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Legal, Institutional, Water Sharing, Cost Sharing, Management and Dam Operation	PB D000/00/4603	400/8/1/P-10	3692/97331
Specialist Report on the Environmental Flow Requirements - Riverine	PB D000/00/4503	400/8/1/P-07	3519/97331
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Water Conservation and Demand Management	PB D000/00/4903	400/8/1/P-12	3487/97331
Dam Development Options and Economic Analysis – Volume 1	PB D000/00/4403	400/8/1/P-05	3484/97331
Dam Development Options and Economic Analysis – Volume 2 (Appendices)	PB D000/00/4403	400/8/1/P-05	3484/97331
Environmental Assessment of the Proposed Dam Sites on the Orange River	**PB D000/00/4503**	**400/8/1/P-06**	**3873/97331**
Vioolsdrift/Noordoewer Joint Irrigation Scheme: Assessment of Viability	PB D000/00/4803	400/8/1/P-11	3525/97331
Public Consultation	PB D000/00/4503	400/8/1/P-09	3869/97331
Inception Report	PB D000/00/4102	400/8/1/P-01	3365/97331

EXECUTIVE SUMMARY

This initial comparative environmental assessment aims to compare the potential environmental implications of the preferred dam sites that were identified during the screening process. Accordingly, this initial assessment compares the Vioolsdrif (at three different full supply levels) and Komsberg sites, although some of the specialist studies commissioned near the beginning of the study include consideration of the Boegeberg site, which was later discarded at the Options Assessment Screening Workshop.

The purpose of this report is to:

(a) document the key environmental issues, at a pre-feasibility level of the LOR;
(b) gather focussed information on the most relevant environmental parameters at the Komsberg and Vioolsdrif sites;
(c) provide a comparative assessment of the two dam sites in order to compare the potential impacts and to ascertain whether either should be rejected on environmental grounds; and
(d) identify areas of uncertainty that need further investigation.

The study is restricted to the ecological, social and heritage issues. The effect of downstream flows and downstream impacts on the river and estuary are covered in the Specialist Report on the Environmental Flow Requirements – Riverine and the Specialist Report on the Determination of the Preliminary Ecological Reserve on a Rapid Level for the Orange River Estuary (LORMS Reports 400/8/1/P-07 and 08).

From an environmental perspective, the Komsberg site is not preferred due to the impact on the Augrabies National Park. As no fatal flaws have become apparent with the two smaller Vioolsdrif Dam options, this site could be considered further from an environmental perspective.

However, it is critical that a detailed Environmental Impact Assessment (EIA) is undertaken to improve the confidence in the assessment and guide the formulation of mitigation measures. This Environmental Impact Assessment should be undertaken as part of the Feasibility Study (see Further Studies: Scope of Work, LORMS Report 400/8/1/P-14). The EIA should meet the legal requirements of both Namibia and South Africa and comply with international best practice. Furthermore, the EIA should address the entire project, i.e., the dam and associated infrastructure, as well as the broader implications of further river regulation and water usage.

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ABBREVIATIONS

DWAF	:	Department of Water Affairs and Forestry (RSA)
EFR	:	Environmental Flow Requirement
EIA	:	Environmental Impact Assessment
IAPs	:	Interested and Affected Parties
LOR	:	Lower Orange River
LORMS	:	Lower Orange River Management Study
MAR	:	Mean Annual Runoff
MAWRD	:	Ministry of Agriculture, Water and Rural Development (Namibia)
ORRS	:	Orange River Development Project Replanning Study
PP	:	Public Participation
PWC	:	Permanent Water Commission
RSA	:	Republic of South Africa
ToR	:	Terms of Reference
VAPS	:	Vaal Augmentation Planning Study
WC & DM	:	Water Conservation and Demand Management

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1 INTRODUCTION

1.1 Background to the Lower Orange River Management Study

1.1.1 Introduction

The Republics of Namibia and South Africa initiated a joint investigation, the Lower Orange River Management Study (LORMS), aimed at improving the management of the Lower Orange River (LOR). This is the first time that these two countries have collaborated as full partners to develop agreed strategies and management plans for the Orange River.

South Africa and Namibia share a 600 km border along the lower and western reaches of the Orange River before it flows into the Atlantic Ocean (**Figure 1-1**).

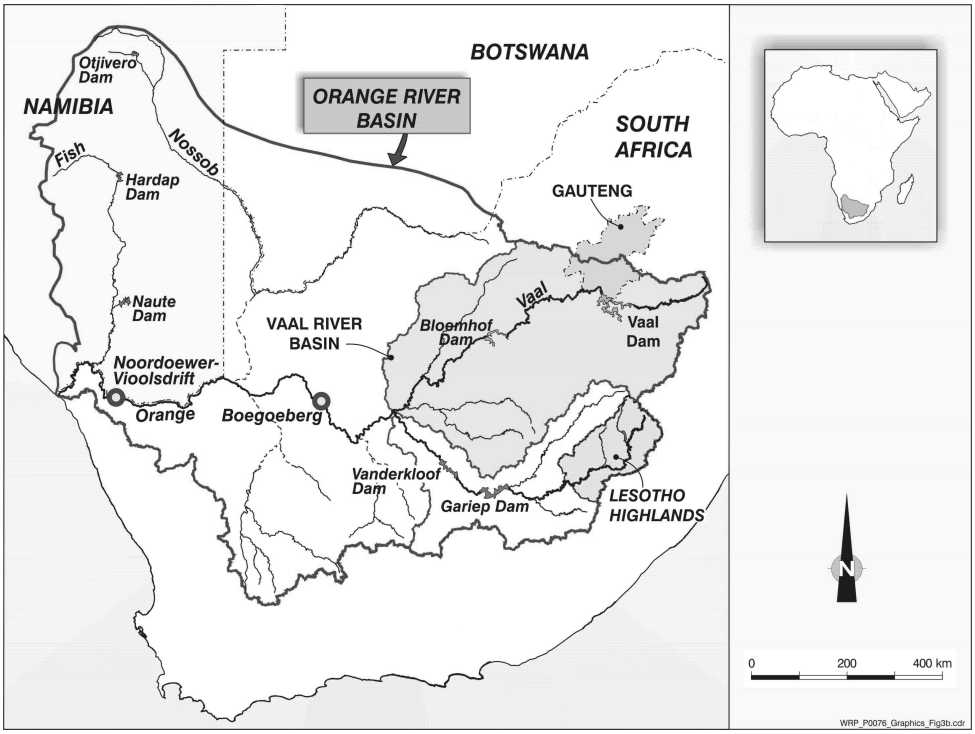

Figure 1-1: The Orange River Basin

Regulation of the LOR is largely determined by dams in South Africa and Lesotho. The location of these dams results in socio-economic and environmental inefficiencies and reduced water security for Namibia. At the same time, there are considerable development opportunities, along the LOR that would benefit from improved management of the water resource.

The main purpose of the LORMS, which falls under the control of the Permanent Water Commission (PWC) between Namibia and South Africa, was to investigate and make recommendations on the more efficient management and use of available water resources in the LOR. Water conservation and demand management (WC & DM) are seen as options to achieve this goal, as well as new infrastructure developments, including new dams.

LORMS follows on from the Orange River Development Project Replanning Study (ORRS) that, between 1994 and 1999, investigated more than 30 development options for South Africa's largest and most strategic water resource.

The Terms of Reference (ToR) for this Pre-feasibility Study into measures to improve the management of the LOR and to provide for future developments along the common border between Namibia and South Africa emphasise the need for a multi-disciplinary approach, including an initial environmental assessment of water resource development options.

1.1.2 Project Objectives

The Orange River forms the border between Namibia and South Africa, and both countries will benefit from measures to improve the management of the LOR. It is for this reason that any future projects relating to this common resource should be undertaken jointly by the two countries, with due consideration of the equitable and reasonable requirements of other basin states.

The strategic objectives of the project are:

- Regional economic development;
- Poverty reduction;
- Job creation;
- Protection of the environment;
- Water resources management aligned with government policies; and

- Assuring water supply to downstream users (which is of particular importance to the Namibian Government).

1.1.3 Project Consultants

A Namibian/South Africa Consortium, Lower Orange River (LOR) Consultants, is responsible for undertaking the LORMS. The Namibian members of this consortium are Burmeister & Partners, Windhoek Consulting Engineers and Alexander and Becker. The South African members are WRP (Pty) Ltd and Ninham Shand (Pty) Ltd. The consortium is supported by a multi-disciplinary team of sub-consultants.

