WATER RESOURCES MANAGEMENT PLAN FOR THE KUISEB BASIN

ENVIRONMENTAL ISSUES IN KUISEB BASIN PERTINENT TO RIVER BASIN MANAGEMENT

Ecology, Water Quality and Environmental Impact Assessments

Shirley Bethune
Ecology, Water Quality and Environmental Impact Assessment specialist
Wetlands Working Group of Namibia

1. INTRODUCTION

This narrative report explores the environmental issues pertinent to the management of the water resources of the Kuiseb Basin in terms of the general ecology of the Kuiseb River and its basin as well as water quality and pollution management. Current and potential environmental impacts as well as ecologically sensitive areas are identified as are gaps in existing information. The report is intended to inform the Kuiseb Basin Management Committee about our current understanding of the Kuiseb Basin environment to help them to better understand and manage the river basin they are responsible for and to help them think about and plan for future changes and threats. This narrative report is written in support of the Action Plans that make up the Water Resources Management Plan for the Kuiseb Basin, particularly Action Plan 3 Water Quality and Pollution Prevention Management.

Environment is a very broad concept encompassing a comprehensive and dynamic system of different, interdependent physical, ecological, social, economic and political components. For the purposes of this report on the environmental issues in the Kuiseb River Basin, it is used in a somewhat narrower way that focuses mainly on the bio-physical or ecological components.

All water resources are closely linked to the hydrological cycle and 24 hydrological basins can be identified in Namibia (Bittner & Dierkes 2004). One of these is the Kuiseb River Basin, which drains the Khomas Hochland Mountains near Windhoek. It continues westwards over the steep escarpment onto the Namib Desert plains, where it takes a southward loop before disappearing into the sand close to the Atlantic Ocean near Walvis Bay. Figure 1 on page 2 shows all the main hydrological basins in Namibia and their boundaries.

The new Water Resources Management Act 24 of 2004 makes provision for Basin Management Committees to manage each river basin. As it would be difficult to have committees for all 24 basins, experts have proposed to reduced these to eleven water management units. This was done using agreed criteria that take into account both surface and groundwater sources as well as present water transfer schemes, so combining the water source, water use and water users. Figure 2 on page 2 shows these proposed main basin management units, (Bittner & Dierkes 2004), one of which is the Kuiseb Basin under the care of the Kuiseb Basin Management Committee, KBMC.

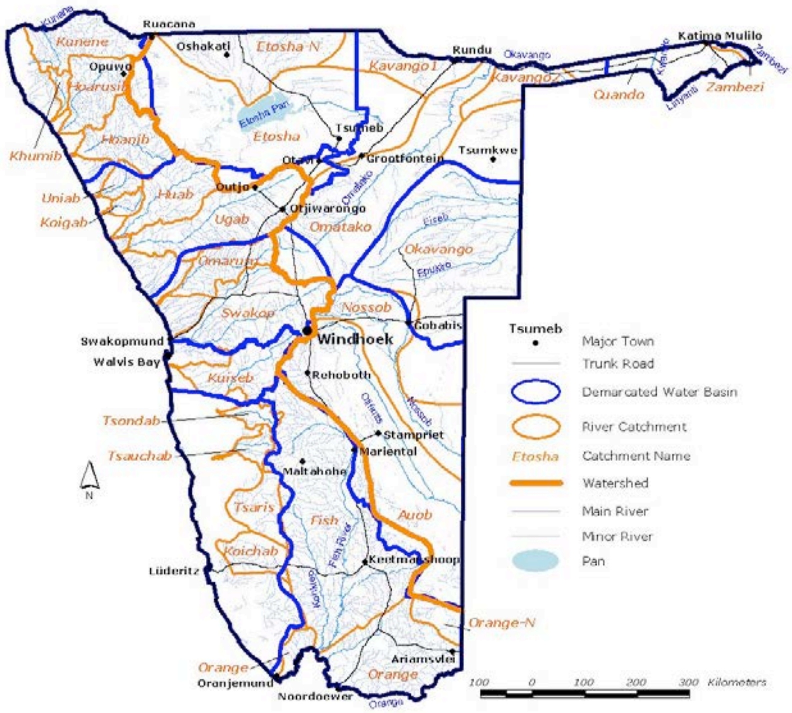

Figure 1. Map showing the hydrological river basins or catchments and proposed Basin Management Units within Namibia (Bittner & Dierkes 2004)

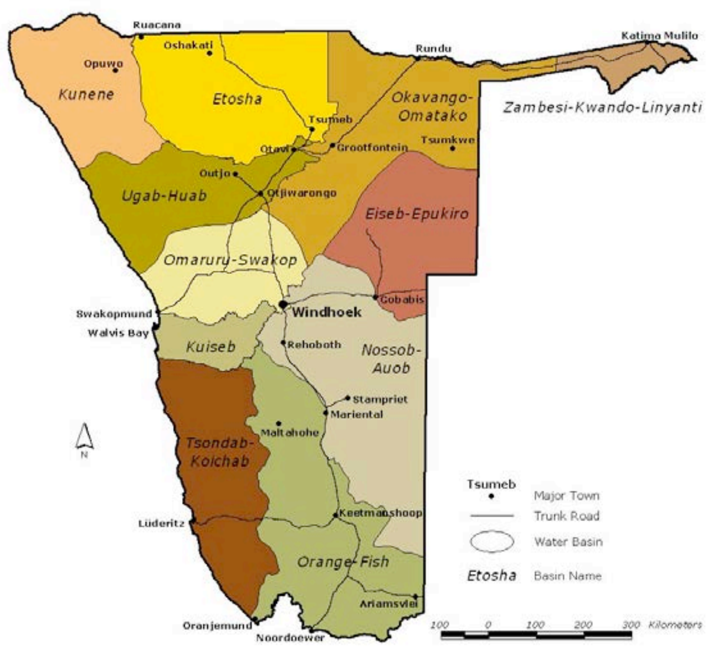

Figure 2. Proposed Basin Management Units (Bittner & Dierkes 2004)

1.1 Basin Management Committees and the Kuiseb Basin Management Committee

According to the new Water Resources Management Act, the aim of river basin management committees, like the Kuiseb Basin Management Committee, is integrated river basin management "to ensure equitable access to, and sustainable use of, water resources without detriment to the environment or functioning of the water cycle." (MAWF,2004). Such an integrated management approach takes the water resources, their uses, all users and their impacts into account. This integrated basin management approach is a community-centred, environmental approach that links people, water, land, plants, animals and the whole basin ecosystem, that aims "to ensure equitable access to and sustainable use of water resources; to decentralise water resources management to communities; to recognise the unity of the hydrological cycle and to encourage stakeholder participation in the management of our national water resources." (MAWF, 2004)

To devolve water resource management to the lowest appropriate level, the Water Resources Management Act makes provision for River Basin Management Committees that will allow stakeholders within each designated river basin to manage their own water resources. To date, two have been officially established and approved by the Minister. The first was the Kuiseb Basin Management Committee (KBMC) established in 2003 as a pilot example prior to the Act being passed (Botes *et al*. 2003, Manning and Pallett 2004). Since then the Ishana sub-basin Management Committee (IBMC) was established in the Cuvelai in 2005. Now several more, for the Omaruru, Okavango, Fish and Ugab rivers have been initiated. There are two active groundwater basin committees, one for the Karstveld aquifer and another for the Stampriet aquifer. Currently, the KBMC includes representatives from twelve different institutions: the Coastal Environmental Trust of Namibia CETN, the commercial and communal farmers, NamWater, Government service providers – DEES, DWAF, MET, RWS, the Erongo and Khomas regional councils, the Walvis Bay Municipality and the Gobabeb Research and Training Centre (Usurua 2008).

This new law states that the establishment of basin management committees can be initiated by Government or by interested persons. It further requires that: it should be an open and transparent process with the focus on hands-on management; the members should undertake to communicate with the communities they represent and that although their main task is advisory, their active support with data collection, water use monitoring, planning of water-related development activities and financing the committees is encouraged (MAWF, 2004, DRFN, undated).

1.2 Ephemeral rivers in Namibia

As shown in Figure 1, all Namibia's perennial rivers border on neighbouring countries, whilst the ephemeral rivers are within the country. Ephemeral means that they flow only in direct response to good rains, usually for a few days to a few weeks, and sometimes not for several years or in good rain years, they may flow several times (Bethune *et al.* 2008). These rivers, although dry, serve as "linear oases" in that they recharge groundwater and thus maintain a dense strip of riparian vegetation alongside the rivers in otherwise arid conditions (Heyns *et al.* 1998). This narrow strip of vegetation and good groundwater is essential to the health and productivity of the riparian vegetation and wildlife associated with these rivers as well as the survival of man and his livestock particularly where these rivers cross deserts and semi-arid areas (Jacobson *et al.* 1995, Seely *et.al* 2003). Good floods in these rivers are essential for the germination of plants and to recharge the alluvial aquifers. Often too many dams upstream can severely reduce these floods to the detriment of the downstream aquifers and riparian vegetation. Already there is evidence that reduced flooding in rivers such as the Swakop River, where the Von Bach and Swakoppoort dams often hold back all of the annual floods, trees like the Ana tree, *Faidherbia albida,* are dying. Scientists working on the Kuiseb River think that consistently less water reaches the Kuiseb Delta aquifers that sustain coastal towns and mines (Seely *et. al.* 2003).

1.3 The Kuiseb River Basin

The Kuiseb River is one of Namibia's twelve westward flowing ephemeral rivers. It links the wetter Khomas Hochland plateau, where most of the rainfall feeding the river occurs, to the dry coastal plains of the Central Namib. On its way it traverses through commercial farmlands in its upper reaches, through the Namib Naukluft Park where it keeps the extensive Namib Sand Sea at bay, past Gobabeb, home of the Gobabeb Research and Training Centre, and ten communal villages settled by the Topnaar people in the middle, to finally form the important alluvial aquifer at the Kuiseb Delta that supplies water to the city of Walvis Bay, other coastal towns and mines.

The Kuiseb Basin covers and area of 21 877 km^2 and can be divided into three sub-basin sections (Gardiner *et al. 2008*) as shown in Figure 3 below.

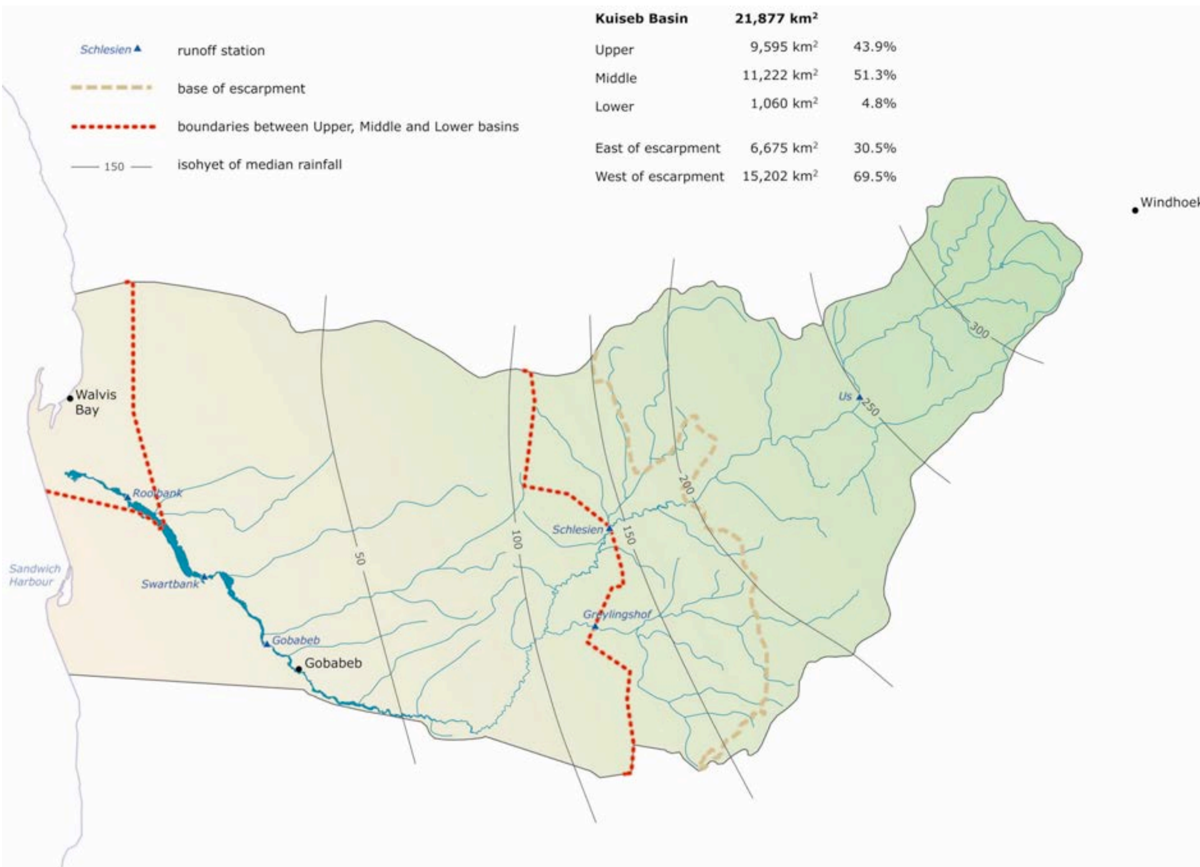

Figure 3. The Kuiseb Basin showing the Upper, Middle and Lower sub-basins. (Gardiner *et al.* 2006) Prepared by Carole Roberts for the Kuiseb Profile.

According to the latest information gathered for the Kuiseb Profile and used by Gardiner *et al*. (2006) for the WADE study, the Upper Kuiseb, covers an area of 9 995 km^2 coinciding roughly with the commercial farm land in the Khomas Hochland and extending to the bottom of the escarpment. The Middle Kuiseb covers a slightly larger area of 11 222 km^2. Its eastern edge is the Namib Naukluft Park border. In the south it follows the Kuiseb River to near Natab before cutting through the dunes to the sea to include the groundwater system beneath them. The Lower Kuiseb sub-basin covers 1 060 km^2 and includes the Kuiseb Delta area and the Kuiseb Water Supply scheme.

