious potential impact of powerlines in this area.
- The access tracks required for construction have minor negative impacts on vegetation.

These factors need to be taken into account in selecting the powerline route. It should be as far away from the river as possible, and should pass through the more widespread habitat types (e.g. Kalahari woodland), preferably through the most disturbed areas.

Noise

The main sources of noise during operation would be from the turbines and the power house. However, the noise is unlikely to be heard at a distance above the sound of the water passing through the weir. Noise during operations is therefore not considered to be a significant impact

During construction, noise will be generated from activities such as blasting and earthmoving. The noise of construction from weir site 2, is likely to have a short term impact on the tourist camps near the falls. Partial mitigation could be achieved by ensuring that noisy activities are stopped from sunset to sunrise.

Sense of Place

Popa Falls and its surroundings is not a pristine area, but it has a special character which attracts tourists. Tourism has increased in recent years since the military convoy was no longer required on the Trans Caprivi Route. “Sense of Place” is a subjective matter and one that is difficult to assess. However, the following issues can be expected to impact on the sense of place for the weir site options.

Weir site 2 would inundate a large area of riverine forest on the east bank, with a large expanse of water replacing the view of forest in the landscape. Weir sites 4 & 5 would destroy numerous wooded islands. These islands have, in the author’s view, a high “special place” character.

A large expanse of water could be appealing to tourists. However, to many Namibians encountered during the public participation programme who value the Popa Falls area for its unique character, forest remnants, and “wild feel”, the project is felt to have a negative impact on the “sense of place” that they attach to this area.

7.3.8 Impacts on future Conservation Potential of the Area

A number of authors have previously emphasised the uniqueness of the Mukwe – Popa Falls area in the Namibian context. This area has long been identified as an area in need of conservation. Mendlesohn and Roberts (1997) describe the Okavango valley woodlands as "probably one of the most threatened habitats in the region" which, with the exception of the Mahango Game Park are largely unprotected. These woodlands have amongst the highest species indexes for both plants and birds of any habitats.

Maggs *et al.* (1998) point out that due to relatively high rainfall and habitat diversity, the vegetation alongside the Okavango River is very rich in species, but under threat from human pressure, agricultural activities, overgrazing and large development projects, and that the current level of protection is not adequate.

Barnard *et al* (1998) shows that although perennial rivers and their adjacent woodlands, particularly in the Kavango and Caprivi Regions, are amongst Namibia's top priority areas in terms of biodiversity, only a small section is protected. Along the Okavango River 0.25 km^2 lies within the Popa Game Park and 244.62 km^2 lies within the Mahango Game Park. Although the Caprivi Game Park was declared in 1968 there is little effective protection of that side of the river. Barnard *et al* concluded that it is a priority to extend the protected areas network to include components such as this riparian woodland.

Hines (1997) found that the few remaining mammals, many of the vulnerable bird species and the only viable populations of amphibians and reptiles in this area, occur almost exclusively in the woodland on the islands, on the banks of the river on the Caprivi side, and in the small Mahango Game Park.

From a conservation point of view, the Mukwe – Popa Falls – Mahango section of the Okavango River has a number of advantages: -

- High biodiversity of plants, birds and fish,
- High diversity of habitat, including habitats that are unique in the Okavango river – such as the rocky sections of the river, and the remnants of riverine and island woodlands,
- High diversity of birdlife in the riverine and island woodlands and the wetlands downstream,
- It has the further advantage that both banks of a perennial river are within Namibia, and perennial rivers are seriously under-represented within conservation areas in Namibia,
- Rocky sections of the river are a special habitat that support at least two rare and specialised species of fish - *Clariallabes platyprosopos* and *Aethiomastacembalus vanderwaali,*
- This section of the river has considerable tourism potential,
- This section of the river was identified by the Ministry of Environment and Tourism for consideration as a proposed Ramsar site, or wetland of international importance.
- A number of authors have recommended that it should be given formal conservation status as one of Namibia's biodiversity "hotspots" (Bethune 1992, Hines, 1997, Mendelsohn and Roberts, Barnard *et al* 1989, and Maggs *et al* 1998).

Although the creation of an impoundment may have a certain appeal for tourists if the remaining islands and woodlands were conserved, the hydro power project could have a significant negative impact on the conservation potential of the area in two ways. Firstly, the destruction of a large proportion of the forest would result in fragmentation of the remaining forest areas. By severing links with other forest areas, their ecological viability will be diminished to some degree. Secondly, if the hydro power project goes ahead, it will tend to encourage the perception that the area has been degraded – which may reduce the likelihood of any further conservation initiatives being successful in this area in the future.

Furthermore, given the known presence of many Red Data species of plants, fish, birds, and some terrestrial animals, and the unique nature of the affected habitats, the significance of the area for conservation at present is considered to be high. To the extent that bio-diversity in the area is reduced, it is considered likely that the value of the area for conservation will be seen to be reduced. Therefore, the project may lead to a reduced commitment by government to conserve this area. Thus the impact of the project on conservation initiatives is expected to go far beyond the impacts on certain species. For this reason, the impact of the project on the conservation potential of the area is considered to be **highly** significant. However, if the Ministry of Environment & Tourism committed itself to conserving the remaining area and encouraging the development of tourism potential, then the significance of the impact on future conservation initiatives could be reduced.

7.3.9 Impacts on Archaeological and Cultural Sites

Kinahan (1986) found that the presence of archaeological sites was 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 Park, with very low frequencies south of that point. This pattern confirms local traditions that the Mahango area was maintained as a chiefly hunting area in pre-colonial times.