Specifically, for this environmental report, Chris Brown (Namibia Nature Foundation) acted as co-author of the report, while specialist input was provided by: Tim Hart (ACO) – heritage, John Kinahan (Quaternary Research Services) – heritage, Alfons Mosimane – social, Tim Hart (RDC) – social, Cate Brown (Southern Waters) – aquatic ecology, Ben Benade (Eco-Impac) – aquatic ecology and Antje Burke – terrestrial ecology.

1.1.4 The Study Area and Need for the LORMS

The Orange River rises in the Lesotho Highlands and discharges in the Atlantic Ocean at Oranjemund, some 2 200 km to the west. The lower part of the river, west of longitude 20° east, is flanked by increasingly arid landscapes as it approaches the coast. It also forms the western-most border between Namibia and South Africa. The Orange River Basin is one of the largest river basins south of the Zambezi, with a catchment covering about 1 million km^2.

The Fish River, which originates in Namibia, is the only major tributary that regularly contributes to the Orange River downstream of the Orange/Vaal confluence. The Fish River is ephemeral, flowing only periodically at the surface.

The Orange River Basin has an estimated natural runoff of about 11 300 million m^3/a at the river mouth. The Lesotho Highlands and areas contributing to the Vaal, Caledon, Kraai and Middle Orange River jointly contribute 10 500 million m^3/a of runoff, whereas the catchment downstream of the Orange/Vaal confluence generates 800 million m^3/a – or less than 8% of total estimated natural runoff of the Orange River Basin.

Much of the runoff originating from the Orange River west of the Orange/Vaal confluence is highly erratic and cannot be relied on to support the various downstream water demands unless further storage is provided.

Based on 1992-development levels, the current mean annual runoff (MAR) at the Orange River mouth amounts to about 5 300 million m^3/a or just over 50% of the estimated natural runoff. This is mostly due to extensive water utilisation for irrigation, domestic and industrial purposes in the Vaal River Basin, but large volumes of water are also used to support extensive irrigation and some mining demands along the Orange River downstream of the Orange/Vaal confluence. Orange River water is also used for irrigation in the Eastern Cape. Evaporation losses from the river and riparian vegetation amount to 500 to 1 000 million m^3/a. The environmental water requirements at the mouth of the Orange River have been estimated at 300 million m^3/a (but see Specialist Report on the Environmental Flow Requirements – Riverine and the Specialist Report on the Determination of the Preliminary Ecological Reserve on a Rapid Level for the Orange River Estuary, LORMS Reports 400/8/1/P-07 and 08).

In the natural state, the perennial flow of the Orange River is highly seasonal and severely affected by periodic droughts. The river has been regulated by a number of dams in Lesotho, South Africa and Namibia in order to ensure reliable and long-term water availability. South Africa has about 25 dams larger than 12 million m^3 storage capacity in the Orange River Basin. Water is also transferred into the Vaal River catchment (the main tributary to the Orange River) from the upper reaches of the Orange River in Lesotho and from various other river systems. Water transfers are also made from both the Vaal and Orange catchments to other basins, particularly the Fish and Sundays Rivers in the Eastern Cape.

Namibia has five dams, each exceeding 12 million m^3 storage, in the Orange River catchment. Despite these dams, the regulation of water supply for human and environmental needs along the LOR can be improved.

Key factors that contribute to this state of affairs are:

- Due to the distance from the sea, releases from the Vanderkloof Dam must be made two to three weeks in advance of the Orange River water reaching the river mouth, so they cannot take into account any contributions that the Fish River could make to the Orange River; and

- A considerable amount of water is lost due to difficulties in releasing precise volumes of water for users downstream of the Vanderkloof Dam and through constantly changing evaporation along the river.

Namibia is a riparian state with rights to Orange River water, yet it has limited control over the availability of the resource. This is largely due to the lack of a regulating facility west of 20° east – which makes Namibia particularly vulnerable during low flow events when its access to Orange River water is limited to releases from upstream dams controlled by South Africa.

It is against this background of water scarcity; historical imbalance and complexity in management of the shared resource that both Namibia and South African have agreed to try and improve the management of the resource. Both countries have identified considerable development opportunities either side of the lower Orange River that require water.

In Namibia, such developments include the:

- Skorpion lead and zinc mine;
- Proposed Kudu gas-fired power station at Oranjemund and Haib copper mine; and
- Irrigation projects for commercial and communal farmers.

Similar potential also exists on the South African side of the river, with a particular need to develop irrigation opportunities for resource poor farmers in order to help address poverty alleviation.

Given these economic opportunities and the current difficulties in effective management of water resources in the region, Namibia and South Africa have indicated that they would like to study the possibility of improving efficiency and considering new dam developments on the LOR. Such a dam would provide:

- A storage facility forming an integral part of the Orange River management system;
- Allow regulation of the water releases to improve assurance of supply to downstream users; and
- A secure source of water to meet long-term requirements along Namibia's southern border (estimated to be in the order of 207 million m^3/a).

A new dam would be a multi-purpose facility to provide water for different users. It would also facilitate more efficient use of Orange River water as a whole and may assist in meeting the environmental flow requirements (EFRs) of the river and estuary.

1.1.5 Previous Work

Numerous studies and investigations have been undertaken by both South Africa and Namibia to establish water requirements and availability of water in the Orange River Basin.

Studies undertaken by the South African Department of Water Affairs and Forestry (DWAF) include:

- The Vaal River System Analysis (1985 – 1991) and subsequent updates (1997 – 1999);
- The two-phased Orange River System Analysis (1988 – 1994);
- The Vaal Augmentation Planning Study (VAPS) (1994 – 1996); and, most recently;
- The Orange River Development Project Replanning Study (ORRS) (1994 – 1999).

Separate studies on WC & DM have also been undertaken by South Africa and Namibia. Studies commissioned by the DWAF have indicated that the resources available in the Orange River Basin are sufficient to support existing and reasonable future water demands.

While the information and results from these studies is generally accepted by the Namibian Ministry of Agriculture, Water and Rural Development (MAWRD), it has yet to be verified using their own personnel and technical advisors.

Overall, the ORRS concluded that there was considerable scope for improving efficiency of water use along the LOR, particularly through improved irrigation practices or different crops. It also recommended that additional storage downstream of the Orange/Vaal confluence be provided. The only viable options identified were at Vioolsdrif/Noordoewer on the RSA/Namibia border and at Boegoeberg, upstream of Upington.

1.1.6 Aspects to be addressed in the LORMS

The LORMS provides an integrated approach by both Namibia and South Africa towards the assessment, planning, utilisation, conservation, management and development of the water resources in the 600 km, common reach shared by the two neighbours. It takes account of future water requirements in the whole Orange River Basin, flow contributions from the Fish River in Namibia, as well as initial estimates of the environmental water requirements of the river and its mouth.

The key technical aspects of the study are:

- Assessment and/or confirmation of present and future water requirements and reliability requirements.
- Demonstration of the opportunities for and potential benefit of WC & DM.
- Review of the South African hydrological database by Namibian consultants, as well as the re-assessment of the Fish River hydrology, which will then be incorporated into an agreed hydrological database.
- Selection of upstream development scenarios in the Orange River catchment (including the Vaal River System) for assessing the future water balance.
- Assessing the benefits of a possible dam at Boegoeberg or Vioolsdrif, taking account of contributions from the Fish River.
- Assessment of the social and environmental benefits and impacts of all management options, including dams and water conservation, with potential mitigation measures.
- An economic analysis to establish the most appropriate management actions to ensure that available water resources are used efficiently.
- Consolidating the information on each management option, or combination of options, into management reports so that decision-makers from Namibia and South Africa can make informed decisions.
- Ensuring that the public – and particularly the stakeholders who may be directly affected – are informed and their opinions are taken into account and recorded.

The study relies heavily on previous work undertaken by both South Africa and Namibia.

1.2 Purpose of this report

This initial comparative environmental assessment aims to compare the potential environmental implications of the preferred dam sites[1]. It was initially envisaged that the Boegoeberg and Vioolsdrif Dam sites would be subject to further environmental investigation. However, the Boegoeberg site was rejected during the screening exercise (see **Chapter 3**), and the Komsberg site was added as a potential option for further review. Accordingly, this initial assessment compares the Vioolsdrif and Komsberg sites, although some of the specialist studies commissioned near the beginning of the study include consideration of the Boegoeberg site. After the screening of the options, it became apparent that there was insufficient environmental (and costing) information available, especially on the Komsberg site, to inform a comparative assessment, and consequently further field work was commissioned.

