Orange-Senqu River Basin

Orange-Senqu River Commission Secretariat
Governments of Botswana, Lesotho, Namibia and South Africa

UNDP-GEF
Orange-Senqu Strategic Action Programme
(Atlas Project ID 71598)

Consequences of Scenarios on Ecosystem Services

Research Project on Environmental Flow Requirements of the Fish River and the Orange-Senqu River Mouth

Technical Report 26
Rev 3, 30 October 2013

UNDP-GEF
Orange-Senqu Strategic Action Programme

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Research Project on Environmental Flow Requirements of the Fish River and the Orange-Senqu River Mouth

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This document has been issued and amended as follows:

Revision	Description	Date	Signed
0	Initial draft for internal review by Dr B Rydgren and Mr W Hendley	Feb 2013	DL
1	Consolidated first draft	May 2013	DL
2	Second draft including recommendations of reviewers	Jul 2013	DL
3	Final draft for comment	30 Oct 2013	GH, DL, JT

Project executed by:

UNOPS

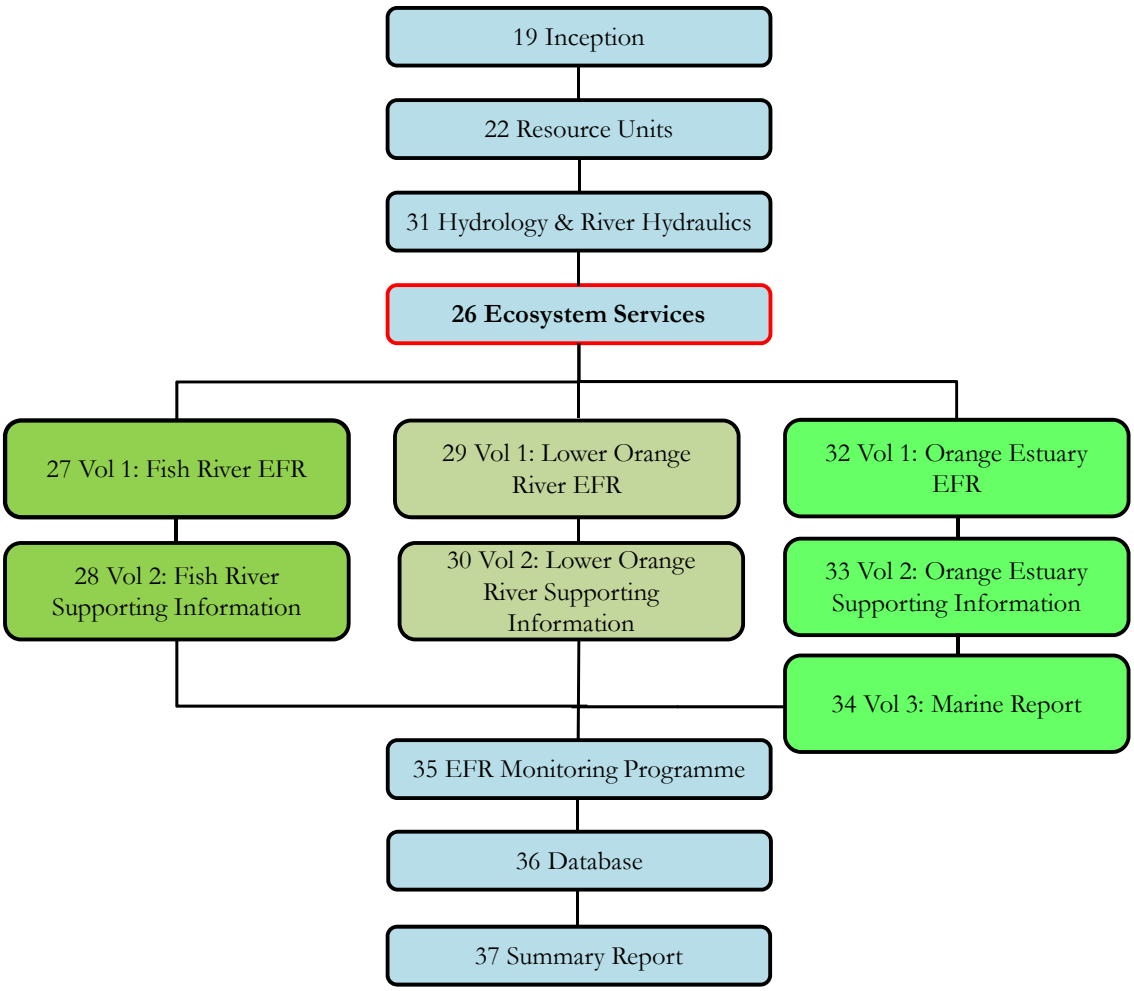
Report list

A list of the Technical Reports that form of this study is provided below. A diagram illustrating the linkages between the reports is also provided.

Technical Report No	Report
19	Inception Report, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
22	Delineation of the Study Area – Resource Unit Report, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
26	**Consequences of Scenarios on Ecosystem Services, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth**
27	River EFR assessment, Volume 1: Determination of Fish River EFR Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
28	River EFR assessment, Volume 2: Fish River EFR, supporting information Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
29	River EFR assessment, Volume 1: Determination of the lower Orange River EFR Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
30	River EFR assessment, Volume 2: Lower Orange River EFR, supporting information Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
31	River and Estuary EFR assessment, Hydrology and River Hydraulics Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
32	Estuary and Marine EFR assessment, Volume 1: Determination of Orange Estuary EFR Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
33	Estuary and Marine EFR assessment, Volume 2: Orange Estuary EFR: Supporting Information Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
34	Estuary and Marine EFR assessment, Volume 3: Assessment of the Role of Freshwater Inflows in the Coastal Marine Ecosystem Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
35	EFR monitoring programme, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth
36	Database, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth

Technical Report No	Report
37	Summary Report, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth

Bold indicates current report.



Acknowledgements

The following persons and institutions are gratefully acknowledged for assisting with information presented in this report:

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Executive summary

Introduction

This report provides a qualitative description of the socio-economic contribution made in the form of ecosystem services supplied by the lower Orange-Senqu River system, including its estuary and main tributary, the Fish River. The study was based on site visits and a limited number of interviews with key stakeholders, as well as examination of existing published and unpublished information. This is followed by an assessment of how the supply of these services might be impacted under different scenarios, based on the predictions of ecological specialists as to how the characteristics and functioning of the river and estuarine ecosystems are likely to change.

Natural habitats and ecosystems such as rivers and estuaries provide a range of goods and services that contribute to human well-being. Their value to society depends both on the structure and functioning of the ecosystems in question, which determines their capacity to supply useful services, and on their socio-economic context, which determines the demand for those services. The principles of sustainability require that these values and the ecological functioning that underlies them are not unduly compromised.

Ecosystem services provided by rivers and estuaries include their attributes that provide aesthetic, recreational, cultural and spiritual value, the provisioning of goods such as fish and raw materials, and the ecosystem functions that save costs, such as water quality amelioration and nutrient cycling or provide inputs into production processes elsewhere, such as the provision of nursery areas for fish and invertebrates exploited by marine fisheries. Collectively, these are known as ecosystem services. The capacity to provide ecosystem services depends on the nature of the ecosystem, as well as its integrity.

Study area

The lower parts of the Orange-Senqu River basin fall in a highly arid environment characterised by low population densities. As such, the number of people benefiting directly from ecosystem services of this part of the system is much lower than for the upper parts of the basin, particularly in South Africa and Lesotho. Nevertheless, when considering both direct and indirect benefits, ecosystem services generated by this area are more important than might otherwise be assumed by the low population densities. The rivers and estuary of the lower Orange-Senqu system contribute to the livelihoods of a few small communities in the study area, where they can be locally significant, and also contribute to the economy of the small towns of the area, mainly through their tourism benefits in association with the /Ai-/Ais–Richtersveld Transfrontier Park and the Ramsar Status of the estuary.

Method

The baseline assessment was carried out on the basis of site visits, interviews with key informants, and existing information.

For the lower Fish River the assessment was based on afield trip was conducted along the Fish River from Mariental to the confluence during the winter period, key stakeholder interviews, and consultaion of reports specific to the area. For the lower Orange River the assessment was based on a site visit to key parts of the study area, interviews with stakeholders and community members in the key settlements and analysis of secondary data. For the Orange Estuary the assessment was based ona site visit, interviews with community members, the Department of Nature Conservation in Springbok and individuals in Alexander Bay from the Alexcor security services, the border police services and the hospitality industry. Secondary data was also consulted. This included demographic data and literature sources.

Description of ecosystem services

Lower Fish River

Despite low population densities and distances that many people live away from the river, important riparian goods and services are present and form a key component of many vulnerable peoples' livelihoods. In particular, subsistence livelihoods supplemented with harvested goods on the communal lands around the Neckartal Dam site are important.

Most people along the Fish River obtain their water from deep boreholes that are located some distance away from the river, rather than river water or groundwater that is associated with the river. Important exceptions to this include the Hardap Irrigation Scheme and the town of Mariental which are dependent on water from the Hardap Dam. The /Ai-/Ais Hot Springs Resort depends on a shallow alluvial aquifer in the Fish River for most of their water requirements.

Fishing from the pools provides an important and affordable source of protein for, especially, the poorer communities living close to it, e.g. in Snyfontein and Gibeon, as well as for farm workers and other labourers working in the area. Fishing takes place year round, except at high flows, from the river and pools. The pools are also used as watering points for livestock and banks provide valuable grazing, especially during dry times

Some, albeit limited harvesting of reeds takes place for handicrafts. Wood is the main source of energy for cooking in the area and the river is the main source of this wood. Other resources harvested include veld foods and medicines. Sand is quarried intermittently along the river at varying scales, for example at Seeheim. Cultivation in the area is limited to small household gardens and bana grass along the river banks for fodder.

Extensive small-stock farming supplemented with hunting traditionally on freehold land downstream of Neckartal Dam to /Ai-/Ais Richtersveld Transfrontier Park boundary. Increasingly

however, land use is moving over to landscape-based tourism, especially further south. With regard to recreational use, local residents partake in picnicking, swimming and fishing at settlements along the river.

Hardap irrigation scheme, Gibeon and the /Ai-/Ais Hot Springs Resort were identified as contributing to the pollution in the river in the form of untreated sewage and agro-chemicals. Blackfly larvae were noted in the river at the bridge between Tses and Berseba. Flow of the river, as well as reed beds that have become established, provide important purification services. Reducing flow of the river, as well as large-scale removal of reeds such as the spraying operation below Hardap, will negatively affect these services.

Orange River downstream of the Fish River confluence

Because population densities are low, the utilisation of natural resources is relatively insignificant. However, there is some degree of reliance on natural resources by people of Nama descent and by other people who are resident in the area. Interviews revealed that the Orange River and its resources are used, to a limited extent, for the following:

- Fishing – recreation, but also subsistence.
- Gathering of sedges and reeds, as well as timber and firewood.
- Grazing.
- Hunting.

Representatives of the Nama communities who were interviewed indicated that fishing is an important source of subsistence. It was reported that fishing may be the primary source of income for a small number of individuals and families. Fishing takes place throughout the year, but venturing into the river during months of high flows is believed to be dangerous. Fishing gear is mostly confined to rods and hand-lines but traps and gillnets are also used.

Reeds (*Phragmites australis*) are harvested from the river banks to construct traditional *matjieshuise* (or *haru oms* in Nama). In the informal settlement areas many of these huts form the primary residential structures. Reeds are also used to make floor mats and sleeping mats. Sedges such as *Cyperus marginatus* are available but are only used to a very limited extent.

The riparian zone is also used for grazing and browsing by livestock. *Cynodon dactylon* is one of the important species for grazing in this river stretch. There appears to be an increase in utilisation of the area by goats, particularly of *Seasia pendulina*, *Diospuros lyceoides* and *Acacia karroo*. *Tamarix usneoides* is an indigenous plant species that is used by cattle and small game as a natural salt lick.

In terms of cultural services, tourism is important. The Orange River is a central feature of the /Ai-/Ais Richtersveld Transfrontier Park, which is an important tourist destination. The presence of the /Ai-/Ais Richtersveld Transfrontier Park and its unique position within an Arid Biodiversity Hotspot on Earth makes it an attractive tourist destination. The Orange River is a key feature of

the park, and is used for canoeing, rafting, swimming, fishing as well as contributing to the aesthetic value of the landscape. It is also important for nature-based activities such as bird watching.

Other cultural services include ritual use which is of low magnitude given the low densities of people. The significance of ritual use is however high and the Orange River occupies a central place as a feature in people's lives. Purification rituals were mentioned as of particular importance with respect to the river. The river also plays an important role in local mythologies.

The river has waste assimilation and dilution attributes linked closely to base flows and flooding. In the study area the impacts associated with upstream farming are evident, as are some mining-related water quality issues. Outbreaks of cyanobacteria, have been reported in recent years.

Orange Estuary

The estuary forms the western part of the boundary between Namibia and South Africa. There are two small towns adjacent to the estuary i.e. Oranjemund in Namibia, and Alexander Bay in South Africa. These two towns, which both exist by virtue of the diamond mining activities along the Namibian and South African coasts, are linked by a bridge that spans the estuary near its head.

The estuary offers provisioning services in the form of sand, pebbles, fish, game, grazing and plant resources such as *Phragmites* reeds. With the possible exception of fish, grazing and illegal dog-hunting, there is currently little demand for these services, and hence they have low value.

There is no legal commercial fishery on the estuary but illegal gillnetting does take place. It appears that very little use is made of the estuary for recreational purposes although easier boat access may change this. Marine shore-angling at the river mouth area, both into the estuary and surfzone, is more popular than angling in the estuary proper. Participants comprise anglers from within the settlements of Alexander Bay and Oranjemund as well as a substantial number from beyond the local community. Both settlements have angling clubs which, apart from catching fish, are also important from a social perspective. The magnitude and spatial and temporal distribution of angling effort has shifted according to changes in fishing and environmental management measures by both the Namibian and South African authorities. Implementation of cross-border bag-limits by the Namibian government saw effort displacement to the Northern Cape coast, especially the mouth of the Orange Estuary. Shore-angling effort is strongly seasonal with peaks during floods and high flows and corresponding aggregations of kob and steenbras. The level of sophistication is quite high with anglers co-ordinating their trips according to flow reports from dams in the upper catchment. Catches may be exceptionally high and the popularity of the venue is enhanced by the virtual absence of any fisheries law enforcement. On the other hand, the prohibition on offroad vehicles on beaches as well as the removal of the causeway that provided access to the beach, reduced fishing effort on the South African side. This situation is set to change as the SA Department of Environmental Affairs and Tourism has provided a concession to the Richtersveld Community to operate a boom and charge offroad vehicle users for access to the beach on the South African side. Fishing effort on the Namibian side has remained unchanged and is still

relatively high to effort elsewhere on the west coast. Fishing regulations such as bag and size limits differ between the two countries, even though anglers are fishing in the same waters at the Orange River mouth.

The estuary also attracts visitors who come to see the river mouth, or for bird watching. The river mouth in itself is an impressive site, particularly with its setting in a desert landscape.

Regulating services provided by estuaries typically include nursery functions for species utilised in fisheries beyond the estuary, exports of nutrients and sediments, water treatment functions and carbon sequestration. The level of carbon sequestration is dependent on the plant growth forms in the estuary, and their extent and productivity and carbon sequestration of saltmarshes in temperate regions is important. If the saltmarsh in the Orange Estuary was rehabilitated, carbon sequestration would likely once again become a significant function of the Orange Estuary.

The Orange Estuary is thought to be particularly important as a nursery area since it is one of only four permanently open systems on the west coast of South Africa, accounting for about one third of the estuarine area. The next estuary north of the Orange River is the Cunene in northern Namibia. Furthermore, the high diversity and abundance of estuarine dependant and marine species suggests that the Orange Estuary is a more important nursery area than was previously thought. It is also an important coastal waypoint, aggregation area and temperature refuge for exploited nomadic fish species such as kob moving back and forth between Namibian and South African waters.

Rivers carry nutrients from their catchments which they discharge into the marine zone. Sediment outputs from rivers can play an important role in maintaining benthic habitats offshore, which has knock-on effects for demersal (bottom dwelling) fisheries. The continental shelf offshore of the mouth of the Orange Estuary is thought to be a critical nursery areas for several fish stocks that make up a large proportion of the value of commercial fisheries in South Africa. Juvenile anchovy *Engraulis encrasicolus*, a mainstay of the pelagic industry utilise the turbidity plume as a nursery whereas west coast sole *Austroglossus microlepis* distribution and abundance varies according to the amount and type of sediment discharged from the catchment. Although their importance is indisputable, these linkages are not well understood.