2. ENVIRONMENTAL ISSUES

To share information about the river amongst the diverse stakeholders in the Kuiseb Basin, the Desert Research Foundation of Namibia, DRFN, has started to compile information to produce a Kuiseb Basin Profile (Roberts, in prep.) It will outline the water and other natural resources of the basin and highlight current concerns such as the high water supply requirements of the new and proposed Uranium mines. It is strongly recommended that funding be found so that work on this can proceed and that new or pertinent information from the Water Resources Management Plan for the Kuiseb Basin reports be incorporated into the Kuiseb Profile as appropriate. Material collected and maps compiled for the Kuiseb Profile have already proved valuable to the international project to determine floodwater recharge of alluvial aquifers in dryland environments or WADE.

One of the documents produced for the WADE project (Gardiner *et.al.* 2006) on "*Site Characterisation for Kuiseb Riparian Ecosystems* " captures most of the pertinent information on the geography, climate, hydrology, riparian habitat and users of the Kuiseb Basin resources. As there is no point in repeating the contents of that report here, it is recommended that the KBMC request DRFN to obtain permission from WADE to print and bind copies of the WADE site characterisation report by Gardiner *et al*, (2006) to use as background information to the Kuiseb riparian ecosystems until the Kuiseb Profile is available.

2.1. General Ecology of the Kuiseb Basin

Useful background information on the ecology of the Kuiseb Basin is contained in several books and articles that have been published on Namibian water resources (Bethune, 1996, Heyns *et.al.* 1998,), Namibian wetlands (Shaw *et al* 2004, Shigwedha and Bethune, 2006, Bethune *et al.* 2008) and their biodiversity (Barnard *et. al* 1998, Curtis *et.al* 1998), on ephemeral rivers (Jacobson *et al.* 1995), on the Namib desert and its ecology (Louw and Seely, 1982, Huntley,1985, Seely, 1987), southern African deserts (Lovegrove 1993) and Namib plants (Craven and Marais 1986, Curtis and Mannheimer 2005). There are also now over 1000 scientific publications that refer to scientific studies undertaken at Gobabeb or by the Desert Research Foundation of Namibia. It is not within the scope of this report to review them. Instead some information on the ecology of the Kuiseb River Basin that may be useful to the KBMC to managing the water resources of the Kuiseb Basin is given, based mainly on the information analysed for the Kuiseb profile (Roberts in prep.)

Figure 4 on page 6 shows the five main landscapes that the Kuiseb Basin can be divided into, each supporting distinctly different types of plants as the river descends from the highlands to the coast. They are:

- The hilly, Khomas Hochland Plateau, where the altitude varies from 1, 700 – 2, 000 m, with typical highland savanna vegetation with trees such as *Combretum apiculatum* and *Acacia hereroensis* and good grazing grasses such as *Brachiaria nigropedata* (Muller, 1985)*;*
- The small section of the Rehoboth Plateau around Weissenfels, where the deeper sand supports a grassland savannah with camel thorn trees, *Acacia erioloba.*;
- The steep escarpment steeply descends 1000m to the coastal plains and is characterised by shallow soils supporting plants typical of the semi-desert savanna transition zone, *Ozoroa* and *Commiphora* species and the well known resurrection plant, *Myrothamnus flabellifolius.*
- The gravel desert plains with isolated Inselbergs, gradually descend westwards to the coast, here the river forms a 200m deep canyon for some of its length, rainfall is low and only a few desert adapted plants can survive, although the "inselbergs" support a greater diversity of life as they provide more habitats and receive more moisture from fog.
- The Namib sand sea of dunes south of the Kuiseb River supports virtually no vegetation.

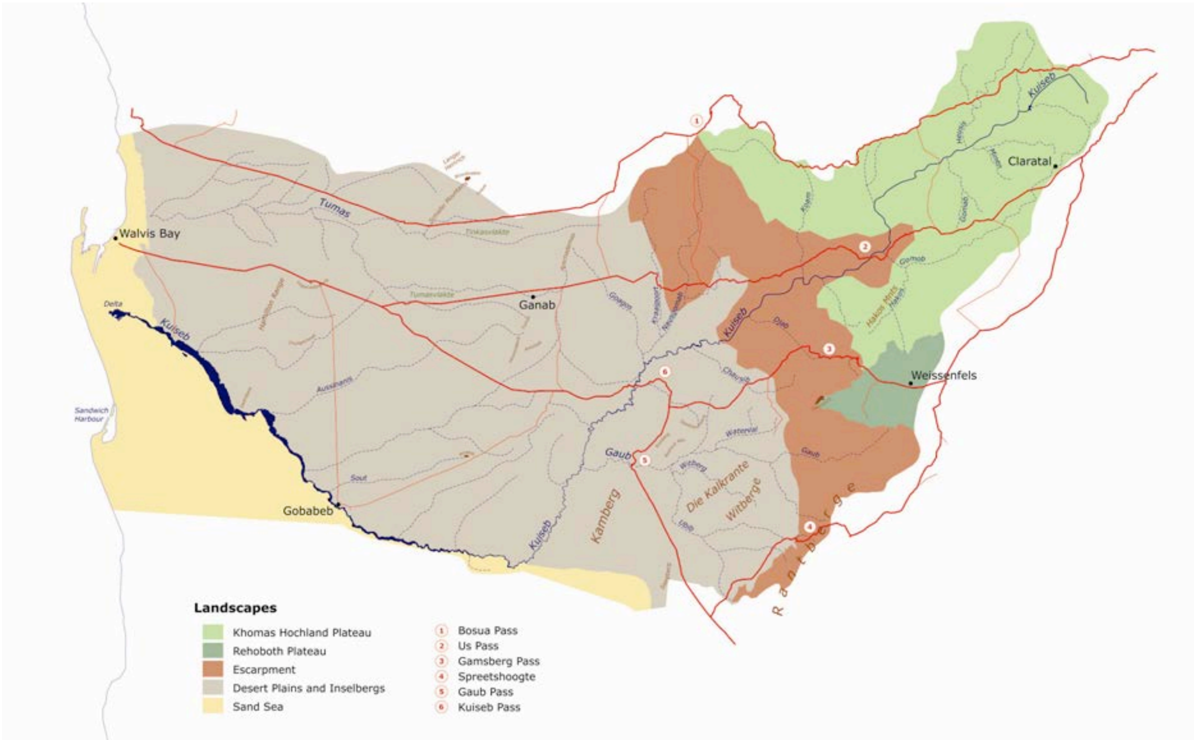

Figure 4. The five main landscapes within the Kuiseb Basin (Gardiner, 2006) adapted from Mendlesohn *et al.* 2002. Prepared by Carole Roberts for the Kuiseb Profile.

2.1.1 Khomas Hochland and Escarpment farms – ecology

The rolling topography of the Khomas Hochland provides many suitable sites for small, fairly deep farm dams, but the high erosion rates have caused many of these dams to silt up with time, they are also prone to break during flash floods. Most of the commercial farms are managed for beef production yet an increasing number are diversifying to include game farming and run guest farms that cater for hunters. Some farms nearer to Windhoek provide tourist accommodation and game viewing and several on the edge of the escarpment also cater for tourists offering exceptionally clear views of the night sky. A separate report on the impact of Agricultural land use has been prepared by Frank Wittneben and Patrik Klintenberg for the KBMC Water Resources Management Plan.

Friedenau Dam lies within this upper catchment area and is mainly used for recreation. It is of ecological importance because, unlike most dams, it has developed a fairly stable marginal zone, more typical of lakes than dams. The low demands on the water has kept the water level fairly stable and allowed plants more typical of natural lakes to become established around the edges. The water is also very clear allowing good visibility of the aquatic plants and fish and its depth allows good practical demonstrations of limnological field techniques. All this makes it an ideal field site for teaching aquatic ecology. It is regularly used by the Polytechnic of Namibia for practical aquatic ecology classes and for five years was used a site for the SADC/UNAM Fisheries Management training course and until recently as a Youth Centre. It is recommended that the KBMC make NamWater aware of the ecological and educational value of Friedenau Dam and that it should not ever be used as a short-term emergency water supply as rapid draw-down will kill the marginal shallows that have taken several decades to become established and will dry out the nesting sites of the bass that inhabit the dam.

2.1. 2 The Kuiseb River as an linear Oasis

One of the major management challenges is to manage dams in the upper catchment of ephemeral rivers. Too large or too many dams reduces the quantity and frequency of downstream water flows. Even though the team of SDP students (Dausab *et al.* 1994) did not rate the impact of the over 400 farm dams at the time as significant to downstream flow. It would be important to re-evaluate this finding in the light of new research by the WADE group that shows that it is particularly the medium and large floods, with a depth of at least 15 – 20 cm that recharge the delta aquifer. One would assume that over 500 farm dams in the upper catchment would reduce both the magnitude and frequency of such flows to the detriment of the delta aquifers. Aquifer recharge is not only important for water supply but ecologically this provides the water that sustains the riparian woodlands typical of our ephemeral rivers and provides the seeps that allow wildlife to survive in the desert. Many animals rely on groundwater shallow enough to be reached by digging.

The flood dynamics of ephemeral rivers has been well described by Jacobson *et.al* (1995) and Barnard *et al.* (1998). Essentially summer thundershowers in the upper catchment cause runoff into the rivers. The amount of runoff generated is dependent on the intensity and duration of the rain, the soil type and compaction, vegetation cover and evaporation rates. In the highland areas this runoff is turbulent, turbid and rapid, often occurring as flash floods. The duration and distance of flow varies and can be altered by retention in farm dams. All along the distance of the flow, some of the water infiltrates into the river sand or alluviums and it is this water that supports the riparian trees and recharges the boreholes in and close to the river. The water also forms temporary pools in deeper or shaded sections of the river and where the groundwater is shallow seeps may feed these pools. These are essential to the wildlife living in and near the river. It is not only water that is transported downstream by these floods but also nutrients, silt, seeds and debris, all important to the productivity of the river downstream and to plant recruitment. For much of its length the Kuiseb River also has the ecological function of scouring the river bed and stopping dune encroachment. This ecological process sustains a narrow band of vegetation all along the river that is referred to as a linear oasis, because it provides a long narrow line of water, shelter and food to desert organisms and to man.

Trees typical of these linear oasis, are *Faidherbia albida*, the Ana-tree, *Combretum imberbe,* the leadwood tree, *Acacia erioloba*, the camelthorn, *Ziziphus mucronata*, the buffalo thorn, *Salvadora persica,* the mustard bush and *Tamarix usneoides*, the wild tamarix (Curtis and Mannheimer, 2005). Also dependent on the infrequent flows of the Kuiseb River is the !Nara bush, *Acanthosicyos horridus,* that has sustained the Topnaar people living in the Namib for hundreds of years. This riparian vegetation is extremely important to people and wildlife living alongside the river, in fact the pods, shade, shelter, wood and fodder they provide allow their survival in an otherwise hostile environment. A 1996 it was estimated that there were some 10 000 Ana-trees in the lower Ugab River, each tree can produce 10 – 50 kg of pods/year, some large trees producing over 150 kg and that the pods from a single tree was worth N$ 200 then as fodder. As *Faidherbia* is a legume, these trees also fix nitrogen and so improve soil fertility. Should the flow in these rivers be held back by dams, new trees would not germinate, groundwater would not be recharged, productivity would decline, there wood be less fodder and fewer pods for livestock. Of ecological concern is the growing number of alien invasive plants also supported by these linear oasis. Typical species found alongside the Kuiseb River are, *Prosopis glandulosa,* the mesquite from central America, *Ricinus communis*, the castor oil bush with dense stands near Gobabeb, *Nicotiana glauca*, wild tobacco and a variety of Thorn apples or *Datura* species (Bethune *et. al* 2004, Henderson 1995, Brown *et al.* 1985). In South Africa the working for Water programme has successfully improved groundwater resources by removing alien invasive trees. At Okombahe youth are involved in a IWRM project harvesting *Prosopis* trees both to improve groundwater levels and to provide employment and an income from selling the charcoal, poles and planks made from the wood.

2.1.3 Protected areas Namib Naukluft Park and conservancies

The northern section of the Namib Naukluft National Park is a century old and the entire park now covers an area of 50 000 km^2 making it the third largest in Africa. Until recently it was the only national park that had people living inside it. There are ten Topnaar villages alongside the Kuiseb River as well as the Gobabeb Training and Research Centre originally established as the Namib Desert Research Station in 1962. The park is home to a diversity of well-studied desert adapted plants and animals (Friends of the Namib 2007). Because they live within the park, the Topnaar community have not been able to join the 50 other Namibian communities that have set up communal conservancies to benefit from their wildlife (NACSO, 2007).

2.1.4 Coastal wetlands of international biodiversity importance

As a signatory to the Ramsar Convention, Namibia is committed to the conservation of its internationally important wetlands (Kolberg undated). The main aims of the convention are to prevent the loss and degradation of wetlands worldwide and to ensure that they are used wisely and sustainably, while conserving their biodiversity values and ecosystem services. Namibia acceded to the convention in December 1995 designating the Walvis Bay wetlands, Sandwich Harbour, the Orange River Mouth and Etosha Pan as its first four Ramsar sites (Shaw *et al.*2004, Bethune *et al.* 2008, Kolberg & Kolberg undated). The Walvis Bay and Sandwich Harbour wetlands are both within the Kuiseb Basin. These wetlands are thus important to the KBMC who should continue to co-operate closely with the Coastal Environmental Trust of Namibia, CETN, to conserve and wisely manage these internationally important wetlands. The Walvis Bay wetlands include the lagoon, supporting for than 40 wetland bird species as well as mudflats, shore, salt pans and sewage works. Together they support 70 000 – 100 000 birds in winter and up to 250 000 when the migrants return in spring (Bethune *et.al* 2008). Unfortunately the Walvis Bay wetlands do not yet have any official protective status. The Sandwich Harbour wetland, that supports some 4 000 – 5 000 birds of 37 different species is fortunately protected within the Namib Naukluft Park. The KBMC should lobby MET to have the Walvis Bay wetland, which is increasingly threatened by coastal development, officially proclaimed as a protected area.

2.1.5 Archaeology of the Kuiseb River Basin

The Kuiseb Basin is one of the most important archaeological environments in the country. The entire archaeological sequence is represented, from terminal Pleistocene artefact-scatters associated with pans along the lower reaches of the river, to evidence of the contact period, which in the especially isolated example of Nambia, began in the late 18th century and continued into the early 20th century (Jill Kinahan, pers. comm.. 2008).