The purpose of this report is therefore to:

(a) document the key environmental issues, at a pre-feasibility level of the LOR;
(b) gather focussed information on the most relevant environmental parameters at the Komsberg and Vioolsdrif sites;
(c) provide a comparative assessment of the two dam sites in order to compare the potential impacts and to ascertain whether either should be rejected on environmental grounds; and
(d) identify areas of uncertainty that need further investigation.

The study is restricted to the ecological, social and heritage issues. The effect of downstream flows and downstream impacts on the river and estuary are not covered in this document as these are covered in the Specialist Report on the Environmental Flow Requirements – Riverine and the Specialist Report on the Determination of the Preliminary Ecological Reserve on a Rapid Level for the Orange River Estuary (LORMS Reports 400/8/1/P-07 and 08).

1.3 Approach to this Component of the Study

Being an initial comparative environmental assessment, the report is based primarily on a desktop study with limited site visits. This report does not aim to meet the requirements of any specific legislation. As a public participation (PP)

[1] Environmental comment relating to other management options, including water conservation, was provided as input at the Options Assessment Screening Workshop and is not repeated in this report

exercise was conducted for the LORMS (see Public Consultation, LORMS Report 400/8/1/P-09), no PP was undertaken as part of this initial environmental assessment. However, some consultation was undertaken, and is reported upon in this report, as part of the social impact task (see **Annexure G**).

There is also some overlap of this task and the work done on the riverine and estuarine environmental flows, each of which is reported upon in separate volumes (LORMS Reports 400/8/1/P-07 and 08), and is therefore not repeated in this report.

This comparative environmental assessment was undertaken over a period of months in two phases. During the first phase, inputs were provided on the environmental implications of a large range of possible water resource development options as part of the screening of options, followed by further work to address identified key gaps in knowledge, specifically around the Komsberg Dam site, to inform the comparative assessment.

Seven specialist studies, covering the areas of ecological importance, aquatic ecology, vegetation, heritage, archaelogy and social, where undertaken to gather the data for this report and these are presented in the appendices. These studies comprise:

1.3.1.1 A study on the Impacts on the Aquatic Ecology Pertaining to the Construction of Large Dams in the Lower Orange River (see Annexure A).

The study was based on existing information and focuses on the barrier and inundation effects of a dam on the riverine ecosystem. The following activities were undertaken for this study:

- Site visits to the proposed Vioolsdrif Dam site and to the Boegoeberg Dam.
- A helicopter/fixed wing aeroplane aerial reconnaissance of the LOR.
- A literature survey of ecological issues related to large dams on rivers.
- A specialist session where the ecological issues specific to the LOR were discussed and highlighted.
- Individual discussions with key biophysical and engineering specialists.

1.3.1.2 A Desktop Report on the Ecological Importance and Sensitivity of the LOR Down-stream of 20º Latitude to the Orange-Fish River Confluence (see Annexure B).

This study was undertaken as an initial desktop study with no site visits. This report discusses the following aspects:

- Flow as an ecological/ environmental driving force.
- An ecological description.
- Issues of concern in respect of dam construction.
- The ecological importance of different river reaches.

1.3.1.3 A Vegetation Specialist Study with Reference to the Potential Vioolsdrif and Komsberg Dam Sites (see Annexure C).

A field survey was undertaken during the period 22 October to 3 November 2003. The potential dam sites were accessed by vehicle (where possible), boat or on foot and a description of the vegetation was compiled. In addition, descriptions were also made of the vegetation along possible access routes and of parts of the areas that would be inundated by the potential dam sites. These descriptions also included notes of affected habitats and land-use.

1.3.1.4 A Report on the Heritage Sensitivity of the LOR Region between 20° East and the Fish River Confluence (see Annexure D).

This study was undertaken for the South African (south) side of the river and was an initial desktop study with no fieldwork. The findings are based entirely on reliable anecdotal observations by archaeologists, published documents, dissertations and unpublished reports and papers.

1.3.1.5 A Preliminary Archaeological Assessment of the LOR (see Annexure E).

This was a preliminary desktop study undertaken for the Namibian side (north) of the Orange River. The information was extrapolated from other sites within and beyond the study area in order to inform potential impacts.

1.3.1.6 Archaeological Assessment of Potential Dam Sites on the LOR (Vioolsdrif & Komsberg) (see Annexure F).

This study entailed a follow up site visit to two potential dam sites in order to obtain site specific information to inform a comparative assessment of the Vioolsdrif and Komsberg Dam sites.

1.3.1.7 A social survey of the Vioolsdrif Dam Site (see Annexure G)

The communities along the LOR that could be affected by the Komsberg or Vioolsdrif Dams were visited and key informants interviewed in a structured manner in order to ascertain the likely social impacts.

It should be remembered that this is an initial comparative environmental assessment based primarily on a desktop study with limited site visits. Accordingly, the information contained herein is appropriate to a pre-feasibility level of investigation, but more detailed investigations are required if any developments are to be considered further.

2 THE AFFECTED ENVIRONMENT

2.1 Introduction

This chapter provides a brief description of the existing biophysical and socio-economic environment for the LOR, with a focus on the area below the Augrabies Falls and where appropriate, within the inundation area of the proposed Komsberg and Vioolsdrif Dams. It draws on existing knowledge from previous investigations, specialist investigations and discussions with various role-players and site visits. It serves to present the context against which the positive and negative impacts of the proposed activity can be assessed (see **Chapter 3**).

2.2 The Biophysical Environment

2.2.1 Climate

The Northern Cape/Southern Namibia comprises a large, dry region of fluctuating temperatures and varying topographies. Rainfall is very low (50 to 350 mm per year) and unpredictable. Annual potential evaporation exceeds 3 000 mm in places. Variability in inter-annual rainfall tends to increase with increasing aridity. Mean maximum temperatures in mid-summer (January) exceed 40°C, whereas mean minimum mid-winter (July) temperatures are below freezing.

2.2.2 Geology and Soils

The course of the LOR downstream from Augrabies Falls is generally deeply incised, with narrow, poorly developed alluvial terrace deposits. The surrounding area consists mainly of exposed Namaqua Metamorphic Complex rocks, with some granites belonging to the Vioolsdrif and Haib groups. Very extensive Quaternary outwash fans, with mainly dry, braided pattern drainage are an important feature of the terrain.

Three major components of the Orange River valley terrain are easily separated, viz:

- Gorge sections (<1 km wide), with steep rubble footslopes and poorly developed silt terraces.
- Narrow valley sections (1 – 1.5 km wide), with wide silt terraces and minor tributary valleys.

- Broad valley sections (>1.5 km wide), with silt and gravel terraces, and major tributary valleys.

Gorge-like sections of the Orange River are generally difficult of access, with silt terraces prone to undercutting or whole-scale removal during high floods. Narrow valley sections have relatively stable silt terrace relics, often showing some hummock dune development. Broad valley sections have well-preserved expanses of silt and gravel terrace, as well as extensive outwash fans from tributary streams (Kinahan, 2003).

2.2.3 Hydrology

Before the construction of the major impoundments, such as the Gariep and Vanderkloof Dams, the flow in the lower section of the Orange River was known to stop. These low-flow or no-flow periods coincided with the dry periods in the catchment area and normally occurred during August and September. Since the construction, the dams and river flow has been regulated with more constant flow throughout the year in order to ensure a high assurance of supply users as far downstream as the estuary.

In addition to modifying the low flow regime, the dams attenuate the medium sized floods and absorb the smaller floods. Future water demand from the Upper Orange River System will reduce the availability of water to the LOR. Further details of the hydrology are contained in the reports Hydrology, Water Quality and Systems Analysis (Vol A and B) and Specialist Report on the Environmental Flow Requirements – Riverine, LORMS Reports 400/8/1/P-03 (Vol B), 04 (Vol A) and 07.

2.2.4 Water Quality

The water quality in the Lower Orange is affected by the return flows from the extensive urban and agricultural areas in the middle and Upper Orange, as well as the Vaal System. This not withstanding, the water quality of the LOR is not of major concern at present, but any increase in retention time, such as what would occur in a reservoir, may result in detrimental effects. Detailed descriptions of the water quality and related issues are contained in LORMS Reports 400/8/1/P-03, 04 and 07.

