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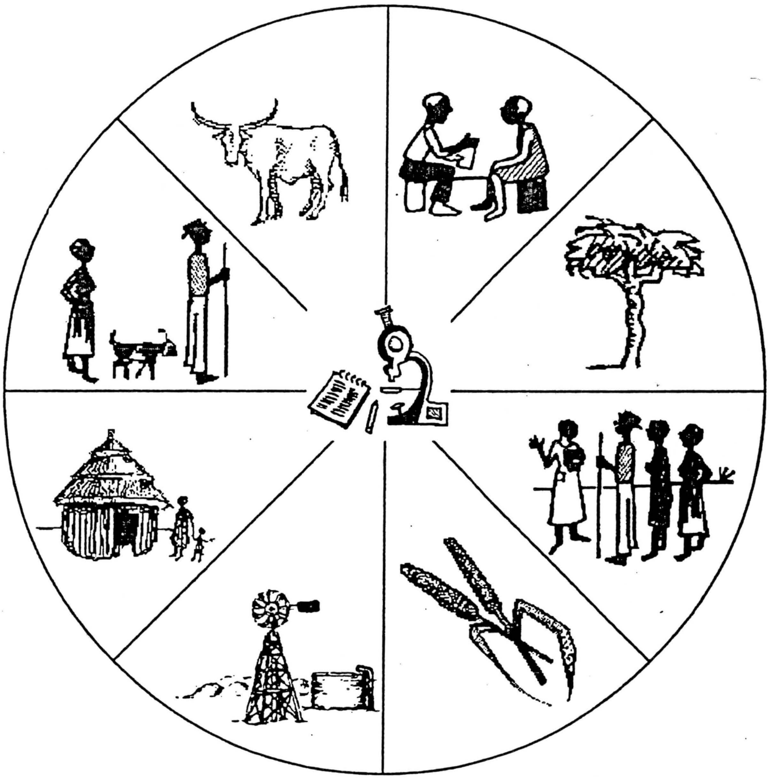
Summer Desertification Programme 8: Determining a Water Reserve for the Kuiseb River

November 2000



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SUMMER DESERTIFICATION PROGRAMME 8

Determining the Water Reserve for the Kuiseb River

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ABSTRACT

The Kuiseb River is a hydrologically dynamic river (Jacobson et. al 1995). The river's vegetation and groundwater support the wildlife, communal and commercial farmers and towns of Walvis Bay and Swakopmund. Due to the increased dependence on the river's limited water resources, SDP 8 took the initiative to determine an environmental reserve for this river.

The commercial farmers in the upper Kuiseb are said to influence the water dynamics of the Kuiseb as their farm dams limit water runoff to lower parts of the catchment. The commercial farmers form an integral part of the Namibian economy and according to them boreholes alone are not sufficient to supply water. Farm dams are therefore built in support of the boreholes. There is a relationship between number of dams and downstream runoff and this relationship is exponential, i.e. the larger the number of dams the smaller the runoff to the lower Kuiseb and the fewer the number of dams the bigger the runoff. In this study, land use and management were studied in relation to water availability. Land use in the upper Kuiseb is dependent on rainfall and the variability of rainfall affects farming practices.

It was learned from this study and previous studies that the Topnaar communities within the middle and the lower Kuiseb do not have a great influence on the dropping water levels of the Kuiseb river. The socio - economics within the Kuiseb was studied and it has been found that almost all income generating activities are dependent on water. The Topnaars are particularly very dependent on natural resources. The state of the environment in the middle and the lower Kuiseb were studied. The vegetation in the lower Kuiseb was observed to be dying. When the middle and the lower Kuiseb are compared in terms of the status of land, the lower Kuiseb appears to be degraded. One reason given for trees dying in the lower Kuiseb is the excessive water abstraction from the lower Kuiseb aquifers. NamWater abstracts water from the lower Kuiseb to supply the towns of Walvis Bay and Swakopmund. The water demands in the two towns are increasing significantly and to meet the demand, the aquifers are over-abstracted.

Apart from the water uses mentioned above a great percentage of water from the Kuiseb River catchment is lost naturally through evaporation and evapotranspiration. This report thus looks at the water inputs and outputs from the Kuiseb River with the aim of creating a balance between the two.