The area around Popa Falls has not been extensively surveyed and it is possible that archaeological sites may be discovered there. The west bank within the study area has been disturbed by settlement to a degree that makes further significant finds unlikely (Kinahan, March, 2003 – **Appendix N**). The east bank has not been surveyed due to its military history and the presence of landmines to this day.

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.

A group of islands upstream of Andara has been used by the Mbukushu until recently, as burial grounds. The most important islands are belived to be Dikuyu, Thipanana and Gororo (refer to **Figure 2**). Within the past decade, a new burial site has been established on the west bank of the river opposite Gororo Island. A weir with a full supply level at 1010m.a.m.s.l. will not have any influence on the above-mentioned sites, all of which are upstream from Andara. However, the above information is based on a site inspection led by a single informant from the local community. A more comprehensive survey is considered necessary in the full Environmental Assessment.

At the northern end of the quartzite outcrop forming Popa Falls, the rock is overlain by 3m of coarse alluvium. Here lies an undisturbed deposit of stone artefacts. Kinahan (March 2003) places these as Middle Stone Age and Later Stone Age deposits. This site will not be affected if there is no diversion canal. (A diversion was originally proposed for weir site 2, but was found to be uneconomical).

Other archaeological deposits are likely to be uncovered or destroyed at any point upstream of Popa Falls where earthworks are caried out. Accelerated soil erosion as a result of draw-down of water in the impoundment for sluicing may also expose sites. Mechanical bush-clearing on the less disturbed east bank may also expose sites. Kinahan considers that sites on the west bank would have only a **low** significance, while sites on the east bank would have a **medium** significance, on the grounds that the sites have not been investigated and are expected to be undisturbed – thus raising their potential information value. Because most sites are within 500m of the river, it is almost certain that some sites, not yet discovered, will be inundated by the impoundment. Kinahan considers that draw-down for sluicing operations would lead to erosion of islands and banks resulting in further loss of archaeological sites.

7.3.10 Clearing of landmines

In the area north of the Trans Caprivi Trunk Road and east of the River, there are still unexploded landmines, which have caused a number of fatalities and casualties in the past two years. Anti-personnel mines are made of plastic, and may float if they are eroded out from the riverbanks. Thus they may pose a threat to the turbines or to people, animals or even fish downstream. The impoundment area would have to be cleared of vegetation before the filling to prevent rotting vegetation from causing anaerobic conditions. Labourers involved in clearing vegetation would therefore be at risk. It will therefore be necessary to clear the area of landmines before clearing vegetation.

7.3.11 Socio-economic Impacts in Botswana

Wildlife and Tourism

Tourism in Botswana is one of the mainstays of the country's economy and a major source of foreign exchange earnings. Therefore any negative impacts of the project on the Okavango Swamps would be unacceptable to Botswana. Moreover, the Okavango Swamps is a wetland of international importance. Because the tourist industry in Botswana is based entirely on its natural environment and wildlife resources, this aspect of its economy is dependent on maintaining its environmental integrity. Therefore, to the extent that the natural environment in Botswana is degraded, secondary impacts of a socio-economic nature will follow.

In section 7.2 various potential bio-physical impacts on the Okavango River and Swamp system were identified. This preliminary assessment has not been able to assess the potential downstream impacts because further investigations on key issues such as sediment transport are required first. However, the most important issues that need to be addressed in the next study phase are: -

- to ensure that sediment supply is not interrupted,
- that there is no perturbation in the hydrograph that is greater than would occur in the natural regime of the river at any particular time of the annual hydrological cycle,
- to design the weir and fish by-pass to ensure that the migration of all migratory species of fish is not interrupted,
- to ensure that water quality is not adversely affected,
- considerations of water quality should also take into account habitat destruction on the riverbanks and the cumulative impacts of agriculture,
- further consideration and quantification of the cumulative impacts of water loss and abstraction from the river.

If the design of the project can ensure that there is no interruption of sediment transport, and there is no significant perturbation of the hydrograph, then the factors in the Swamps that result in channel switching, removal of salts, and ecosystem renewal will not be significantly affected by the hydro power project. It should be possible to assess the mitigation measures in regard to the above two issues at the design stage and full Environmental Assessment. If these two issues are fully mitigated, then there should be no significant impact on Botswana's wildlife and tourism industry.

However, issues of water quality, fish migrations, and the cumulative impacts of future developments in agriculture and water abstraction on the river cannot be assessed with any certainty. These issues will pose significant ecological risks. It is the impacts on aquatic ecosystems that will be most difficult to assess with full confidence.

Fishing

Subsistence fishing is at least as important in Botswana as it is in Namibia, and the sale of fish brings in a little cash for some households. Fish resources are under pressure. Any impact on the aquatic ecosystems has the potential to affect the fish resources downstream. It is impossible to predict the magnitude of such impacts at this stage. However, to the extent that the project has a negative impact on fish resources, it could further marginalise the communities that are dependent on subsistence fishing.

Sports fishing (on a tag-and-release basis) is also increasingly important in Botswana as part of the tourist attraction.

The significance of the potential for adverse impacts in Botswana should be regarded as **potentially high**, until it can be shown, beyond reasonable doubt that the sediment issue, and other impacts mentioned above can be effectively mitigated.

7.3.12 Need for Socio-economic Assessment within a Cost-benefit Framework

Given the fact that there are significant social, ecological, and economic risks associated with the hydro power project, it is recommended that a full socio-economic assessment be undertaken in order to weigh up the benefits against the economic and environmental costs of the hydro power project. This study should be carried out for the affected areas in Namibia, and Botswana.