2.2.5 Riverine and Riparian Ecology

The aquatic and riparian ecosystems of the LOR System evolved in response to the natural seasonal flow pattern, inclusive of the flood regime. This natural flow regime has been increasingly modified, principally due to the construction of large dams, such as the Gariep and Vanderkloof Dams. It is anticipated that the aquatic ecosystem has, and will continue to respond, to this change over time.

A number of aquatic microphytes and aquatic and semi-aquatic macrophytes are present in the LOR. Filamentous Phycophyta (e.g., *Spirogyra spp*.) are fairly abundant in the side streams of the LOR, and the blue-green alga (*Cyanophyceae*), *Gloeotrichia natans*, occurs in the lower stretches of the river.

With regard to riparian vegetation, a number of relatively pristine stretches of shoreline and island vegetation have been observed in the mountainous and less accessible areas. The river reed, *Phragmites australis*, is the dominant semi-aquatic macrophyte along the whole of the Orange River. This indigenous plant can reach pest proportions, especially downstream of irrigation areas, due to increased disturbance and possibly an increase in nutrients. The exotic tree, *Prosopis* species, has invaded large areas of the riparian forest.

A number of exotic plant species have invaded the channel of the LOR. These include the American floating water fern, *Azolla filiculoides*, the Broad-leaved Pondweed, *Potamogeton schweinfurthii*, the Fennel-leaved Pondweed, *P. pectinatus*, the Curled Pondweed, *P. crispus*, and the Willow-herb, *Ludwigia stolonifera*.

The invertebrate populations appear to be rather homogenous throughout the entire length of the Orange River. This is likely to be due to the natural unpredictable, erratic nature of the flow regime. The Freshwater Shrimp, *Caradina nilotica*, and the Freshwater Mussel, *Corbicula africana* are found in the LOR.

The Orange River from Augrabies falls downstream is very important with regard to fish species. This is due to the fact that 12 of the 15 indigenous freshwater fish of the Orange River are found in the Lower Orange. These include one unique Red Data listed endemic (*Barbus hospes*), one unique indigenous (*Mesobola brevianalis*), two endemic Red Data listed (*B. kimberleyensis* and *Austroglanis sclateri*) and two vulnerable indigenous (*B trimaculatus* and *B. paludinosus*) fish species. A gradual downstream increase in the occurrence of freshwater fish being

infested by parasites, as well as an increase in fish parasite diversity have been observed, possibly due to a deterioration in water quality.

For further detail, please refer to **Annexures A** and **B**.

2.2.6 Terrestrial Ecology

Outside of the floodplain of the Orange River lie the semi-arid Nama Karoo and Succulent Karoo Biomes, the latter of which is the most diverse desert system in the world. Although the eco-region contains many endemic plants, the fauna of the Nama Karoo is relatively species-poor. Grazing pressure from sheep and goats have impacted on the vegetation and altered habitat for native wildlife in many areas.

For further detail, please refer to **Annexure C**.

2.3 Socio-economic Environment

2.3.1 Land Ownership

The northern bank of the Orange River in Namibia is made up of several commercial farms, privately-owned land and large tracts of state land. South African citizens own some of the commercial farmland and rent it out to Namibian farmers. The border is currently on the northern side of the river. The southern bank is mainly privately-owned between Augrabies falls and Vioolsdrif/Noordoewer.

2.3.2 Land-use

Along the banks of the Orange River, the water and deeper alluvial soils have enabled extensive crop irrigation, the most important being - cotton, lucerne, maize, table grapes, and sultanas upstream of Augrabies. Further downstream, crops include grapes, dates and vegetables. Elsewhere, the lack of irrigation restricts farming to small stock, mainly Dorper Sheep and Boer Goats. Some of the state land is used for seasonal grazing by pasturalists from neighbouring communal lands, such as Warmbad. Mining and prospecting occurs in the area, but is more prevelant downstream of Vioolsdrif.

2.3.3 Demographics

The area is sparsely populated, with dispersed settlements almost entirely concentrated along the banks of the Orange River (e.g., Goodhouse, Vioolsdrif and Noordoewer).

Housing in the towns and on commercial farms is of a relatively high standard. Housing for farm workers varies from formal brick houses to temporary structures, comprising corrugated iron sheets or reeds. The workers generally do not own the structures in which they are housed and accordingly, there is little security of tenure. For further details, please see **Annexure G**.

2.3.4 Recreational/Tourism Value

Recreational activities along the Orange River are focussed mainly on water and are dependent on flow. White water rafting, kayaking and canoeing are popular sports undertaken in this reach. Fishing, as well as swimming, and bird watching are associated with the river, while activities such as hiking, camping, rock climbing, photography, abseiling, 4x4ing, bird watching and game viewing extend into the drier areas away from the river.

2.3.5 Level of Public Services

Very limited public services are available on the farms due to the low population settlement density. In Namibia, the farmers and farm workers make use of public service facilities at the towns of Karasburg, Ariamsvlei and the settlement of Warmbad. Most of the farming communities are visited by mobile clinics once a month and some communities have a permanent nurse to render first aid and health care services.

Children attend school at Karasburg, Warmbad and Ariamsvlei - children visit their parents during weekends and school holidays. Komsberg farming community has a pre-primary school built from reeds and corrugated iron sheets.

Most farms use diesel engines to generate the electricity needed to pump water for irrigation and household use. The farmers would like to have electricity to be able to develop more land for irrigation and in the process, increase productivity. A few farms receive electricity from ESKOM or NAMPOWER.

For further details, please refer to **Annexure G**.

2.3.6 Archaeological/Heritage

The Orange River, a permanent source of water within an arid landscape, has been populated continuously during prehistoric times and within the last 2000 years by Khoekhoen Herders and San Hunter Gatherers. The river also provided a conduit by which a number of early European travelers ventured into the interior.

Northern Namaqualand and Southern Namibia were occupied by the Great Namaqua who kept goats, sheep and cattle. The Namnykoa (a highly riverine group) and Einiqua occupied the area close to and east of the Augrabies Falls (Middle Orange River). Interspersed with these groups were smaller San communities and other "Hottentot" groups who resided in an uneasy relationship with their more powerful neighbours.

By the 1770s, *trekboers* had penetrated the interior, and so began a vicious frontier war with the indigenous groups. By the early 19th century, various missionary groups began to exert their influence along the LOR and the descendants of the Khoekhoen were limited to mission land in various parts of Namaqualand and the marginal lands of the Richtersveld where their language, Nama, is still spoken today.

Prior to the construction of the Vioolsdrif high-level bridge in 1956, most vehicular traffic to and from Namibia was routed via the main road through Nakop, or by way of several river crossings, or drifts, which had been in use since the late 1700s. Among the most important crossing points were those at Goodhouse and Raman's Drift, linking Namaqualand and the newly established mission settlement at Warmbad and the Namibian interior. These early colonial farming, trading and mission settlements and river crossings are of varying historical importance.

For further details, please refer to **Annexures D**, **E** and **F**.

3 PROPOSED DAM SITES

3.1 Identification of Dam Sites

In the Inception Phase of the project, it was envisaged that the two most favourable dam sites would be at Boegoeberg and Vioolsdrif, as these had been identified as the preferred sites in the ORRS. However, as part of the LORMS, all potential sites on the Fish and LOR, were marked on 1:50 000 maps, 1:10 000 photo maps or aerial photographs, where available. The sites where then screened from a technical perspective.

Thereafter, the shortlist of dam sites, as well as other system operation and WC & DM options were subjected to a multi-disciplinary screening exercise. The purpose of the screening exercise was to select options suitable for more detailed Pre-feasibility level study. During the Options Assessment Screening Workshop exercise, held in Windhoek on 13 and 14 October 2003, the dam options were divided into larger storage dams (with a capacity greater than 500 million cubic m), and smaller re-regulating dams (with a capacity in the order to 200 million cubic m).

The results of the Options Assessment Screening Workshop (for the dam options) are summarised in **Figure 3.1** for storage dams of comparable yield and **Figure 3.2** for the re-regulating structures.