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ACRONYMS

RDM: Resource demand management

DWA & F: Department of water affairs and forestry

GIS: Geographic information systems

QLU: Discharge leaving the upper Kuiseb

QLM: Discharge entering the middle Kuiseb

QLL: Discharge leaving the lower Kuiseb

ICZM: Integrated coastal zone management project

UFW: Unaccounted for water

SDP 8: Summer desertification programme (the 8th year)

UK: Upper Kuiseb

CHAPTER 1: GENERAL INTRODUCTION AND BACKGROUND

1.1 Geographic description of study area

Namibia lies on the south- western coast of Africa. It is the driest country in sub-Saharan Africa, with 92% of the country classified as arid or semi arid and only 8% as sub-humid. All the country's perennial rivers, rivers that have surface water all year long, originate in neighbouring countries, thus there are no perennial rivers within the country.

A great part of the country relies on its ephemeral rivers, rivers that have surface water only after good rains, for water supply. These ephemeral rivers are dry channels throughout most of the year but containing water underground in alluvial aquifers. Namibia receives summer rains, therefore the rivers flow during this period, if at all in any one year.

Namibia has twelve major Western ephemeral river catchments that are important sources of water for people and the environment (appendix 1). These river catchments support the vegetation, wildlife, agriculture, tourism and supply Namibia's western towns, as well as the capital of Windhoek, with water. There is a continuous increase in use of the catchments' limited resources and a previous study on all the major ephemeral rivers indicated that the current utilisation of these resources is unsustainable (Jacobson et al 1995).

The Kuiseb River catchment is one of the twelve western catchments and is the focus of this study. It originates 24-30km west of Windhoek in the Khomas Hochland and drains a catchment of about 14 700km^2 and flows 503km westward through the Namib Desert to the Atlantic Ocean (Huntley, 1985). The river course follows a south-westerly direction from its origin and changes to a north-westerly direction as it emerges into the Namib desert. From here it forms a boundary between the sand dunes on its southern bank and the gravel plains on its northern bank. As it approaches the sea, dunes surround it on both sides (SDP 2, 1994).

For the purpose of this study the catchment was divided into three compartments, i.e. the Upper Kuiseb, the Middle Kuiseb and the Lower Kuiseb. The map below shows

APPENDIX 2:

Table 2.1: Hydrological model for the Upper Kuiseb

Year	PPt. in UK	Evaporation	Evapotrans	Infiltration	Q(lu)obs	Q(lu)cal	Losses	Loss %	Storage
1986	4465.7	3706.531	625.198	44.657	17.12	89.314	59.894	67.0600	12.3
1987	3405.3	2826.399	476.742	34.053	6.998	68.106	48.808	71.6647	12.3
1988	4859.6	4033.468	680.344	48.596	17.651	97.192	67.241	69.1836	12.3
1989	2784.4	2311.052	389.816	27.844	11.561	55.688	31.827	57.1523	12.3
1990	3720.6	3088.098	520.884	37.206	13.098	74.412	49.014	65.8684	12.3
1991	3248.1	2695.923	454.734	32.481	2.21	64.962	50.452	77.6638	12.3
1992	2399.2	1991.336	335.888	23.992	0.34	47.984	35.344	73.6578	12.3
1993	2960.9	2457.547	414.526	29.609	12.858	59.218	34.06	57.5162	12.3
1994	2485.6	2063.048	347.984	24.856	2.542	49.712	34.87	70.1440	12.3
1995	1852	1537.16	259.28	18.52	4.9	37.04	19.84	53.5637	12.3
1996	2149.9	1784.417	300.986	21.499	1.411	42.998	29.287	68.1124	12.3
1997	4230.9	3511.647	592.326	42.309		84.618	72.318	85.4640	12.3
1998	1860.8	1544.464	260.512	18.608		37.216	24.916	66.9496	12.3
1999									
Median	2960.9	2457.547	414.526	29.609	6.998	59.218	35.344	68.1124	12.3
Mean	3109.461	2580.853077	435.324615	31.09461	8.244454	62.18923	42.91315	68.0000	12.3

All units are in Mm^3

Table 2.2: Hydrological model for the Middle Kuiseb

year	rainfall	Input	Qem(obs)	Qlm(obs)	Evapo.	ET	Infiltration	Losses	Abstrac	Recharge
1986	54	71.12	17.12	8.117	44.82	7.56	0.54	9.003	0.018	1.062
1987	79.5	86.498	6.998	1.96	65.985	11.13	0.795	5.038	0.018	1.572
1988	68.2	85.851	17.651	16.213	56.606	9.548	0.682	1.438	0.018	1.346
1989	48.1	59.661	11.561	6.062	39.923	6.734	0.481	5.499	0.018	0.944
1990	45.6	58.698	13.098	6.807	37.848	6.384	0.456	6.291	0.017	0.895
1991	38.5	40.71	2.21	0.669	31.955	5.39	0.385	1.541	0.017	0.753
1992	18.8	19.14	0.34	0.232	15.604	2.632	0.188	0.108	0.018	0.358
1993	89.6	102.458	12.858	8.291	74.368	12.544	0.896	4.567	0.018	1.774
1994	64.5	67.042	2.542	2.301	53.535	9.03	0.645	0.241	0.018	1.272
1995	45.2	50.1	4.9	6.92	37.516	6.328	0.452	-2.02	0.017	0.887
1996	321.9	323.311	1.411	3.149	267.177	45.066	3.219	-1.738	0.012	6.426
1997	30.1	30.1			24.983	4.214	0.301		0.013	
1998	1.7	1.7			1.411	0.238	0.017		0.013	
1999	0	0			0	0	0		0.017	
median	46.85	59.1795	6.998	6.062	38.8855	6.559	0.4685	1.541	0.0175	1.062
mean	64.692	70.3712	8.24445	5.520090	53.6950	9.057	0.646928	2.72436	0.0166	1.57172