Many environmental costs cannot be evaluated in monitory terms. However there is a need to take these costs into account in some way so that they can be internalised by NamPower as part of the project costs. For example, people who are relocated may lose access to grazing lands, while others may suffer as a result of reduced fish resources. The value of these resources needs to be considered as a cost of the project to the affected local communities.

To the extent that the project reduces the conservation and tourism potential of the area, there will be an opportunity cost. Tourist developments that could have brought revenue into the area on a sustainable basis, may be forfeited. These kinds of issues need to be identified and weighed up as part of the cost of the project before a decision can be made regarding the net benefits of the project.

7.4 Cumulative & Synergistic Impacts, and Issues Related to the Planning Process

7.4.1 Cumulative Impacts of Water Abstraction or Loss, & Climatic and Land Use Changes

The discharge of the Okavango River to the Okavango Swamps is, and will be affected in the future, by a number of demands on this resource in Angola, Namibia and Botswana. Each activity on its own would probably have little impact on the Okavango Swamps. However, in combination the total demand could result in a significant negative impact on the Swamps.

Water demand for irrigation along the Okavango River in Namibia					
Area (ha)		Water demand (million m^3 /yr)		Water demand (proposed rate of abstraction) (m^3 /s)	
Existing	Future	Existing	Future	Existing	Future
770	7,793	11.55	116.90	1.54	13.91
8,563		128.45		15.45	

Figures supplied by the Directorate of Agriculture, Namibia

When the rates of abstraction are considered in relation to the lowest flow on record of approximately 80 m^3/s the total demand on the flow at Mukwe amounts to about 19% of that minimum flow rate. The location of the Mukwe Irrigation Project is shown in **Appendix O**.

The table below shows some of the known demands for Namibia.

Demand	Volume (million m^3/year)	% of Mean Annual discharge
Irrigation	128.45	1.34 %
Evaporation from the weir impoundment (est. max.)	6.33	0.07 %
Seepage from the weir impoundment	unknown	-
Domestic supply to Windhoek & Central Areas of Namibia in the next 5 – 30 years (M.Harris, NamWater, pers comm)	20.0	0.21 %
Demand for Angola	unknown	-
Demand for Botswana	unknown	-

The proposed irrigation projects are completely independent of the hydro power project. The figures above are provided in order to indicate the potential importance of the cumulative impacts of water demand from all activities. The water loss from the impoundment due to evaporation and seepage would probably not be significant in isolation, but in combination with all other water demand factors, these losses could become significant for the Okavango Swamps.

The likely water loss due to seepage needs further investigation. However, at this stage, it appears unlikely that evaporation and seepage from the proposed impoundment would influence a decision about the project.

However, the significance of cumulative impacts in the medium to long term are potentially **high.** It is therefore recommended that studies should be undertaken to determine the total loss of water from the system that could be permitted without significant adverse impact on the Swamps, and then apportion that water in some way between the three countries that share this river. Such matters lie within the scope and function of OKACOM.

The impact of climatic change on the long-term viability of the project has not been determined. It will be necessary to use tha latest climate and runoff models to predict climate change and viability of the project.

Similarly, the impact of changing land uses in the catchment on water flow, quality and sediment production will need to be modelled for a variety of scenarios under changing climatic conditions.

7.4.2 Need for a Strategic Assessment of the Resources of the Okavango River in Relation to the Okavango Swamps

The public in Botswana, through the public participation process for this PEA, called for a strategic assessment of the resources of the river. The need for such a study is justified in terms of water demand alone, as shown in the preceding section.

Angola, Namibia and Botswana have signed regional undertakings of co-operation such as OKACOM, the Joint Permanent Water Commission, the SADC Protocol on Shared Rivers as well as commitments to international environmental conventions such Ramsar and the United Nations Convention on Biological Diversity. These various agreements place on obligation on member states sharing the river basin to ensure ecologically sound management of the water resources.

8 SUMMARY OF KEY IMPACTS

In this section the key environmental impacts and issues are summarised, and their significance for decisions about the project is given as a synthesis of the assessment criteria that were applied to each impact (refer section 7.1).

The **Significance** of the impact, in relation to decisions about the project, is defined as follows: -

- **Low** - means that the assessed impact would not have an effect on the decision to approve the project or the particular project alternative,
- **Medium** - means that the assessed impact should have an effect on the decision unless it is effectively mitigated,
- **High** significance - means that the decision should be influenced regardless of any mitigation.

Environmental Impact or Issue	Significance rating	Possible Mitigation	Further Investigation Required
Impact on river discharge due to evaporation and seepage	**Low** for this project but cumulative impacts could potentially be high.	No mitigation possible, except to reduce the area of the impoundment	Accurately determine the volume of evaporation and seepage.
Impact on hydrograph – one-off filling & operation at full supply level	**Medium**, but **Low** if filled during high flow period and the rate of change of the water level does not exceed the normal rate of change.	Fill during high flow period at a slow rate so that the rate of change in water level does not exceed the normal rate of change.	Further details of design and operation, and their implications for the hydrograph, are needed at the Feasibility stage.
Impact on hydrograph/ water levels due to sluicing: rapid draw down and refilling will lead to changes in water level that are far more rapid than the natural condition.	**High** For this and other negative impacts, **sluicing is <u>not</u> recommended**.	Sluicing can only be practised during high flow. No power can be generated during sluicing, which places time constraints on the draw-down and refilling time. As a result the rate of change in water level would be far more rapid than the natural rate of change in water level.	If sluicing is pursued contrary to the recommendation of this report, then investigation of the ecological impacts, and optimum timing of sluicing in relation to ecological processes would need to be investigated.
Impact of pumping of sediment on hydrograph / water levels	**Low**	No mitigation required	Engineering design and analysis of effectiveness of pumping to ensure sediment transport.