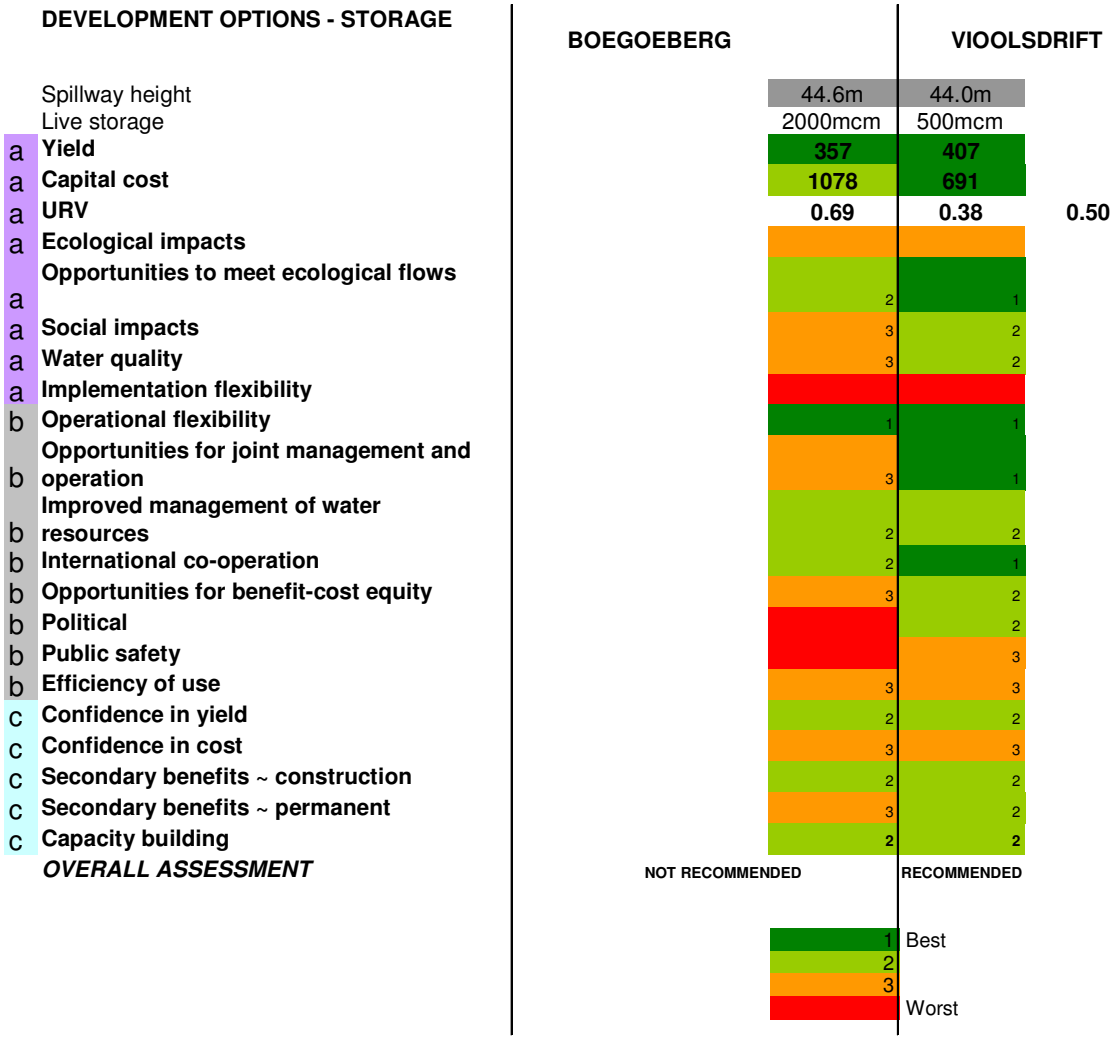

Figure 3-1: Results of Screening of Storage Dam Sites

DEVELOPMENT : RE-REGULATION DAMS

		BOEGOEBERG	VIOOLSDRIFT	KOMSBERG
	Spillway height	19.8m	25.1m	~22m
	Live storage	103mcm	110mcm	~
a	**Yield**	62	170	126
a	**Capital cost**	192	318	230
a	**URV**	0.35	0.26	0.24
a	**Ecological impacts**	2	3	3
a	**Opportunities to meet ecological flows**	2	2	2
a	**Social impacts**	2	2	2
a	**Water quality**	2	2	2
a	**Implementation flexibility**	3	3	
b	**Operational flexibility**	3	3	3
b	**Opportunities for joint management and operation**	2	1	1
b	**Improved management of water resources**	3	2	2
b	**International co-operation**	2	1	1
b	**Opportunities for benefit-cost equity**	3	2	3
b	**Political**	3	2	
b	**Public safety**	3	3	3
b	**Efficiency of use**	3	3	3
c	**Confidence in yield**	3	3	
c	**Confidence in cost**	2	2	
c	**Secondary benefits ~ construction**	3	3	3
c	**Secondary benefits ~ permanent**	3	3	3
c	**Capacity building**	3	3	3
	OVERALL ASSESSMENT	NOT RECOMMENDED	RECOMMEND	CONDITIONAL RECOM

1 Best
2
3
Worst

Figure 3-2: Results of Screening of Re-regulation Dam Sites

As a result of this screening exercise, the Boegeberg site was rejected and the some further work on the Komsberg site was undertaken to address areas of uncertainty. Consequently, this initial environmental assessment compares the merits of three alternative dam sizes at Vioolsdrif and, one at Komsberg as follows:

- Vioolsdrif: Dam wall heights of 25 m; 44 m and 55 m;
- Komsberg: Dam wall height of 23 m.

The Vioolsdrif Dam site is located some 9 to 10 km upstream of the existing Vioolsdrif Weir. Alternative sites further upstream are also possible.

This Komsberg site is situated approximately 7 km downstream of the border at 20° longitude. Most of the area inundated by the reservoir will therefore be in South Africa and the reservoir will inundate parts of the Augrabies Falls National Park, but not the canyon area. The dam would not inundate much irrigable land,

areas of mining and prospecting licenses, towns or villages, road infrastructure, or powerlines.

See **Figure 3.3** for the two locations of the dam sites and areas that would be inundated by the different dam wall heights.

Figure 3-3: Location of the Vioolsdrif and Komsberg Dam Sites

4 DESCRIPTION OF POTENTIAL IMPACTS

4.1 Introduction

This chapter describes the potential impacts on the biophysical and socio-economic environments, which may occur due to the development of the proposed dams described in **Chapter 3**.

4.2 Assessment Methodology

As this is an initial, scoping level assessment, the significance of the impacts has been estimated using a simple five-point scale from very high negative impact to positive effect:

- positive effect
- no impact to negligible impact;
- low impact;
- moderate impact,
- high impact, and
- very high impact.

The current investigation has identified several environmental impacts that are likely to emanate should either of the proposed dam sites be developed. Due to the paucity of information, these potential impacts are assessed without the implementation of possible mitigation measures. The assessment has been divided into long-term, operational phase impacts on the biophysical environment, and on the socio-economic environment and construction phase (i.e., temporary) impacts.

4.3 Operational Phase Impacts on the Biophysical Environment

4.3.1 Impact of Access Roads on the Aquatic and Terrestrial Ecosystems

Construction of either dam would require extensive road construction to secure construction and permanent access. The location of access roads has not been established, but is likely to entail significant earthworks, and would affect large areas of terrestrial vegetation and possibly impact on seasonal tributaries or even the floodplain of the main river. No detailed assessment of these impacts at either of the dam sites has

been undertaken, but it is estimated that they would similar and could be of a high significance (See **Table** 4.1).

Table 4.1: Impact of Access Roads on the Aquatic and Terrestrial Ecosystems

Dam Site	Vioolsdrif 25 m	Vioolsdrif 44 m	Vioolsdrif 55 m	Komsberg 23 m
Significance	High	High	High	High

4.3.2 Impact of the Dam on Sediment Dynamics on the Downstream Environment

The natural processes of scouring and deposition will be altered through the entrapment of sediments and changes in the downstream flow regime.

The river channel immediately downstream of the dam is likely to erode and armour as a result of the release of 'sediment-hungry' water from the impoundment. In contrast to this, the sediments in the reaches further downstream are likely to have a larger proportion of fine material than at present. This is due to the dam trapping the larger sediments, while fine grains stay in suspension and will therefore be transported through the reservoir. Further to this, the reduction in gravel will reduce the formation of bars and islands that are an important part of the river ecosystem.

The dam will, after the flow regime downstream of the dam, which may reduce the competence of the river to transport sediment. The result of this would be a smothering of rocky habitat used by aquatic organisms. It is estimated that the result will be an impact of a moderate significance for all options (**Table 4.2**).