The sequence of archaeological sites in the Kuiseb Delta yields uninterrupted evidence of the early acquisition of pottery in the 4th century AD, to the indigenous response to contact arising from the global spread of Western commerce. The Kuiseb Delta is unique in that the limited growth and development of Walvis Bay over an extended period, along with the difficulty of access to the dunefields has preserved archaeological evidence whereas, in other parts of southern Africa, and indeed the world, this evidence long disappeared under the foundations of cities which grew fast at the trading entrepôts of the coast. On private farmland in the upper reaches of the Kuiseb Basin, archaeological sites are significant for evidence of both pre-colonial and historic copper-working. Indigeous copper-working inland produced beads that passed through networks of trade and alliance down to the coast, and are found on contact sites in association with the glass trade beads of Europe (Jill Kinahan, pers. comm. 2008.). For more detail please see the separate specialist report by J. and J. Kinahan, *Archaeology of the Khuiseb River Basin* and the map they compiled which show the sensitivity of different areas in the basin and includes a comprehensive bibliography of published and unpublished sources.

2.2 Water Quality

As elsewhere, water quality in Namibia depends on both natural factors, such as the chemical composition and solubility of rocks, the gradient and vegetation of the catchment area, as well as rainfall, water temperatures and decomposition of debris and man-made factors such as pollutants or contaminants from domestic and agricultural waste or runoff, mine and factory effluents and fuel leaks or spills (Tarr and National Water Awareness Campaign 2002, Roberts *et al.* 2007).

2.2.1 Water Quality Requirements

The drinking water quality guidelines (NamWater 2008, DWA Undated), are based on requirements set out in the old Water Act, No 54 of 1956, and classify drinking water into 4 classes:

- Class A – excellent,
- Class B- good or acceptable,
- Class C- low health risk, not yet critical but should receive attention
- Class D- a higher health risk, or unsuitable for human consumption – needs urgent attention

These are currently being revised and will form part of the new regulations under the new Water Resources Management Act No 24 of 2004. However, given that the health issues associated with the concentrations of different chemicals in the water do not change with time, the guidelines should not be considered in any way inappropriate as they provide a sound indication of water quality. Throughout this discussion, the water chemistry measurements collected are related to these guideline limits and the four classes of drinking water. (See Annexure 1:The NamWater Guidelines).

The concentration of Total Dissolved Solids, TDS, provides a good indication of the concentration of chemicals e.g. Calcium, Magnesium, Sodium, Nitrates, Sulphates and Fluorides dissolved in the water i.e. its mineral content. Generally, the lower the TDS concentration is, the purer the water. Rainwater and thus the water flowing into our rivers have a relatively low TDS. But, as water is a universal solvent, minerals contained in the soil and surrounding rock slowly leach into the water and in some places such as the Karstveld, this causes extremely high TDS values. Drinking water should have a TDS lower than 2 000 mg/ℓ, whilst it is safe to use water with a higher TDS for stockwatering.

Although there are no legal chemical concentration limits for Stockwatering, the NamWater guidelines include a table for these. See Table 4 in Annexure 1. These limits for livestock are all well beyond the range of groundwater concentrations found in the Kuiseb River Basin e.g. the TDS limit is 6 000 mg/ℓ. Although NamWater sets this upper limit of 6 000 mg/ℓ for stockwatering, it is better to be cautious and follow the advice of the groundwater quality map given in the *Atlas of Namibia* (Mendelsohn *et al.* 2002) that highlights areas with a TDS above 5 000 mg/ℓ as unusable even for livestock. In due course, water quality requirements will also be developed for wastewater, water re-use and irrigation water (Cynthia Ortmann pers.comm 2008).

2.2.2 Groundwater Quality in the Kuiseb Basin

Most of the water used in the Kuiseb Basin is groundwater. Groundwater quality is largely determined by the underlying geology of the catchment, as different amounts and proportions of minerals from the rocks and soils leach into the water flowing over, or percolating through, them (Davies and Day 1998). Within the Kuiseb Basin the groundwater is generally considered to be suitable for drinking.

The groundwater quality map included in the *Atlas for Namibia* (Mendelsohn *et al.* 2002) shows that most of the Kuiseb Basin has potable quality groundwater, i.e. suitable for drinking and domestic use.

Some higher TDS concentrations of 2 000 – 2 600 mg/ℓ are found closer to the escarpment and at one site in the lower Kuiseb (possibly Gobabeb or Klipneus). It also shows that for much of the middle Kuiseb there was no data and cautions that there is much variation at a more local scale.
The earliest national water quality maps are the 1982 set of four national groundwater quality maps, one each for TDS, Flouride, Sulphate and Nitrate-Nitrogen. These were derived from detailed surveys conducted by the Council for Scientific and Industrial Research, CSIR, during the 1970s. Unfortunately the data on which these maps are based seems no longer to be available and are unlikely to be in digital format. Although these maps cover the entire country some areas were not surveyed. Within the Kuiseb River Basin, the survey covered the entire upper commercial farmland area, and then a section along the Kuiseb River from Gobabeb to Urusus and a strip alluvial aquifer between Dorob southwards to Sandwich harbour following this branch of the alluvial aquifer.

Based on visual inspection of the maps that are on display at the Division Water Environment, TDS concentrations in the groundwater, in the upper catchment ranges from below 1000 mg/ℓ increasing up between 1000 – 2000 mg/ℓ at some sites along the escarpment. Between Gobabeb and Urusus, TDS values are again less than 1000 mg/ℓ with the exception of around Klipneus where the map indicates a TDS of 2000 – 3000 mg/ℓ. TDS varies greatly in the section between Dorob and Sandwich Harbour with values in the extreme south exceeding 10 000 mg/ℓ.

The Flouride map shows mainly low concentrations within the basin, lower than 1 mg/ℓ in most of the upper catchment and in the desert (Class A -excellent), with a few pockets in the upper catchment having concentrations between 1 and 2 mg/ℓ (Class B – good) and isolated cases between 2 – 3 mg/ℓ. (Class C – low health risk. A concentration of about 1 mg/ℓ is considered beneficial to prevent tooth decay and is sometimes added to drinking water where natural concentrations are low.
Sulphate concentrations shown are mostly below 250 mg/ℓ (Class A – excellent) although west of Dorob this increases 500 – 1000 mg/ℓ and in patches to 1000 – 2000 mg/ℓ (Class C – low health risk) Nitrate levels are shown as 0 – 20 mg/ℓ throughout the basin
(< 10 =Class A - excellent, 10 – 20 Class B- good).

Blom and Bouwer (1985), monitored TDS levels in a series of boreholes along the Kuiseb River between Narabeb and the Sout River confluence, and compiled a Kuiseb River regional ground water quality map dated March 1982, showing TDS concentrations measured as ppm (parts per million) , for the area from Klipneus to the sea. Up to Rooibank and then along the river to Swartbank the concentrations are below 600 ppm but westwards beyond Rooibank and south of the river the water quality decreases to TDS values between 600 and 2000 ppm, with the most saline groundwater found as expected closest to the sea – 2000 - >6000 ppm. However, they found no evidence that the inferior water quality entering the production boreholes. High TDS near one of the Swartbank recorders was explained by excessive salt concentrations due to evaporation from an open pan nearby. (See the map in Figure 5 on page 9 to locate Swartbank and Rooibank)

A more recent detailed study of groundwater quality in the lower Kuiseb, undertaken as part of the BGR investigation in 1993/94 (BGR 1995), confirms that, the water quality in the alluvial aquifer is better than elsewhere in the basin and most saline near the coast. They report TDS levels of up to 500 mg/ℓ in the river floodwater and average TDS levels of 600 mg/ℓ at Swartbank, 950 mg/ℓ at Rooibank A and 1 450 mg/ℓ at Klipneus. Marked variations in groundwater quality provide evidence that his aquifer is more likely to be discontinuous than continuous.

Water Quality records obtained from the NamWater database, were studied for this report. The Kuiseb record covers the last decade, from late 1997- 2008 and includes some 475 samples each analysed for 22 different water chemistry parameters. The record covers mainly the production boreholes at Swartbank (max. 20 boreholes), Rooibank A (max. 8), Rooibank B (max. 8) and Dorop South (max. 10 boreholes) as well as the reservoirs at Rooikop Airport and Mile 7. Figure 5 on page 11 shows the location of these sites.

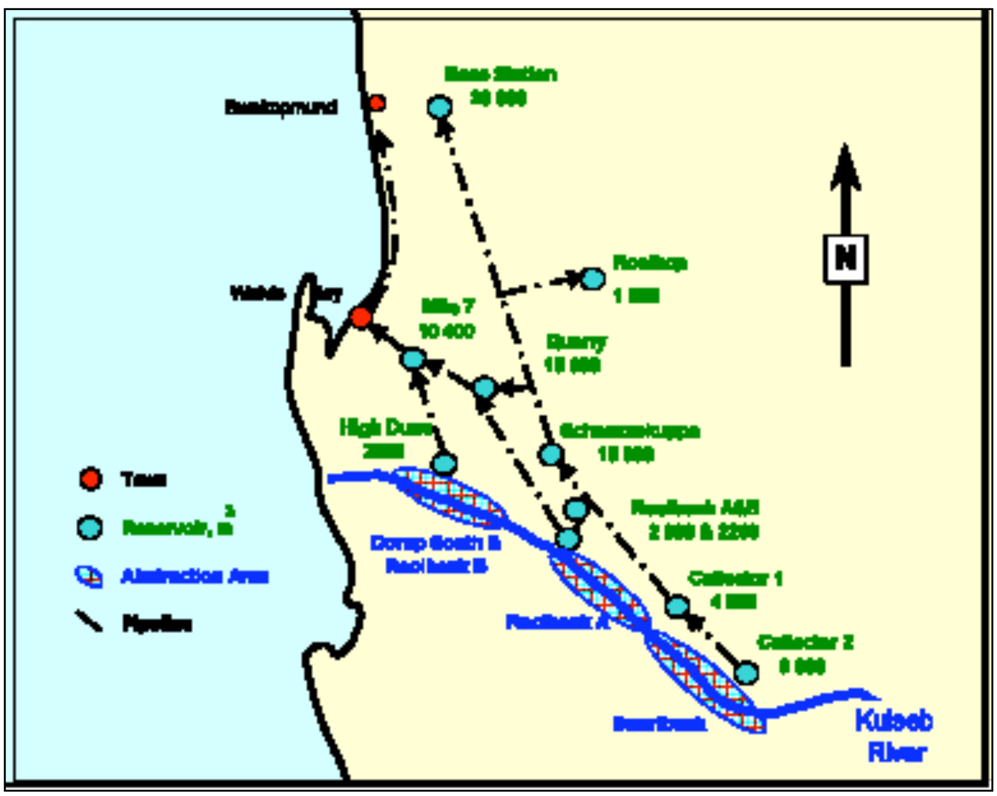

Figure 5. Schematic map of the Kuiseb Water Scheme from Heyns (2008)

According to the Water Resources Management Plan for the Kuiseb Basin report by Heyns (2008) on water planning and use, the Kuiseb Water Scheme consists of the Lower Kuiseb Aquifers and all bulk water infrastructure up to and including the Mile 7 reservoirs near Walvis Bay and the terminal reservoir at Swakopmund. The green numbers refer to the capacity of each reservoir in m^3.

NamWaters' frequency of sampling varied but was usually twice a year for the boreholes and the reservoirs. No samples were analysed from Rooibank A and Dorop S after December 2005 or from Rooibank B and Swartbank after December 2006. The reservoirs were sampled twice a year until 2006 and quarterly after that, possibly because regular sampling of the individual boreholes had been discontinued. Also included were ad hoc analysis for "Kuiseb flood water" (Feb 05), borehole No 10012 in the "Kuiseb area' (5 – 12 April) and Walvis Bay town (May 07) presumably in response to perceived problems. Although time did not allow for any statistical analysis of the data some conclusions could be made. See Table 1 on page 12. It sums up these main preliminary findings.
As can be seen in Table 1, the water quality of the boreholes in the lower Kuiseb and the reservoirs where this water is collected is usually either excellent (Class A) or good (Class B) for all the paramenters tested. Occasionally, in the drier years, this can deteriorate to Class C particularly for those chemicals associated with hard water. By comparing the analysis results over the decade monitored by NamWater there is no evidence of salinisation or sea water intrusion even at Dorop South. Changes are more likely to simply be concentration of salts in the drier years when there is no or little recharge and dilution following major flood events. This was confirmed in discussion with the water chemist at NamWater (Merylinda Conradie pers.comm. 2008). The State of the *Environment Report on Water in Namibia* (WET, 1999) recommended that NamWater analyse groundwater samples from "sentinel boreholes" at the end of the dry season each year to detect changes in groundwater salinity/TDS. This is been done twice a year for the Kuiseb delta aquifers.

Table 1. Water Chemistry of Kuiseb Aquifer boreholes based on NamWater samples 1998 – 2006 and for the reservoirs at Rooikop and Mile 7 1997 – 2008 for parameters included in the drinking water guideline. (no class limits for TDS, alkalinity, silicate SiO_2 nor Nitrite NO_2 – N)

CHEMICAL PARAMETER	MAIN TREND	QUALITY COMMENT
pH	7.7 – 8.8	6 – 9 = Class A – excellent
Colour mg/ℓ platinum units	< 20 , few up to 24	< 20 = Class A – excellent
Turbidity Nephelometric turbidity units NTU	< 1, Dorop S up to 10 Swartbank 25 in June 02	< 1 = Class A – excellent 1-5 Class B, 5 – 10 Class C
Conductivity mS/m 25° C	Usually 50 – 150, 140 – 190 Dec 05 Dorop S, and Jan 05 Rooibank A 374 Rooibank A Dec 05	Class A – excellent Class B (up to 300) – good Class C – low health risk
Sodium Na^+ mg/ℓ	Usually below 100 Dorob S often 170 – 205 Rooibank once 340 + 363	Class A – excellent Class B – (100 – 400) good
Potassium K^+ mg/ℓ	9 – 29	Class A (up to 200) – excellent
Calcium Ca^{++} mg/ℓ as $CaCO_3$	Mostly 90 – 300 Rooibank A once 500 Rooibank A once 577	Class A (up to 375) – excellent Class B (up to 500) - good Class C (up to 1000) – low risk
Magnesium Mg^{++} mg/ℓ as $CaCO_3$	Mostly < 70 Dorop S up to 160	Class A (up to 390)- excellent

Sulphate $SO_4^=$ mg/l	Usually below 200 but can be to 600	Class A (up to 200) – excellent Class B (up to 600) – good
Nitrate NO_3 – N mg/l	Mostly below 10 Occasionally up to 20	Class A – excellent Class B – good
Flouride F mg/l	Usually 0.1 – 0.2, Once 0.3	Class A (up to 1.5) – excellent Class B (1.5 to 2) – good Class C (2 – 3) – low risk
Chloride Cl mg/l	Usually 50 – 200 Dorob S occasionally 300 +	Class A (up to 250) – excellent Class B (250 – 600) – good
Iron Fe mg/l	Usually less than O.1 mg/l Occasionally up to 0.96	Class A (< 100 µg/l = 0.1 mg/l Class B 100 –1000 µg/l = 1mg/l
Manganese Mg µg/l	Mostly only traces < 10 µg/l Occasionally up to 46	Class A (1 – 50 µg/l) Class B (50 – 1000 µg/l)
Copper Cu µg/l	Usually only traces, but up to 0.03 mg/l = 300 µg/l	Class A (< 500 µg/l) excellent
Zinc Zn mg/l	Usually below O.1 mg/l	Class A (< 1 mg/l)
Cadmium mg/l	Undetectable < 0.01 mg/l	Class A (< 10 µg/l= 0.01 mg/l
Lead Pb mg/l	Undetectable < 0.02 mg/l	Class A (< 50 µg/l=*0.05* mg/l)

As no water quality database yet exists at the Department of Water Affairs only a few records of water analysis for the Kuiseb River could be found and all for the period 2001 – 2005, mostly related to particular problems, half of them were for sewage water analysis. One was for drinking water at Walvis Bay (March 01) finding that it was of good quality. Two dealt with boreholes at Swartbank, which in March 2002 were unacceptably saline with a Conductivity of 466 mS/m equivalent to a TDS of over 3000 mg/l, a Chloride concentration of 1050 mg/l (Class low risk), and Calcium and Magnesium concentrations of 500 mg/l and 375 mg/l respectively, that were within the Class B or good/acceptable/range. The second Swartbank analysis 4 years later showed that the water quality had improved and was considered good.