Environmental Impact or Issue	Significance rating	Possible Mitigation	Further Investigation Required
Sediment deposition behind the weir resulting in scour downstream	In the absence of mitigation, the significance of this impact would be considered **high**. Since mitigation appears to be feasible, it is rated **medium** at this stage. This may be reduced to **low** significance if it can be proved that mitigation will be highly effective using tried and proven technology.	Pumping (or sluicing) of sediment. Any mitigation would have to be continued forever after decommissioning of the weir, or the weir would have to be removed.	Determine effectiveness of mitigation, (pumping prefered). Determine effects of scour downstream.
Impacts of sluicing	**High**, but needs to be quantified. Notwithstanding further investigations, the ecological risks are expected to be high as it will be extremely difficult to predict all ecological impacts. For reasons of the known impacts and the ecological impacts that are difficult or imposible to predict, **sluicing is <u>not</u> recommended.**	None	Investigate: **-** • effectiveness of sluicing, • redistribution of sediment downstream (deposition and scour), • erosion of islands in impoundment, • water quality impacts, • turbidity and effects on public perceptions, • impacts on breeding Skimmers, • benthic fauna, • impacts on hydrograph and water levels, • fish breeding, • other ecological processes.
Impacts of pumping sediment	**Low**	Full backup system to ensure uninterupted transport in the event of power failure or equipment failure. Removal of weir as part of decommissioning.	Model the effectiveness of pumping. Evaluate the impacts on benthic fauna.

Environmental Impact or Issue	Significance rating	Possible Mitigation	Further Investigation Required
Impacts on terrestrial plants in the impoundment area	**High** This rating is based on both the loss of habitat, which is rare and unique in Namibia, as well as the likely impacts on rare and endangered species.	Reduction in height of the weir, or selection of site will reduce the impacts but possibly not sufficiently.	Determine the distribution of Red Data species. Inventory of plants and habitats that will be lost.
(a) Risk of alien weed infestation. (b) Risk of reed encroachment towards sediment trap.	(a) **Medium** for the risk of alien **a**quatic weed introduction and spread as the consequences are high, but the risk can be managed. (b) **Low** for encroachment of reeds or papyrus as maintenance should be possible.	(a) Alien weeds have colonised many dams in southern Africa. Controls are needed during construction and operations to ensure that weeds are not imported on boats, vehicles or equipment. (b) Sediments accumulating in the impoundment upstream of the sediment trap could be dredged to prevent reed encroachment.	(a) Controls as part of a management plan for construction and operations. (b) Model the accumulation of sediment between inflow to the impoundment and the sediment trap. Devise a maintenance strategy as part of the project design.
Impacts on probable maximum flood & lower order floods **-** over and above the full supply level	**Low** for the PMF and low magnitude floods; **Unknown** for intermediate to large floods that are less than the PMF.	Consider reducing the height of the weir. There is no other mitigation possible.	
Impacts of possible river diversion for power generation**– no longer proposed.** Site 4 lends itself to temporary diversion during construction due to the existence of an old dry river channel	A diversion for power generation would increase the negative impact on aquatic and terrestrial ecosystems. However this is **not proposed** as it was found to be uneconomical. So there will be no impact. The impact of a temporary diversion for construction requires further assessment. A **fish by-pass** is needed.	A **fish by-pass** is essential to facilitate migrations of fish.	The impact of a temporary diversion during construction requires further investigation in the full EA Further investigation of requirements for fish migrations and construction of a fish by-pass is needed.

Environmental Impact or Issue	Significance rating	Possible Mitigation	Further Investigation Required
Impacts on plant communities / floodplains downstream	This impact could be highly significant if not effectively mitigated. However in view of the likelihood of success of proposed mitigation, it is regarded as of **medium** significance at this stage. If mitigation can be shown to be highly efficient, based on tried and proven technology, this may be reduced to low.	Sediment pumping should prevent the risk of scouring.	Determine the effectiveness of mitigation for sediment transport, model the scouring of river bed.
Impacts on Okavango Swamps	Proper evaluation not yet possible, pending further investigation (e.g. sediment transport). **Potentially highly significant**. However, effective mitigation of sediment transport, fish-migrations, water quality and impacts on the hydrograph could reduce impacts considerably.		Further investigations required regarding sediment transport, fish migrations, water quality, turbidity, and effects on the hydrograph / changes in water level (if any).
Fauna (mammals, reptiles & amphibians)	Not yet evaluated.	Minimise inundation of rocky sections of the river in the impoundment zone. Ensure that the wetlands downstream are not affected. Avoid damaging quartzite koppies	Inventories of species to be lost from the area
Avifauna (birds) (a) Impoundment areas (b) Wetlands downstream	(a) **High** due to reduction in the area of breeding and feeding habitats. (b) Potentially **high** without sediment transport mitigation, but **medium** or even low depending on the success of sediment transport measures.	As for sediment transport.	Resolve sediment issue. Inventory and further assessment of species affected.
Impacts on water quality – construction and operation	Not yet evaluated	Avoid sluicing in favour of pumping	Further investigation and assessment required. Monitoring against baseline data will be required during construction and operation.
Impacts on aquatic ecosystems	Not yet evaluated in detail.	Minimise loss of rocky aquatic habitat. Fish by-pass is essential	Further investigation required including fish migrations, benthic fauna, water quality.
Quarrying for construction stone	**Low**	Avoid koppies with Red Data species, if present.	Prior assessment of quarry site options