Consequences of scenarios (Orange River and Estuary) and release options (Fish River) on ecosystem services

Scenarios were evaluated in terms of their potential impacts on the supply of ecosystem services, and the value or benefits derived from these. The assessment was based on expert opinion of the direction and approximate magnitude of changes (for example, no change = 1, a 50% increase = 1.5, and a 20% decrease = 0.8). The estimates for this assessment were based on estimates of ecosystem changes made by ecological experts.

Fish River ecosystem services consequences

The release options consist of a range of environmental flow releases from 0% release of the inflow to an environmental release of 50% of the inflow. Only release options 40% and 50% were considered to have sufficiently low negative impacts to be acceptable. These consequences are summarised per ecosystem service in the table below. The colours refer to the following:

- Red denotes a scenario with an overall negative impact with a substantial/moderate implication for either the significance or the magnitude of ecosystems services.
- Orange denotes a scenario with an overall negative impact with a minor implication for either the significance or the magnitude of ecosystems services.
- Light green denotes a scenario with status quo maintained or an overall positive impact with a minor implication for either the significance or the magnitude of ecosystems services.
- Dark green denotes a scenario with an overall positive impact with a substantial/moderate implication for either the significance or the magnitude of ecosystems services.

Summary of the consequences of release options on the Fish River ecosystem services

Services Values	***Description***	***RO 0%***	***RO 20%***	***RO 30%***	***RO 40%***	***RO 50%***
Harvested resources	Fish, reeds, riparian foods, medicines					
Grazing	Important in dry periods					
Recreational	Swimming, picnicking					
Nature-based tourism	Important in lower reach					
Water quality amelioration	Pollution (irrigation return flows, waste water from settlements)					
Pest control	Control of black fly larvae					

Orange River ecosystem services consequences

The impacts of Scenarios OF 2 and OF 3 were similar, although they differed by the inclusion of a recommended EFR release from the Neckartal Dam, and were generally low. Scenarios OF 6 and OF 7 included the Polihali, Vioolsdrift and Boskraai Dams. Although scenario OF 6 included more irrigation development, the impacts of these two scenarios were also similar, and in this case were considered to be severe and unacceptable. The consequences are summarised in the table below.

Summary of the consequences of release options on the Orange River ecosystem services

Services Values	***Description***	***Sc OF 2, 3, 4, 5, 8***	***SC OF 6***	***Sc OF 7***
Harvested resources	Limited number of people (important)			
Grazing	Limited number of people (important)			
Recreational	Limited number of people (important)			
Nature-based Tourism	Associated with Orange River and Park			
Water quality amelioration	Upstream pollutants			
Pest Control	Control of Black Fly			

Orange Estuary ecosystem services consequences

Impacts of scenarios OF 2, OF 3 and OF 4 are relatively small, and the values of the services involved are small. Scenario OF 4 has a negligible impact if not a slight improvement in value. Impacts are slightly greater under scenario OF 5, and are significant under scenarios OF 6 and OF 7. Because the value of sediment exports to the marine environment is unknown and could be high, the latter scenarios pose an unacceptable level of risk. The consequences are summarised below.

Summary of the consequences of release options on the Orange Estuary ecosystem services

Services/values	***Description***	***Sc2&3Sc4***	***Sc 5***	***Sc6***	***Sc 4+anth****
Harvested resources	Negligible				
Grazing	Small herd supported				
Recreation	Moderate value				
Nature-based tourism	Small value in the order of <R1m				
Water quality amelioration	Negligible value				
Export of nutrients	Small localised value in inshore environments				
Export of sediments	Low value due to human influence				
Nursery function	Contributes about R7.5m of the value of Western Cape fisheries				

* Sc 4 plus anthropogenic measures.

Conclusions

For the Fish River the environmental release options can be ranked, in terms of impacts on ecosystem goods and services, in order of the overall amounts of water released. Given the relationship between flows and the ecosystem services this is to be expected. As such RO 0% has the greatest negative impacts while RO 50% has the least negative impact. For the lower Orange River, Sc OF 2 and OF 3 will have virtually no impact, while Sc OF 6 and OF 7 will have marked impacts on virtually all of the ecosystem goods and services.

For the estuary the impacts of Sc OF 2, OF 3 and OF 4 are relatively small, and the values involved are small. Sc OF 4 has a negligible impact, if not even a slight improvement, on value. Impacts are slightly greater under Sc OF 5, and are significant under Sc 6 and 7. Because the value of sediment exports to the marine environment is unknown and could be high, the latter scenarios also pose an unacceptable level of risk.

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Abbreviations

AMD	Acid mine drainage
EFR	Environmental flow requirement
GFRCC	Greater Fish River Canyon Complex
IDP	Integrated Development Plan
MAR	Mean Annual Runoff
MAWF	Department of Water Affairs, Ministry of Agriculture, Water and Forestry, Namibia
MEC	Member of Executive Council
OFRB	Orange-Fish River Basin
RMC	Richtersveld Mining Company
RO	Release option
RVC	Richtersveld Community
SANParks	South African National Parks
Sc	Scenario
ZAR	South African Rands

1 Introduction

1.1 Background and terms of reference

The Orange-Senqu Basin is the third largest river basin in southern Africa. It is located within the territories of Botswana, Lesotho, Namibia and South Africa. In its lower reaches, the Orange-Senqu River forms the border between South Africa and Namibia before draining into the Atlantic Ocean. The estuary represents a unique ecosystem in what is otherwise a wave exposed, arid coastal area with few freshwater inputs, and is recognised as a wetland of internationally importance under the Ramsar Convention. The Fish, an ephemeral river rising in central Namibia, is the western-most significant tributary of the Orange-Senqu River. The health of these ecosystems, and their capacity to deliver ecosystem services to society, will be affected by water resource management throughout the Orange-Senqu River basin. This study forms part of a larger study to assess the current status and value of the Fish River, lower Orange-Senqu River and the Orange-Senqu Estuary, to evaluate the potential outcomes of alternative water resource development scenarios for the Orange-Senqu Basin as a whole, and to determine environmental flow requirements. This study forms the ecosystem services, or resource economics component of the study.

The aims of this study were:

- to provide a qualitative description of the socio-economic contribution made in the form of ecosystem services supplied by the lower Orange-Senqu River system, including its estuary and main tributary, the Fish River, based on existing published and unpublished information, site visits and interviews with key stakeholders;
- to assess how the supply of these services might be impacted under alternative future scenarios, based on the predictions of ecological specialists as to how the characteristics and functioning of the river and estuarine systems are likely to change.

1.2 Overview of ecosystem services and their values

Natural habitats and ecosystems such as rivers, wetlands and estuaries provide a range of goods and services that contribute to human well-being. Their value to society depends both on the structure and functioning of the ecosystems in question, which determines their capacity to supply useful services, and on their socio-economic context, which determine the demand for those services.

Ecosystem services provided by rivers, wetlands and estuaries include their attributes that provide aesthetic, recreational, cultural and spiritual value, the provisioning of goods such as fish and raw materials, and the ecosystem functions that save costs, such as water quality amelioration or provide inputs into production processes elsewhere, such as functioning as nursery areas for fish and invertebrates caught in marine fisheries. Collectively, these are known as ecosystem services. The capacity to provide ecosystem services depends on the nature of the ecosystem, as well as its integrity.

The value provided by ecosystem services is usually described in terms of the total economic value framework, which breaks values into direct use, indirect use, option and non-use values.

Direct use values associated with ecosystem services can be derived from consumptive use (such as fishing, hunting and the harvest of plant resources) or non-consumptive use (such as photographic tourism). Grazing by livestock, harvesting medicinal plants and animals, and harvesting indigenous or endemic plants for roadside sale constitute productive activities whose economic values are realised in the form of profits from sale of final goods such as livestock, medicinal services, and the natural resources themselves.

Indirect-use values are derived from ecosystem functions such as production of nutrients, maintenance of well-functioning riverine ecosystems, water purification, maintenance of specific gaseous qualities and hydrological cycles, and formation of soil and organic matter. These values do not accrue directly to users but support direct use by people. Very important in the context of the Orange River is the capacity of a water body to assimilate or dilute wastes. This represents a real economic value when the costs of water-quality impacts are considered.

Option values are values attached by individuals to the maintenance and preservation of environmental goods in order to reserve an option to use them, directly or indirectly, in the future. A different notion of option value known as vicarious value relates to creating use options for contemporary generations. Value is not derived from use but from creating an option for use by others in the same generation.

Non-use value is the value derived from knowing that something exists, and can be realised in monetary terms. For example, people living in Johannesburg may be willing to pay a donation to help secure the future of the biodiversity of the Orange-Senqu Estuary.

This study focuses on the direct and indirect use values, particularly provisioning, cultural and regulating services, associated with the lower Orange-Senqu River system.

2 Study area

The study area comprises the lower parts of the Orange-Senqu River basin, and was divided into three sections, as follows:

- The lower **Fish River** between Hardap Dam and its confluence with the Orange River, a distance of about 500 km. This was subdivided into two reaches for the assessment:
    - from the Hardap Dam to the propsed Neckartal Dam;
    - from the proposed Neckartal Dam to the Orange River confluence.
- The lower **Orange River** between the Fish River confluence and the head of the estuary, a stretch of about 140 kilometres.
- The **Orange Estuary**, which stretches from just upstream of the Harry Oppenheimer bridge, approximately 13 km from the sea, to the river mouth.

2.1 The lower Fish River

The lower Fish River lies within Namibia's Orange-Fish River Basin (OFRB), which includes sub-basins of smaller rivers flowing directly into the lower Orange from southern Namibia, such as the Gamkab, Hom, etc. (Biggs, 2009.) It has its headwaters on the Rehoboth Plateau just south and west of Rehoboth, at a latitude of approximately 23.5° S, and flows several hundred kilometres in a mostly southerly direction to the Orange River. The confluence of the Fish and the Orange rivers is about 30 km south-west of Ai-Ais (just south of 28° S), between Aussenkehr and Sendelingsdrift.

The Fish River is ephemeral and flows in most years for at least some period of time, but only flows with any intensity during high rainfall years. Pools of water tend to remain in the dry season, especially in the river's lower reaches. The Fish River has two main tributaries, the Löwen that rises in the Karas Mountains to the east and joins the Fish River south of Seeheim and the Konkiep that rises in the west and joins the Fish just upstream of the Orange–Fish River confluence.

Runoff in the Fish River and its ephemeral tributaries is highly variable from year to year, like the rainfall from which it is derived, but is greater than for any other ephemeral river catchment in Namibia – even those that rise in higher rainfall areas. This is not only due to the large catchment area it covers, but also due to the scanty vegetation, paucity of soils and impermeable geology characteristic of much of the basin.

The Hardap Dam supplies the town of Mariental and an irrigation scheme (2,200 ha of mostly cereals). It is the largest dam in Namibia. The Naute Dam on the Löwen tributary supplies Keetmanshoop with fresh water and a smaller irrigation scheme (~425 ha under grapes, dates, pecan nuts and pomegranates in 2013; pers. comm. Mous Boshoff). A third dam, the Neckartal, is planned on the Fish River downstream of Hardap, but upstream of the confluence with the Löwen,

almost due west of Keetmanshoop. Neckartal Dam will have a storage capacity three times that of Hardap Dam and is being designed to irrigate 5,000 ha.

The arid nature of the area makes dams inefficient: they all have high evaporation losses and low assured yields. The variability of rainfall and runoff means that the dams do not reach capacity in most years, and they are not large enough in years of very high flows. Severe floods in Mariental were experienced most recently in 2000 and 2006 due to large, sudden inflows and releases of water from Hardap Dam.

Figure 1. Fish River from Seeheim bridge, May 2006

2.2 The lower Orange River

Below its confluence with the Fish River, the lower Orange River meanders for about 140 km to the estuary. The river forms the boundary between South Africa (to the south) and Namibia (to the north). The river meanders through an area regarded as arid and in parts is very difficult to access. It falls within the Succulent Karoo biome that has the highest biodiversity of any desert ecosystem in the world.

Figure 2. Orange River in Richtersveld

2.3 The Orange Estuary

The Orange Estuary is defined as the portion of the river that is influenced by the sea, and extends some 13 km upstream from the river mouth. Because of the marine influence and the dynamics of the estuary mouth, the estuary has a range of variable habitats. The estuary is taken to include the channel, the islands within the channel, and the estuary-associated wetland vegetation, including reedbeds and saltmarsh, which extends into a supratidal floodplain area. All of these habitats occur within the 5 m contour, and thus for management purposes the area within the contour is taken to be the 'estuarine functional zone'.

Figure 3. Aerial view of the Orange Estuary mouth and lower half of the estuary (photoby P. Morant)

3 Methods

3.1 Baseline assessment

The baseline assessment was carried out on the basis of brief site visits, interviews with key informants, and existing information, as follows:

3.1.1 Lower Fish River

The assessment of the lower Fish River was based on the following:

- a field trip was conducted along the Fish River from Mariental to the confluence during the winter period, 18 – 22 June 2012. Seventeen key sites were visited along the river (see Appendix A);
- eighteen key stakeholders, including community members, were interviewed. Interviews took place either on site or in Windhoek. Two other stakeholders were contacted by telephone (see Appendix B). It should be noted that whilst some of the interviewees have been in the area for a decade or more, they could not comment on the quality and quantity of water resources (pools or groundwater) in longer-term dry periods, such as those experienced in the early 1980s or in the early to mid-1990s. It is recommended that farmers that have been in the area for many years are consulted on this point.
- reports specific to the area were consulted, as well as maps and other data sources.

3.1.2 Lower Orange River

The assessment of the lower Orange River was based on the following:

- a site visit to key parts of the study area undertaken during September 2012 that included visual observation;
- interviews were undertaken with stakeholders and community members in the settlements of Sanddrift, Sendelingsdrift and Lekkersing. Respondents were randomly selected, except in Sendelingsdrift where South African National Parks staff was interviewed;
- telephonic interviews with tourism service operators were undertaken;
- secondary data was consulted. These included demographic data and literature sources;
- maps, including Google Earth images, were consulted.

3.1.3 Orange Estuary

The assessment of the estuary was based on the following:

- a site visit to the estuary was undertaken during November 2012 that included travelling the length of the estuary by boat and extensive on-foot inspection of the estuary surroundings and mouth area;
- interviews were undertaken with community members, the Department of Nature Conservation in Springbok and individuals in Alexander Bay from the Alexcor security services, the border police services and the hospitality industry;
- secondary data was consulted. This included demographic data and literature sources;
- maps, including Google Earth images, were consulted.

3.2 Scenario assessment

Alternative future scenarios were evaluated in terms of their potential impacts on the supply of ecosystem services and value or benefits derived from these. Details regarding the operational scenarios are provided in Technical Report 31 and therefore summarised in this report section. The assessment was based on expert opinion of the direction and approximate magnitude of changes (for example, no change = 1, a 50% increase = 1.5, and a 20% decrease = 0,8). The estimates for this assessment were based on estimates of ecosystem changes made by ecological experts. These estimates were discussed and cross-checked at a specialist workshop held in February 2013. A different set of scenarios (Sc) was analysed for each of the three components of the study area, discussed below.

3.2.1 Lower Fish River

Five release options (ROs) were considered, all of which add the Neckartal Dam to existing water developments and use, but varying in terms of the size of environmental flow requirement (EFR) releases:

- RO 0% – Neckartal Dam developed and no EFR release.
- RO 20% - Neckartal Dam developed, EFR release of 20% of inflow.
- RO 30% - Neckartal Dam developed, EFR release of 30% of inflow.
- RO 40% - Neckartal Dam developed, EFR release of 40% of inflow.
- RO 50% - Neckartal Dam developed, EFR release of 50% of inflow.

3.2.2 Lower Orange River and Estuary

Six scenarios were considered (Table 1), of which two (Sc OF 4 and Sc OF 5) were only evaluated for the estuary. The scenarios and their impacts on mean annual runoff (MAR) are listed below. Incremental changes in specifications from one scenario to the next are highlighted in bold. Present day MAR at the head of the estuary is 39.9% of natural.