The only other analysis were two drinking water samples taken at Gobabeb in November 2004, showing that at that time the hardness of the water classified it as Class C, with an overall conductivity of 340 mg/ℓ and concentrations of Sulphate (350 mg/ℓ), Chloride (650 mg/ℓ) and Sodium (450 mg/ℓ) just beyond the allowable range for Class B. The main problem identified was scaling. Although no recent records were found, one can safely assume that the excellent recharge since then has improved the water quality at Gobabeb to at least, the more acceptable Class B.

2.2.3 Surface water quality in the Kuiseb Basin

Surface water quality is determined by the geology and vegetation cover of the catchment area and in the case of water stored in an impoundment, by the physical, chemical and biological reactions in the dam, particularly to stratification patterns. The only major surface water impoundment on the Kuiseb River is Friedenau Dam, close to Windhoek, originally built to supply water to the Matchless Copper Mine and now used mainly for recreation and to supply water to some nearby farms and the school at Baumgartsbrun.

According to a DRFN report there were some 109 commercial farms with 407 farm dams in the upper Kuiseb catchment in 1994 (Dausab *et al.* 1994), Roberts (in prep) has since revised this based on aerial photographs and estimates that there are 503 dams with storage capacities ranging from 94 m^3 to 59 000 m^3. The Hydrology Division of the Department of Water Affairs and Forestry is planning to conduct a detailed survey to assess the numbers and sizes of all farm dams.

There are no water quality analyses available for any of these farm dams but they can be expected to hold good quality water during the rainy seasons and in the months following, and for chemical concentrations to gradually increase as the dams dry out due to evaporation. Renewed inflows will again dilute this. Due to the high turbidity associated with most river floods, the water is expected to be turbid immediately following inflows, but results from the larger impoundments show that this usually settled out within the first fortnight (own observation). As these dams are often used for both human and livestock, care should be taken to avoid contamination by dung. Shallow dams heavily utilized by livestock tend to become increasingly eutrophic due to this as they dry out.

No water quality data could be found for Friedenau Dam, but it is expected to be similar to that of the other dams nearby. Detailed studies of Swakoppoort, Von Bach, Omatako and Oanob dams reveal good quality water with the expected fluctuations of dilution with rain and concentration due to evaporation in the dry season (Bethune, 1992 and Schachtschneider 1997). Temporary high nutrient levels and often algal blooms followed the breakdown of stratication at the end of summer and the return of warmer temperature in spring. Table 2 on page 14 gives the range of water quality parameters for Von Bach, Swakoppoort and Oanob.

Assuming that the climatic and geological factors for Friedenau or any future large impoundment in the upper Kuiseb catchment will be similar to these three nearby dams, the water quality is expected to be as good. The maximum conductivities and chemicals concentrations were measured during extremely dry years when water levels in the dams were very low and can be considered exceptions. Based on the drinking water quality guidelines used by both NamWater and the Department of Water Affairs and Forestry (Namwater 2008, DWA, undated) still based on the requirements of the Water Act No 54 of 1956, the water chemistry of these dams would classify the water as Class A – excellent i.e. having a pH between 6 and 9 (excellent), Chloride well below 250 mg/ℓ (excellent), Sodium well below 100 mg/ℓ (excellent), Potassium below 200 mg/ℓ (excellent), Sulphate well below 200 mg/ℓ (excellent), Calcium well below 375 mg/ℓ (Excellent) and Magnesium well below mg/ℓ 290. The conductivity and TDS levels tend towards Class B – water of good / acceptable drinking quality i.e. the dam water conductivity is usually below 300 µS/cm , although in dry years this can be even higher shifting to Class C, suggesting a temporary low health risk.

Table 2: Comparison of water chemistry ranges in Von Bach and Swakoppoort dams (1987 – 1996) and Oanob Dam (1992 – 1996) based on Bethune, 1992 & Schachtschnieder, 1997.

CHEMICAL	VON BACH DAM	SWAKOPPOORT DAM	OANOB DAM *
CONDUCTIVITY µS/cm	117 – 315	202 -580	141 – 264
TDS mg/ℓ	73 – 209	200 – 425	93 – 174
Total alkalinity mg/ ℓ	57 – 139	99 – 215	62 – 130
pH	6.9 – 8.3	6.9 – 8.8	6.9 -8.3
Cl^- mg/ ℓ	0.5 – 15	8 – 46	0.5 – 9
Na^+ mg/ ℓ	1 – 18	5.5 – 64	< 1 – 20
K^+ mg/ ℓ	5 – 14.5	7.6 – 31	5 – 12.8
$SO_4^=$ mg/ ℓ	< 1 – 20	<1 – 35	<1 – 17.5
Ca^{++} mg/ ℓ *as $CaCO_3$*	37 – 76	48 – 90	45 – 93.5
Mg^{++} mg/ ℓ *as $CaCO_3$*	12 – 39	15 – 59.5	15 – 25
SiO_2 mg/ ℓ	< 0.5 – 6.5	< 0.5 – 8	0.5 – 9

2.3 Potential Water Pollution

The main concern is potential groundwater pollution particularly from the new Uranium mines.
One of the impacts identified in scoping meetings and reports on the possible impacts of the current surge in exploration for Uranium in the area is groundwater contamination particularly from accidental seepage from the tailings dams (Swiegers, 2008, Pallet, 2008, Kohrs 2008). It is recommended that in addition to each mine carefully monitoring any contamination of the groundwater downstream of their operations a joint environmental monitoring programme for all mining and associated development activities be implemented by an independent authority to regularly check and control these impacts (Kohrs, 2008). The KBMC, as representative of all the stakeholders in the Kuiseb Basin could take the lead and possibly appoint an organisation within the basin such as the GTRC to co-ordinate such

a long-term monitoring programme and keep the stakeholders informed of the results though KBMC meetings.

2.3.1 Prevention of water pollution:

The Division Water Environment within Water Affairs in the Ministry of Agriculture, Water and Forestry is legally responsible for the control of water pollution and they exercise this control through issuing waste water and effluent disposal exemption permits. All water users engaged in any activity that produces waste water is required by law to apply to the Water Environment Division for exemption to dispose of this wastewater or effluent. The permit conditions specific to each case control the safe disposal of this waste water. The application involves completing a standard form requesting technical information pertinent to the water use and activity that produces the waste water and usually a limited period permit for one year is granted pending the gathering of all the necessary information (Gracy Tshipo, pers.comm. 2008).

Once this information is submitted, it is forwarded to both the Ministry of Health and Social Welfare and to the relevant ministry that deals with the particular activity e.g. the Ministry of Mines and Energy for mining activities, the Ministry of Fisheries and Marine Resources for fish factories and the Ministry of Environment and Tourism for lodges, to allow comments from the affected stakeholders, a necessary step until the new Environmental Management Act 27 of 2007 is fully implemented. Their comments are incorporated into the particular set of conditions that the applicant will need to meet to insure safe disposal of effluent. These conditions are intended to protect the environment, specifically water resources from pollution. A permit is valid for 5 years.
Pollution officers from the Water Environment Division monitor the waste water disposal sites to ensure compliance with the conditions set. Each officer is in charge of particular regions, for example, Ms Gracy Tshipo, is responsible for the Erongo, Khomas and Omahake regions, thus the Kuiseb Basin falls under her. She expressed a particular interest in attending Kuiseb Basin Management Committee meetings and felt that the pollution officer responsible should be represented as an important stakeholder on the relevant basin management committee or at least the broader stakeholder forum. The pollution control officers are also responsible for investigating any complaints from any affected stakeholder. Of concern is that very few applications for waste water and effluent disposal exemption are received, for example not one has yet been issued to anyone in Walvis Bay and none of the Guest farms in the Kuiseb basin have one. Schools too need permits and one has been issued to Baumgartsbrunn School. The existing and new uranium mines on the other hand are working closely with Water Affairs to monitor their effluents and to prevent groundwater contamination (Gracy Tshipo pers.comm. 2008)

Once the Environmental Management Act No 7 of 2007 is fully implemented, the environmental clearance certificate that allows a listed activity to go ahead will be an essential requirement for the application of a wastewater and effluent disposal exemption permits. It will show that the necessary scoping of affected stakeholders has been complied with during the Environmental Impact Assessment and this should in future eliminate the need for each application to be first forwarded to other ministries, a procedure that currently slows down the granting of permits.

2.3.2 Water Pollution Monitoring

The Department of Water Affairs and Forestry has compiled specifications for water quality analysis that group sets of analysis to cover specific monitoring needs (DWAF 2008). "Group 1' analysis allow for quick basic monitoring of surface waters in rivers, testing only turbidity, conductivity and sediment load, whilst "Group 2" deals with drinking water and requiring a range of some 19 analyses linked to the drinking water guideline parameters. "Group 3 " deals with effluent or waste- water analysis and includes the nutrient concentrations such as Nitrogen (Nitrate, Nitrite, Ammonia) and Phosphates as well as biological and chemical oxygen demand. "Group 4" is particularly geared towards groundwater and includes the "Group 2" (drinking water) analysis as well as elements such as Fluoride and Bromide that may be present in groundwater. "Group 5" analyses are intended to be used when testing the water quality of new boreholes to detect traces of potentially harmful elements such as

Arsenic, Cadmium and Uranium (Laura Namene pers. comm. 2008). Ms Namene, the chief water pollution officer at MAWF, advises using “Group 2” analysis for any monitoring project to detect possible contamination of groundwater plus special analysis for those contaminants used in the processing or activity likely to cause the contamination, e.g. Nitrates near cattle feedlots, minerals used in mining processes near mines, Sodium and Chlorides to detect salt water intrusion. Rössing Uranium Mine maintains such a monitoring programme in the Khan River to prevent groundwater pollution. Groundwater samples from monitoring boreholes at agreed sites in the Khan River are analysed for a full range of potential contaminants including the ratio of Ur 234 and Ur 238 and detailed annual reports are submitted to the Pollution Control section of the Department of Water Affairs (Gracy Tshipo pers.comm. 20080. New mines should consult Rössing and instigate similar precautions.

2.3.3 Water Quality deterioration and Pollution

Although for the most part, the water quality of the Kuiseb Basin is either excellent or good, there is a need to be vigilant as we cannot afford to pollute the little water that we have and groundwater once contaminated is virtually impossible to clean (Tarr and NWAC, 2002, WWGN, 2007). Similarly the little surface water within the basin as well as the wetlands in the river and in Walvis Bay and at Sandwich harbour should be protected from any environmental degradation including water pollution.

The main areas of concern in terms of water quality are:

- Possible groundwater contamination from the Uranium and other mines in the area. Although established mines such as Rössing Uranium have a good track record of co-operation with the water authorities and continuously monitor nearby aquifers in the Khan River to detect the slightest evidence of contamination, it is important that all new mines even during the exploration phase take care to monitor groundwater chemistry.
- Possible saline intrusion into the production area of the Kuiseb Aquifer, either from the surrounding more saline groundwater to the south and west or with time sea water intrusion may become a problem. Regular monitoring of the production boreholes and others beyond them needs to be done. It is worrying that the regular monitoring or the Kuiseb production boreholes seems to have stopped with only the reservoirs being monitored.
- Possible contamination to both surface and groundwater in the upper catchment area from cattle feedlots or other intensive farming practices. At present there is no regular monitoring of water quality in the upper or middle catchment areas.
- Possible contamination of Friedenau Dam water from the tailings dam at Matchless Mine. These tailing are dangerously close to Friedenau Dam and after years of closure are not being well maintained. Consideration is being given to re-opening the copper mine and this should be subject to an EIA that must include environmentally sound methods to prevent both the old tailings and the waste from renewed production from contaminating either nearby surface waters of the ground water
- Sound waste water and effluent disposal by guest farms and lodges. As the number of guest farms and lodges increase both in the upper and middle catchment areas care must be taken that the proponents obtain the necessary waste water and effluent disposal permits and comply with the conditions set for safe disposal
- Although probably beyond the scope of this report, harbour pollution and the possible contamination of the Walvis Bay lagoon and other wetlands both from the harbour and from land based pollution is of concern.

2.3.4 Water Quality and Pollution Prevention Action Plan

In an attempt to address some of the water quality and pollution concerns raised an Action Plan 3 on Water Quality and Pollution Prevention Management has been developed as one component of the Water Resources Management Plan for the Kuiseb Basin and is included as Annexure 2 to this report. (See Annexure 2)

The Action Plan recommends six short-term actions ranging from the establishment of a Water Quality database for the Kuiseb, identifying strategic sites for regular monitoring and enlisting the help of volunteers to collect samples, to an immediate investigation of the state of the tailings dam at Matchless Mine, improved awareness of water pollution and encouraging stakeholders to apply for wastewater and effluent disposal exemption permits and comply with the conditions. Longer term actions include keeping up monitoring and awareness, expanding the database, monitoring possible sea water or saline intrusion, putting in place a sound groundwater monitoring programme for the mines, checking potential pollution from intensive agricultural activities such as cattle feed lots and remaining vigilant with regard to potential pollution of the harbour and Walvis Bay wetlands.