Environmental Impact or Issue	Significance rating	Possible Mitigation	Further Investigation Required
Impacts on subsistence livelihoods	**Medium**	Affected communities may need assistance in developing alternative livelihoods	Full socio-economic assessment
Impacts of relocation	**Medium**	To be developed with the community	Full socio-economic assessment
Potential diseases	**Medium**	Education	
Impacts on tourism (Namibia)	**Low**	Ensure that sediment does not choke channels, especially below the falls	
Aesthetic impacts – sense of place	**Medium**		
Impacts on future conservation initiatives in the affected area.	**High**	A commitment from MET to give formal conservation status to the remaining areas of high quality habitat would reduce this impact.	Further evaluation of the impacts on Red Data species and rare habitats. Explore options for formal conservation with MET.
Impacts on archaeological sites	**Low** on west bank **Medium** on east bank	Identification and possibly excavation and documentation of sites before bush clearing.	Look for evidence of sites before bush clearing
Clearing of landmines	**Low**	It will be essential to clear landmines on east bank of impoundment area, but this should not affect a decision about the project.	
Impacts on tourism in Botswana	Not yet evaluated. Potentially highly significant. However, if the sediment issue is successfully resolved, and impacts on aquatic ecosystems are effectively mitigated, the impact on tourism in Botswana could possibly be reduced to low significance.	The impact on tourism in Botswana is related to the bio-physical impacts. Therefore if mitigation of the following issues can be made highly effective, then there should be no significant impact on tourism in Botswana: - sediment transport, water quality, fish migrations – as explained in section 7.	Full socio-economic assessment required. Determination and assessment of ecological risks.

Environmental Impact or Issue	Significance rating	Possible Mitigation	Further Investigation Required
Cumulative impacts of water loss / abstraction from the Okavango River	Not yet evaluated. Potentially highly significant. The contribution of the hydro power project to this issue needs to be further established.	Limit the abstraction / loss of water by each country e.g. by limiting the development of irrigation, which is likely to be the biggest consumer.	Cumulative assessment required as part of a catchment management plan. The loss of water due to the hydro power project (through seepage and evaporation) needs to be determined at the full EA stage. Strategic assessment of the resources of the Okavango river is required. If the loss of water as a result of this project is insignificant in relation to the flow of the river, then this issue need not be an obstacle to the project.
The synergistic effects of climate change, and changes in land use in the catchment and their impacts on the long-term viability of the project have not been determined.	Undetermined	Undetermined	Modelling and scenario planning.

9 CONCLUSIONS & RECOMMENDATIONS

9.1 Key Impacts in the Impoundment Area and Upstream

On the basis of this preliminary Environmental Assessment, the impact on unique habitats at all three weir sites is potentially a major negative impact, which needs a considerable amount of futher investigation during the full EA to properly quantify in terms of significance. The key habitats affected are: -

- Sandy Islands,
- Depositional Islands,
- Riverine fringing forests,
- Rocky rapids and pools in the river,
- Dry quartzite ridges (much less affected due to their elevation).

A number of Red Data Species (plants, birds, animals and fish) are known to occur within those habitats and the distribution of these species needs to be further investigated and assessed. In the case of the first four of the five habitats listed above, there will definitely be a substantial loss of available habitat as a direct result of the impoundment. For this reason, it is likely that certain plant, bird, fish and possibly animal species may be lost from this area. Populations of other species are likely to be significantly reduced as well, due to the reduced availability of suitable breeding and feeding sites.

More specifically, the occurrence and distribution of the following need to be established to determine the degree and significance of impacts which may be caused by the proposed scheme:

- Six species of orchids on the Red Data List for Namibia are known to occur on the islands or close to the river between Mukwe and Divundu, A rare protea was recorded here in the past but it is now thought to be extinct in Namibia,
- Two species of fish are on the Red Data list because they inhabit specialised rocky river habitat which is scarce – mainly occurring between the Angolan border and Popa Falls. These could be at risk as a result of the project,
- The spottednecked otter is known to occur in the impoundment area. This is a rare and specialised species that needs near-pristine rocky habitats in a river,
- Eighteen species of mammals, eight species of reptiles, and ten species of frogs are dependent on the array of wetland habitats, but their distribution in the impoundment area and their specific habitat requirements are not known,
- The area from the Angolan border to the Botswana border has the highest diversity of birdlife in Namibia (over 450 species). At least four Red Data Species could suffer a significant loss of habitat in the impoundment area. These include the Rock Pratincole that breeds on rocky rapids, and the critically endangered Pels Fishing Owl. Two other endangered species may also be adversely affected. Two species of Pelican may benefit if there are enough fish in the impoundment,
- Several species of fish are known to migrate through the area, and these species would be negatively impacted if their migrations are obstructed. It will therefore be necessary to design a fish by-pass that is suitable for all migratory species in this section of the river,
- Little is known about the aquatic invertebrates in the Okavango River but these will be important in the food chain. The impacts of an impoundment and the methods to ensure

sediment transport need to be further investigated in relation to invertebrates, especially benthic fauna.

Much emphasis can be placed on rare or endangered species. However, while Namibia has an obligation, under the Convention on Biodiversity, to protect its endemic species, rare species may contribute little to ecosystem functioning. The loss of important habitat, which is unique in the context of Namibia and/or Okavango River, is therefore just as important, if not more so, than the local loss of species.