1.2 Water uses and demands in the Kuiseb

The predominant land use in the Upper Kuiseb is commercial farming. When the farms were established in the late 1800's, these farmers relied on springs and boreholes for water supply. Soon, however, the farmers had to build farm dams to support the boreholes (Stakeholders' Workshop, Windhoek, 1999).

The Topnaars, the indigenous people in the Middle and Lower Kuiseb, started making a living from this river long ago. It is apparent that water was abundant then as they used to dig wells between 1m to 4m deep (results of Rooibank workshop, 2000). Rooibank, which is one of the Topnaar settlements, used to be a natural fountain with semi-permanent springs and pools of water forming on the surface (SDP 2, 1994). Groundwater then could sustain large Nara fields and the riverine plant communities that supported game and livestock on which these semi-nomadic herders depended.

Over the last century, water demands on the Kuiseb River increased substantially. Numerous farm dams were built in the Upper Kuiseb. To supply water in the vicinity of the Lower Kuiseb, a small desalination plant was established in 1899 in Walvis Bay that provided water of high cost (1 pound per m^3) (Heyns, 1992). With town expansion and population growth water requirements by the town exceeded the supply capacity of this plant. The S.A. Railways and Harbors then developed a water supply scheme at Rooibank in the Lower Kuiseb to replace the desalination plant. By 1923 the Rooibank aquifer supplied Walvis Bay with all its water (Wilken & Fox, 1978).

Initially the water supply to Swakopmund was from the Swakop River but in 1963 an increase in salination of water from this river was detected (SDP 2,1992). Therefore, Swakopmund also turned to the Rooibank aquifer water scheme in the Lower Kuiseb. The establishment of the Rossing mine inland from Swakopmund in the 1960s and 1970s and the development of the nearby township of Arandis meant more water to be abstracted from the Kuiseb River. The Rooibank aquifer alone could not meet all these demands therefore the Swartbank aquifer became part of the Lower Kuiseb scheme in the late 1960's (Heyns, 1992). The Rossing mine alone used twice the amount of water used by Walvis Bay and Swakopmund combined. However, in 1981 the mine cut down their water consumption through reclamation and reduction in evaporative losses from tailing dams and there was also a drop in production due to drop in uranium prices (SDP 2,1992).

Meanwhile, the water table of the Lower Kuiseb River dropped significantly due to the demands it had to meet. At present Swakopmund and Arandis including the mine, can no longer depend on the Kuiseb aquifers alone because of the drop in water tables of these aquifers (SDP 2, 1992). To contribute to supplying this demand, the Omdel artificial recharge dam in the Omaruru River was established.

1.3 The project

The project reported on in this document was undertaken by the Summer Desertification Programme (SDP8) of the Desert Research Foundation of Namibia (DRFN). Twelve students from the University of Namibia and five supporting staff of the DRFN investigated water use and management throughout the Kuiseb catchment. Given the conditions prevailing in this catchment, SDP8 students undertook to determine a water reserve for the catchment that would enhance sustainable use of the river.

The overall aims of the project were (1) to test whether the generic procedure for determination of the water reserve, elaborated by the South African Department of Water Affairs and Forestry while drafting their new Water Act, could be applied in Namibia with necessary changes. Also, (2) the study was used to test the validity of the Namibian Monitoring and Information System (Namis). Namis is a methodology of obtaining data through participatory workshops and Participatory Rural Appraisal (PRA) methods with emphasis on participation and interaction. Depending on the success of this methodology it may be used for information collection in the Namibian Programme to Combat Desertification. It involved the generation and exchange of information on the status of the environment, focusing on both biophysical and socio-economic aspects.