Table 1. Summary of the scenarios considered for the lower Orange River and the estuary assessment

Scenario	***Orange River drivers***	***Fish River drivers***
Sc OF 1	Modelled present day current releases and use included.	
Sc OF 2	Metolong Dam, Tandjieskoppe, acid mine drainage (AMD) treated.	Neckartal Dam. Increase in Naute Dam irrigation.
Sc OF 3	Metolong Dam, Tandjieskoppe, AMD treated.	Neckartal Dam with EFR release. Increase in Naute Dam irrigation.
Sc OF 4	Metolong Dam, Tandjieskoppe, AMD treated, 2010 EFR flows released. Optimised releases from dams.	Neckartal Dam with EFR release. Increase in Naute Dam irrigation.
Sc OF 5	Metolong Dam, Tandjieskoppe, AMD treated, 2010 EFR flows released, Polihali Dam, Vioolsdrift Balancing Dam (small). Optimised releases from dams.	Neckartal Dam with EFR release. Increase in Naute Dam irrigation.
Sc OF 6	Metolong Dam, Tandjieskoppe, AMD treated, Polihali Dam, Large Vioolsdrift Dam (no EFR), Boskraai Dam. Optimised releases from dams.	Neckartal Dam. Increase in Naute Dam irrigation.
Sc OF 7	Metolong Dam, Tandjieskoppe, AMD treated, Polihali Dam, Large Vioolsdrift Dam (no EFR), Boskraai Dam. Optimised releases from dams.	Neckartal Dam with EFR release. Increase in Naute Dam irrigation.
Sc OF 8	Metolong Dam, Tandjieskoppe, AMD treated, Polihali Dam, Large Vioolsdrift Dam (EFR O4 released), Boskraai Dam. Optimised releases from dams.	Neckartal Dam with EFR release. Increase in Naute Dam irrigation.

4 Ecosystem services

4.1 Lower Fish River

4.1.1 Socio-economic context

The Fish River flows through the administrative regions of Hardap and Karas with the basin covering eight of the 12 constituencies that make up these two regions. The area through which the Fish River flows and the catchment from which it draws water can be divided into four tenure types: state, freehold, traditional authority and local authority (Figure 2). For the purpose of water management, Namibia is divided into 11 basin management areas and the Fish River and southern tributaries of the Orange River and their catchments make up the so-called ORFB. The largest area (72%) within the OFRB in Namibia is freehold land, which is owned by private individuals or companies and state. This land comprises mostly of commercial farmland. While irrigated agriculture takes place in the area immediately below Hardap Dam (and at Naute Dam on the Löwen River), most of the farming is extensive livestock framing. In more recent years, however, land use is changing on freehold land and moving more to conservation (private parks) and tourism, especially the land adjacent to the Fish River south of Seeheim in the Karas Region. Freehold land owned by government is partly utilised for resettlement.

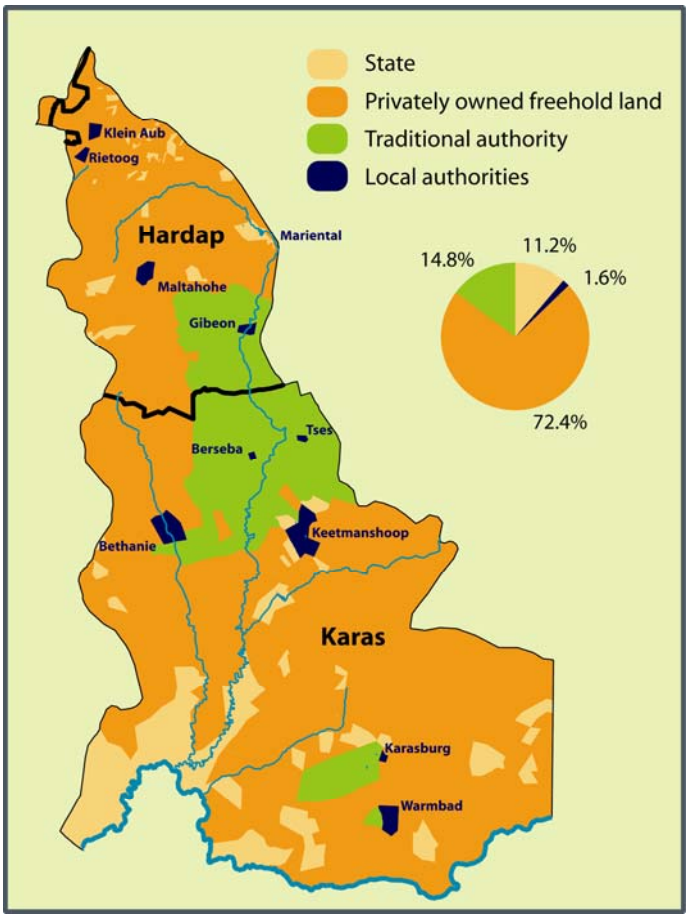

Figure 4. Land ownership along the Fish River. Adapted from Mendelsohn et al. (2002)

Fifteen per cent of the land in the basin is communal, which is owned by the government but controlled by a range of bodies, mostly Nama traditional authorities, and regional and local authorities. Many of the people living on this land are settled in the villages of Berseba, Gibeon, Tses and other small rural settlements. Apart from a few

conservancies, much of the land here is used for subsistence farming focused on small stock (goats and sheep). Many of the larger herds on this land are owned by people with employment in Keetmanshoop, Mariental and other larger towns in Namibia.

The remaining 13% of the area within the OFRB which mainly comprises protected areas (national parks), farmland under jurisdiction of central government and urban areas under local authorities.

The population density of southern Namibia is extremely low, estimated to be approximately 0,5 inhabitants per km^2 in the OFRB, with approximately 66% of the population living in small, scattered towns, villages and rural settlements (Dierkes, 2009). Although few settlements are situated directly on the river, they are close enough for the river to provide goods and services in different ways. Population figures showed significant migration of people into the area between 1996 and 2001, especially to Karas Region and mostly of people aged between 20 to 35 years (census figures as reported in Dierkes, 2009). This trend is likely to continue while there is hope for employment at mines and irrigation projects set to increase when Neckartal Dam construction and operation begin.

Table 2. Population figures of settlements close to the Fish River for 2008

Place	***Population***	***Source***
Ai-Ais	200–700	This study
Berseba	2,170	Dierkes (2009)
Gainachas	770	Dierkes (2009)
Gibeon	3,000	Dierkes (2009)
Keetmanshoop	25,000	Dierkes (2009)
Mariental	14,000	Dierkes (2009)
Snyfontein	420	Knight Píesold (2010)
Tses	2,590	Dierkes (2009)

The percentage of the 5 – 14 years age group in the OFRB is a relatively low 21%, compared to the Namibian average of 26%. The 2001 population figures per enumeration area show that there are 36,338 females and 40,409 males living in the OFRB, which results in a sex ratio of 111, indicating 100 females for every 111 males. The age structure and sex ratio for this area are to a large degree the result of a relatively high proportion of migrant labour and job seekers to the mines and irrigation farms, especially in the Karas Region. Migration is highest amongst those who are 20–35 years old.

In southern Namibia as a whole, there are more male-headed households than female-headed ones, especially in rural areas (Hardap 71,6%, Karas 70%), which is far above the Namibian average of 53%. In the OFRB, 68% of households are headed by men compared to 32% headed by females. The Mariental Rural and Rehoboth Rural constituencies of the Hardap Region as well as the Keetmanshoop Rural and Oranjemund constituencies of the Karas Region show figures above 70% for male-headed households.

The two major languages spoken in households in the area are Afrikaans and Nama/Damara. Afrikaans and Nama/Damara is equally spoken by 44% of the households in Hardap Region, while 40% of households in Karas Region speak Afrikaans compared to 26% who speak Nama/Damara. The proportion of Oshiwambo speaking households is higher in the Karas than in the Hardap Region (23% opposed to 7%), largely due to higher migration of labour from other areas of Namibia to Karas.

In 2001, 51% of households in the basin used wood as an energy source for cooking, 22% used gas and 24% electricity (CBS, 2003). Some 47% of the households use electricity for lighting while approximately a third use candles. Wood is also important for household heating, especially in rural areas. In general, the use of wood in rural homes (up to 80%) is much higher than in urban homes (as low as 8% in Oranjemund) (Dierkes, 2009).

Water is supplied in bulk from surface and groundwater sources by NamWater (Namibia Water Corporation) to irrigation schemes, towns,villages and mines. NamWater supplies surface water from Hardap Dam (on the Fish River) to the irrigation scheme and town of Mariental, from Naute Dam (on the Löwen River) to the irrigation scheme and Keetmanshoop, from Dreihuk (on the Hom River) and the Bondels (on the Satco River) dams to Karasburg. From groundwater abstraction schemes they supply many of the other places, including /Ai-/Ais Hot Springs Resort from an alluvial aquifer in the Fish River. Farming communities are almost wholly reliant on groundwater sources, and are supplied by the Directorate of Water Supply and Sanitation Co-ordination (communal areas and resettlement farms) or are self-supplied. Ninety-one per cent of people living within the OFRB have access to safe drinking water, out of which 72% of the households are supplied by piped water within their compound and only 13% need to fetch water from a public pipe and 6% from a borehole. Access to water within the area does vary though. In the Berseba Constituency, only 55% of households have access to piped water within their compounds and 10% rely on unsafe water sources (Dierkes, 2009).

The area is not as well developed with respect to sanitation services, with an estimated 33% still using bush toilets in the OFRB (Dierkes, 2009). Bucket toilets are also quite common in small settlements in this area of Namibia. Towns and villages struggle to provide adequate and efficient sanitation services, and sewage-system overflows are not uncommon.

While the area offers more job opportunities in the mining, tourism and irrigation farming sectors than many areas of Namibia, unemployment rates are still high. There are very limited opportunities for employment in the towns, villages and rural settlements, and most are dependent on the farming of small stock in an area constrained by aridity. Especially pensions, and to a lesser degree remittances and grants, play an important role in helping people get by (Seely, 2009).

Significant socio-economic features in the study area include:

- commercial production of agricultural products at Hardap Irrigation Scheme;
- town of Mariental, administrative capital of Hardap Region and support industries to the farming community in the area;

- villages of Gibeon and Berseba and farming communities, such as Snyfontein, on communal land, living along the river or in close proximity to it and dependent on subsistence farming to a greater or lesser degree, and the use of various river products;
- commercial small-stock farming on freehold land, sometimes supplemented by tourism or hunting activities;
- private conservation parks and tourism ventures, such as Gondwana Cañon Park and Canyon Nature Park;
- Ai-Ais National Park and hot springs and the associated tourism activities.

The river and its area of influence were divided into two subareas for the purpose of the study: 1) the area between Hardap Dam and the site of the proposed Neckartal Dam and 2) the area between Neckartal and the confluence of the Fish with the Orange River. The upstream section includes Hardap Irrigation Scheme, some commercial small-stock farms on freehold land and the communal area previously known as 'Namaland'. The downstream section includes commercial farming on freehold land, private conservation and tourism on freehold land, and state-owned Ai-Ais National Park and tourism ventures.

4.1.2 Provisioning services

Water

The river flows every year, for a variable length of time, in the rainy season (December to April). Generally, from May/June to December, the river stops flowing, but this depends on the rainy season each year, and the specific section of the river. Along the river, some pools remain after the river stops flowing. Those downstream of Berseba seem to be mostly perennial, whereas those around Berseba seem to dry up or at least become very salty during the dry season. At the Farm Schlangkopf just north of Seeheim, there are two standing pools at the river that remain in both low and high rainfall years under natural runoff conditions. If water is not pumped, the pools remain perennial; if water is pumped, they dry up in Nov/Dec.

Most people settled along the Fish River obtain their water from deep boreholes that are located some distance away from the river, rather than river water or groundwater that is associated with the river. Important exceptions to this include:

- the Hardap Irrigation Scheme and town of Mariental, dependent on water from the Hardap Dam;
- /Ai-/Ais Hot Springs Resort that depends on a shallow alluvial aquifer in the Fish River for up to 180 m^3 of water per day for most of their water requirements. A hot water spring in the river downstream of the alluvial aquifer provides water for the spa facilities there. Tap water for drinking, ablutions, etc. is supplied from six boreholes in the river about 2,2 km upstream of the camp. The water is supplied by NamWater and monitored on a daily basis. The deepest pump at Ai-Ais is situated at a depth of 18 m in the alluvial aquifer. The water table is, however, usually much shallower than this, depending on the flow of the river and the time of year. The NamWater technician reported that in December (the end

of the dry season), the water table is usually about 8 m deep and the water starts to smell and taste of iron. In the past ten years (earliest memory of respondents at Ai-Ais), the river has flowed every year, which recharges the boreholes. This usually happens between January and June in this downstream stretch of the river. During high flows, the pipes are sometimes washed away. In very high floods (if more than 1,500 m^3/s are released from Hardap), the camp will also be flooded. Depending on how busy the camp is, between 90 and 180 m^3 of water are pumped per day. Water quality is tested every six months;

- walking- and mule-trail hikers and operators in the canyon area of the Fish River (south of Seeheim) depend on the pools in this stretch of the river;
- commercial and subsistence farmers living alongside the river, depend on pools and alluvial groundwaters for livestock watering especially, but also for domestic use and cultivation of fodder and other crops on a small scale;
- farmers living along the river who use river water during flows and water from hand-dug wells for household purposes;
- poorer households from Gibeon and Snyfontein were also reported to depend on water from pools and other sources in the river to meet their needs.

Gibeon is at the confluence of the //Khom!garib and Fish rivers and people were first attracted to settling there because of the spring close to the confluence. The spring water seems to be of questionable quality due to contamination from overflows from the vacuum sewerage system in the village, amongst other things. NamWater pipes groundwater approximately 60 km to the village from a farm just south of Mariental. Unemployment is high in Gibeon and the village council has run up large debts with the bulk supplier. NamWater have closed the supply to the village on occasion to encourage the council to address their debt, forcing people to use the spring water.

Some of the local residents along the southern parts of the Fish River reportedly have small backyard gardens with a few maize plants, vegetables, fruit trees and occasionally grapes, which they irrigate from the river or even from pools.

Fish

Fishing from the pools provides an important and affordable source of protein for, especially, the poorer communities living close to it, e.g. in Snyfontein and Gibeon, as well as for farm workers and other labourers working in the area. Fishing takes place year round, except at high flows, from the river and pools.

Five different types of fish were reported to be found in the pools at Snyfontein (yellowfish, mudfish, carp, catfish and barbel), all of which are targeted by fishers. Some households fish every week. November and December were reported as being the peak fishing season. A few (3 – 5) households in the community depend on fishing for a livelihood. Fishermen in these households sell to other households (~N$15/kg). Wire baskets (similar to the grass fishing baskets used in northern Namibia) are used in summer to fish from pools before the rains; hooks and lines are used

during the colder months or when the flow is stronger. Fish is perceived to be an important part of the diets of the community and is eaten 2 – 3 times a week.

Fish contributes to livelihoods in Mariental, especially for people who have settled there from Kavango who use it for home consumption and sell it to other community members. Fishermen in Gibeon catch for home consumption and for sale.

Workers on freehold land – farms and private conservation areas – fish from the river for home consumption, while the farmers and their families living along the river fish for recreation, but do not necessarily eat the fish.

Raw materials

In general, dense riverine reed growth is only found in patches along the Fish River. Most notably, they are found below Hardap Dam and irrigation scheme and downstream of Ai-Ais. These areas of significant reed growth are probably largely an effect of polluted return flows to the river – nutrient-rich agricultural return flows in the case of Hardap and raw sewage from the faulty trickle system at /Ai-/Ais Hot Springs Resort.

Dense reed growth in the river at Hardap, choking the water course, was identified as a contributing factor to the flooding of Mariental and the Hardap irrigation scheme in the 1999/2000 and 2005/06 rainy seasons. For this reason, the Mariental Flood Task Force aided by the Division of Hydrology (Department of Water Affairs, Ministry of Agriculture, Water and Forestry (MAWF)) sprays the reeds each year along the course of the river from just below the dam wall to just beyond the bridge on the road to Maltahöhe.

Apart from the role of the reeds in removing nutrients from the return flows, they are harvested by community members for producing various crafts – baskets, blinds (thin reeds) and tables, chairs, fencing (thick reeds). Although this craft industry is relatively new, it was initiated before the reed-spraying programme commenced. This craft initiative is supported by the Hardap Regional Council and the local councillor's office as a job creation initiative. As craft production (especially from reeds) is not common in southern Namibia, funding was sourced and some training provided on basket-making.

Although the community project started off with about 32 potential community craft producers (2010); only ten remained (three males and seven females). The members vary in age between 37 – 50 years old. Most local Nama members have dropped out and those originating from Kavango Region remain. Reeds are harvested throughout the year, as they need them. All ten members harvest. Three Zimbabweans in Mariental not involved in the community project have their own reed craft business selling to Windhoek and various lodges.

Reeds are found at Snyfontein, but are not abundant, nor used. There are few or no reeds in most other sections of the river in the study area.