The river forms an important ecological link, as a corridor for the movement and migration of animals, fish and birds, and even the distribution of plant species. The impoundment will lead to fragmentation and disruption of ecological linkages. This may have a significant impact on the conservation value of the area, particularly with regard to riverine fringing forest, islands and rocky rapid sections of the river. The Mukwe Irrigation Project (which is proposed for development independently of the hydropower project), would also destroy large areas of forest, but this is mostly Kalahari Woodland rather than the rare riverine fringing forest. However, synergistic impacts may occur between these two adjacent project areas.

There is also a possibility of alien aquatic weeds being imported into the system during construction and operation, which could have a major impact on the native species and the operation of the hydro power plant. This potential impact will need to be managed for the life of the project (construction and operations) to prevent infestations.

Socio-economic impacts on displaced peoples who practise a subsistence lifestyle based on the natural resources of soil, wood, fish etc could be significant. While it may be possible to mitigate this impact by assisting the people to acquire alternative livelihoods, this will require active involvement with displaced peoples. Simply compensating people financially for the value of their properties is not considered adequate to mitigate the potential loss of lifestyle occupations.

The areas upstream of Popa Falls have considerable tourism potential based on the bio-diversity and natural beauty of the area. In particular, there is opportunity for community based tourism as part of Namibia's CBNRM programme. If the hydro power project leads to perceptions that the area has been degraded, then the tourism potential may be adversely affected. Conversely the presence of an impoundment may add value to any such community-based tourism programme if recreational use could be made of it. If the project goes ahead, NamPower should consider contributing towards ensuring that the remaining sensitive habitat is set aside for conservation and community-based tourism.

9.2 Comparison of Weir Sites

Weir site 2, with a full supply level at 1007.5 m.a.m.s.l., this site would have the least impact on the islands and riverine forest upstream from Divundu. However, one large area of forest on the east bank, south of the Trans Caprivi Trunk Road would be susceptible to inundation. Partial protection, by means of an earth embankment, may be possible. Site 2 would have a greater impact on settlements and infrastructure than sites 4 and 5. The socio-economic impacts can, however, be mitigated to a large degree, whereas the potential destruction of unique habitats or loss of species from the area cannot be mitigated.

Weir sites 4 & 5, with a full supply level at 1010.0 m.a.m.s.l., these two weir sites would have similar impacts, except that site 5 would have a slightly greater area of inundation. Both would have a much greater impact on natural habitats than weir site 2. These two sites would have less impact on settlements, on account of lower population densities upstream from Divundu, but they would nevertheless impact on the resource base on which people depend (subsistence agriculture, grazing land, sources of wood, and possibly fishing grounds).

Weir site 4 has the advantage of a potential diversion during construction, via an old river channel, although this would have an impact on additional terrestrial habitat.

For any of the weir sites, it will be necessary to construct a fish-bypass. This will have to be designed for the local migratory species, with low gradients, riffles and pools that resemble this section of the river.

A degree of mitigation of the impacts of inundation of forest and riverine habitats could be achieved by reducing the height of the weir.

9.3 Canalisation for Power Generation

The pre-feasibility study found that diversion of a portion of the river flow for power generation was economically sub-optimum. It was therefore not considered in any detail in this report.

9.4 Comparison of Alternatives for Sediment Transport

Two alternatives are under consideration to ensure that sediment is passed through the weir.

9.4.1 Sluicing of Sediment

Sluicing is the least preferred solution because the negative environmental impacts of this method are expected to be significant, potentially including the following: -

- Choking of channels downstream, with consequent impacts on boating from lodges,
- The possibility that sand would be deposited below the falls and would take a long time to be redistributed downstream – during which time channel deepening could occur further downstream,
- Erosion of sandbanks that are used for breeding by birds (including the endangered African Skimmer),
- Smothering of benthic microfauna, with implications up the food chain,
- The necessity for fairly rapid draw-down of water level resulting in significant perturbation of the hydrograph, exceeding the natural rate of change in water level,
- Erosion around the perimeter of the impoundment and islands due to draw down – with consequent impacts on vegetation,
- Reduction in water quality. Some of the organic matter and clays in the river will be concentrated in sediments in the impoundment. When these are released during sluicing, the products of decomposition in the sediments will be released downstream. In a worst case scenario, it is possible that the sediments could become anaerobic due to a high biological oxygen demand in the 10-11 months before sluicing. This could result in fish kills or other adverse ecological impacts when this material is released downstream.
- The turbidity in the river during sluicing will increase considerably compared to its normal clear condition. In addition to any ecological impacts this may have, it would create a very negative impression and is likely to attract criticism of the project from users of the river downstream.

For all of the above reasons, sluicing of sediment is not the preferred option. However, if no alternative solution can be found, then considerably more investigation would be required to establish, with a high level of confidence, that the physical and ecological impacts would be within acceptable limits. However, given the complexity and natural variability of riverine ecosystems, the available knowledge is unlikely to be sufficient to identify and eliminate all ecological risks.

9.4.2 Pumping of Sediment

If sediment can be pumped at a high level of efficiency (close to 100%) then this would be a far better solution than sluicing. The advantages are: -

- A continuous supply of sediment downstream,
- Reduced risks of error in the physical modelling or prediction of ecological impacts,
- Reduced risk of impacts on benthic organisms,
- No need for rapid fluctuations in water level within the impoundment – thus minimising the risk of erosion and enabling vegetation to become established along the margins of the impoundment. This would in turn reduce ecological impacts in the impoundment and downstream,
- No significant perturbation of the hydrograph downstream,
- Fine silt and clays are normally present in very low concentrations, and pumping may transport much of this material with the sediment, thus reducing the amount of fine particles and organic material that settles in the impoundment.