2.4 Ecological Water Requirements

Ecological water requirements are essentially the water that is needed by the river itself to maintain the ecosystems dependent on the water of that river. For perennial rivers this is fairly obvious. It is the volume as well as the timing and duration of river flows that keep the aquatic and semi-aquatic systems linked to the rivers functioning and productive. For ephemeral rivers such as the Kuiseb, this is less obvious as there is seldom any visible flow. Nevertheless, the ecological flow require-ment is the water needed as both surface flow and as groundwater to maintain a healthy, functioning river ecosystem or “ linear oasis” that so depends on the groundwater and occasional medium to large floods in the river. As with perennial rivers and their floodplains the ecosystems dependent on ephemeral rivers extend not only in a line along the river-course but may extend for some distance on either side of the river too, depending on the direction of groundwater flows, e.g. the essential freshwater seepage that maintains the wetlands at Sandwich Harbour.

The process of determining the ecological water requirements of a river is called an environmental flows assessment and goes beyond strictly the ecological water requirement, taking into account broader environmental issues, be they hydrological, biological, social or economical. River scientists define the environmental flow as: “the water that is purposely left in a river or released from a dam to maintain the river in a desired condition” (Brown and King 2002.) The more natural this desired condition, the greater the proportion of the flow volume that will be needed to meet the environmental flow requirement. For example, for the Kuiseb River that flows through a National Parks and where it is essential that the occasional large floods reach far enough downstream to sustain and recharge an important alluvial aquifer near the mouth (Benito, 2008) this desired state would be to keep the river as natural as possible. This is what the KBMC should aim for.

As there is not yet a tested method to determine the ecological water requirements or to do environmental flow assessments for ephemeral rivers, and because even if there were, this would require at least two years of intensive field work by a multi-disciplinary team of experts it was not possible to attempt to determine the ecological water requirement of the Kuiseb River as part of this water resources management plan. However, it is recognised as an essential step to understand-ing and managing the river water resources and it is recommended that the KBMC continue to encourage river scientists in Namibia to co-operate with scientists elsewhere in southern Africa to work towards developing a method to assess the environmental flow requirements of ephemeral rivers and to test this on the Kuiseb River. Realising the need to work towards a method suitable for ephemeral rivers, the current National Development Plan, NDP3, includes “developing methods to determine environmental flow assessments and test this on one ephemeral river.” The KBMC should lobby to make this *one river* the Kuiseb River and continue to include the determination of the ecological water requirements of the Kuiseb as a long-term goal and seek funding for this work.

To assist the KBMC to understand what ecological flows or water requirements are, a brief overview based on a presentation (Bethune and Roberts 2008) given at the Healthy River Basins Conference in Rundu in April, is given. The realisation of the importance of ecological flow requirements came about some 50 years ago when around the world ecologists noted a decline in river health due to river flow

manipulation, increasing pollution and the worldwide tendency to focus on human benefits and direct costs rather than environmental health and long term benefits. Over the years the terminology used to refer to the water needs of rivers themselves has changed as our understanding of the role and importance of river flows increased. In the 1960's and 70's the emphasis was on ensuring "minimum" flows, in the 70's and 80's the "hydraulic habitat" was deemed important, in the 1990's it was the maintenance of "in-stream flows" and "ecological water requirements" and since then it went beyond the river to include "environmental flows". '
In Namibia, the recognition of the importance of ecological water requirements and environmental flows can be traced through nearly two decades of national policies and legislation from the Namibian Constitution to the draft Wetland Policy (Amakali *et al.* 2002, Bethune *et al.* 2005):

- The Namibian Constitution includes the important "environmental clause" Article 95 l;

- Compensatory releases from dams were included in *Namibia's Green Plan* presented by the founding President at Rio in 1992;
- The National Water Policy of 2000 includes the principle of Ecosystem Values and Sustainability, it stipulates the need for "legislation to provide for environmental water reserves" and the need to ensure adequate water quality and quantity to sustain ecosystems;
- The Water Resources Management Act of 2004 calls for the protection of ecosystems" to the maximum extent" and makes provision for the "reservation of water resources to protect aquatic and wetland ecosystems". It also sets out the duties of river basin management committees to protect and manage river basins.
- The MET Environmental Management Act of 2007 calls for "equitable access to sufficient water for ecological systems to ensure sustainability" and it makes Environmental Assessments prior to development activities mandatory for listed activities;
- the Vision of the draft Wetland Policy is that: " Namibia shall manage national and shared wetlands wisely by protecting their vital ecological functions, life support systems and biodiversity for current and future benefit of people's welfare, livelihoods and socio-economic development." and one of the legislative principles is to set aside water for aquatic ecosystems.

The determination of ecological water requirements through an ecological flow assessment requires time, a multi-disciplinary approach and adequate funding. A good flows assessment can be a valuable water resources management tool that can provide answers to long-term sustainable use and wise management of the water resources of the river. The aim is to manage the river in a way that will ensure sufficient flows, and, to time them to maintain the environmental integrity of the river whilst also allowing economic development and social justice (Bethune *et al,* 2008.).

Among the successful methods used for assessments in perennial rivers are the Building Block Methodology and DRIFT (Downstream Response to Imposed Flow Transformations), both holistic methods that compare a variety of probable development scenarios and their impacts on flows as well as the impacts of these altered flows on the river to determine acceptable losses and gains to all stakeholders (Brown and King 2002). In Africa, environmental flow assessments have been done for perennial rivers in South Africa, Lesotho, Tanzania and Mocambique, but none yet for ephemeral rivers.

Namibia is currently involved in a pilot study to assess the environmental flows of the perennial Okavango River. This project was initiated by the Harry Oppenheimer Okavango Research Centre, HOORC in Maun together with the BioKavango Project for the Okavango Delta and has now been expanded to cover the entire river basin with the assistance of the regional OKACOM GEF/EPSMO (Environmental Protection and Sustainable Management of the Okavango) project (Mazvimavi and King, 2008) Over the next year, teams of experts from the three riparian counties, Angola, Namibia and Botswana, will work together to conduct a preliminary environmental flows assessment. The results will be used to feed into the future Integrated Management Plan, IMP, of this shared river.

The WADE project and the results of these studies on the Kuiseb River, provide an important start for future assessments of ecological water requirements of this and other ephemeral rivers. Most importantly it has improved our understanding of the relationship between river flows and recharge.

2.4.1 The WADE Project

Recently the DRFN and the Hydrology Division of the DWAF co-operated with international scientists in a project known as WADE. They investigated floodwater recharge of alluvial aquifers in dryland environments in ephemeral rivers aquifers in four countries. The study sites were the Kuiseb River, the Buffels River in South Africa, the Nahal Arava in Israel and the Andarax in south- east Spain. One of the conclusions from this study is that the “water reserve”; i.e. the water that should remain in the river to meet the needs of people and the environment, should be quantitatively estimated and that priority uses be allocated to what remains of the groundwater. Benito (2008) adds that the WADE study results can be used to supply important groundwater information for assessing ecological water requirements. WADE has provided an improved understanding of groundwater and flood interactions for the water authorities that manage these resources. One of the outputs of the study in the Kuiseb has been the development of an integrated flood-groundwater model for use by NamWater and DWAF. The study took four years (2004 – 2008) and proved that the long-term behaviour of aquifers in response to rare flood events can be studied and quantified (Benito, 2008).

The WADE project investigated how dependent alluvial aquifers and the water resources they supply are on floodwater recharge. To determine this, the scientists had to measure and analyze the processes that control flood recharge and link these to long term climatic cycles (Benito *et al,* 2005). Fortunately during the study period the Kuiseb experienced several floods of different sizes that were then carefully monitored using sophisticated TDR (time domain reflectometry) probes installed in the river close to Gobabeb. Extensive fieldwork was also done to document and age paleo-floods. Direct measurements were taken at each site to monitor any surface flow, the groundwater levels and water infiltration through the “vadose zone” or the sub-surface area between the river bed and the saturated groundwater layer (Dahan 2006).

The main findings of the WADE project (Benito 2008) that provide a better understanding of the Kuiseb River system and would be of interest to the KBMC to guide future management of the river, include:

- The estimated infiltration rate is 8.5 mm/h.
- Recharge is mainly from medium to large floods.
- Recharge depends on: the duration of the flood, the width of the actively flowing channel and the alluvial soil composition. In the Kuiseb the unconsolidated sand grains and gravel allow for excellent water storage between the sand particles (Gardiner *et al*. 2006).
- Surface flow at least 15 – 20 cm deep is needed to initiate recharge.
- Infiltration under dams is surprisingly low and inefficient, in fact dams reduce groundwater recharge. (contrary to the popular belief that surface dams enhance recharge of boreholes).
- The alluvial aquifer has a ‘compartmental” structure and is thus discontinuous.
- For optimal management, exploitation of the aquifer along its entire length is recommended, although this may prove disastrous for the riparian vegetation dependent on this groundwater and to the desert animals such as warthog, oryx and baboons who rely on shallow groundwater in the riverbed that can be reached by digging.
- The total groundwater recharge potential at Gobabeb is 210 000 m^3/km/a.
- Transpiration by trees alongside the river uses 15 – 20% of the total aquifer volume.

2.5 Environmental Impact Assessments

Although the KBMC is unlikely to conduct Environmental Impact Assessments they may well be required to comment on EIAs undertaken within the Kuiseb Basin and need a clear understanding of what EIAs are and the new Environmental Management Act. Therefore a brief overview of both is given here. An EIA, is simply a way of finding out the probable impact that a project is likely to have on the environment and its significance (NORAD, 1993). EIAs are not "anti-development ", but are intended to encourage good management. To be most effective they need to be done early in the decision-making process so that key findings can be incorporated into the design of development projects. They are relatively inexpensive, usually costing only about 1% of the total project value, but the benefits of allowing early mitigation of any negative impacts far outweigh the costs. Good EIAs lead to environmentally and often economically sound choices. Whilst an EIA is extremely useful tool during the planning of a project, environmental monitoring should not stop there. An environmental management plan should be designed for the construction and operational phases and a clear decommissioning plan prepared for when the project ends. The Minerals (Prospecting and Mining) Act 33 of 1992 makes provision for environmental management (Schneider and Shivolo, 2008) and all mines now have to have clear decommissioning plans.

A comprehensive EIA should include studies of both the natural environment and resource base it supports as well as the man-made environment (cultural, urban, historical, archaeological, An EIA should look at the future management of natural resources as well as at future development plans, and include social factors and health issues. It should consider direct impacts, secondary impacts and cumulative impacts of the proposed development and related developments.

2.5.1 The Environmental Management Act No 27 of 2007 (MET, 2007)

Namibia recently passed its long-awaited Environmental Management Act. The main points of interest to the KBMC are summarised briefly in paragraph 2.5.1 below. For a more comprehensive explanation of the Act it is recommended that all the KBMC members be given copies of the excellent "*Guide to the Environmental Management Act No 7 of 2007*" recently produced in simple English for the layman by the Ministry of Environment and Tourism (Hubbard, 2008).

The stated aim of the Environmental Management Act includes, "to provide for a process of assessment and control of activities that may have significant effects on the environment".
To assist the Government to implement this Act, it makes provision for the establishment of a "Sustainable Development Advisory Council" and the appointment of an "Environmental Commissioner" and environmental officers. The Act requires "identified organs of state" whose functions may impact on the environment to prepare "Environment plans". The list of organisations that will need to draw up such environmental plans has yet to be published in the Government Gazette. It is not known if Basin Management Committees will be included in this list. Once the plans are approved, the organisations will be expected to comply with their plans and will be monitored by the environmental officers under the Environmental Commissioner.

The Act sets out the steps to be followed in a consultative EIA process in Part 8 (MET, 2007). This basically starts with initial screening to determine if a project needs an EIA. All project proponents are required to apply for an "Environmental Clearance Certificate". For projects that clearly have no significant environmental effects, an assessment will be deemed unnecessary and a environmental clearance certificate will be granted allowing the project to go ahead, possibly under stipulated conditions. Should an assessment be needed, the commissioner should assess the scope of the project, advice the proponent how to proceed and prescribe the EIA procedure to be followed. The final report is reviewed and if in order an environmental clearance certificate will be granted and conditions set under which the project may proceed. The Environmental Commissioner reserves the right to suspend or cancel this certificate if the conditions are not complied with.

2.5.2 Possible shortcomings of the Environmental Management Act 27 of 2007

Although in essence, the Environmental Management Act, if properly implemented, can help to ensure that future development and natural resource use is sustainable and should protect the environment, there are several loopholes for the less scrupulous that the KBMC should note.

Earlier drafts of the Act included a list of activities requiring EIA's. The Act now passed does not. Although it makes provision for the Minister to publish a list of "activities that *may not* be undertaken without an environmental clearance certificate", the Act itself is not specific enough about the types of activities that EIAs should be mandatory for. Within the Act it merely stipulates ten very broad activities that '*may*' be included in the yet to be published list (MET, 2007). They are:

- land use and transformation,
- water use and disposal,
- resource removal, including natural living resources,
- resource renewal,
- agricultural processes,
- industrial processes,
- transportation,
- energy generation and distribution,
- waste and sewage disposal: chemical treatment,
- recreation.

As yet, no list has yet been published in the Government Gazette and even once an activity is officially listed, the Minister retains the right to remove it from the list. It is of further concern that the Minister may also grant exemption to a developer in respect to even listed activities.

Although the Act makes provision to establish a Sustainable Development Advisory Council and to appoint an Environmental Commissioner and environmental officers to assist with monitoring etc., there is unfortunately no stipulation that the commission be independent. It is most likely that the commissioner and his officers will be officials within the MET and, as stipulated in the law, at least half (4/8) the members of the Sustainable Development Advisory Council will be civil servants.