Figure 5. Reed growth in Fish River below Hardap Dam in 2009, prior to spraying programme; river from the same bridge in 2012, after a few years of spraying

Many people in urban areas of southern Namibia use paraffin, gas or electricity to cook. In Mariental, Berseba and Gibeon, firewood collection and selling (mostly Mesquite) for cooking and heating was reported. This wood is mostly collected from river and stream courses. In Snyfontein, most households use wood (Mesquite, camel-thorn, Umbrella Thorn). Wood is also collected from the river for sale locally and in Keetmanshoop. Gas and paraffin are the main sources of energy for cooking on freehold farms that do not have electricity; water is heated using Mesquite wood (donkey) collected in the area.

Mesquite is only used for construction in a few areas, e.g. Gibeon. Training in charcoal production from Mesquite was provided in Gibeon, but it has not led to a charcoal industry there.

Sand for mixing cement is collected from the tributaries and main river in Berseba, Gibeon and Snyfontein. A commercial sand-mining operation on the river near Seeheim (26° 48' 46.4"S; 17° 47' 37.9" E) is operated by SuperSand based in Keetmanshoop. Slate is collected at Snyfontein, although not necessarily from the river. It is sold for construction and used locally.

Rock, sand and reeds from the area have been used in constructing buildings at Canyon Nature Park (Fish River Lodge) and the Gondwana facilities. Apart from the reeds, most of these building materials were obtained from the plateau and not from the river.

Livestock forage

A large part of the area south of Mariental to the proposed Neckartal Dam is communal land. The main villages close to the river include Gibeon (on the river) and Berseba (about 10 km west of the river). Many of the residents in these villages have farming interests. There are also a number of people living in scattered rural settlements, on 'Odendaal farms' and on resettlement farms in the area. Whilst many living there consider themselves farmers, they only own a handful of goats, sheep, donkeys, horses and in some cases cattle. Small-scale livestock farmers use the river in the vicinity of Hardap and Mariental; a small herd of goats seen below the dam wall helped confirm this.

Although the stock numbers of many households are low, they form an important part of people's livelihoods and are sold when cash is required to pay school fees, etc. The Fish River and its tributaries are an important source of water, grazing and browsing for stock, especially during the dry season. Reed beds, where they occur (e.g. on Schlangkopf), and grasses growing on the river banks, are considered important grazing.

At Snyfontein there are approximately 2,000 goats, 100 cattle, >1,000 sheep, 70 – 80 horses and a similar number of donkeys. Most of these animals are owned by 'weekend farmers'; the local community members have 'just a few goats'. Much of the land around Snyfontein (east side of the river) is overgrazed, so many households make use of grazing away from the village on the west side of the river (to which the Neckartal Dam will act as a barrier when it is constructed).

Almost 80% of households in Gibeon were reported to own livestock. Numbers vary from a couple of goats, to emerging commercial farmers in the area that have between 20 and several thousand. Pods are collected in drought years, especially in other areas of the constituency (not Gibeon itself). In Mariental, residents collect Mesquite pods in November and December. They bag and sell them to farmers as feed for sheep and other livestock at about N$0.70/kg or N$20 for a large bag (50 kg maize sack). These pods are usually stored for use in winter. Harvesting and selling Mesquite pods is done on an individual basis, not as a co-operative. The pods of *Acacia karroo* and A. erioloba are also collected as livestock feed. Mesquite is also considered an important fodder plant by many commercial farmers in the area.

Veld foods and medicinal plants

Interviewees in Snyfontein indicated that there are plants in the area used for foods (such as berries collected in summer) and for medicinal purposes. Veld foods include the berries from *Grewia* spp. (*flava* and *tenex* are found in the area) and *Ziziphus mucronata*; seeds of *Parkinsonia africana* (the lemonthorn) are roasted and crushed for coffee. In areas further south, *rooibessies* ('red berries', the fruit of *Papea capensis* and otherwise known as the jacket-plum) are collected and eaten or made into a juice with sugar. The seeds are used to make beads and used in cleaning and softening skins and hides.

Interviewees reluctantly admitted (as most of it is illegal) that hunting of kudu, oryx, springbok, birds (guineafowl, bustard, sandgrouse and ostrich) takes place on the communal lands, for home consumption. Methods include snares, dogs, horses and guns.

Plants[1] collected for medicinal purposes include:

- *Hoodia gordonii* (locally known as *!khoba*) used for stomach problems (and slimming);
- *Harpagophytum procumbens* (devil's claw, field potatoe or locally known as *Gomakhu*) for stomach, menstrual and labour pains.

1 Identifications and scientific names provided by Coleen Mannheimer and through reference to Von Koenen, E. (1996).

- *!Gaebe* (likely *Nymania capensis*) is a root that is ground up, stirred into warm water and drunk to relieve labour pains;
- *Thamnosma africana* (Rutaceae; known locally as *#Khana*) is added to hot water as a steam inhalant or as tea for chest problems;
- *!Khuxa* (possibly *Aptosimum albomarginatum*) is used in teas for headaches, can induce vomiting, and as general body cleanser.

The plants are generally found in the riparian zone, but many are not limited it. While many people in the community use them, only a few collect them. Other veld medicines that were reported to be used include:

- Ostrich egg shell is powdered and applied to the chest and other areas of the body to help reduce fever;
- *!âularu* (crystallised rock hyrax urine) is used during and after birth and for menstrual pains.

4.1.3 Cultural services

Tourism

Since Namibia's independence, there has been a movement away from farming to conservation and tourism in the study area. The area supports a lot of wildlife, much of which is associated with the river, including Cape clawless otter, fish eagle, kudu, klipspringer, springbok, oryx, steenbok, zebra, and baboon. Other river attractions include ancient pictoglyph and Stone Age tool sites.

There are now several large tourist operations based on the Fish River south of Seeheim, which form part of the wider Greater Fish River Canyon Complex (GFRCC) – a stakeholder group with similar interests in this area. These include:

- Fish River Lodge, a 40-bed lodge based in the private 43,000 ha Canyon Nature Park on the western side of the Fish River, which includes 75 km of river canyon frontage. Tourism activities include scenic drives and a five-day, guided, walking trail. This facility is relatively new (~ 3 years) and expected an occupancy of 30% in 2012;
- Gondwana Cañon Park, a privately owned nature park situated 20 km from the Fish River Canyon and covering an area of 1,260,000 ha. The park has about 300 beds in a variety of facilities, and has an occupancy rate of about 50%. Activities include a 2 – 4 day walking trail with mules along the Fish River Canyon (5 – 10 people per trail, three trails per month, April – August). Guests stay in semi-permanent camps and use water from either the Löwen or Fish rivers for ablutions (flush loos with septic tanks) and use bottled water for drinking. The trails start at Horseshoe Camp, approximately 50 km upstream of the Canyon Lookout Point and start of the Fish River Canyon trail;
- /Ai-/Ais Hot Springs Resort, run by Namibia Wildlife Resorts (a parastatal), with 100 beds and 55 campsites. The resort is situated in the /Ai-/Ais–Richtersveld Transfrontier Parkat the southern end of the Fish River Canyon and marks the end of the 80-km canyon hiking trail that starts at Hobas. The main attraction at the resort is the spa complex, which is fed by one of the sulphurous springs;

- a campsite at Hobas, located at a natural spring, about 10 km away from the Fish River Canyon lookout;
- at Snyfontein, construction of what could be a very attractive community campsite was started, but this has not been completed.

The canyon trail is open from beginning of May to mid-September. During that period, up to 30 people can enter the canyon per day (~4000 people per year). Peak season of the park – Ai-Ais, Hobas and the walking trail – is in the winter months, especially during the South African winter school holidays (July), when Ai-Ais is close to 100% occupancy. All activities centre around the river canyon and its resources.

Most, if not all, tourism in the area is nature-based, and hiking activities are influenced by river flows:

- if river flow is too high, these activities cannot take place as it is dangerous and river crossings impossible. In 2011, 14 people on the hike were trapped by a late, high flow of the river and had to be rescued;
- if river flow is too low, drinking water has to be carried making it less attractive to tourists and less viable for operators.

Recreation

Local residents along the Fish River also use the river for recreational purposes – picnicking, Sunday braais and swimming. This was reported in Mariental, Gibeon and Snyfontein.

4.1.4 Regulating services

Refugia

Pools that remain, in and around the river course, when the river stops flowing, vary in their size and permanence, with the larger perennial pools forming important refuge areas for aquatic biodiversity. The pools provide important refuges for fish, and other aquatic species, and important water sources for various wildlife species. They provide important water sources and refugia to various animal (kudu, zebra, oryx, klipspringer, steenbok, springbok, etc.) and plant species. The pools have abundant fish: catfish, some of which are reported to be large (several feet in length and 20 – 25 cm head width), and carp were mentioned. There are also large numbers of smaller fish in the pools (especially the deep ones) which are apparently breeding successfully. Since the floods in 2006, otters have been seen in the pools as far upstream as Snyfontein, and in lower reaches since 2002. These pools are also important for hikers.

Water purification

Hardap irrigation scheme, Gibeon and /Ai-/Ais Hot Springs Resort were identified as contributing to the pollution in the river in the form of untreated sewage and agro-chemicals. Blackfly larvae were noted in the river at the bridge between Tses and Berseba. Flow of the river, as well as reed

beds that have become established, provide important purification services. Reducing flow of the river, as well as large-scale removal of reeds such as the spraying operation below Hardap, will negatively affect these services.

4.2 Lower Orange River

4.2.1 Socio-economic context

The original inhabitants of the area were nomadic people of San and Nama descent. More recently, additional groups became part of the community, including Xhosa-speaking peoples that were forced to seek an alternative place to live and farm following the imposition of Apartheid.

Because of the aridity of the area, population densities are low. Population densities would be even lower, were it not for mining. Significant socio-economic features of the river include the following:

- the /Ai-/Ais–Richtersveld Transfrontier Park with associated infrastructure in close proximity to the river;
- a series of mining operations either alongside the river or drawing on river resources. These include the Trans Hex Operations, Baken, Rosh Pinah and Daberas. Most are large scale operations;
- the Sendlingsdrift Border Post and associated settlement;
- the Brandkaros Alexcor development with associated agricultural business;
- the town of Sanddrift associated with the mining operation;.
- the Grootderm settlement – located just upstream of the estuary.

The South African side of this river section falls within the Richtersveld Local Municipality. The Richtersveld Municipality had a population of 14,614 people according to the 2001 Census.[2] The majority of this population live in the larger towns of Port Nolloth and Alexander Bay. The only settlement of any size within the defined Study Area is Sanddrift. In 2002 Sanddrift recorded a population of 1,146 people. In keeping with its profile as a mine-related settlement the majority of the population (52%) was male. The majority of the population of Sanddrift (72%) was classified as 'Coloured'. The bulk of the population was classified as Afrikaans-speaking (83%). Using a generic growth rate of 2,4%, the current population of Sanddrift is anticipated as being around 1,500 people. In interviews in the town, this was acknowledged as a likely figure. Outside of the main town, the remainder of the population of the Richtersveld Local Municipality was recorded as 552 people. This would include Sendelingsdrift. Again, using a 2,4% growth rate this could have grown to about 715 people by 2012. This figure should be treated with caution as indicators of population trends in South Africa generally point to declining rural populations. As such, the total population of the Study Area, for the purposes of this section of the report, on the South African side, is probably less than 2,000 people. As indicated earlier, population densities are therefore very low.

2 At the time of writing the first results of the 2010 South African National Census were being made available. However, results are limited to a national and provincial overview and are not yet available at more "fine-grained" settlement level.

The Namibian side of this stretch of river falls within the Oranjemund Constituency of the Karas Region. The population dynamics of the Namibian side of the Study Area mirrors those of the South African side. Current estimates (2010) are that the bulk of the population in the Oranjemund constituency are in the towns of Oranjemund itself and Rosh Pinah. Oranjemund is outside of the primary considerations of this section as it falls more closely within the estuarine section. Rosh Pinah is 15 km from the Orange River, but for the purposes of this report is considered to fall within the area under consideration because it is supplied with water from the river. The population on the Namibian side of the Study Area is probably very close to that of the South African side, and unlikely to exceed 2,000. The population in Rosh Pinah was estimated at 8,480 in a local census in 2008.

4.2.2 Provisioning services

Because population densities are low, the utilisation of natural resources is likely to be relatively insignificant. However, there is some degree of reliance on natural resources by people of Nama descent and by other people who are resident in the area.

The Namas were traditionally a nomadic people moving their home, stock (predominantly goats) and family in search of grazing. The Nama people of the Richtersveld today are now largely transhumant pastoralists, moving their livestock between stock posts with the changing of seasons. The rotation of pastures has helped to preserve the land from overuse. There are, however, indications that the mobility of people is becoming more restricted and the nomadic lifestyle is becoming modified. Interviews in the greater project area revealed that while a number of people who are of Nama descent, or who claim kinship with Nama groupings, pursue a traditional lifestyle there are factors that impose a degree of restriction. These include involvement in more sedentary agricultural practises, and the advantage being taken of new economic opportunities that require less mobility.

The total population of Nama and associated communities in the greater Richtersveld area probably number around 4,000 people. These residents are associated with the settlements of Eksteenfontein, Lekkersing, Khubus and, to some extent, Sanddrift. With the exception of Sanddrift these are largely outside of the study area. While these communities do make use of the resources in the study area, this utilisation is less pronounced than the use that is made of resources within the wider conservation area. Interviews revealed that the Orange River within the Study Area and its resources are used, to a limited extent, for the following:

- fishing – recreation, but also subsistence;
- gathering of sedges and reeds, as well as timber and firewood;
- grazing.

Fishing and hunting

Representatives of the Nama communities who were interviewed indicated that fishing is an important source of subsistence. Yellowfish, barber (*Clarias* sp.), carp and sandfish were mentioned as the key species. It was reported that fishing may be the primary source of income for a small

number of individuals and families, but this would be a minority. Fishing takes place throughout the year, but venturing into the river during months of high flows is believed to be dangerous. Fish are reportedly most plentiful in early summer.

Subsistence fishing is carried out using line with hooks or with nets. Larger returns of catches are associated with nets and those who rely on fish as a primary or substantial source of income usually use nets. The number of fish caught by a fisherman depends to a great extent on the equipment available and the amount of time invested in the activity. Fish are usually sold locally. People who invest heavily in fishing as an activity could make 2,000 – 3,000 ZAR in a good month. The bulk of fishing is for home consumption as a subsistence activity. The bulk of the fishing probably takes place in the river reaches associated with the conservancy (outside of the study area) rather than the national park areas that are inside the study area. Again, the exception is Sanddrift.

A limited amount of hunting takes place, mostly of waterfowl, but this was not reported to be an important subsistence activity.

Raw materials

Reeds (*Phragmites australis*) are harvested from the river banks to construct traditional *matjieshuise* (or *haru oms* in Nama). These huts require about 200 kg of reeds, which are woven into mats and laid over wooden frames (usually *Tamarix* sp.). In the informal settlement areas many of these huts form the primary residential structures. Reeds are also used to make floor mats and sleeping mats. Sedges such as *Cyperus marginatus* are available but are only used to a very limited extent.

In addition to the Tamarisk, other tree species are harvested. The main indigenous timber and fuel-wood species are *Acacia erioloba*, *Acacia karroo* and *Ziziphus mucronata*. The main uses of exotics in the area are timber and fuel wood. Common exotic species in the Study Area include *Mesquite glandulosa, Eucalyptus camuldensis* and *Nicotiniana glauca*. Respondents reported substantial harvesting of medical plants in the area, such as '*Xhoba'* (probably *Hoodia gordonii*), but very little of this comes from the riparian zones.

Livestock forage

The riparian zone is also used for grazing and browsing by livestock. *Cynodon dactylon* is one of the important species for grazing in this river stretch. There appears to be an increase in utilisation of the area by goats, particularly of *Seasia pendulina, Diospuros lyceoides* and *Acacia karroo*. *Tamarix usneoides* is an indigenous plant species that is used by cattle and small game as a natural salt lick.

4.2.3 Cultural services

Tourism

The Orange River is a central feature of the /Ai-/Ais–Richtersveld Transfrontier Park, which is an important tourist destination. The local community, which owns the entire area, manages the National Park in conjunction with South African National Parks (SANParks) and is entirely

responsible for management of the World Heritage Site to the south of the park. Both areas are used by traditional nomadic herders to practise their ancient lifestyle and culture. It is arguably the last significant place where the traditional way of life of the KhoiKhoi (of whom the Nama are the surviving clan), survives to any great extent.

The presence of the /Ai-/Ais–Richtersveld Transfrontier Park and its unique position within an Arid Biodiversity Hotspot on Earth makes it an attractive tourist destination. The Orange River is a key feature of the park, and is used for canoeing, rafting, swimming, fishing as well as contributing to the aesthetic value of the landscape. It is also important for nature-based activities such as bird watching.