The efficiency of pumping would need to be determined, based on tried and proven technology. The impacts on benthic fauna would also need to be determined.

Any sediment management measures would place a high onus on the power station operator to ensure that the systems were operated efficiently according to an Environmental Management System. In the case of sluicing, the optimum timing and magnitude of interventions would need to be determined in relation to the biological processes in the river (e.g. breeding, migration etc). In the case of pumping, the design of the system would need to ensure that (a) back-up systems were on standby at all times so that there is no interruption of sediment supply. If sediment got past the sediment trap-and-pump system, and was deposited in the impoundment, it would be difficult to remove. (b) The design would need to be adequate for the highest possible daily transport of sediment, allowing for a large margin of error because there would be some uncertainty in estimating the highest daily transport event. Flow records are available for only 50 years.

After decommissioning of the hydro power plant, it would be necessary to continue pumping (or sluicing) indefinitely or, preferably, to remove the weir from the river.

9.5 Key Impacts Downstream

The weir has the potential for negative impacts on the hydrograph. It must be emphasised that the level of the Okavango River fluctuates very slowly, and that aquatic organisms are not adapted to rapid variations in flow. The impact on the hydrograph of one-off filling and then operation at full supply level can be minimal if filled slowly during the high flow period.

However, sluicing would necessitate fairly rapid draw-down as mentioned above – which is a source of concern. This would also apply to any other manner of operation that resulted in fluctuations in flow, or changes in water level, that exceeded the natural rate of change.

Should sediment pumping or sluicing fail to effectively transport sediment through the weir, then a number of impacts could be expected to occur downstream, such as channel scouring, sedimentation and changes in the extent and frequency of flooding, all of which would affect the complex downstream wetland ecosystems. If the impact on wetlands was severe, many Red Data species of birds, and certain species of mammals, reptiles and amphibians could be adversely affected. The magnitude and significance of such impacts will have to be determined during the next phase of the project through the use of kinetic sediment flow models and ecosystem models.

Further downstream in the Okavango Swamps, the supply of sediment results in periodic channel switching, resulting in shifting of the distribution of water in the Delta, constant ecosystem renewal, and prevention of salinisation of the Swamps. Interrupting the sediment supply would result in stabilisation of the system, with the result that nutrient cycling and removal of salts from the system would be impeded. This could have serious negative consequences for the Okavango Swamps. Secondary impacts could, in a worst case scenario, include impacts on subsistence- and sports- fishing, and impacts on the tourism industry in Botswana.

The sediment issue is therefore a potential fatal flaw, but at this stage it seems likely that a solution will be found by pumping the sediment to ensure a continuous supply. The effectiveness of this mitigation needs to be established to a very high level of confidence using tried and proven technology.

If sediment pumping can be shown to be highly efficient, continuous and without interruption, then the project may have very little impact on the wetlands and terrestrial systems in the Okavango Delta.

In addition to the sediment issue, other potential impacts could also affect the Delta - possible changes in water quality (short-term during construction, and annually if sluicing is practised) and possible interruption of fish migrations. Perturbations of the hydrograph must also be minimised by: -

- Slow once-off filling and operation at full supply level,
- Keeping any fluctuations in the hydrograph well within the natural variability in all respects.

The complexity and natural variability of ecosystems means that there will never be full understanding of the biological processes and therefore all decision–making should be guided by the "precautionary principle". In other words, where there is doubt about certain impacts, the benefit of the doubt should be given to the natural environment. During the public meetings and in other fora, the Botswana community has stated that they would not accept experiments with the Okavango River (or being used as "guinea pigs").

9.6 Cumulative Impacts and Precedents

Water Abstraction and Loss

Factors affecting the discharge of the Okavango River to the Swamps are of concern in Botswana. The hydro power project on its own is not expected to have any significant impact on the discharge, although the combined volume of evaporation and seepage needs to be accurately determined. However, the combined effects of water abstraction for irrigation, and domestic supply in Angola, Namibia and Bostwana, are likely to become highly significant over the next few decades. Therefore some strategic planning is required to determine the acceptable limits of water loss and abstraction, and then apportion the use between the three countries through some negotiated process. In this way the total water consumption that can be used sustainably without having adverse impacts on the swamps can hopefully be achieved. The sustainable and equitable allocation of water resources between these three countries is the mandate for OKACOM.

Climatic Change and Land Use in the Catchment

The effects on runoff of regional climatic change and changes in land uses in the catchment have not been investigated at this preliminary stage. These need to be investigated in relation to both the long term viability of the project, and the cumulative impacts thereof.

Effects of Reduced Discharge on Sediment Transport

Cumulative impacts of water loss or abstraction would also affect the rate of supply of sediment in the long term. Since the transport of sediment is a function of flow velocity, which is in turn related to the discharge (for a given river profile) then as discharge is reduced, so too will be the supply of sediment.

Irrigated Agriculture and Cumulative Impacts of Habitat Destruction and Nutrient Loading

The cumulative impacts of agriculture, together with the hydro power project, have the potential for major habitat destruction in this region of Namibia (refer Appendix O). The proposed Mukwe Irrigation Project, (which is independent of the hydro power project), in the manner in which it is currently proposed (refer to the map in Appendix O) would destroy a large area of Kalahari Woodland close to the river. The hydro power project would destroy substantial areas of the unique island habitats and remaining riverine forest - depending to some extent on the weir site chosen. These two influences in combination, can be expected to reduce biodiversity in the areas upstream from Divundu, and may therefore be detrimental to any future conservation initiatives in the Mukwe-Divundu-Bagani area.