Earlier drafts set out the procedure for EIAs, now this is not specified but left to the Commissioner. Despite this, it is possible to link the provisions in the Act to the main stages in an EIA process:

- SCREENING – to asses projects needing EIAs and type of EIA needed, (List: Section 27).
- SCOPING – the definition of key issues, opportunities for broad consultation and for public participation of all interested and affected stakeholders, be they public, government or NGO (Consultative process specified section 33 and public hearing included in the review stage).
- EIA PREPARATION – the scientific investigation and analysis of the project and its impacts and rating the significance and importance of the impacts identified (Vaguely in Section 35).
- REVIEW – Review of the EIA document and findings by an independent panel to advice government (Review: Section 36 and possibly part of the duties of the Sustainable Development Advisory Council: Section 7).
- MONITORING – To check that recommendations are carried out and conditions complied with and to check for any environmental impacts or quality changes in the environment as a result of the project (Task of the Environmental Commissioner and officers: Sections 17-19).
- AUDITING – To check if the predictions made had been accurate, to test the value and success of any mitigations and to check on and if necessary update environmental management practises. To learn from past mistakes. (Although not specified in the Act could be assumed to be included in the tasks of the Environmental Commissioner).

2.6 Environmental Issues to be addressed in the Kuiseb Basin

Most of environmental concerns in the Kuiseb Basin at present are related to the potential impacts of mining. Other concerns include the impact of upsteam dams on the riparian vegetation and on groundwater recharge to the alluvial aquifer, continued over-abstraction of these aquifers and the possibility of sea or saline water intrusion, the impacts of alien invasive plants and sand harvesting along the river, water contamination from intensive agricultural activities such as feedlots, disturbance of the wilderness aspect of the desert by to tourist activities such as quad biking and because of new power and water supply infrastructure and roads, as well as the impacts of increasing urban and industrial development at the coast on the wetlands.

2.6.1: Mining activities

Currently much concern is being expressed regarding both the potential water use and possible groundwater pollution of both the existing and the proposed Uranium mines within or close to the Namib Naukluft National Parks in the lower Kuiseb Basin. The two existing mines, Rössing and Langer Heinrich, as well as most of the areas covered by the exploration licenses are within the ecologically sensitive Namib gravel plains area and in some cases even within the Namib Naukluft National Park. Figure 6 below shows the locality of the present and proposed mines. These concerns prompted a special edition of the Namibian Environment and Wildlife Society newsletter, *Roan News* (NEWS, 2008). From the article by the Ministry of Mines and Energy (Schneider and Shivolo, 2008) it is clear that the Ministry is fully aware of its obligation to protect environmentally sensitive areas from potential damage by mining activities.

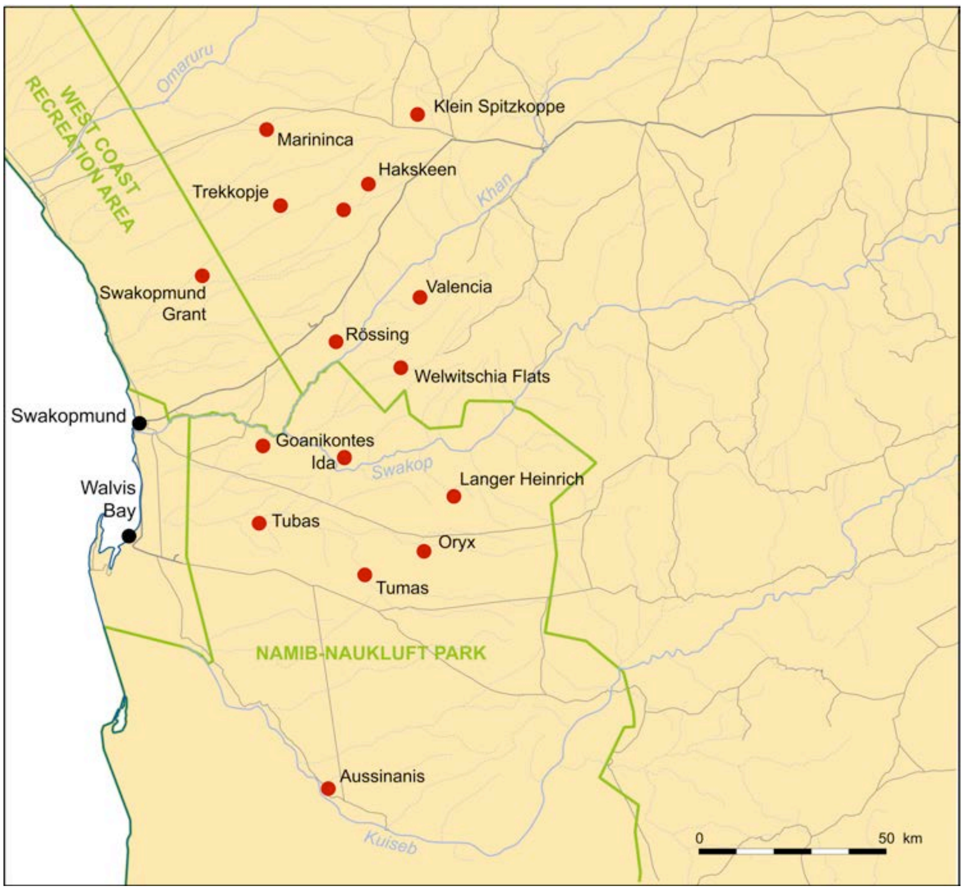

Figure 6. Uranium deposits being explored or mined and the protected area. Reproduced with permission of the editor of *Roan News* from Hoadley and Limpitlaw (2008).

To assess the cumulative impacts of mining in the lower Kuiseb area, the Ministry and the Southern African Institute for Environmental Assessment, SAIEA, has initiated a Strategic Environmental Assessment, SEA, in addition to the Environmental Impact Assessments, EIAs, that each mine has to do (Roberts, 2008, Swiegers, 2008). These cumulative impacts will go beyond the impacts of mining in the Namib-Naukluft National Park. It should include: potential groundwater contamination; the co-ordination and provision of housing, schools, roads and other services for people attracted to the area; cumulative water and power demands; and options for alternative water and energy supplies; the fragmentation or even loss of the intrinsic value of the Namib wilderness; public health aspects including dust pollution and airborne radiation; as well as activities to ensure economic viability after the mining boom (Swiegers, 2008, Pallet, 2008, Kohrs 2008, Hoadley and Limpitlaw, 2008, Henshel

2008). According to Swiegers (2008), DRFN is to assist with compiling "Guidelines for Environmental Management in Mining", GEMM. The KBMC has an important role to play in ensuring that all these and other stakeholder concerns are fully taken into account in the Strategic Environment Assessment, SEA.

Concern has been expressed that Namibia should perhaps exercise caution and take into account the strategic value of the Uranium resources for the future. Developing all these non-renewable resources now when the life span of such mines is short (8 – 20 years) is perhaps short sighted. It is no accident that three of the countries seeking to exploit Namibia's Uranium resources, Canada, Australia and Russia, have their own reserves, but are strategically keeping these in reserve for when the world supplies become even more limited (Schultz, 2008) Does it make sense to risk our desert environment and long-term potential tourism earnings for short term? (Schalken, 2008, Berry, 2008). The SEA should take the long-term strategic value of these resources into account too.

Whatever the outcome of the SEA, there will be some degree of mining development in the lower Kuiseb over the next few years, therefore it is essential that following the SEA, a very specific environmental monitoring programme be developed to regularly check and control the impacts of mining and other development activities (Kohrs, 2008) Here the KBMC needs to take the lead to ensure that stakeholders within the basin are monitoring these impacts. It is also important that this monitoring be undertaken by an independent body with no vested interest in the mining – possibly the GTRC. The results should be available to interested stakeholders and the general public.

2.6.2 Upstream dams and reduced flows

One of the concerns already discussed at some length in section 2.1.2 dealing with the Kuiseb River as a linear oasis on page 7 of this report is the impact of upstream dams on the riparian vegetation and on groundwater recharge to the alluvial aquifer. Despite suggestions that this may not be a major environmental concern in the Kuiseb Basin (Dausab *et.al.*1994), other accounts clearly see reduced floods as a threat reducing recharge, preventing germination, even killing established riparian trees (Seely *et.al* 2003). It is worth investigating further, particularly in the light of recent studies undertaken at Gobabeb (Benito 2008). It is recommended that such investigations should form part of an environmental flows assessment to attempt to determine the ecological water requirements of the Kuiseb River ecosystem.

2.6.3 Over-abstraction from the aquifers

According to the Geohydrological report prepared for the Water Resources Management Plan for the Kuiseb Basin, the most recent figures for the total sustainable yield of the active Kuiseb aquifers, based on NamWater calculations in 2001, is 7 Mm^3/ a between Swartbank and the Delta (Falke, 2008). According to an earlier NamWater report (NamWater 1998) the lower Kuiseb aquifers (Dorop S, Rooibank A and B and Swartbank were being overutiized to supply the demand. At that time the average abstraction was 8.34 Mm^3/a. Since then abstraction rates have declined.
Although there is no evidence of sea water intrusion into the Kuiseb aquifer from the water quality analysis over the last ten year, it may be is possible that continued over-abstraction of these aquifers could cause saline water intrusion. There is anecdotal evidence that the productivity of !nara fields in the vicinity of the delta have declined and even been abandoned. Further upstream in the river, villagers have reported that they can no longer dig wells deep enough to reach the groundwater (WADE, 2005) and decreasing groundwater levels will also affect the wildlife that depend on groundwater seeps or being able to dig to reach water in the riverbed.

2.6.4 Alien invasive plants

Environmental concern that invasive plants, particularly those growing alongside rivers, reduce groundwater levels has led to some drastic suggestions that include removing all riparian vegetation.

A clear distinction needs to be made between naturally occurring or indigenous trees and alien invasive species. Both must transpire and both draw on groundwater for their moisture. The WADE project was able to detect daily fluctuations in groundwater levels in the Buffels River in South Africa that could only have been caused by evapotranspiration as the water levels dropped by day and rose again at night (Todd and Hoffmann 2006). Transpiration losses calculated for four indigenous tree species in the Kuiseb showed that about 15 – 20% of the available groundwater is lost in transpiration each year. *Faidherbia albida* had the highest rate (1.5 g H_2O/g/hr), and *Euclea pseudobenus* the lowest (0.54 g H_2O/g/hr) with *Tamarix usneoides* and *Acacia erioloba* being about the same (1.07 g H_2O/g/hr and 1.03 g H_2O/g/hr respectively) (Bate and Walker 1993).

But indigenous trees belong in the river and are well- adapted to living there and make up the important riparian vegetation that allows humans and animals to live there, whereas alien species have encroached on the natural vegetation and are often not well adapted to the arid conditions along our ephemeral rivers and may use larger volumes of water than the naturally occurring species would. Preliminary tests done in the Omaruru River at Okambahe this year seem to indicate that *Prosopis* transpiration rates are higher than that of other trees occurring in alongside the river, but that the rates for *Faidherbia* were also quite high. (Heimo Gariseb, pers.comm. 2008)

2.6.5 Sand harvesting

With growing development at the coast, the demand for building sand has escalated. Many construction companies are collecting sand from ephemeral river beds, creating concern about the impact this sand harvesting has on the river ecosystem. This year the sand harvesting diggings near Swakopmund prevented the river from reaching the sea as the water pooled up in the excavations left by the diggers. The Forestry Act makes it an offence to harm or damage any plant in or within 100m of a river-course. Inspection of this and other sites has shown that the islands with trees are left between the excavations but that it is only a matter of time before these will be washed away or erode. The DWAF is in the process of developing regulations to control sand harvesting and Municipalities such as Swakopmund are taking steps to curb excessive removal of sand (Dr Stephan de Wet. Pers.comm. 2008).

2.6.6 Intensive agriculture

As discussed in the section on Water Quality and potential pollution, there is a chance that water downstream of intensive agricultural activities such as cattle feedlots could become contaminated. It is not clear if such intensive farming occurs in the Kuiseb Basin though. What is more likely is that dung that has collected in the dry river beds during the dry months, as cattle and wildlife seek shade under the trees alongside the river beds, washes into farm dams and impoundments when it rains, causing temporary algal blooms that can cause taste and odour problems in treated water (Tarr and NWAC, 2002, Roberts and WWGN,2007). This year Friedenau Dam experienced a bloom of filamentous algae as a result of nutrients washed in during the rains (personal observation)

2.6.7 Wilderness loss

One of the most difficult environmental concerns to quantify is loss of wilderness. One of rthe main attributes of the Namib is its sense of space and isolation and this is what attracts so many tourists. This serenity is easily shattered even by the tourists themselves as we have seen with the proliferation of quad biking since South Africa banned driving on beaches. Similarly the sight of new power and water supply infrastructure and new roads to supply the new mines and sound of vehicles will rob the area of its trademark tranquillity.

2.6.8 Urban and industrial expansion at the coast.

The coastal wetlands are under threat from increasing urban and industrial development both in Walvis Bay and up the coast towards Langstrand. Pollution from fish factory effluent and other land based activities also threatened the harbour and the bird life in the lagoon. Some years ago the DWAF initiated a pollution monitoring project in co-operation with the Walvis Bay Harbour Authority. It is not clear if this is still ongoing.

2.6.9 Archaeological sites

The Kuiseb Basin is archaeologically the most significant area of Namibia, as the whole archaeological sequence is represented, and many of these sites have been central to new approaches to key issues in southern Africa. The Kuiseb River Basin is well known as an area rich in archaeological remains that have been intensively researched and internationally published. All archaeological remains in Namibia are protected in terms of the National Heritage Act (27 of 2004), and this extends to objects and sites more than 50 years old that may be considered to have national heritage significance. Sections 51 (3) and 55 (5) of the Act require that an archaeological impact assessment is carried out where large development projects are intended in areas of known archaeological significance, and proper mitigation of archaeological impacts is required (J. Kinahan, pers.comm. 2008). For more detail please see the separate specialist report by J. and J. Kinahan, *Archaeology of the Khuiseb River Basin* and the map they compiled which show the archaeological sensitivity of different areas within the Kuiseb Basin.

It is essential that any development in the Kuiseb Basin in the fields of mining, road construction, power transmission, water supply, tourism, urban development, planning and research take account of the significance and vulnerability of the archaeology. Fortunately, in response to the accelerated development of the Namibian economy and infrastructure after Independence and recognition of the need to provide specialist archaeological consultancy services, *Quaternary Research Services* was established in 1990 (Jill Kinahan, pers.comm. 2008).

Allthough outside the Kuiseb Basin, a very significant recent archaeological find has been the uncovering of a Portuguese vessel carrying Spanish gold and ivory near to Oranjemund this year (Dieter Noli, pers. comm.2008). Given that the Kuiseb Basin extends to the Atlantic Ocean and includes the only two safe harbour sites along over 1000 km of hostile coastline, often used by early mariners, there may be other significant finds hidden within the lower Kuiseb Basin. Even more reason to take care to include an archaeological component in future EIAs within the Kuiseb Basin particularly for developments that involve mining, roads, water and energy supply, tourism and urban expansion or development.