There are at least eight sizable businesses that offer guided canoeing or rafting trips for parties of 12 people and upwards lasting up to six days. A larger number of smaller operators also offer trips. The most important river stretch for these activities is between the Fish River confluence and Sendelingsdrift. Trips are offered all year round, but the more popular months are those either side of mid-winter with late summer and autumn being particularly desirable. Based on interviews with some of the operators and the SANParks officials, we estimate that these activities (including upstream of the study area) attract around 8 – 10,000 visitors and generate about ZAR 25 million per annum in visitor expenditure.

There are also some specialised operations that offer fishing safaris on parts of this stretch of river, using fishing camps established along the river. Fly-fishing, particularly for the large- and small-mouth yellowfish, is increasingly popular. The sharptooth catfish is also regarded as desirable species for recreational fishing. Other species of note with regard to fishing include barb species, *Tilapia* and carp. Recreational fishing is said to be best during the winter months when the river is lower. The core months are said to be May to November, although fishing does take place in other months as well. In addition to organised fishing safaris, interviews in Sendelingsdrift and Sanddrift indicated that residents of these settlements undertake recreational fishing as a key recreational pastime.

Recreation

Recreational hunting in the area is not part of a larger enterprise, but mostly small-scale and outside of the park. Small-scale recreational hunting and poaching (mainly geese and ducks) takes place on a very restricted basis. There are, however, limited amounts of riparian animals that are hunted.

Cultural use

Ritual use in terms of magnitude of use is low given the low densities of people. However, the makeup of the area is such that the significance of ritual use, for those people resident in and around the area, is high and the Orange River occupies a central place as a feature in people's lives. Purification rituals were mentioned as of particular importance with respect to the river. The river also plays an important role in local mythologies.

4.2.4 Regulating services

Water quality amelioration

The river has waste assimilation and dilution attributes linked closely to base flows and flooding. In the study area the impacts associated with the upstream farming are evident, as are some mining-related water quality issues. Outbreaks of cyanobacteria, have been reported in recent years.

4.2.5 Dis-services

Blackfly

The blackfly (*Simulium chuteri* as well as *S. impukane*) is a pest species that breeds in rivers and is a major irritant for livestock. Alteration of river flows has led to increased outbreaks of this pest, at considerable cost to livestock production. Outbreaks of pest blackflies occur at high flows, particularly when these are preceded by elevated winter low flows. Elevated winter flows provide more habitat for eggs and larvae to survive during the dry season, and are the precursor to an outbreak when flows increase. Costs of lost production in the study area have been estimated at ZAR 7.7 million per year (Palmer et al., 2007).

4.3 Orange Estuary

4.3.1 Socio-economic context

The estuary forms the western part of the boundary between Namibia and South Africa. There are two small towns adjacent to the estuary – Oranjemund in Namibia, and Alexander Bay in South Africa. These two towns, which both exist by virtue of the diamond mining activities along the Namibian and South African coasts, are linked by a bridge that spans the estuary near its head. Nevertheless, access to the estuary is not easy. Features of the area include:

- the towns of Oranjemund and Alexander Bay;
- desert conditions and diamond mining operations on either side of the estuary;
- A bridge spanning the estuary;
- remains of old bridges and causeways spanning the estuary;
- sports fields and golf courses within the estuary floodplain on both sides;
- several pumpstations on either side of the estuary;
- agricultural fields within the estuary floodplain on the South African side and some on the Namibian side just downstream of the bridge;
- several roads, causeways and canals constructed within the floodplain area;
- sewage oxidation ponds within the estuary floodplain area on the South African side;
- the Pachtvlei picnic area/campsite on the south bank of the estuary near its head;

- the Hohenvels (high rocks) picnic area/campsite on the north bank of the river near the head of the estuary;
- a coastal sandspit in the mouth area which is accessible to 4x4 vehicles;
- old mining equipment buried in the sandspit and causeway.

The South African side of the estuary falls within the Richtersveld Local Municipality, within the Namakwa District. The population growth rate since the last census is under debate and is between 1,.5% and 5% (Richtersveld IDP, 2012). The total population of the Richtersveld Local Municipality has been estimated to be in the order of 14 – 15,000 people (Richtersveld IDP, 2012), the majority of whom reside in the two main towns of Port Nolloth (46%) and Alexander Bay (14%, or about 2,000 people). The population is dominated by working-age people (62% are in the 18 – 65 age category), and only 5% are pensioners, which suggest that people leave the area when they are no longer economically active. Most of the population is Afrikaans-speaking, and 31.5% are classified as poor, according to the 2001 census). The population is also characterised by high unemployment levels, which has been amplified by the downscaling of mines and the low numbers of people with tertiary qualifications.

The Namibian side of the estuary falls within the Oranjemund Constituency of the Karas Region. The town of Oranjemund is situated near the estuary, although somewhat more removed from the estuary than Alexander Bay. Oranjemund has a population of about 4,000 including some Herero and Ovambo peoples from northern Namibia.

Both Alexander Bay and Oranjemund were established following the discovery of alluvial diamonds in the Orange River and the adjacent coasts, in 1927 and 1936, respectively. Oranjemund was run by Namdeb (formerly Consolidated Diamond Mines), now a subsidiary of De Beers, who developed a large recreational complex and better infrastructure than most towns in the south of Namibia. Access to Oranjemund has been very restricted, although it was proclaimed as an open town in 2012. A relaxation on access is being promoted as tourism is seen as a viable economic strategy for the area.

Alexander Bay was established in 1927 after the discovery of diamonds in the area. It is a private mining town that was designed and built by Alexkor around their mining activities. The town offers a few services, including a hospital, garage and post office. Activities in Alexander Bay have also included some agro-industry, mariculture and tourism. It is not a well laid out town, it is highly dispersed, lacks a centre, and does not take advantage of its location near the estuary. Indeed, while many South African estuaries have small populations associated with them, this one is unusual in that the nearby towns do not 'interact' very much with the estuary. This is at least partly an artefact of access to the estuary being strictly controlled from both sides of the border in the past.

Oranjemund is set back a considerable distance from the estuary, and Alexander Bay, while located on the edge of the estuary, does not have good views of the system, nor good proximity to the waters' edge due to the extensive floodplain area.

The Richtersveld Community (RVC) lodged a claim for land restitution of certain land in Alexander Bay in 1998, which was settled in 2007. The community now owns the town, while Alexkor remained the holder of the marine mining rights, the Richtersveld Mining Company (RMC) became the holder of the land mining rights, and Alexkor and RMC put their mining rights under the full control of a Joint Venture. Since then, agribusiness operations have ceased, so that the once green agricultural areas surrounding the town have become desert wastelands. The camping and picnic areas just upstream of the town have become neglected and structures derelict. In contrast, Oranjemund reportedly remains green and attractive, and the remaining residents of Alexander Bay make frequent visits to Oranjemund for shopping and recreation.

The land around the Orange Estuary is generally characterised by low agricultural potential and low livestock carrying capacity. The banks of the river are suitable for irrigation farming but do not have high potential soils (Richtersveld IDP, 2012). Travelling around the area is made difficult by long distances and poor gravel roads, and public transport is non-existent. Nevertheless, the Richtersveld area as a whole is thought to hold some development potential. "Taking advantage of the opportunities presented by the location of the Richtersveld Local Government along the West Coast and Orange River on the border with Namibia" is listed as a key issue in the Integrated Development Plan (IDP) and "Proclamation of Orange River mouth as conservation area" is listed as one of the priorities for the next five years (2012 – 17).

4.3.2 Provisioning services

While the estuary offers provisioning services in the form of sand, pebbles, fish, grazing and plant resources such as *Phragmites* reeds, there is currently little demand for these services, and hence they have low value.

There are no legal commercial or subsistence fisheries on the estuary. Illegal gillnetting in the estuary brings in an estimated catch of 5 – 10 tonnes per annum, of which about 80% is harders, *L. richardsonii*, and the rest is made up of mainly *M. cephalus, P. saltatrix, A. inodorus* and various freshwater species (CSIR, 2011). Both Alexander Bay and Oranjemund have angling clubs and effort levels are high. Most angling takes place either side of the berm (sandspit) at the mouth of the estuary. Angling levels on the South African side of the estuary have increased over the past 10 years due to effort displacement arising from strict enforcement of bag-limits and other regulations at Namibian border posts. Catches of kob *A. inodorus* and *A. coronus* may be exceptionally high both before and during floods and high flow and angling trips may be planned in advance (2 weeks or more) due to the lag between rainfall in the upper catchment and flow reacing the estuary. Some dam operators in the Orange-Senqu catchment are reportedly on a stipend to inform anglers of impending high flow. In addition, some illegal hunting, mainly with dog teams, reportedly takes place from time to time on the islands, with gemsbok, *Oryx gazella,* being the main target. These are not values that should be recognised; they detract from other values, such as the export of fish and tourism value.

One inhabitant of Alexander Bay has permission to graze her small livestock herd within the estuary area. While we did not interview the livestock owner, we counted 23 head of cattle and 32 sheep on the estuary. It was reported that some of the folk inhabiting the dairy farm on the banks

of the estuary produced handicrafts from wetland plants, but that this production ceased after the farm stopped its operations in 2008.

Diamond mining is the dominant extractive activity in the adjacent inshore marine environment. Commercial line and lobster fishers operate up to Alexander Bay. The legal gillnet fishery for harders *Liza richardsonii* does not operate much further than Port Nolloth but there is an illegal fishery using large-mesh gillnets to target mostly kob *Argyrosomus* spp. and west coast steenbras *Lithognathus aureti* in the nearshore from the estuary mouth 10 km southwards. Catches by this fishery are ostensibly greater than 100 t per annum.

4.3.3 Cultural services

Cultural services are those that rely on the attributes of the estuary area, such as scenic beauty, rare species and other features such as water depth and flow rates. Values generated from this category of services include the recreational, spiritual and aesthetic values gained as a result of these attributes, which can manifest themselves in a variety of ways, ranging from the intangible, such as sense of wellbeing or happiness, to tangible benefits, such as property value premiums gained from estuary views, or income from tourism.

It appears that very little use is made of the estuary for recreational purposes, apart from the use of the rugby field and golf course within the estuary floodplain area. Even then, it would be a stretch to call this use of the estuary. The locals do fish in the estuary from time to time for recreational purposes, and like to catch the odd Yellowfish, especially at Easter time, where it makes a traditional cultural contribution to the table in many homes. This is just regular rod-and-reel fishing, not flyfishing. No anglers were seen in the estuary during the site visit, but this is more likely to be a weekend past-time for a few. Marine shore-angling at the river mouth area is reportedly more popular than angling in the estuary, but this seems to be mainly by anglers from beyond the local community. Angling was once a bigger sport among the locals on the South African side, particualalryl those employed as minsers, but interest in this declined after the decline in mining and reduction in mine staff, along with some of the angling spots down the coast became inaccessible due to the ban on the use of offroad vehicles on beaches. In the past, the causeway that bisected the saltmarsh allowed access to the beach, berm and sandspit without anglers having to pass through the restricted mining area. The causeway has since been broken through to facilitate reconnection of the estuary with the saltmarsh and the only access to the beach is along the edge of the estuary to the south. Local anglers cite this as the main reason that they no longer fish in the mouth region. More recently, the South African Department of Environmental Affairs has granted a concession for the local Richtersveld community to operate a boom and charge an access fee for offroad vehicles to the beach. The legality of this concession is still in question but angling effort is set to increase. While some angling does take place within the closed areas, those anglers are not allowed to bring their fish out of the area. Thus the once very active Alexander Bay Angling Club, which used to run regular competitions, has become more of a social club (pub) in the town. Oranjemund reportedly supports a more active shore-angling community. From time to time, anglers aggregate in the mouth area after freshwater releases, which bring sediments to the

nearshore zone, create excellent conditions for catching kob *Argyrosomus* spp. These anglers reportedly also come from quite far afield, even Cape Town.

The estuary also attracts visitors who come to see the river mouth, or for bird watching. The river mouth in itself is an impressive site, particularly with its setting in a desert landscape, and is also a 'must-see' for some as the most westerly point and the north-west 'corner' of South Africa. However, reaching it is somewhat of a challenge, not only because it is far off the beaten track for visitors on the Namibia-Cape route or visiting the Richtersveld-Ais-Ais complex, but requires driving in an off-road vehicle along the sandy berm or a long walk. We also encountered business visitors to both Port Nolloth and Alexander Bay making a diversion to visit the mouth.

A steady trickle of bird watchers visit the Orange Estuary to see its aggregations of flamingos, cormorants and other waterbirds in the mouth area, including rarer species such as Damara Tern and Chestnut-banded Plover, which occur here in greater abundance than anywhere else in South Africa. Access is not easy for birdwatchers, so the estuary tends to attract the relatively avid birdwatchers.

Occasionally, people that paddle down the Orange River in canoes or kayaks travel all the way to the mouth.

Although the estuary does attract a small number of visitors as described above, very few of them overnight in Alexander Bay. Perhaps 1% of the bed-nights filled at the Alexkor Guesthouses are by tourists, as opposed to visitors on business. The Spogplaas Guesthouse above the head f the estuary attracts more tourists as clientele and the Brandkaros campsite and chalets, 35 km upstream have recently re-opened after long closure. The campsite/picnic area at Pachtvlei attracts very few visitor groups, reportedly in the order of five a month. By November 2012 they had only one booking for the December holiday period. The aesthetic value of the estuary is not manifested in property value, since few, if any, properties have good scenic views of the estuary, and none have good access.

Turpie & Clark (2007) estimated the recreational value of the Orange Estuary to be in the order of ZAR 690,000 (inflated to 2012 ZAR). This estimate is still believed to be reasonable at present.

The Orange Estuary form two Ramsar Sites (one in Nambia and the other in South Africa) due to the spectacular aggregations of birds that it has supported in the past (Anderson et al., 2003). While the estuary has since become severely degraded in parts, there are plans to declare a nature reserve in the estuary area and restore its ecological functioning. These plans, if they come to fruition, will affect the future value of the area. The declaration of the nature reserve has been complicated by two factors – (i) the length of time that it has taken to gain acceptance and commitment by the provincial Member of Executive Council (MEC), who has changed twice since the process began, and (ii) getting agreement on the position of the international boundary between South Africa and Namibia. While the boundary officially lies on the north bank of the estuary, international convention requires it to be in the centre of the river, and this in turn, requires that the Ramsar Site and the future Nature Reserve need to be transboundary in nature. It involves negotiation with the local community as it requires that agriculture will not be restored in the floodplain area.

Nevertheless, Northern Cape Nature Conservation is confident that the Nature Reserve will be proclaimed within the current political cycle. This will lead to major improvements in the estuary, notably through rehabilitation of the severely damaged salt marsh and floodplain areas. In addition, the management of the estuary as a nature reserve will include developments that facilitate growth in nature-based tourism in the area.

4.3.4 Regulating services

Regulating services provided by estuaries typically include nursery functions for species utilised in fisheries beyond the estuary, exports of nutrients and sediments, water treatment functions and carbon sequestration. The level of carbon sequestration is dependent on the plant growth forms in the estuary, and their extent and productivity, and is typically significant for highly productive mangrove estuaries in tropical climes. Carbon sequestration is not likely to be a significant function of the Orange Estuary.

Nursery area

Estuaries provide nursery areas and habitat for several fish species that are exploited in recreational and commercial fisheries (Lamberth & Turpie, 2003). The Orange Estuary is thought to be particularly important as a nursery area since it is one of only four permanently open systems on the west coast of South Africa, accounting for about 1/3 of estuarine area. The next estuary north of the Orange River is the Cunene in northern Namibia. Furthermore, the high diversity and abundance of estuarine dependant and marine species suggests that the Orange Estuary is a more important nursery area than was previously thought (van Niekerk et al., 2008).

A least 19 of the fish species that occur in the estuaries of the west coast region are utilised in coastal fisheries. Of these, eight fall in category II (juveniles use estuaries), nine in category III (marine species that occur in but not dependent on estuaries) and two species fall into category IV (catadromous species). Of particular importance are the category II species, for which management of estuaries plays a crucial role in inshore fisheries. Numbers of estuarine species in catches increase from west to east around the South African coast (Lamberth & Turpie, 2003).