Moreover, irrigation close to the river could also lead to increased nutrient loading in the river (as a result of the use of fertilisers). This would lead to increased turbidity, increased growth of aquatic plants, and potentially alien aquatic weeds (if accidentally introduced), all of which could have negative impacts on the efficient operation of the hydro power scheme. Thus the impoundment could have synergistic impacts with irrigated agriculture in this regard.

Precedents

An Environmental Assessment is a decision-making tool – to enable environmental issues to be considered along with technical and economic considerations in the planning process.

In the case of a shared river, decisions taken will have international significance. Therefore OKACOM and the authorities in Angola, Namibia and Botswana should take into account that decisions taken will set precedents that can be expected to influence future decisions. Future project proponents may demand the right to expect consistency on the part of co-ordinating bodies such as OKACOM. The question of 'precedent' should therefore be taken into account in the decision-making process.

9.7 Consideration of Alternatives

A decision about the feasibility of the Popa Falls Hydro Power Project will need to made after weighing up the benefits of the project against the costs, both in social, economic and environmental terms.

It is recommended that a comprehensive socio-economic study should be undertaken that will enable the costs to society (in Namibia and Botswana) to be weighed up against the benefits of the project.

Certain social and environmental costs can be translated into economic terms. For example, it should be possible to put an economic value on the resources of fish, grazing land, and agricultural land that may be adversely affected. Thus the potential loss of amenity can be understood as the cost of replacing those resources with alternative sources of food. Other environmental costs are, however more difficult to express in economic terms. The "wellbeing" derived from lifestyle occupations is difficult to evaluate. Aesthetic impacts, "sense of place", and conservation of habitat and creatures that have no utility to people, are difficult to evaluate. To some extent, these things may translate into economic terms through their benefits for tourism. However there will always be issues that cannot be valued in economic terms, but must still be weighed up against the benefits of the project. Where such value judgements are unavoidable, the input obtained from the stakeholders during the public participation process (in Namibia and Botswana) should be used to assist in making these judgements.

In the context of Namibia's total power demand, the Popa Falls project has a relatively modest electricity output (20MW). Although this would make a valuable contribution for the northeast of Namibia, the benefits of the hydro power project should be weighed up against the "costs" to society, as well as the alternative forms of energy supply that are available (refer section 3).

Namibia's current aim of achieving self sufficiency in power generation also needs to be considered in light of abundant sources of power from hydro power schemes on the Zambezi River and/or from the Kudu Gas Plant.

9.8 Consideration of the Criteria used in Environmental Economics

Three criteria are recognised in Environmental Economics for evaluating the costs and benefits of a proposed development. These criteria are *Efficiency, Equity* and the *Intergenerational Criterion*. They are explained in Fuggle and Rabie (1983).

An activity is deemed to be *efficient* if there is a net gain to society. If there are winners and losers, then the winners must be able to compensate the losers and still be better off. The ***efficiency criterion*** needs to be applied not only to economic costs and benefits, but must also include environmental costs.

How the costs and benefits of a project are distributed in society brings us to the ***equity criterion***. Often a development benefits certain parties, while many of the costs are borne by the wider society. These "costs" should be seen not only in economic terms, but also in environmental terms. For the purpose of illustration, if there is a risk to resources such as fish in the river, the subsistence fishermen in Namibia and Botswana would carry that risk, but would derive few, if any of the benefits of the project. For communities whose lifestyle is affected, the same would apply.

To the extent that unique habitats and species are lost in Namibia, the environmental cost of the project would be borne by the Namibian and international communities. To the extent that tourism was affected in Namibia and Botswana (if at all) the costs of the project would be borne by others.

The ***intergenerational criterion*** places the considerations of equity within an intergenerational time context. Many environmental assets, once they are destroyed are lost forever. Therefore "…a special premium should be attached to environmental costs that are irreversible i.e. environmental resources which are characterised by some rare attributes may have no suitable substitutes, and if these resources are not producible, growth in demand for their services cannot be met by an increase in their supply. This means that the resource's scarcity value will increase over time, relative to that for goods which can be produced, or which may have suitable substitutes". Thus "the scarcity value of certain natural amenities and ecological processes increases".

"Considerations of irreversibility coupled with risk aversion properly result in a lowering of the present value of the activity. Environmental economics has a long-term planning perspective; the guiding principle is that benefits should continue to exceed costs over intergenerational time periods." (Fuggle and Rabie, 1983, p.105-106).

Related to the intergenerational equity criterion is the question of response to environmental risks. Integrated Environmental Management recognises the "***precautionary principle***". This means that where there is uncertainty concerning the magnitude or severity of an impact, the benefit of the doubt should be given to the environment. This is nowhere more important than in the case of potential loss of endangered species or habitats, since their loss would represent a loss to all future generations.

9.9 Recommendations for Further Investigations

On the basis of this Preliminary Environmental Assessment, there is insufficient information available to permit a conclusion on the environmental acceptability of the project particularly in terms of its impacts downstream. However, the key issues have been identified and recommendations have been made – particularly throughout Chapter 7 – concerning those impacts that will need to be mitigated to an acceptable level. Recommendations for further investigation of a number of issues, as part of the full Environmental Assessment, have also been made in Chapter 7.