The role of the KBMC in this is to ensure that this archaeologically sensitive area is treated with the necessary respect and that all EIA's investigate potential impacts on the vulnerable archaeological record and include archaeologists in the scientific investigations that form part of the EIA process.

2.7 Vulnerability assessment of environment

The ecologically sensitive and vulnerable areas within the Kuiseb Basin identified in the course of this review were many and varied. Potential impacts threaten all mine sites, the aquifers downstream of them and indeed the entire area that may soon be criss-crossed by power lines, water pipes and roads to supply these mines. The entire river-course is vulnerable due to water being held back in farm dams upstream, continued water abstraction, invasive plants and wood harvesting, that threaten its function as a linear oasis in a very arid area. The alluvial aquifer itself is at risk from over-abstraction, potential saline intrusion and groundwater contamination. The internationally important freshwater wetlands at Sandwich Harbour are rapidly dwindling as the amount of freshwater seepage decreases and the sand bar protecting the wetland gradually erodes. Intensive farming poses a threat to water quality in the rock aquifers as well as in the farm dams. Friedenau Dam too is vulnerable to an accidental spill from the tailings dam at Matchless mine and to eutrophication caused by nutrients entering the dam with runoff. The wilderness aspect of sections of the Namib Naukluft Park, arguably its greatest asset may be lost. The Walvis Bay wetland, one of the top three coastal wetlands in Africa, is threatened by human development and disturbance of the birds at this Ramsar site. Significant archaeological sites are scattered throughout the Kuiseb Basin.

3. CONCLUSION

This report deals briefly with the ecology of the river basin, assesses the status of water quality of the Kuiseb Basin, explains what ecological water requirements are and the implications of the new Environmental Management Act. It highlights the major environmental impacts of present and future activities in the Kuiseb Basin and lists the ecologically vulnerable and sensitive area within the basin and make recommendations to the KBMC on environmental issues. This report provides the background that informed the development of Action Plan 3 "Water Quality and Pollution Prevention Management" for the Water Resources Management Plan for the Kuiseb Basin commissioned by the KBMC. This action plan is intended to advise the KBMC on sound water quality monitoring to prevent future water pollution. The recommendations made in the report are summed up below:

Recommendations

- The KBMC should find funds and commission DFRN to complete the Kuiseb Profile and in the meantime the KBMC should request DRFN to obtain permission from WADE to print and bind copies of the WADE report: *Site Characteisation for Kuiseb Riparian Ecosystems* by Gardiner *et.al*, (2006) as useful background information to the Kuiseb riparian ecosystems.
- It is recommended that the KBMC make NamWater aware of the ecological and educational value of Friedenau Dam.
- Two Ramsar wetlands, the Walvis Bay wetlands and Sandwich Harbour fall within the Kuiseb Basin and it is important that the KBMC continues to co-operate closely with the Coastal Environmental Trust of Namibia, CETN, to conserve and wisely manage these internationally important wetlands.
- The KBMC should lobby MET to have the Walvis Bay wetlands, that are increasingly threatened by coastal development, officially proclaimed as a protected area.
- The KBMC has an important role to play in ensuring that all the concerns that have been raised by stakeholders with regard to the expansion of mining in the Kuiseb Basin be taken fully into account in the Strategic Environment Assessment, that the MME is proposing to do.
- The KBMC, as representative of all the stakeholders in the Kuiseb Basin, could take the lead and possibly appoint an organisation within the basin such as the GTRC to co-ordinate a long-term water quality monitoring programme, to detect impacts of present and new mines and should keep the stakeholders informed of the results at KBMC meetings.
- The water pollution officer from the MAWF, responsible for the Erongo Region and thus the Kuiseb Basin, should be represented on the KBMC or at least on the broader Kuiseb Basin Stakeholder Forum. The KBMC should consider inviting this official from the Water Environment Division to participate in future meetings. All stakeholders should be informed of the need to apply for wastewater and effluent disposal exemption certificates and the procedure to follow.
- The KBMC should ensure that at all the mines in the Kuiseb Basin regularly monitor groundwater at agreed sites in watercourses downstream of any tailings dams. These should undergo "Group 2" analysis as well as tests for a full range of potential contaminants including the ratio of Ur 234 and Ur 238. Detailed annual reports should be submitted to the Pollution Control section of the Department of Water Affairs and KBMC. New mines should be advised to consult Rössing Uranium and instigate similar precautions.
- Similarly the little surface water within the basin as well as the wetlands in the river and the Ramsar sites at Walvis Bay and at Sandwich Harbour should be protected from any environmental degradation including water pollution.
- The KBMC should continue to encourage river scientists in Namibia to co-operate with scientists elsewhere in southern Africa to work towards developing a method to assess the

environmental flow requirements of ephemeral rivers and to test this on the Kuiseb River. The results of the WADE study should be used as a basis to start determining the ecological water requirements of the Kuiseb.

- The impact of the over 500 farm dams in the upper catchment should be revaluated and this should form part of the environmental flows assessment to attempt to determine the ecological water requiremments of the Kuiseb River ecosystem.
- All the KBMC members should be given copies of the excellent "*Guide to the Environmental Management Act No 7 of 2007*" recently produced in simple English for the layman by the Ministry of Environment and Tourism.
- An environmental monitoring programme needs to be developed to regularly check and control the future impacts of mining and other development activities. Here the KBMC needs to take the lead to ensure that stakeholders within the basin are monitoring these impacts. The KBMC should be in a position to insist that this long-term monitoring be undertaken by an independent body with no vested interest in mining, possibly the GTRC, and that the results should be available to interested stakeholders and the general public.
- The KBMC should ensure that the rich archaeological heritage of the Kuiseb Basin be treated with the necessary respect and that all EIA investigations include impacts on the vulnerable archaeological record and that archaeologists be included in the EIA process.

At present the most pressing environmental concerns in the Kuiseb Basin are related to the potential impacts of Uranium mining. All KBMC members should read the special edition of *Roan News* on Uranium Mining and Mining in Parks (Roberts, 2008) to better understand the issues.

Other environmental concerns identified in the report include:

- The impact of upstream dams on the riparian vegetation and on groundwater recharge.
- Continued over-abstraction of alluvial aquifers and the possibility of sea or saline water intrusion, the impacts of alien invasive vegetation and sand harvesting along the river,
- Groundwater contamination and eutrophication of dams from intensive agricultural activities such as cattle feedlots.
- Disturbance of the wilderness aspect of the desert by to tourist activities such as quad biking and because of new power and water supply infrastructure and roads.
- Impacts of increasing urban and industrial development at the coast on the wetlands.

Based on these discussions the main ecologically sensitive and vulnerable areas within the Kuiseb Basin can be identified as:

- All Mine sites and mineral exploration areas ,
- The areas downstream of mine sites, particularly the groundwater aquifers
- The entire gravel plain area criss-crossed by infrastructure to supply mines
- The entire river-course - Linear oasis
- The entire length of the alluvial quifer
- Sandwich Harbour wetland
- Areas downstream of intensive farming activites, particularly groundwater aquifers
- Friedenau Dam
- Namib Naukluft Park
- Walvis Bay wetlands
- All Archaeological sites

Action Plan 3 on Water Quality and Pollution Prevention was developed based on the findings of this report in terms of Water Quality. This Action Plan recommends six short-term actions ranging from the establishment of a Water Quality database for the Kuiseb, identifying strategic sites for regular monitoring and enlisting the help of volunteers to collect samples, to an immediate investigation of the state of the tailings dam at Matchless Mine, improved awareness of water pollution and encouraging stakeholders to apply for wastewater and effluent disposal exemption permits and comply with the conditions. Longer term actions include keeping up monitoring and awareness, expanding the database, monitoring possible sea water or saline intrusion, putting in place a sound groundwater monitoring programme for the mines, checking potential pollution from intensive agricultural activities such as cattle feed lots and remaining vigilant with regard to potential pollution of the harbour and Walvis Bay wetlands.

The most serious gap identified in the preparation of this report is that the Water Resources Management Plan for the Kuiseb Basin does not include a specific environmental management Action Plan. The new Environment Act requires all “organs of state” to develop an Environmental Plan. Based on the definition of an organ of state as “any Government office, Ministry, or agency at national, regional or local level “including “any other institution or person who is exercising a power or a function under the Namibian Constitution, or any public office or function under any Namibian law” (Hubbard, 2008) the KBMC will be required to develop an Environmental plan in future. This plan will need to be backed up by a much more detailed review and field –based investigation of the plants, animals and ecology of the Kuiseb Basin and be able to identify species of particular value and vulnerability and recommend suitable monitoring and conservation measures.

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5. REFERENCES

Amakali, M., S. Bethune and K.S. Roberts. 2002. Incorporation of Environmental flows into Namibia's National Water Policy, National Development Plan, new water legislation and national strategies. Paper presented at the Environmental Flows for river systems and fourth international Ecohydraulics symposium in Cape Town, 3 – 8 March 2002.

Barnard, P., S. Bethune & H. Kolberg. 1998. Biodiversity of terrestrial and freshwater habitats : 57-187. In: *Biological Diversity in Namibia: a country study.* Namibian National Biodiversity Task Force, Windhoek.

Bate, G.C. and B.H. Walker. 1993. Water relations of the vegetation along the Kuiseb River, Namibia. *Madoqua.* 18 : 85 – 91.

Benito, G. (In Press /2008). WADE Final Report. Floodwater recharge of alluvial aquifers in dryland environments. 141 pp.

Benito, G., V. Throndycraft, C. Coetzee, O. Dahan, W. Engelbrecht, Y. Enzel, T. Hoffmann, C. Kuells, G, van Langenhove, A, Matros, H. May, T. Ouarda, R. Rohde, M. Seely and S. Todd. 2005. What is WADE? Water Management in Drylands based on floodwater resources. In: Wade Newsletter No 1, October 2005 : 2 – 4.

Berry, H. 2008. Bad and good tourism vs bad and good mines. *Roan News.* : 42 – 43.

Bethune, S. 1992. Results of the limnological monitoring of the impoundment Von Bach, Omatako and Swakoppoort dams on the Eastern National Water Carrier, 1987 – 1990. DWA, Research Division Report no RR/92/4. 51 pp.

Bethune, S. 1996. Namibia's challenge Sustainable water use. In: *Namibia Environment* Vol. 1: 185 – 189.

Bethune, S and K.S. Roberts. 2008. Integrated Flow Management. Paper presented at the Healthy River Basins conference held in Rundu, 2 – 4 April, 2008.

Bethune, S., Amakali, M. and K.S. Roberts. 2005. Review of Namibian legislation and policies pertinent to environmental flows. *Physics and Chemistry of the Earth.* 30 : 894 -902

Bethune, s., M. Griffin and D. Joubert. 2004. National Review of Invasive Alien Species Namibia. Report to Southern African Biodiversity support programme, MET, Windhoek. 110 pp

Bethune, S. (Editor), D. Shaw, K.S. Roberts and the Wetlands Working Group of Namibia. 2008. *Wetlands of Namibia*. John Meinert printing, Windhoek.

Bittner, A. and K. Dierkes. 2004. Demarcation of Water Basins on National level. Unpublished report by Biwac to GTZ* and the Department of Water Affairs Namibia. Windhoek.

Blom, L.W.R. and P.M. Bouwer. 1985. Geohydrology of the Kuiseb River. In: The Kuiseb environment: the development of a monitoring baseline. (Ed B.J. Huntley). South African National Scientific Programmes Report 106. CSIR. : 33 -50.

Botes, A., J. Henderson, T. Nakale, K. Nantanga, K. Schachtschneider and M. Seely. 2003. Ephemeral rivers and their development: testing an approach to basin management committees on the Kuiseb River, Namibia. *Physics and Chemistry of the Earth.* 28 : 853 – 858.

Brown, C. and J. King. 2002. Environmental flows: requirements and assessment.: 111 - 133 In: *Defining and Mainstreaming Environmental Sustainability in Water Resources Management in Southern Africa*. World Bank, Sida, IUCN and SARDC, Maseru/Harare/Washington DC.

Brown, C.J., I.A.W. Macdonald and S.E. Brown. 1985. Invasive alien organisms in South West Africa/Namibia. South African National Scientific Programmes Report No 119. 74 pp.

Curtis, B.A. and C.A. Mannheimer. 2005. *Tree Atlas of Namibia.* NBRI, Windhoek.

Curtis, B., K.S. Roberts, M. Griffin, S. Bethune, C.J. Hay and H. Kolberg. 1998. Species richness and conservation of Namibian freshwater macro-invertebrates, fish and amphibians. *Biodiversity and Conservation 7:* 447 – 466.

Desert Research Foundation of Namibia. undated. *Basin Management Approach. A Guidebook.* Desert Research Foundation of Namibia, Windhoek.

Dahan, O. 2006 Wade. Floodwater infiltration and groundwater recharge. Presentation at WADE Conference held in Cape Town, 20 – 26 January 2006.

Davies, B. and J. Day. 1998. *Vanishing Waters*. U.C.T. Press, Cape Town.

Department of Water Affairs, undated. Guidelines for the evaluation of drinking-water quality for human consumption with regard to the chemical, physical and bacteriological quality. MAWF, Windhoek.

Department of Water Affairs and Forestry. 2008. Specifications for water analysis services. Unpublished Tender specification document , MAWF, Windhoek.

Dausab, F. , G. Francis, G. Johr, J.R. Kambatuku, M. Molopo, S.E. Shanyengana, and S, Swartz. 1994. Water Usage patterns in the Kuiseb Catchment area. DRFN Occasional Paper 1. 118pp.

Friends of the Namib, 2007. Namib –Naukluft Park 100 years. *Sandpaper* 7 : 4 – 18.

Gardiner, M., A. Matros-Goreses, C. Roberts and M. Seely. 2006. Site Characterisation for Kuiseb Riparian Ecosystems. Report for WADE project, Work Package 2. 58 pp.

Henderson, I. *Plant Invaders of Southern Africa*. Plant Protection Research Institute Handbook no 5. Agricultural Research Council, Pretoria.

Henschel, J. 2008. The value of the Namib. *Roan News.* : 34 – 36.

Heyns, P., S. Montgomery, J. Pallett, and M.K. Seely (eds.) 1998. *Namibia's water – a decision maker's guide.* Department of Water Affairs and Desert Research Foundation of Namibia, Windhoek.

Heyns, P. 2008. Water planning and utilization in the Kuiseb Basin. Development of a Water Resources Plan for the Kuiseb Basin and a Generic Water Resources Planning Procedure. Report for the KBMC, Kuiseb Basin Water Resources Management Project. 48 pp.