Because of the nature of the upwelling systems in the area, it is likely that the nursery benefits from this system would be experienced mainly in South Africa, but would also include the recreational fishery in southern Namibia, which is mainly close to the mouth. Fisheries along the West Coast that would benefit from the nursery function of the Orange-Senqu Estuary include the beach seine and gill net fisheries, the commercial line fishery, recreational shore angling and recreational boat angling. Gill-net fisheries target harders and St Joseph sharks, *Calorhynchus capensis*, as well as species on the 'bait list' such as horse mackerel *Trachurus trachurus*. The beach-seine fishery targets mainly harders. Numbers of commercial line fishing boats in South Africa were greatly reduced in the 1990s from 2581 to 450, following the declaration of a state of emergency with linefish stocks. Very little work has been done to quantify the extent of recreational angling in South Africa, but in the 1990s it was estimated that there were about 26,000 shore anglers and 210 boat based anglers using the west coast (McGrath et al., 1997; Brouwer et al., 1997; Sauer et al., 1997). The majority of

anglers come from the upper two quintiles of income earners in South Africa (McGrath et al., 1997).

The contribution of different categories of estuary-associated species to inshore marine fisheries on the west coast of South Africa is summarised in Table 3. Species (e.g. white steenbras), which are entirely dependent on estuaries, generally make up a relatively small percentage of catches, ranging from 0,5% of recreational boat and spear fishing catches to about 1,0% of commercial net catches. Historically, prior to stock collapse, IIa species (white steenbras and dusky kob) made up a substantial part of catches. The proportion of category IIb species in catches is generally lower than of category IIa species, but category IIc species are highly important in the commercial net fisheries and recreational shore fishery (Table 3). The category IIc species are dominated by harders in the commercial net fisheries. The main species in these fisheries are shown in Table 4.

Table 3. Percentage contribution of different categories of estuarine associated fish to the inshore marine fisheries on the west coast. All percentages in terms of biomass except recreational shore angling, in terms of numbers

Inshore marine fisheries	***Estuary dependence category***				
	IIa	***IIb***	***IIc***	***III***	***Total***
Recreational shore	0.51	0.17	41.26	13.81	55.75
Recreational boat	0.02	<0.01	0.80	0.10	0.92
Commercial boat	0.09	<0.01	0.80	0.10	0.91
Seine and gill-net	1.05	0.04	80.86	1.10	83.06

Table 4. Percentage contribution of the main estuary-associated species to inshore marine fisheries on the South African west coast (% of total catch by weight)

Estuary-associated species	***Category***	***Commercial Gill/seine***	***Commercial boat***	***Recreational shore***	***Recreational boat***
Harders	IIc	79.0	0.1	9.5	0.1
Elf	IIc	1.0	0.1	0.1	0.1
Strepie	IIc	0.1	0.1	0.3	0.1
Dassie	IIc	0.1	0.1	1.0	0.1
White Steenbras	IIa	0.1	0.1	0.5	0.1

Based on the estimates of Lamberth & Turpie (2003), and accounting for the fact that the effort and catches in the commercial boat-based linefishery have been reduced by about 60% through management measures since that study was done, it was estimated that the total value of west coast inshore fisheries is probably over ZAR 00 million (Table 5).

Estuarine fish make up about 25% of the value of the gill- and seine-net fisheries and 0.3% of the value of the commercial boat fisheries on the west coast, or about 8% of the overall value of West Coast inshore marine fisheries (Table 5). However, not all of these fish are equally dependent on estuaries. Category IIa species are 100% dependent on estuaries to complete their life cycles. Because the juveniles of Category IIb species are largely confined to estuaries, their level of dependence on estuaries was considered to be very high, and was estimated as 90%. For Category

IIc species, whose juveniles mainly occur in marine environments, it was estimated that 30% of the marine catches can be attributed to estuarine export. Thus, adjusting values according to the level of contribution that estuaries make to the catches of species of different categories, the estimated contribution from estuaries to inshore marine fisheries on the West Coast is 3.2% of the total value, or about ZAR 23,3 million per year (2012 ZAR, Table 5). The latter estimate is the value that would be lost if estuaries or their fish fauna were 'removed'.

Table 5. Percentage contribution of estuarine associated fishes to the total value of the inshore marine fishing sectors on the West Coast, the total annual values of the fisheries, the amount and % of total which is comprised of estuary-associated species, and the contribution of estuaries to total fishery values (2012 ZAR).

	Recreational shore	***Recreational boat***	***Commercial boat***	***Seine and gill-net***	***Total***
% Estuary-associated species					
IIa	0.6	0	0.04	3.89	
IIb	0.03	0	0	0.02	
IIc	18.05	0.39	0.78	72.9	
III	2.24	0.01	0.05	1.86	
Total value: (ZAR million)	248.8	263.8	177.9	28.1	718.5
Estuary fish contribution					
ZAR million	52.1	1.1	1.6	22.1	76.7
%	20.92	0.41	0.88	78.67	7.9
Value due to estuaries					
ZAR million	15	0.3	0.7	7.2	23.3
%	6	0.1	0.4	25.7	3.2

The nursery function of estuaries contributes an estimated R23,3 million to the value of fisheries on the South African west coast.[3] The proportional contribution of each estuary is unknown, and depends on several factors such as estuary size and mouth status, as well as geographical location. The Orange Estuary makes up about 32% of the estuary area on the southern African west coast (not including the upper Berg estuary floodplain which is largely a freshwater habitat). Thus a preliminary estimate of the nursery value of the Orange Estuary is some ZAR 7,5 million per year (2012 ZAR). This is slightly higher than Turpie and Clark's (2007) rapid estimate of between ZAR 1,4 and 6,9 million per year (2012 ZAR) for the nursery value of the Orange Estuary.

Furthermore, it is thought that the Orange and Cunene estuaries, which share a number of important species such as kob, *Argyrosomus coronus*, and leerfish *Lichia amia*, may play an important role in linking fish populations among Angola, Namibia and South Africa, helping to maintain the range of some species over more than a thousand kilometres (Lamberth, 2008; CSIR, 2011).

3 Note that this is a rough estimate, as a more thorough estimate needs to be based on an analysis using up-to-date commercial fisheries data. Up-to-date data does not exist for the recreational fisheries.

Sediment and nutrient exports

Rivers carry nutrients from their catchments which they discharge into the marine zone. This function is particularly important in tropical areas where it might be the main source of nutrients in trophic systems, but is unlikely to be important in the upwelling zones of the west coast of southern Africa, which are already very high in nutrients. Sediment outputs from rivers can play an important role in maintaining benthic habitats offshore, which has knock-on effects for demersal fisheries. The continental shelf offshore of the Orange River Mouth is thought to be critical nursery areas for several fish stocks that make up a large proportion of the value of commercial fisheries in South Africa. Theses linkages are not well understood.

Water quality amelioration

Rivers provide a water quality amelioration service through dilution or assimilation of excess nutrients discharged into them as waste products of human activities in their catchment areas. While this is likely to be a very important service throughout much of the Orange-Senqu River Basin, there is little discharge occurring into the estuary itself.

4.3.5 Opportunity costs

It should be noted that much of the estuary has been reclaimed in the past, for other uses. These other uses have values that have to be compared with the values that would have been otherwise provided by the intact estuary system. These activities include irrigated pastures for a dairy operation, and wastewater (sewage) oxidation ponds. Agriculture within the floodplain area was once fairly extensive, but has now ceased. The oxidation ponds have now been relocated above the 5m contour (i.e. away from the estuary), and those within the estuary floodplain area were due to be closed at the end of November 2012. Unfortunately, the cessation of these activities has not yet resulted in the restoration of estuary functionality and values in those areas. Even though the main causeway across the saltmarsh to the beach has been breached, the berms, roads and canals continue to obstruct water flows into those areas. The only remaining activities within the estuary area that have involved transformation of estuary habitat are sports fields.

5 Consequences on ecosystem services

The consequences of different scenarios (which include environmental release options) on ecosystem services are described in terms of impacts on the identified ecosystem services which are sensitive to flow changes.

5.1 Fish River from Neckartal Dam site to Löwen River confluence

All of the Fish River environmental release options involve the development of the Neckartal Dam. If developed, the dam will be located on the boundary between the commercial farms and land under traditional authority oversight. Population densities are very low and the actual numbers of people typically making use of ecosystem goods or benefiting from services is consequently also low. However, the vulnerability of people who depend on these ecosystem goods and services should not be underestimated.

5.1.1 Impacts on natural resources

Fish

Many fish species are used for subsistence fishing by farm workers. The expected impacts on these species are as described in Table 6. The table indicates that the impact expected on the *Labeobarbus* species (yellow fish), that represents a significant portion of local catch, would be very large under RO 0%, with a potential loss of approximately 80% of the stock. Some of the more robust species (*Labeos, Cyprinus carpio* (carp), *Clarias gariepinus* (barbel), etc.) may not suffer as greatly, but a significant decline is still anticipated.

Table 6. Impacts of environmental release options on utilised fish species

Fish Species	***Comment***	***Release option***				
		0%	***20%***	***30%***	***40%***	***50%***
Large- and smallmouth yellowfish (*Labeobarbus kimberleyensis* and *L. aeneus)*		0.2	0.5	0.7	0.9	0.9
Mudfish (*Labeo capensis* and *L. umbratus*)	Scarce at present.	0.5	0.6	0.8	0.9	0.9
Carp (*Cyprinus carpio*)		0.6	0.8	0.9	1.0	1.0
Catfish/barbel (*Clarias gariepinus*)	Scarce at present.	0.6	0.8	0.9	1.0	1.0
Mozambique tilapia (alien/introduced species) (*Oreochromis mossambicus*)	Increasing in distribution and abundance over time.	0.6	0.8	0.9	1.0	1.0
Smaller species and juveniles (small barbs/ghielemientjies), possibly introduced banded tilapia, as well as juveniles of the indigenous species)	Primarily caught with traps. Utilisation limited.	0.5	0.6	0.7	1.0	1.0

Under RO 20%, the biggest difference between this and the previous scenario relates to yellowfish that would become progressivelyless impacted as higher and more flows would benefit stock maintenance. All other species would be less affected, although overall the degree of impact remains high. Impacts are relatively small under RO 30%, and almost negligible under RO 40% and RO 50%.

Plant resources

Impacts on utilised plant species are described in Table 7. Under RO 0%, the potential 'drying up' of the system would mainly impact on the *Digitaria eriantha* used for grazing. Given the nature of parts of the reach and the population reliant on grazing of livestock this would be a critical impact. The other species identified as commonly used for grazing and generally found within the reach are not likely to be impacted in any of the scenarios.

Under RO 20%, some species, particularly sedges and the exotic mesquite (*Mesquite glandulosa)* would improve. Less impact of high flows would allow these species to thrive. However the important *Digitaria* grazing grasses remain negatively impacted. The impacts are similar for RO 30%. Under RO 40% and RO 50%, the impacts are almost nil and in some cases, are positive. Only the important grazing grasses remain negatively impacted.

Table 7. Impacts of environmental release options on utilised plant species

Category			***Release option***				
	Species	***Comment***	***0%***	***20%***	***30%***	***40%***	***50%***
Sedges							
	Cyperus longus (mainly)	Harvested and grazed.	0.5	1.1	1.1	1.1	1.1
Reeds							
	Phragmites australis	Very important for range of livelihood and subsistence purposes.	0.8	1.3	1.3	1.2	1.2
Grazing							
	Cynodon dactylon	Grazing of livestock.	0.5	0.7	0.7	0.9	0.9
	Digitaria eriantha	Grazing, palatable grass.	0.2	0.4	0.4	0.6	0.6
Other							
	Euclea pseudebenus	Wood (building), saplings used for browsing by livestock.	0.9	1.0	1.0	1.0	1.0
	Mesquite glandulosa	Alien species, wood, used for browsing by livestock - pods.	1.0	1.2	1.2	1.4	1.4
	Salix mucronata subsp. *mucronata*	Wood for subsistence.	0.6	1.0	1.0	1.1	1.1
	Searsia lancea	Wood, saplings used for browsing by livestock.	0.9	1.0	1.0	1.1	1.1
	Acacia karoo (Sweet thorn)	Wood and gum (saplings used for browsing by livestock, pods).	1.0	1.1	1.1	1.3	1.3

Category		*Release option*				
Species	***Comment***	***0%***	***20%***	***30%***	***40%***	***50%***
Tamarix usneoides	Wood, salt lick.	1.0	1.0	1.0	1.1	1.1
Ziziphus mucronata	Wood, fruits, used for browsing by livestock, religious and ritual use.	0.9	1.0	1.0	1.1	1.1

5.1.2 Impacts on cultural services

Impacts on tourism, recreational and cultural use are given in Table 8. These activities are compromised most under RO 0%, with ecotourism being significantly impacted under all environmental release options.

Table 8. Impact of environmental release options on cultural services

Service	***Description and comment***	***Release option***				
		0%	***20%***	***30%***	***40%***	***50%***
Swimming	Swimming is important particularly in the hot summer months and provides a recreational outlet in areas that have few such opportunities.	0.5	0.7	0.8	0.9	0.95
Ritual Use	Ritual use is important in parts of the system. This depends on the integrity of the river, and will be compromised	0.5	0.7	0.8	0.9	0.95
Ecotourism – aesthetic	Bird watching: Apart from birding in the private conservation areas (mule trails, day hikes), this reach does not support any organized tourism effort that is focused on riverine fauna.	0.5	0.6	0.6	0.7	0.7
Ecotourism – game watering	Game in private conservation areas: Most animals are drought adapted and will utilise isolated pools.	0.7	0.7	0.8	0.8	0.8

5.1.3 Impacts on regulating services

Impacts on other ecosystem services are described in Table 9. The impact on flood attenuation is rated as positive and potentially increasing by as much as a factor of 50%. This however should not be seen as a 'good' ecosystem service, since it will mean that releases from the dam will travel and recharge fewer pools and shorter sections of the riparian groundwater aquifer. The groundwater recharge function would be severely compromised. Groundwater recharge services would be severely impacted under RO 20%, and would remain impacted under RO 30%, RO 40% and RO 50%.

Both the waste assimilation and the waste dilution functions would be compromised under most environmental release options, severely so under RO 0%.

Table 9. Impacts of environmental release options on regulating services

Service	***Comment***	***Release option***				
		0%	***20%***	***30%***	***40%***	***50%***
Flood attenuation	Pools are good for flood attenuation, and as flows decline and more pools/reaches of the river dry up, attenuation of subsequent floods will be progressively higher.	1.5	1.3	1.2	1.2	1.0
Bank protection	Well-established vegetation protects the bank and enhances flood attenuation.	0.9	1.0	1.0	1.0	1.0
Groundwater recharge	Important – many small landowners are dependent on the riparian aquifer which is recharged by the Fish River.	0.3	0.6	0.7	0.7	0.8
Waste assimilation	Although waste assimilation (of nutrients) does not have a direct relationship with flow, a reduction in flows (e.g. RO 0%) will result in elevated nutrient levels.	0.5	0.7	0.7	0.8	0.8
Waste dilution	Fluctuating flows have a direct impact on the dilution of toxicants such as selected metals seen in the data record.	0.7	0.8	0.8	1.0	1.0

5.1.4 Impacts on blackfly

Impacts on blackfly were also examined as they are major pests in the area. Outbreaks of pest blackflies, *Simulinum chutteri*, are expected when flows exceed 150 m^3/s, as this is when the average current speed exceeds 0,6 m/s (i.e. ideal conditions for the pest blackfly). The probability of outbreaks under present day conditions is low, and estimated at 0,42, which is equivalent to a recurrence interval of 2,4 years. The duration of outbreaks in the Fish River is expected to be short, lasting no longer than a few weeks. The probability of outbreaks under RO 0% is reduced to 0,26, which is equivalent to a recurrence interval of 3,5 years. This is a positive impact, as fewer outbreaks would be beneficial. Outbreaks of blackflies under the remaining environmental release options would also be reduced, but less than in RO 0%. However, RO 40% and RO 50% reduces the frequency of high flow spillage compared to 0%, so the risks of outbreaks are lower than in RO 0%.

5.1.5 Summary

The environmental release options can be ranked, in terms of impacts on ecosystem goods and services, in order of the overall amounts of water released. Given the relationship between flows and the Ecosystem Services this is to be expected. Results are summarised in Table 10 and Figure 7.

Table 10. Summary of the consequences of the environmental release options

Release option	*Summary*
0%	Major impact on the delivery of ecosystem goods and services.
20%	An improvement on RO 0% but continues to have a critical impact on key aspects of ecosystem goods and services
30%	A further improvement from RO 20%, but continues to have a largely negative impact on key aspects of ecosystem goods and services.
40% and 50%	For the most part, limited impact on key ecosystem goods and services.