Table 4.2: Impact of the Dam on Sediment Dynamics

Dam Site	Vioolsdrif 25 m	Vioolsdrif 44 m	Vioolsdrif 55 m	Komsberg 23 m
Significance	Moderate	Moderate	Moderate	Moderate

4.3.3 Impact of the Dam as a Barrier to the Migration of Plant Matter, Invertebrates and Fish

Animals such as fish, crabs, eels and invertebrates migrate up- and downstream between river reaches. The proposed dam wall and reservoir would either hinder

or completely halt such movements, especially in an upstream direction. In this regard, the Komsberg site, just downstream of the Augrabies Falls, would have the least impact, as fish species cannot move upstream past the Augrabies Falls in any case (**Table 4.3**). The height of the proposed dam walls may preclude the effective use of fish ladders, but the possibilities for these should be investigated in detail, and should be budgeted for adequately in the estimates of construction and on-going management costs.

The proposed dam at Vioolsdrif would split the range of *Barbus hospus* and would result in fragmentation of fish populations in the LOR, resulting in genetic compartmentalisation and inbreeding of aquatic populations. This would enhance the manifestation of poor genetic characteristics, weakening populations and may in some instances lead to extinctions (**Table 4.3**).

With regard to invertebrates, a dam would trap those presently carried down the Orange River, thereby reducing both the resistance and the resilience of the system as a whole.

Constructing a dam on the river would affect recruitment of plant species in the river reaches downstream of the dam, due to the trapping of seeds.

Table 4.3: Impact of the Dam as a Barrier to Migration

Dam Site	Vioolsdrif 25 m	Vioolsdrif 44 m	Vioolsdrif 55 m	Komsberg 23 m
Significance	High	High	High	Low

4.3.4 Impact of the Thermal Stratification in the Dam on the River Water Chemistry

Thermal stratification (marked changes in water temperature at different levels of the dam) is common in large dams (**Table 4.4**). When water is released from the dam, it can have significant effects on the downstream aquatic biota due to the unnatural (either warmer or cooler) water temperatures. Thermal stratification occurs at the Vanderkloof Dam, with detrimental downstream effects. Water temperature triggers a wide range of responses in aquatic plants and animals, and changes in temperature regimes downstream of a dam can retard or halt, inter alia:

- fish spawning and growth; and
- flowering times, growth rates and size at maturity of riparian vegetation.

This effect becomes greater with an increase in dam wall height and resultant depth of the dam and thus, it is most significant in the two higher dam wall options for the Vioolsdrif Dam site (**Table 4.4**). However, more detailed modelling will be needed to determine the extent of the stratification impacts for the dams. The thermal impacts can be ameliorated by the use of a multilevel outlet works.

Table 4.4: Impact of the Thermal Stratification in the Dam on the River Water Chemistry

Dam Site	Vioolsdrif 25 m	Vioolsdrif 44 m	Vioolsdrif 55 m	Komsberg 23 m
Significance	Moderate	High	High	Moderate

4.3.5 Impact of the Dam and Related Activities on Water Quality

A dam in either of the proposed locations will result in the manifestation of the upstream water quality problems in the LOR. High flows will flush pollution from the upstream catchment into the proposed dam. Dam construction and river regulation will result in an increase in irrigation agriculture resulting in increased irrigation return flows to the lower river. All of these factors will, in turn, inevitably lead to further deterioration in the water quality in the downstream river, such as an increase in nutrients, conductivity and salinity (**Table 4.5**).

There is an excellent chance that a dam in the LOR will develop algal problems, given the current nutrient inputs from upstream. All of the major impoundments (Gariep, Cook's Lake, Disaneng, Lotlamoreng and Modimola) in the upstream reaches have Trophic Status classifications of eutrophic to hypertrophic, and act as growth nurseries for algal development, chiefly *cyanobacterial* (blue-green algae). One of the factors that may exacerbate this problem will be the nutrient state of the geology in the area inundated by the proposed dam.

It is very likely that eutrophication and algal blooms will be a problem and have an impact of moderate significance on the river ecosystem for all of the dam options.

Furthermore, a reservoir would result in the evaporation, and hence loss to the system, of significant volumes of water.

Table 4.5: Impact of the Dam and Related Activities on Water Quality

Dam Site	Vioolsdrif 25 m	Vioolsdrif 44 m	Vioolsdrif 55 m	Komsberg 23 m
Significance	Moderate	Moderate	Moderate	Moderate

4.3.6 Impact of Inundation on the Riparian Ecology

Inundation will result in the loss of large areas of riparian ecosystem. These riparian ecosystems will not re-establish around the dam margins due to the soil types and especially the variable water levels.

The proposed site for the Komsberg Dam is in a natural gorge, where the riparian vegetation is sparse, but because of the inaccessibility of the floodplain along this stretch, there are a number of near pristine stretches of shoreline and island vegetation. Furthermore, the area supports some rare riparian forest (**Table 4.6**).

Sections of the river near Vioolsdrif also have riparian vegetation that is in a relatively natural condition (**Table 4.6**). The islands in the LOR support much of the good-quality riparian vegetation, and furthermore, these islands represent valuable sources of seeds and vegetative material.

Table 4.6: Impact of Inundation on the Riparian Ecology

Dam Site	Vioolsdrif 2 5 m	Vioolsdrif 44 m	Vioolsdrif 55 m	Komsberg 23 m
Significance	Moderate	Moderate	High	High

4.3.7 Impact of the Inundation on the Terrestrial Ecology

In addition to the area affected, the condition, importance and uniqueness of the ecosystem determines the significance of the impact of inundation.

A dam site in the Vioolsdrif area would generally affect a less developed stretch. In contrast, a dam at Komsberg would affect areas of relatively pristine vegetation, but these are interspersed by agricultural developments. Both dam sites would inundate in access of 50 km^2 of land and thus, the impact is of a large scale.

The vegetation types encountered in these areas (*Sisyndite spartea* shrubland, *Zygophyllum* cf *album* dwarf shrubland, *Sisyndite spartea* shrubland, *Monechma spartioides* shrubland, *Commiphora gracilifrondosa* shrubland) are not restricted and are reasonably common adjacent to the areas to be inundated.

An overview of the type of terrestrial vegetation in the two areas, as well as the existing disturbance in these areas and alien vegetation present are given in **Table 4.7** and **Table 4.8** below.

Table 4.7: Summary of Terrestrial Vegetation Types, Existing Disturbance and Alien Vegetation for the Areas to be inundated by the Two Proposed Dam Sites

	Vioolsdrif	Komsberg
Terrestrial vegetation	• *Sisyndite spartea* shrubland • *Zygophyllum* cf album dwarf shrubland	• *Sisyndite spartea* shrubland • *Monechma spartioides* shrubland • *Commiphora gracilifrondosa* shrubland
Existing disturbance	• small stock and cattle grazing on north-bank and islands • extensive fishing from north-bank • signs of burning	• sections with irrigation agriculture on north- and south-banks • fishing and burning of riparian woodlands in vicinity of agricultural developments
Alien vegetation	• *Argemone ochroleuca* • *Prosopis* species (*P. glandulosa* and *P. velutina*) • *Ricinus communis* • *Nicotiana glauca*	• *Nicotiana glauca* • *Ricinus communis*

In general, the areas outside of the floodplain of the Orange River have vegetation in contrast to the lush valley/ floodplain. The drier, desert like areas can be broadly characterised as fitting into the "Nama Karoo" eco-region. This eco-region is a vast, open, arid region dominated by low-shrub vegetation, punctuated by rugged relief. The flora and fauna is not remarkably rich in species or endemism.

Table 4.8: Impact of the Inundation on the Terrestrial Ecology

Dam Site	Vioolsdrif 25 m	Vioolsdrif 44 m	Vioolsdrif 55 m	Komsberg 23 m
Significance	Low	Low	Moderate	Low

4.3.8 Impact of Inundation of the Aquatic Ecology

The LOR contains the most diverse fish assemblage in the whole Orange River System, with the diversity increasing downstream of Augrabies. The inundation of large sections of river channel would significantly reduce the available spawning habitat, thereby threatening the reproductive viability of fishes in isolated reaches. As 12 out of the 15 indigenous Orange River System freshwater fish species occur in this river stretch the loss of some 50 to 70 km of habitat would represent a major impact on the fish assemblage of the Orange River as a whole (**Table 4.9**).