Hoadley, M. and D. Limpitlaw. 2008. Managing the socio-economic impacts of uranium mining in Namibia. *Roan News.* : 28 - 30

Hubbard, D. 2008. *Guide to the Environmental Management Act No 7 of 2007*. Ministry of Environment and Tourism, Windhoek.

Huntley, B. J (Editor). 1885. In: The Kuiseb environment: the development of a monitoring baseline. South African National Scientific Programmes Report 106. CSIR. 138 pp.

Jacobson, P.J., K.M. Jacobson and M.K. Seely. 1995. *Ephemeral rivers and their catchments – sustaining people and development in western Namibia.* Desert Research Foundation of Namibia, Windhoek.

Kinahan, J and J. Kinahan. 2008. *Archaeology of the Khuiseb River Basin*. Report to KBMC for the Water Resources Management Plan for the Kuiseb Basin by Quartenary Research Services.

Kolberg, C. and H. Kolberg Undated. *Walvis Bay* and *Sandwich Harbour* Pamphlets on "wetlands of international importance" Ramsar sites,. Ministry of Environment and Tourism, Windhoek.

Kohrs, B. 2008. Earthlife's concerns regarding uranium mining in Namibia. *Roan News*. :19 – 21.

Lenz, R., H. Grobbelaar and M. Djama. 1995. Groundwater exploration in the Kuiseb Delta Area: Report Volume D-1 Parts 1 – 3. BGR.

Louw, G. N. and M.K. Seely. 1982. *Ecology of Desert Organisms*. Longman, London.
Lovegrove, B. *The living deserts of Southern Africa.* Fernwood Press, Vlaeberg.

Manning, N. and J. Pallett. 2004. Kuiseb Basin Management Committee, the first of its kind in Namibia. *Conservation and Environment in Namibia*. : 26 – 27.

Mazvimavi, D. and J. King. 2008. Environmental flow assessment study within the Okavango River Basin. Project Plan submitted to OKACOM, GEF EPSMO (Environmental protection and sustainable management of the Okavango project.

Mendelsohn, J., A. Jarvis, C. Roberts and A. Robertson. 2002. *Atlas of Namibia. A portrait of the Land and its People.* David Philip, Cape Town.

Ministry of Agriculture, Water and Forestry. 2004. Water Resources Management Act no 24 of 2004. Government Gazette, Windhoek.

Ministry of Environment and Tourism. 2007. Promulgation of Environmental Management Act, 2007 (Act No. 7 of 2007). Government Gazette of the Republic of Namibia. No 3966 : 1 – 32

Muller, M.A.N. 1985. Grasses of South West Africa / Namibia. John Meinert, Windhoek.
NACSO, 2007. *Namibia's communal conservancies*: a review of progress 2006. NACSO, Windhoek

NamWater, 1998. The impact of the 1997 Flood events in the lower Kuiseb River on the recharge to the Lower Kuiseb aquifers. Geohydrology Division Report NWC-WR-7/1/6/3

NamWater, 2001. Re-assessment of the long-term sustainable yield of the Lower Kuiseb Aquifers. Final Water Resources Report NWC-WR-CNP.

NamWater, 2008. Guidelines for the evaluation of drinking-water for human consumption with regard to chemical, physical and bacteriological quality. Namibia Water Corporation, Windhoek

NEWS, (2008). Ed. C.S. Roberts. *Roan News* Special edition on uranium mining and mining in parks. John Meinert, Windhoek

NORAD. 1993. Environmental impact assessments (EIA) of development aid projects. Checklists for the initial screening of projects. NORAD, Oslo. 28 pp.

Pallet, J. 2008. Cumulative environmental risks of Uranium mining. *Roan News*. : 13 – 14, Roberts, C.S. and T. Sguazzin (Eds.) and the Wetlands Working Group of Namibia. 2007. *Caring for our water. A resource book for upper primary teachers and learners.* John Meinert Printing, Windhoek.

Rberts, C.S. 2008. Latest developments for a strategic environmental assessment – *Roan News* talks to Peter Tarr. *Roan News.* : 44 – 45

Roberts, C.S.(Editor) 2008. *Roan News Special Edition on Uranium mining and mining in Parks.* March 2008. 46pp.

Roberts, C.S. (In Prep). Kuiseb Basin Profile. DRFN

Schachtschneider, K. 1997. Results of the limnological monitoring of the Von Bach and Swakoppoort impoundments, as well as the baseline and monitoring results of Oanob impoundment, 1992 – 1996. DWA, Water Environment Division Report no RR/97/4. 69 pp.

Schalken, W. 2008. Exporting our national parks – uranium vs tourism. *Roan News.* : 39 - 41

Schneider, G.I.C. and E. Shivolo. 2008. Uranium mining in Namibia: The role and responsibility of the Ministry of Mines and Energy. *Roan News* : 7 – 8.

Schultz, R. 2008. Too much to soon. *Roan News.* : 37 - 38

Seely, M.K., J. Henderson, P. Heyns, P. Jacobson, T. Nakale, K. Natanga, and K. Schachtschneider. 2003. Ephemeral and endoreic river systems: Relevance and management challenges. : 187 – 212. In: Turton, A., P. Ashton and P. Cloete (Eds.) *Transboundary rivers, sovereignty and development: Hydropolitical drivers in the Okavango River basin*. AWIRU and GCI.

Shaw, D, S. Bethune, K.S. Roberts and the Wetlands Working Group of Namibia. 2004. *Wetlands of Namibia*. Solitaire Press, Windhoek

Shigwedha, A. and S. Bethune. 2006. Namibian wetlands. Wetlands are special places – let's preserve them! *Conservation and the Environment in Namibia. 2006/7. :*48 -50.

Swiegers, W. 2008. Uranium in Namibia: Perspectives from the Chamber of Mines. *Roan News* :9 -10

Tarr, J. and the National Water Awareness Campaign. 2002. *Water Pollution A resource book for IGCSE in Namibia.* John Meinert Printing, Windhoek.

Todd, S. and T. Hoffmann (2006) Riparian vegetation patterns and processes in the Buffels River Namaqualand. Presentation at WADE conference held in Cape Town 20 – 26 2006.

Usurua, U. 2008. The Kuiseb River Basin Management Committee. Summary and Presentation. In: Bethune, S., C. Ortmann, S, Nakanwe, K.S. Roberts and the World Water/Wetland Day committee. 2008. Proceedings of the World Water/Wetland Day conference " Healthy River Basins" held in Rundu, Namibia 2 – 4 April 2008.

WADE, 2005. The Socio-economic importance of alluvial aquifer for communities in the lower Kuiseb river, Namibia.

Water and Environment Team *. 1999. State of the Environment Report. Water in Namibia. Volume 1. Ministry of Environment and Tourism. Windhoek. 79 pp. * Windhoek Consulting Engineers, Inter-Consult and DRFN.

Wetlands Working Group of Namibia, 2007. (C. Roberts Ed.), *Caring for our water. A resource book for upper primary teachers and learners.* John Meinert Printing, Windhoek.

ANNEXURE 1

NAMWATER	**Namibia Water Corporation Ltd.**
GUIDELINES FOR THE EVALUATION OF DRINKING-WATER FOR HUMAN CONSUMPTION WITH REGARD TO CHEMICAL, PHYSICAL AND BACTERIOLOGICAL QUALITY	

1. INTRODUCTION

1.1 Water supplied for human consumption must comply with the officially approved guidelines for drinking-water quality.

1.2 For practical reasons the approved guidelines have been divided into three basic groups of determinants, namely:

- Determinants with aesthetic or physical implications, see TABLE 1 attached.
- Inorganic determinants, see TABLE 2 attached.
- Bacteriological determinants, see TABLE 3 attached.

2. CLASSIFICATION OF WATER

2.1 The concentration of and limits for the aesthetic, physical and inorganic determinants define the group into which water will be classified. See TABLE 1 and TABLE 2 for these limits.

GROUP A: Water with an excellent quality
GROUP B: Water with good quality
GROUP C: Water with low health risk
GROUP D: Water with a higher health risk, or water unsuitable for human consumption

2.2 Water should ideally be of excellent quality (Group A) or good quality (Group B), however in practice many of the determinants may fall outside the limits for these groups.

2.3 If water is classified as having a low health risk (Group C), attention should be given to this problem, although the situation is not critical yet.

2.4 If water is classified as having a higher health risk (Group D), urgent and immediate attention should be given to this matter. Since the limits are defined on the basis of average lifelong consumption, short term exposure to determinants exceeding their limits is not necessarily critical, but in the case of extremely toxic substances such as cyanide, remedial procedures should immediately be taken.

2.5 The group in which the water is classified is determined by the determinant which complies the least with the guidelines for the quality of drinking-water.

2.6 The bacteriological quality of drinking-water is also divided into four groups, namely:

GROUP A: Water which is bacteriologically very safe
GROUP B: Water which is bacteriologically still suitable for human consumption
GROUP C: Water with a bacteriological risk for human consumption which requires immediate action for rectification
GROUP D: Water which is bacteriologically unsuitable for human consumption

3. FREQUENCY FOR BACTERIOLOGICAL ANALYSIS OF DRINKING-WATER SUPPLIES

The recommended frequency for bacteriological analysis of drinking-water supplies is given below in TABLE 4.

TABLE 4	FREQUENCY FOR BACTERIOLOGICAL ANALYSIS
More than 100 000	twice a week
50 000 - 100 000	once a week
10 000 - 50 000	once a month
Minimum analysis	once every three months

4. PROMULGATION

The Cabinet of the Transitional Government for National Unity has approved the guidelines for evaluating drinking-water for human consumption with respect to the chemical, physical and bacteriological qualities, by Cabinet's Approval 461/85 and reporting on the evaluation of drinking-water according to the new guidelines took effect as from 1 April 1988.

GENERAL MANAGER : ENGINEERING & SCIENTIFIC SERVICES
June 1998

TABLE 1	DETERMINANTS WITH AESTHETIC/PHYSICAL IMPLICATIONS				
DETERMINANTS	**UNITS**	**LIMITS FOR GROUPS**			
		A	**B**	**C**	**D***
Colour	mg/l Pt**	20	-	-	-
Conductivity	mS/m 25^0C	150	300	400	400
Total hardness	mg/l $CaCO_3$	300	650	1300	1300
Turbidity	N.T.U.***	1	5	10	10
Chloride	mg/l Cl	250	600	1200	1200
Chlorine (free)	mg/l Cl	0.1-5.0	0.1-5.0	0.1-5.0	5.0
Fluoride	mg/l F	1.5	2.0	3.0	3.0
Sulphate	mg/l SO_4	200	600	1200	1200
Copper	µg/l Cu	500	1000	2000	2000
Nitrate	mg/l N	10	20	40	40
Hydrogen Sulphide	µg/l H_2S	100	300	600	600
Iron	µg/l Fe	100	1000	2000	2000
Manganese	µg/l Mn	50	1000	2000	2000
Zinc	mg/l Zn	1	5	10	10
pH****	pH-unit	6.0-9.0	5.5-9.5	4.0-11.0	4.0-11.0

***** **All values greater than the figure indicated.**
****** **Pt = Platinum Units.**
******* **Nephelometric Turbidity Units.**
******** **The pH limits of each group exclude the limits of the previous group.**

TABLE 2		LIMITS FOR INORGANIC CONSTITUENTS IN DRINKING WATER			
Determinants	**Unit**	**Limit for Groups**			
		A	**B**	**C**	**D***
Aluminium	µg/l Al	150	500	1000	1000
Ammonia	mg/l N	1	2	4	4
Antimony	µg/l Sb	50	100	200	200
Arsenic	µg/l As	100	300	600	600
Barium	µg/l Ba	500	1000	2000	2000
Beryllium	µg/l Be	2	5	10	10
Bismuth	µg/l Bi	250	500	1000	1000
Boron	µg/l B	500	2000	4000	4000
Bromine	µg/l Br	1000	3000	6000	6000
Cadmium	µg/l Cd	10	20	40	40
Calcium	mg/l Ca mg/l $CaCO_3$	150 375	200 500	400 1000	400 1000
Cerium	µg/l Ce	1000	2000	4000	4000
Chromium	µg/l Cr	100	200	400	400
Cobalt	µg/l Co	250	500	1000	1000
Cyanide Free	µg/l CN	200	300	600	600
Gold	µg/l Au	2	5	10	10
Iodine	µg/l I	500	1000	2000	2000
Lead	µg/l Pb	50	100	200	200
Lithium	µg /l Li	2500	5000	10000	10000
Magnesium	mg/l Mg mg/l $CaCo_3$	70 290	100 420	200 840	200 840
Mercury	µg/l Hg	5	10	20	20
Molybdenum	µg/l Mo	50	100	200	200
Nickel	µg/l Ni	250	500	1000	1000
Potassium	mg/l K	200	400	800	800
Selenium	µg/l Se	20	50	100	100
Silver	µg/l Ag	20	50	100	100
Sodium	mg/l Na	100	400	800	800
Tellium	µg/l Te	2	5	10	10
Thallium	µg/l Tl	5	10	20	20
Tin	µg/l Sn	100	200	400	400
Titanium	µg/l Ti	100	500	1000	1000
Tungsten	µg/l W	100	500	1000	1000
Uranium	µg/l U	1000	4000	8000	8000
Vanadium	µg/l V	250	500	1000	1000

***	All values greater than the figure indicated.**

TABLE 3	BACTERIOLOGICAL DETERMINANTS			
DETERMINANTS (COUNTS)	**LIMITS FOR GROUPS**			
	A**	**B****	**C**	**D***
Standard plate counts per 1 ml	100	1000	10000	10000
Total coliform counts per 100 ml	0	10	100	100
Faecal coliform counts per 100 ml	0	5	50	50
E. coli counts per 100 ml	0	0	10	10

***** **All values greater than the figure indicated.**
****** **In 95% of the samples.**

NB If the guidelines in Group A are exceeded, a follow-up sample should be analysed as soon as possible.

TABLE 4:

Determinants	Limits for Stockwatering
pH	< 4.0 and > 11.0
Conductivity	> 895.5 mS/m
TDS	> 6000 mg/l
Na	>2000 mg/l
K	>1200 mg/l
SO^4	>1500 mg/l
NO_3 and NO_2	> 110 mg/l
F	> 6.0 mg/l
Cl	> 3000 mg/l
Total Hardness	>2800 mg/l
Ca	> 2500 mg/l
Mg	>2057 mg/l