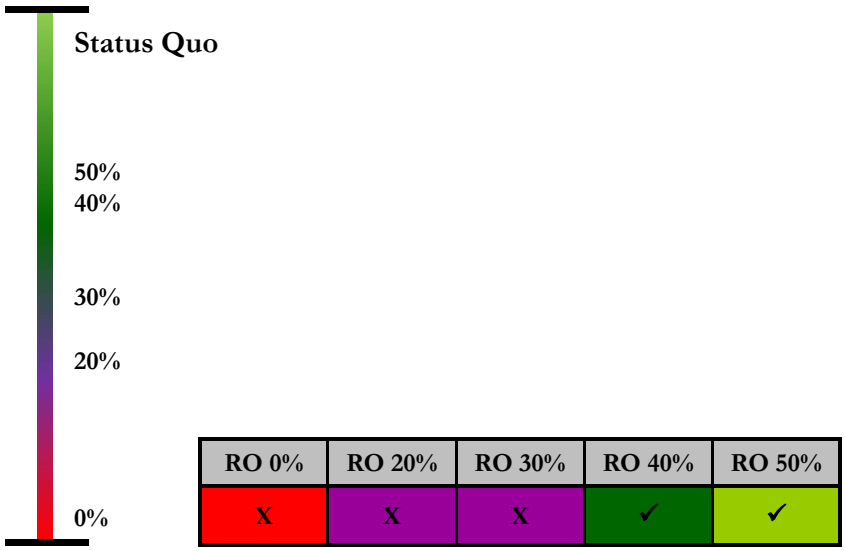

Figure 6. Diagrammatic representation of the consequences on the Fish River below Neckartal Dam

5.2 Fish River from Löwen River confluence to Orange River confluence

5.2.1 Impacts on natural resources

Fish

Several species are used for subsistence fishing by workers at /Ai-/Ais Hot Springs Resort, and also recreational fishing by hikers in Fish River Canyon/Ai-Ais on very small scale. As for the previous reach there is no large scale utilisation by communities. While some small species are included in the above assessment, there is not likely to be significant utilisation of these in this reach.

The expected impacts on fish are described in Table 11. As would be expected, patterns are similar to those found in the reach assessed above the Löwen River confluence, although flows from this river do mitigate impacts to an extent. The impact expected on yellowfish, a significant portion of

local catch, would be high with a decline of approximately two thirds predicted. Some of the more robust species (labeos, carp, barbel, etc.) may not suffer as greatly, but a significant decline is still anticipated.

Under RO 20%, the biggest difference relates to yellowfish which would be less severely impacted due to higher flows allowing stock maintenance. All other species would be incremently less affected although the overall degree of impact remains high. Impacts are less severe under RO 30% and almost negligible under RO 40% and RO 50%.

Table 11. Impacts of environmental release options on utilised fish species

Fish Species	***RO 0%***	***RO 20%***	***RO 30%***	***RO 40%***	***RO 50%***
Largemouth and smallmouth yellowfish (*L. kimberleyensis* and *L. aeneus*)	0.3	0.5	0.7	0.8	0.8
Mudfish (*L. capensis* and *L. umbratus*)	0.5	0.5	0.8	0.9	0.9
Carp (*C. carpio*)	0.5	0.7	0.8	1.0	1.0
Catfish/barbel (*C. gariepinus*)	0.5	0.7	0.8	1.0	1.0
Mozambique tilapia (alien/introduced species) (*O. mossambicus*)	0.5	0.7	0.8	1.0	1.0

Plant resources

Impacts on utilised plant species are described in Table 12. As with the previous reach, the major impact in terms of the potential "drying up" of the system is associated with the *Digitaria eriantha* used for grazing. Given the nature of parts of the reach, and the population reliant on grazing of livestock, this would be a critical impact. The important grazing grasses remain negatively impacted under RO 20% and RO 30%. In terms of the impact on floral and botanical species, the impact of RO 40% and RO 50% is almost nil, and in some cases even positive. Only the important grazing grasses remain negatively impacted.

Table 12. Impacts of environmental release options on utilised plant species

Category			***Release option***				
	Species	***Comment***	***0%***	***20%***	***30%***	***40%***	***50%***
Sedges							
	Cyperus longus (mainly)	Harvested and grazed.	0.5	0.8	0.8	1.1	1.1
Reeds							
	Phragmites australis	Very important for range of livelihood and subsistence purposes.	0.6	1.0	1.0	1.2	1.2
Grazing							
	Cynodon dactylon	Grazing of livestock.	0.3	0.5	0.5	0.9	0.9
	Digitaria eriantha	Grazing, palatable grass.	0.2	0.4	0.4	0.6	0.6
Other							
	Acacia erioloba	Camel thorn used for wood, saplings are	0.8	1.0	1.0	1.0	1.0

Category			*Release option*				
	Species	*Comment*	*0%*	*20%*	*30%*	*40%*	*50%*
		browsed as are pods.					
	Euclea pseudebenus	Wood (building), saplings used for browsing by livestock.	0.7	1.0	1.0	1.0	1.0
	Mesquite glandulosa	Alien species, wood, used for browsing by livestock – pods.	0.8	1.0	1.0	1.1	1.1
	Acacia karoo (Sweet thorn)	Wood and gum (saplings used for browsing by livestock, pods).	0.8	1.0	1.0	1.3	1.3
	Tamarix usneoides	Wood, salt lick.	0.6	0.9	0.9	1.1	1.1
	Ziziphus mucronata	Wood, fruits, used for browsing by livestock, religious and ritual use.	0.7	1.0	1.0	1.1	1.1

5.2.2 Impacts on cultural services

A range of cultural services provided by the river and riparian resources were examined. Swimming and ritual use, both important services in certain parts of the reach, would be compromised. So too would the very important services associated with the extensive ecotourism in the reach (Table 13).

Table 13. Impact of environmental release options on cultural services

Service	*Description and comment*	*Release option*				
		0%	*20%*	*30%*	*40%*	*50%*
Swimming	Swimming is important, particularly in the hot summer months. It is a key part of the tourism hiking experience.	0.5	0.5	0.7	0.8	0.9
Ritual use	Ritual use is potentially marginally important in parts of the system. This depends on the integrity of the river and will be compromised.	0.5	0.7	0.8	0.9	0.95
Ecotourism – aesthetic	Bird watching, riverine mammals: There is increased interest and enthusiasm in bird watching and biodiversity interest (otters, other mammals), amongst hikers, campers and holiday visitors to the private conservation areas and the Fish River Canyon. Thus riverine fauna are becoming increasingly popular and important to ecotourism.	0.5	0.6	0.6	0.7	0.7
Ecotourism – game watering	Game in private conservation areas and the Fish River Canyon: Most animals are drought adapted and will utilise isolated pools. The wild horses living in the canyon will perish with no water (these are different from the iconic wild horses near Aus).	0.7	0.7	0.8	0.8	0.8
Ecotourism Hiking	Hiking is a key activity in the canyon. Water from the river is important for sustenance. With low flows this would be compromised and may even render the hiking impractical under certain conditions or may result in the closing of the hiking route for certain periods of time.	0.2	0.6	0.8	1.0	1.0

5.2.3 Impacts on regulating services

Table 14 summarises the impacts on regulating services. The impact on flood attenuation is rated as positive and potentially increasing by as much as a factor of 60%. Again, however, this should not be seen as a 'good' ecosystem service, since it will mean that releases from the dam will recharge fewer pools and shorter sections of the riparian groundwater aquifer. The groundwater recharge function would be severely compromised.

Both the waste assimilation and the waste dilution functions would be severely compromised under RO 0%. Also of concern, although it may not typically fall neatly under the heading of ecosystem goods and services, is the potential impact on the functioning of the Ais-Ais tourism facility. Under Sc 0% the assimilative function of the river would be severely compromised and would make current operations of the camp very difficult.

Groundwater recharge services would be less severe under RO 20% but would remain severely impacted. Both the waste assimilation and the waste dilution remain compromised as does the impact on Ais-Ais.

Groundwater recharge services remain impacted under RO 30%. Both the waste assimilation and the waste dilution remain compromised as does the impact on Ais-Ais.

Waste assimilation and the waste dilution remain marginally compromised under RO 40% and RO 50%.

Table 14. Impacts of environmental release options on regulating services

Service	***Comment***	***Release option***				
		0%	***20%***	***30%***	***40%***	***50%***
Flood attenuation	Extensive pools are good at flood attenuation, but as flows decline and more pools/reaches of the river dry up, then attenuation of subsequent floods will be progressively higher.	1.6	1.4	1.3	0.8	0.9
Bank protection	Well-established vegetation protects the bank and enhances flood attenuation. Optimal scenario is RO 30% as nature of water releases under RO 40 and RO 50% may marginal negative impacts.	0.8	0.9	1	0.9	0.95
Groundwater recharge	Very important function for this area - many small landowners are dependent on the riparian aquifer which is recharged by the Fish River.	0.2	0.5	0.6	0.7	0.7
Waste assimilation	All variables would be in a poor state under low flows (e.g. RO 0%), with unacceptable impacts for both ecological and anthropogenic users.	0.5	0.7	0.7	0.8	0.8
Waste dilution	Waste dilution capacity is greatly reduced under Sc 0% dry season flows.	0.5	0.7	0.7	1.0	1.0
Eutrophication/organic pollution: Ais-Ais	This score pertains specifically to the Ais-Ais area and incorporates waste assimilation functions.	0.3	0.6	0.6	0.8	0.9

5.2.4 Impacts on blackfly

Impacts on blackfly were also examined as they are major pests in the area. The impacts are the same as for the reach upstream of the Löwen River confluence. The duration of outbreaks in the Fish River is expected to be short, lasting no longer than a few weeks. The probability of outbreaks under RO 0% is reduced to 0,26 which is equivalent to a recurrence interval of 3,5 years. This is a positive impact, as fewer outbreaks would be beneficial.

Outbreaks of blackflies under RO 20% and RO 30% would remain reduced, but less than for RO 0%. Under RO 40% and RO 50%, the frequency of high flow spillage is reduced compared to RO 0%, so the risks of outbreaks are lower.

5.2.5 Summary

The expected impacts are summarised for broad groups of ecosystem services in Table 15.

Table 15. Summary of impacts on ecosystem services

Benefits		***Release option***				
Present	***Current Status***	***0%***	***20%***	***30%***	***40%***	***50%***
Harvested resources						
Fish, reeds, riparian veld foods and medicines for farm workers and households on communal lands	1.0	0.5	0.7	0.8	1.0	1.0
Grazing						
Important especially in dry periods	1.0	0.3	0.5	0.5	0.9	0.9
Recreational						
Swimming, picnicking	1.0	0.4	0.6	0.7	0.8	0.9
Nature-based tourism						
Important downstream of Naute	1.0	0.4	0.6	0.8	0.9	0.9
Water quality amelioration						
From pollution in irrigation return flows and wastewater from settlements, e.g. Hardap, Gibeon	1.0	0.5	0.7	0.7	0.9	0.9
Pest control						
Control of larvae	1.0	1.1	1.1	1.1	1.2	1.3

The severity of the overall impacts is related to the amounts of water released under the different environmental release options. This is described in Table16 and illustrated in Figure 7.

Table 16. Summary of consequences

Release options	***Summary: Consequences***
0%	A major impact on the delivery of ecosystem goods and services.
20%	An improvement on RO 0%, but continues to have a critical impact on key aspects of ecosystem goods and services.

Release options	*Summary: Consequences*
30%	A further improvement on RO 0% and RO 20%, but continues to have a largely negative impact on key aspects of ecosystem goods and services.
40% and 50%	Mostly limited impact on key ecosystem goods and services.

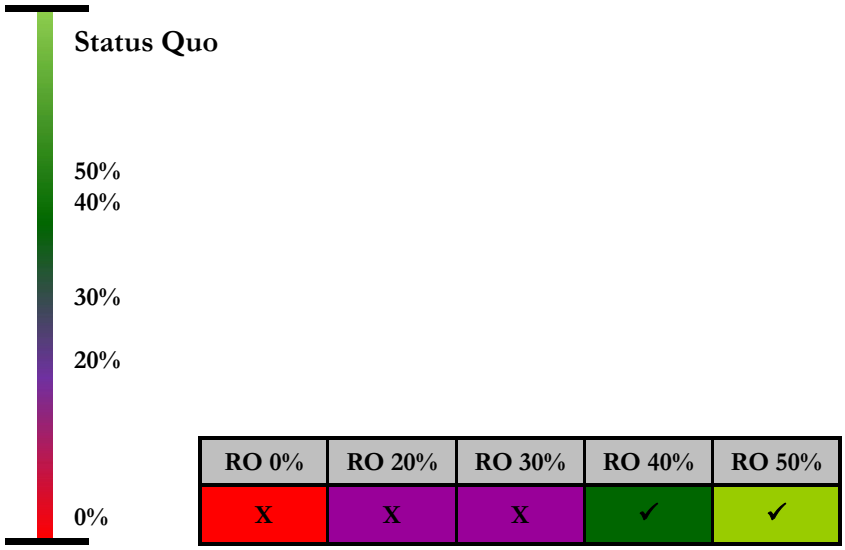

Figure 7. Diagrammatic representation of results for Fish River below Löwen confluence

5.3 Lower Orange River

For the purposes of this report, and following discussions with the team of specialist biophysical scientists, Sc OF 2 and OF 3 have been treated as having the same impact on the lower Orange River, and Sc OF 6 and OF 7 have, likewise, been treated as the same. This results in only two separate evaluations below.

For the most part, there was not expected to be any impacts on the ecosystem goods and services under Sc OF 2 or OF 3. This is largely due to the fact that these scenarios anticipate that the PES is maintained and as such the base score of 1 will not be impacted. There were only two exceptions – fish and blackfly. On the other hand, Sc OF 6 and OF 7 are anticipated as having a considerable impact.

5.3.1 Impacts on natural resources

Fish

The smaller species of fish (e.g. river sardine, small barbs/ghielemientjies, small cichlids/tilapias) are currently under pressure, and Sc OF 2 or OF 3 may create certain conditions where flows will favour them.

Under Sc OF 6 and 7, yellowfish would be considerably impacted as would the *Labeos* (mudfish) and some of the smaller species (Table 17).

Table 17. Impacts of scenarios on fish

Fish Species	***Comment***	***OF 6; OF 7***
Large- and smallmouth yellowfish	Recreational fishing (all methods), subsistence fishing by Richtersveld goat farmers (vee boere) as well as illegal netting (poaching) by Aussenkher.	0.4
Mudfish (*L. capensis* and *L. umbratus*)		0.5
Carp (*C. carpio*)		0.8
Catfish/barbel (*C. gariepinus*)		0.8
Mozambique tilapia (alien/introduced species) (*O. mossambicus*)		0.8
Smaller species and juveniles (small barbs/ghielemientjies (i.e. straightfin barb etc.) and possibly introduced banded tilapia, as well as juveniles of the indigenous species	Mostly illegal use of fish traps (not cultural reed basket traps, but using more commercially available material such as shade nets, steel wire). Utilisation very low in this reach due to law enforcement by Transfrontier Park staff.	0.6

Plant resources

With regard to the floral species as set out in Table 18, there is potentially a positive impact on the reeds (*Phragmites* spp.), but for the rest, the impact is negative.

Table 18. Impacts of Sc OF 6 and OF 7 on plant resources

Category	***Species***	***Comment***	***OF 6; OF 7***
Reeds	*Phragmites australis*	Used for grazing, building, reduced base flows but with some moisture and can expand in extent	1.2
Grazing	*Cynodon dactylon*	Livestock grazing.	0.7
Trees-other flora	*Acacia erioloba*	Used for timber/fuel wood, pods, saplings browsed.	0.9
	Acacia karoo	Used for timber/fuel wood, pods, saplings browsed, gum.	0.8
	Euclea pseudebenus	Used for timber/fuel wood, browsing.	0.9
	Nicotiana glauca	An alien, used by livestock for browsing.	0.7
	Mesquite glandulosa and *P. velutina*	An alien, used for timber/fuel wood, browsing of pods.	0.8
	Salix mucronata subsp. *mucronata*	Used for timber/fuel wood.	0.6
	Searsia lancea	Used for timber/fuel wood.	0.9
	Searsia pendulina	Used for timber/fuel wood, browse.	0.8
	Tamarix usneoides	Salt lick, used for timber/fuel wood.	0.7
	Ziziphus mucronata	Used for timber/fuel wood, browsing, fruits, religious uses.	0.8

A set of other species were identified as part of the range of goods utilised, but the scenarios were not anticipated as having any impact. These were:

- *Maytenus linearis*;
- *Maerua gilgii*;
- *Diospyros lycioides* subsp. *lycioides*;
- *Stipagrostis ciliata* var. *capensis*;
- *Eucalyptus camuldensis*.