Table 4.9: Impact of Inundation on the Aquatic Ecology

Dam Site	Vioolsdrif 25 m	Vioolsdrif 44 m	Vioolsdrif 55 m	Komsberg 23 m
Significance	Moderate	Moderate	High	Moderate

4.3.9 Impact of the Dam on Pest Species and on Human Health

The potential for increased temperatures and slower flowing waters in the LOR will increase the suitability of the lower river as habitat for bilharzia host snails, as well as other parasites. The chance of bilharzia becoming a problem is increased by the fact that the Curled Pondweed, *P. crispus*, a plant that provides habitat for the snail intermediate hosts of bilharzias, has also been observed in the LOR.

With the information available, it is not possible to determine the probability of this impact occurring and therefore it has been assigned a moderate significance for all of the dams.

It can be expected that further river regulation will enhance habitat possibilities for nuisance invertebrates such as blackflies, mosquitos and hydra. The spread of *Phragmites* spp. reeds is likely to increase habitat availability for some aquatic invertebrates, particularly blackflies. Such infestations of these pests have marked long-term impacts on the environment and economic activities and thus this is seen as an impact of high significance for all the dam sites (**Table 4.10**).

Table 4.10: Impact of the Dam on Pest Species and on Human Health

Dam Site	Vioolsdrif 25 m	Vioolsdrif 44 m	Vioolsdrif 55 m	Komsberg 23 m
Significance	High	High	High	High

4.3.10 Impact of the Dam on Increasing Habitat for Invasive Aquatic Vegetation

Artificial lakes provide an ideal habitat for water hyacinth or other floating macrophytes to flourish. Increasing river regulation and catchment utilisation will promote habitat changes suitable for the encroachment and colonisation of plant species such as the American floating water fern (*Azolla filiculoides*), water weeds (*Potamogeton schweinfurthii*, *P. pectinatus*, *P. crispus*, and *Ludwigia stolonifera)* amongst others.

This will result in water quality problems, and impair boating, as well as block irrigation systems. It may also promote the distribution of certain other pest species, such as the Red Billed Quelea (*Quelea quelea*) (**Table 4.11**).

Table 4.11: Impact of the Dam on Increasing Habitat for Invasive Aquatic Vegetation

Dam Site	Vioolsdrif 25 m	Vioolsdrif 44 m	Vioolsdrif 55 m	Komsberg 23 m
Significance	Moderate	Moderate	Moderate	Moderate

4.3.11 Impact of the Dam on Increasing the Suitable Habitat for Alien Fish Apecies

Alien species, such as carp and *Tilapia mosambicensis*, tend to be more sensitive to high flow conditions than the indigenous species (**Table 4.12**). These fish are, however, well suited to lentic conditions, are able to breed there, and are widespread in standing water bodies throughout Southern Africa. It is therefore expected that population sizes of invasive species will increase significantly in the LOR should the river be impounded.

An impoundment would be a supply source for alien species from whence colonisation of the upstream and downstream reaches of the Orange River could take place, which would increase predation pressure on the indigenous species in non-impounded sections of river. This is of concern due to the number and importance of indigenous fish species that would be at risk.

Table 4.12: Impact of the Dam on Increasing the Suitable Habitat for Alien Fish Species

Dam Site	Vioolsdrif 25 m	Vioolsdrif 44 m	Vioolsdrif 55 m	Komsberg 23 m
Significance	High	High	High	High

4.4 Operational Phase Impacts on Socio-economic Environment

4.4.1 Impact of Inundation on the "Sense of Place"

The inundating of large areas of land will have a marked effect on the "sense of place" due to these areas being dry desert areas even though they border on the Orange River. (**Table 4.13**) For the Vioolsdrif dam site (even though indigenous riparian woodlands have been replaced by alien *Prosopis* species along sections of

this stretch of river) the habitat diversity, the scenic landscape of this narrow river valley, the remoteness and the presently undeveloped status make this a special wilderness area, albeit enjoyed by relatively few local inhabitants and visitors.

The section of river upstream of Komsberg provides stretches of almost pristine wilderness, gradating into the Augrabies National Park. As the dam would inundate the lower reaches of the Orange River gorge, this would constitute a significant impact on this conservation area and is likely to be regarded as a fatal flaw.

Even though these wilderness areas are fragmented by large agricultural developments, the inundation of this area would have a marked effect on its character.

Table 4.13: Impact of the Inundation on the "Sense of Place"

Dam Site	Vioolsdrif 25 m	Vioolsdrif 44 m	Vioolsdrif 55m	Komsberg 23 m
Significance	Moderate	Moderate	Moderate	**Very high**

4.4.2 Displacement of Communities as a Result of Inundation

Both dams would require the acquisition of privately-owned land and the displacement of existing rural communities, primarily those associated with agricultural activities (**Table 4.14**).

Both dams would inundate areas of irrigated agriculture and various infrastructures, such as roads, canals, powerlines, buildings and graveyards.

Furthermore, the dams would preclude possible future mining in the inundation area (see LORMS Report 00/8/1/P-05).

Table 4.14: Displacement of Communities as a Result of Inundation

Dam Site	Vioolsdrif 25 m	Vioolsdrif 44 m	Vioolsdrif 55 m	Komsberg 23 m
Significance	Moderate	High	High	High

4.4.3 Impact of Inundation on Historical and Archaeological Sites

Very little is known about the archaeology of the study area. The Richtersveld to the west is known to be very archaeologically sensitive in terms of the unique herder sites that have been identified along its banks. From the information available, as well as extrapolated from work done outside the study area, it is evident that there will be significant archaeological sites affected by inundation (**Table 4.14**). However, it is unlikely that any of these will be of national importance but rather represent a wealth of information of local importance and be important as a part of a series of sub-sites. Probably the most important site is the historic mission station of Pella, which will not be affected by inundation.

The Haib River Mouth, within the inundation area of the Vioolsdrif site, was subjected to further site analysis to confirm the type and importance of archaeological sites that can be expected. The survey found concentrations of both Holocene and Pleistocene stone artefact scatters in the Orange River valley and on the plateau. However, the predominant sites were the remains of nomadic pastoral encampments and historical or colonial sites (**Table 4.14**).

Buried and exposed pottery and fish bone rich sites of ancestors of the Nama, burial cairns of Nama, rock engravings on rocky outcrops, general scatters of Early and Middle Stone age archaeological material, and abandoned Nama herder encampments, as well as historic buildings (early farms, missions), graveyards, possible places of conflict (Anglo-Boer war and Korana uprising) and important historical river crossings occur within the inundation areas of both dams.

Table 4.15: Impact of Inundation on Historical and Archaeological Sites

Dam Site	Vioolsdrif 25 m	Vioolsdrif 44 m	Vioolsdrif 55 m	Komsberg 23 m
Significance	Moderate	Moderate	High	Moderate

4.4.4 Change in Adjacent Activities as a Result of the Provision of Water

In addition to the areas inundated by a dam, the development will affect the character and sense of place of the surrounding towns, while the provision of water and resultant agricultural and other developments would significantly alter areas further afield (**Table 4.16**).

This can be expected to boost local and regional economies and hence, result in a suite of social and economic opportunities for landowners, and those in the service industry. It is expected that there will also be an increase in employment opportunities.

A reservoir is also likely to result in tourism opportunities associated with recreation.

On the other hand, a dam may pose a safety risk to communities in the floodplain downstream associated with the unlikely event of dam failure. A dam would not attenuate moderate to large floods.

Table 4.16: Change in Adjacent Activities

Dam Site	Vioolsdrif 25m	Vioolsdrif 44m	Vioolsdrif 55m	Komsberg 23m
Significance	Positive to low	Positive to low	Positive to low	Positive to low

4.5 Construction Phase Impacts on Biophysical and Socio-economic Environment

There is inadequate information available to provide even an initial assessment of the range and significance of potential impacts that may occur during the construction phase, over and above those described as operational / permanent impacts.

However, from a biophysical perspective, it is expected that the major concerns would be on the downstream aquatic environment. (**Table 4.17**)

Potential social impacts relate to the inevitable migration of people to the area in search of employment opportunities directly or indirectly associated with the construction. This may result in considerable social tension, especially with the predominantly rural communities. On the other hand, the construction phase of the project would result in considerable job creation and economic benefit to this underdeveloped part of southern Africa.

Construction phase impacts can be managed to varying degrees by means of the compilation and implementation of a comprehensive Environmental Management

Plan, which is developed in consultation with the relevant role players and considers all impacts and issues identified during the EIA.

The significance of the construction phase impacts can range from High to Moderate, depending on the impact and degree and success of mitigation. It is likely that the construction phase impacts would be similar for all options, and could range from positive to highly negative, if adequate measures are not taken to manage and mitigate potential impacts.

Table 4.17: Construction Phase Impacts on the Biophysical and Socio-economic Environment

Dam Site	Vioolsdrif 25m	Vioolsdrif 44m	Vioolsdrif 55m	Komsberg 23m
Significance	Positive to high	Positive to high	Positive to high	Positive to high

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions from the Environmental Assessment

Any of the proposed dam sites will have significant negative environmental impacts on the biophysical, as well as the socio-economic environment in the vicinity of the dam site, as well as upstream and downstream. These impacts, and the opportunities for mitigation need to be carefully weighed up against the advantages resulting from the dam.

With regard to biophysical impacts, rivers are interconnected wholes. Impacts that affect one component of the ecosystem do so through their affect on other components of the riverine ecosystem. For instance, reduced habitat availability or quality, fragmentation of the river system or loss of invertebrates will affect fish populations. Changes in the abundance or species composition of fish communities will, in turn, affect the abundance and distribution of other animals and plants, both riverine and terrestrial, as food supplies or preferences change and competition for food and space changes.

Some of the potential biophysical impacts of the proposed dams on the LOR can be ameliorated, through for instance, provision of environmental flows, fish ladders and careful positioning of outlet structures, but others cannot. The LOR has increasingly had the natural checks and balances, that controlled (and promoted) the distribution of species, removed. In their place, a more stable, more predictable flow regime has paved the way for the proliferation of those species best able to adapt to it, at the expense of other, more sensitive or specialised, species. More abstraction, impounding and artificial management of the system is likely to exacerbate these trends, bringing along with it the threats of species extinction and the costs of coping with the resultant problems, such as the proliferation of pest species of both fauna and flora; a deterioration in water quality; and the development of algal blooms.

With regard to social issues, the major areas of concern relate to the displacement of communities and changes brought about directly and indirectly as a result of a dam, as well as heritage impacts.

The main aim of this report is to provide an initial comparative assessment of the possible dam options in order to ascertain whether, based on existing information,

one of the dam sites should be rejected and not considered in further studies. A table summarising the significance of the potential impacts for the Vioolsdrif and Komsberg sites has been compiled and is presented in **Table 5.1**.

Table 5.1: Comparison of the Impacts of the Dam Sites with a Total Rating Value for each Option

Dam Site	Vioolsdrif 25 m	Vioolsdrif 44 m	Vioolsdrif 55 m	Komsberg 23 m
Biophysical Impacts	**Significance Rating**			
Impact of access roads on aquatic and terrestrial ecosystems	High	High	High	High
Impact of the dam on sediment dynamics and hence on the downstream environment	Moderate	Moderate	Moderate	Moderate
Impact of the dam as a barrier to migration of plant matter, invertebrates and fish	High	High	High	Low
Impact of the thermal stratification in the dam on the river water chemistry	Moderate	High	High	Moderate
Impact of the dam and related activities on the water quality	Moderate	Moderate	Moderate	Moderate
Impact of the inundation on the riparian ecology	Moderate	Moderate	High	High
Impact of the inundation on the terrestrial ecology	Low	Moderate	Moderate	Moderate
Impact of the dam on pest species and human health	High	High	High	High
Impact of the dam on increasing habitat for invasive aquatic vegetation	Moderate	Moderate	Moderate	Moderate
Impact of the dam on increasing the suitable habitat for alien fish species	High	High	High	High
Socio-economic Impacts				
Impact of the inundation on the "Sense of Place"	Low	Moderate	Moderate	Very High
Displacement of communities as a result of inundation	Moderate	High	High	High
Change in adjacent activities as a result of the provision of water	Positive to Low	Positive to Low	Positive to Low	Positive to Low
Impact of inundation on historical and archaeological sites	Moderate	Moderate	High	Moderate
Construction phase	Positive to High	Positive to High	Positive to High	Positive to High
INTEGRATED ASSESSMENT	**MODERATE**	**MODERATE**	**HIGH**	**HIGH**

From the above table the following can be concluded that:

- All of the proposed options are likely to have a significant detrimental impact on the riverine and terrestrial ecosystems.
- There will be clear social and economic benefits associated with the provision of further water, but there will be impacts on the local communities.
- The dam at Vioolsdrif with the highest wall (55 m) has the most negative environmental impact and dams with lower dam walls would have relatively less impact.
- The inundation of a portion of the Augrabies Falls National Park by the proposed Komsberg Dam is perceived to be a potential fatal flaw.
- Vioolsdrif site has a number of significant impacts, but does not appear to have a fatal flaw from a biophysical and socio-economic perspective, especially at the lower two full supply levels.
- Although the opportunities for and likely success of mitigation measures have not been considered, some general comments can be made on those impacts, which rated differently for Vioolsdrift (25 m) and Komsberg:
  - Some of the impacts of the barrier effects may be able to be mitigated;
  - The inundation of riparian and terrestrial ecologies cannot be mitigated; and
  - Impact on the "sense of place".

5.2 Recommendations for Further Investigation during Feasibility Study

From an environmental perspective, the Komsberg site is not preferred due to the impact on the Augrabies National Park. As no fatal flaws have become apparent with the Vioolsdrif site, it could be considered further from an environmental perspective.

However, it is critical that a detailed EIA is undertaken to improve the confidence in the assessment and in the formulation of mitigation measures. This EIA should be undertaken as part of the Feasibility Study (see LORMS Report 400/8/1/P-14). The EIA should meet the legal requirements of both Namibia and South Africa and comply with international best practise. Furthermore, the EIA should address the entire project, i.e., the dam and associated infrastructure, as well as the broader implications of further river regulation and water usage.

A comprehensive PP process should be conducted as part of the EIA, in the applicable languages to ensure that all interested and affected parties (IAPs) are informed and have adequate opportunity to provide input to the study. The EIA

should include a detailed mitigation plan, inclusive of the full range of potential options, a cost estimate to implement, and an assessment of their likely success.

Due to the extent of the areas to be affected and range and possible severity of the impacts, a range of specialist studies will be required and the appropriate time and budget allocated to each. The key issues identified during this initial assessment are listed below, but further issues may emerge during the EIA process:

1. Probably the largest impact of any of the dams would be on the downstream riverine and estuarine ecosystems. Accordingly, it is imperative that high confidence EFR determinations are undertaken for the LOR (inclusive of the estuary) in order to inform the design of the outlet works and the volume and timing of releases. In this regard, a Scope of Work has been compiled (see LORMS Report 400/8/1/P-14) and it is recommended that this work is commissioned in advance of any Feasibility Study, so that the findings can inform the preliminary design and in particular the EIA.
2. The likely water quality profiles of the dam, particularly with regard to the potential for algal growth, which will affect the reservoir itself and the downstream environment, should be investigated. This should include an assessment of the nutrient state of the geology in the proposed inundation area. It should also include a study of reservoir stratification and the need for, and design of, multi-level release structures to satisfy both ecological and user requirements.
3. The nature of the riverine habitat (including the riparian zone), as well as the terrestrial habitat likely to be inundated, and its availability outside of the various inundation zones and possible dam wall locations, should be investigated.
4. More detailed field investigations of the in-channel ecosystem, including fish and invertebrates should be undertaken.
5. A detailed heritage impact assessment should be undertaken.
6. A social audit and impact assessment should be conducted within the inundation, and surrounding areas.

ANNEXURE A

A Study on the Impacts on the Aquatic Ecology Pertaining to the Construction of Large Dams in the Lower Orange River

ANNEXURE B

A Desktop Report on the Ecological Importance and Sensitivity of the Lower Orange River Downstream of 20º Latitude to the Orange-Fish River Confluence

ANNEXURE C

A Vegetation Specialist Study with Reference to the Potential Vioolsdrif and Komsberg Dam Sites

ANNEXURE D

A Report on the Heritage Sensitivity of the Lower Orange River Region between 20º East and the Fish River Confluence

ANNEXURE E

A Preliminary Archaeological Assessment of the Lower Orange River

ANNEXURE F

Archaeological Assessment of Potential Dam Sites on the Lower Orange River (Vioolsdrif & Komsberg)

ANNEXURE G

A Social Survey of the Vioolsdrif Dam Site