5.3.2 Impacts on cultural services

Scenarios OF 2 and OF 3 would not have an impact on cultural services. Under Sc OF 6 and OF 7, swimming and ritual use, both important services in certain parts of the reach, would probably not be compromised other than impacts on water quality making swimming potentially less attractive. So too would the very important services associated with the extensive ecotourism in the reach (Table 19).

Table 19. Impacts of Sc OF 6 and OF 7 on cultural services

Service	***Description and comment***	***Impact magnitude***
Swimming	Swimming is important, particularly in the hot summer months – flows are not likely to compromise water quality but quality will be impacted.	0.9
Ritual use	Ritual use is potentially marginally important in parts of the system. This depends on the integrity of the river.	1.0
Ecotourism – aesthetic	Bird watching, riverine mammals: There is increased interest and enthusiasm in bird watching and an interest in biodiversity (otters, other mammals), amongst hikers, campers and canoeists. Increased interest in canoeing on the lower Orange River and the attraction of the /Ai-/Ais–Richtersveld Transfrontier Park will place more emphasis on ecotourism which will encompass birding and biodiversity. Thus riverine fauna are becoming increasingly popular and important to ecotourism.	0.5
Ecotourism – game watering	/Ai-/Ais–Richtersveld Transfrontier Park: Most animals are drought adapted and will utilise isolated pools.	0.8
Ecotourism – hiking	Very little poaching expected.	1.0

5.3.3 Impacts on regulating services

Impacts associated with the regulating services are summarised in Table 20. For the most part these are negligible. The waste assimilation and dilution function will be severely compromised. The incidence of pathogens (a dis-service) will likely increase.

5.3.4 Impacts on blackfly

Outbreaks of pest blackflies on the lower Orange River are expected at high flows, particularly when these are preceded by elevated winter low flows. Elevated winter flows provide more habitat

for eggs and larvae to survive during the dry season, and are the precursor to an outbreak when flows increase. Flows that exceed 300 m^3/s trigger hatching of diapausing blackfly eggs. Furthermore, the availability of suitable habitat for the pest blackfly, *S. chutteri* (i.e. very fast flow on hard substrate) is not limiting at this flow. Under present day conditions, the impact of blackflies on livestock is high, with costs of lost production in the study area estimated at ZAR 7.7 million per year (Palmer et al., 2007). The reason for this is that winter low-flows are elevated and flows exceeding 300 $m^3/$ occur for 10% of the time. No change from present day trigger flows (>300 m^3/s) is expected under Sc OF 2 and OF 3, but winter flows are reduced slightly, so the probability of outbreaks is reduced slightly. Under Sc OF 6 and OF 7, outbreaks of blackflies should decrease.

Table 20. Impacts of Sc OF 6 and OF 7 on regulating services

Service	***Comment***	***OF 6; OF 7***
Floodplain cultivation	(Commercial) cultivation of irrigated grapes on the upper terraces and floodplain pockets.	1.1
Flood attenuation	The wide channels and vegetated riparian zones attenuate large floods; albeit that the frequency of large floods themselves is greatly reduced due to upstream dams.	0.9
Bank protection	Well-established vegetation protects the bank and enhances flood attenuation	0.9
Groundwater recharge	No change expected in the recharge potential of the riparian aquifer	1.0
Waste assimilation	There will be a significant impact on water quality under Sc OF 6. Most water quality variables will be impacted, particularly salt and nutrient levels. Impacts on temperature and oxygen will also be severe due to the abstraction of flows and impact of upstream dams, and any toxicants in the system will be increased due to a drop in dilution capacity.	0.5
Waste dilution	As above.	0.5
Incidents of pathogens	Flows will be reduced so significantly that use of the river will be curtailed a lot of the time. Although parasite (e.g. schistosomatidae) infestations will be increased under slower flowing water, contact between parasites and humans will be reduced. However, the latter statement was removed from the equation and results reflect increases in parasite infestations under very slow-flowing water.	1.5
Pathogens treatments	Extensive treatment not required.	0.9

5.3.5 Summary of scenario impacts on lower Orange River

In summary, Sc OF 2 and OF 3 will have virtually no impact, while scenarios OF 6 and OF 7 will have marked impacts on virtually all of the ecosystem goods and services (Table 21, Figure 9).

Table 21. Summary of impacts on ecosystem services

Services	***Present value***	***OF 2; OF 3***	***OF 6; OF 7***
Harvested resources	Important for limited number of people.	1.0	0.8
Grazing	Important for limited number of people.	1.0	0.7
Recreational	Important for limited number of people.	1.0	0.9

Services	*Present value*	*OF 2; OF 3*	*OF 6; OF 7*
Nature-based tourism	Associated with Orange River and Park.	1.0	0.6
Water quality amelioration	Important with regard to upstream pollutants.	1.0	0.5
Pest control	Control of blackfly.	1.1	1.4

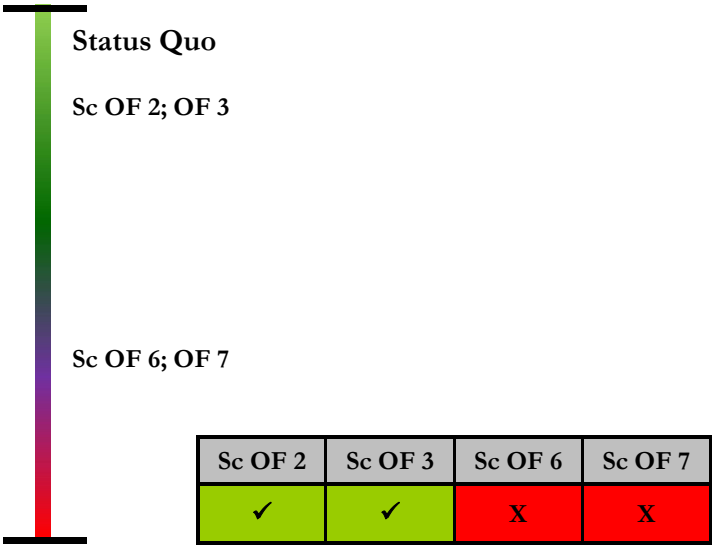

Figure 8 Diagrammatic representation of impact of scenarios on Orange River below confluence with the Fish River

5.4 Orange Estuary

The estuary is already heavily impacted by changes of flows, in that floods have decreased and low flows have been elevated significantly. The estuary was closed for periods under natural conditions, but remains open at present. In some years it was artificially breached to keep it open and the responsibility for this, and consequently breaching position, alternated between the Namibian and South African side. Under all the future scenarios there will be increased closure of the mouth, albeit to a greater extent than under natural conditions, due to reduction in flows during the low flow period. Scenarios OF 2, OF 3 and OF 4 represent a significant improvement on the present due to low flows being less elevated and increases in some floods, while Sc OF 6 and OF 7 will result in a drastic reduction in all flow ranges, with inflows being zero most of the time. In the latter scenarios there would be no resetting floods to scour out estuarine sediments.

The assessment of the impacts of scenarios on estuary services was based on the detailed assessment of the abiotic and biotic components of the estuary that was carried out as part of the estuary EFR assessment. These biophysical impacts are described in detail in the estuary report and a brief summary is presented here.

As was the case for the lower Orange River, it is difficult to distinguish Sc OF 2 and OF 3, and Sc OF 6 and OF 7 in terms of their impacts on ecosystem services. However, because predictions differed within these pairs for some biophysical elements, they are kept separate in this analysis.

5.4.1 Impacts on natural resources

Fish

Fish are presently considered to be only about half as abundant as under the reference condition. Under Sc OF 2, OF 3, and OF 5 they are expected to become slightly less abundant, whereas they become considerably less abundant under Sc OF 6 and OF 7. Abundance is similar to the present under Sc OF 4.

Plant resources

While the supratidal salt marsh area has been drastically reduced from its natural state, the habitats providing resources such as reeds and grazing are probably more abundant than they used to be. Plant communities are expected to remain fairly similar under Sc OF 2, OF 3 and OF 4. One would expect some dieback of intertidal salt marsh, reeds and sedges under Sc OF 2 and OF 3 as they are sensitive to prolonged mouth closure, and an expansion of reeds, sedges and intertidal salt marsh in the lower reaches under Sc OF 4. There would be a drastic decrease in vegetation areas and community composition under Sc OF 6 and OF 7. The mouth would close annually, inundating the intertidal salt marsh,reeds and sedges with saline water, causing die-back.

5.4.2 Impacts on cultural services

Because recreational value is largely derived from fishing, the predicted impacts on recreational value are based on the predicted impacts on fish abundance in the estuary. Scenarios OF 2 to OF 5 would have a relatively minor impact on recreational value, while Sc OF 6 and OF 7 could have a moderate impact.

Nature-based tourism, which is heavily dependent on the birds of the estuary, is expected to be unaffected by Sc OF 2 to OF 4. Slight negative impacts would be experienced under Sc OF 5, but Sc OF 6 and OF 7 could have a severe impact on the tourism value of the estuary, as a result of major losses of biodiversity.

5.4.3 Impacts on regulating services

Services such as water quality amelioration and the exports of nutrients would be significantly reduced under Sc OF 6 and OF 7, but their value is low to begin with, so these are minor impacts. The export of nutrients and sediment, whose values are unknown but possibly large, would be similarly impacted. The nursery and refuge function of the estuary would be reduced to some extent under Sc OF 2, OF 3 and OF 5, and would be moderately impacted under Sc OF 6 and OF 7. The latter would likely lead to measurable effects in the West Coast fisheries.

5.4.4 Summary

In summary, the impacts of Sc OF 2, OF 3 and OF 4 are relatively small, and the values involved are small. Indeed, Sc OF 4 has a negligible impact, if not even a slight improvement, on value. Impacts are slightly greater under Sc OF 5, and are significant under Sc OF 6 and 7. Because the value of sediment exports to the marine environment is unknown and could be high, the latter scenarios also pose an unacceptable level of risk. Assessment of the relative impacts of the scenarios area summarised in Table 22 and Figure 10.

Table 22. Summary of impacts on ecosystem services

Services/values	***Present value***	***Scenario***					
		OF 2	***OF 3***	***OF 4***	***OF 5***	***OF 6***	***OF 7***
Harvested resources	Negligible.	1.0	1.1	1.2	1.0	0.1	0.1
Grazing	Small herd supported.	1.0	1.0	1.0	1.0	1.1	1.1
Recreation	Moderate value.	0.8	0.9	1.0	0.8	0.7	0.7
Nature-based tourism	Small value in the order of <ZAR 1m.	1.0	1.0	1.1	0.8	0.3	0.3
Water quality amelioration	Negligible value.	1.0	1.0	1.0	0.8	0.5	0.5
Export of nutrients	Small localised value in inshore environments.	1.0	1.0	1.0	0.8	0.5	0.5
Export of sediments	Low value due to human influence.	1.0	1.0	1.0	0.8	0.5	0.5
Nursery function	Contributes about ZAR 7.5m of the value of WC fisheries.	0.8	0.9	1.0	0.8	0.7	0.7

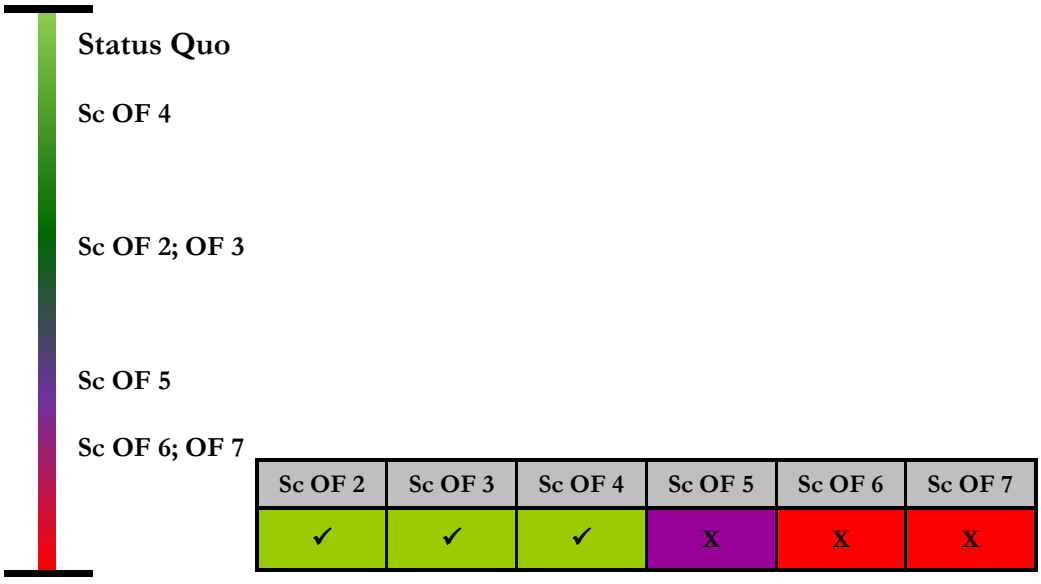

Figure 9. Diagrammatic representation of impact of scenarios on the Orange Estuary

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Appendix A Key sites visited to assess use of goods and services on the Fish River

South			*East*			*Place*
deg	*min*	*sec*	*deg*	*min*	*sec*	
27	28	38.9	17	28	51.2	Fish River Lodge farmhouse.
27	24	15.4	17	11	30.4	Konkiep low-level crossing.
28	5	36.1	17	10	23.2	Fish River bridge.
27	54	11.3	17	30	7	Ai-Ais pump station.
27	37	21.6	17	42	51.2	Spring at Hobas Campsite.
26	48	46.4	17	47	37.9	Sand mine at Seeheim.
26	27		17	48		Snyfontein.
26	33	13.4	17	46	40.3	Urusis Community Campsite.
26	14	58.2	17	48	9.2	Fish River low-level crossing between Snyfontein and Berseba.
25	55	8.2	17	56	24.3	Fish River crossing between Berseba and Tses.
25	9	4.9	17	43	0.4	//Khom!garib low-level crossing in Gibeon.
25	7	55.8	17	45	35.4	Low-level crossing below Hardap Dam.
24	39	20.3	17	56	5.4	River at bridge on C19 (road between Mariental and Maltahöhe.
24	29	53.6	17	52	10.8	Low-level crossing below Hardap Dam.

Appendix B Key stakeholders interviewed

Surname	*Name*	*Organisation*	*Position/interest*	*Place interviewed*	*Date*
Mazambani	Clarence	DRFN	REEDS Project: Community facilitation	Windhoek	11-Jun
!Ganeb	Lucky	DRFN	REEDS Project: Community facilitation	Windhoek	11-Jun
Thomas	Cedric	Snyfontein -- Councillor	Community member and traditional councillor	Windhoek	17-Jun
Haraseb	Ben	DEES, Keetmanshoop	Chief Extension Officer; Chairperson OFBMC	Keetmanshoop	18-Jun
Losper	Anton	DEES, Keetmanshoop	Extension Officer: Berseba	Keetmanshoop	18-Jun
Schnaitman	Ferdie	Farm Schlangkopf	Farm owner	Mariental	18-Jun
Dantu	Ralph	Fish River Lodge	Fish River Lodge Manager	Fish River Lodge	19-Jun
Mbaeua	Reagan	Fish River Lodge	Canyon Park Manager	Fish River Lodge	19-Jun
von Kashka	Otto	Gondwana Canyon Park	Canyon Roadhouse	Canyon Roadhouse	20-Jun
Witbooi	Max	MET, Hobas	Warden: Ai-Ais Park	Hobas Camp	20-Jun
Snyders	Franscois	NWR	Area Manager: Western and Southern Namibia	/Ai-/Ais Hot Springs Resort	20-Jun
Skrywer	Thomas	NWR	Deputy Manager: /Ai-/Ais Hot Springs Resort	/Ai-/Ais Hot Springs Resort	20-Jun
Luke		Lund Consulting	Engineer	/Ai-/Ais Hot Springs Resort	20-Jun
Christian		MET	Engineer	/Ai-/Ais Hot Springs Resort	20-Jun
Hendricks	Guido	NamWater	Technician: Ai-Ais	/Ai-/Ais Hot Springs Resort	20-Jun
April, Ms		Snyfontein school	Headmistress and community member	Snyfontein	21-Jun
Mekondjo		Mariental reeds craftsmen co-op	Chairperson	Windhoek	22-Jun
Hangue	Alma	Gibeon Constituency Council	Chairperson and teacher	Gibeon	22-Jun
Basson	Theresia	Hardap Regional Council	Director: Planning; OFBMC member	Telephone	Jun
Cooper	Trygve	Gondwana Canyon Park	Conservation Manager	Telephone	Jun