In this study NAMIS was a direct link between the SDP8 project and the local community and information for the study was primarily gathered through the NAMIS methodology. The information on the status of the environment collected from relevant stakeholders was compared with information collected during field surveys. Three workshops were held with land users of the upper, middle and lower Kuiseb.

Existing documented data and literature on relevant subjects were consulted and incorporated in the study.

1.4 The concept of a water reserve

A water "reserve" is defined in terms of the quality of water, the quantity and assurance of water that is needed to protect basic human needs and the structure and function of an ecosystem to ensure sustainable development and utilisation. The reserve is intended to protect the resilience of water resources so that basic human needs can be met and ecological functions and processes are sustained (DWA & Forestry SA, 1999).

1.5 Methodology for determining a reserve

The South African Department of Water Affairs and Forestry has established a generic procedure for determination of Resource Directed Measures (RDM) for protection of water resources (Table 1.1). This methodology has several steps leading to the RDM determination that are needed for water reserve determination. In South Africa, this methodology has been focused and tested on perennial rivers. Determining whether this methodology could also be used in Namibia for water reserve determination in ephemeral rivers, is one of this study's objectives. Information for this report was gathered mainly through workshops held with relevant stakeholders.

1.5.1 Testing the generic methodology for RDM in the Namibian context

The steps outlined below are based on the South African methodology (DWA & F, South Africa, 1999).

Step 1: Initiate RDM study

a) Identify water resources in study area

The four aquifers Rooibank A & B, Swartbank, and Dorop in the lower Kuiseb were identified.

b) Delineate geographical boundaries for the RDM study

The study area included the whole Kuiseb catchment area, with special emphasis on the lower Kuiseb where water abstraction is taking place. Both surface and groundwater were incorporated in the study.

c) Select appropriate level of RDM determination

Rules for selecting the appropriate level of RDM determination are summarised in Table 1.1. Level 3 was selected for the study of the lower Kuiseb water resources because of the time period of the study, which was limited to ten weeks.

d) Establish study team composition

The SDP 8 (12 students and 5 supporting staff), which runs for two months was established as the study team.

Table 1.1: Levels of RDM procedure (DWA & F, 1999)

Level	Term	Characteristics	Use
1	Desk top estimate	Very low confidence, about 2 hours per water resource	For use with a National Water Balance only
2	Rapid determination	Low confidence; desktop + quick field assessment of present status, takes about two days	Individual licensing for small impacts in unstressed catchments of low importance and sensitivity
3	Intermediate determination	Medium confidence, specialist field studies, takes about 2 months	Individual licensing in relatively unstressed catchments
4	Comprehensive determination	Relatively high confidence, extensive field data collection by specialists, takes 8-12 months	All compulsory licensing. In individual licensing, for large impacts in any catchment.
5	Flow management plan	Acknowledges present operating constraints on a river; modified operating rules are drawn up between the management agency and RDM study team, which will result in a more environmentally friendly flow regime, as far as possible.	For use in highly regulated systems where present flow control structures do not have outlets from which releases can be made to provide for the water quantity component of the reserve.

Step 2:

2a. Determine ecoregional types

2b. Delineate resource units

2c. Select sites for RDM study

Steps 2a and 2b are closely linked. If a reserve determination is required for a whole catchment, it is necessary to break down the whole catchment into water resource units which are significantly different from each other to warrant their own specification of the reserve and to closely delineate the geographic boundary of each (DWA & Foresry, 1999).

The breakdown of a catchment into water resource units for the reserve determination is done primarily on a biophysical basis, according to the occurrence of different ecological regions within the catchment. For groundwater, water resource units are initially defined on the basis of geo-hydrological response units.

Step 2c is one of the most important steps in the whole RDM determination. The confidence in the determination of the reserve is very dependent on the selection of suitable study sites. The study site in this case was the entire Kuiseb catchment.

Step 3: Determine resource quality reference conditions

a) What are reference conditions?
Reference conditions describe the natural unimpacted characteristics of a water resource (DWA& Forestry, 1999).

b) Natural unimpacted conditions - a stable baseline
The assessment of present status (step4), the selection of the future management class (step5) and the quantification of the reserve (step 6) and resource quality objectives, are carried out relative to the reference conditions for that resource. The reference conditions thus represent a baseline, which is relevant to a particular resource. If the baseline is not stable, then the grounds on which management decisions are made will always be shifting. This opens the door to discrepancies. Hence, reference conditions are set on the basis of a natural unimpacted condition, since it is the most stable baseline available.

c) "Resetting" reference conditions
There may be situations where the water resource has been modified to such an extent, and in such a manner, that ecosystem structure, functions and processes have been irreversibly changed. If there is no practical way of restoring the original ecological characteristics of a particular water resource, then there may be justification for resetting the reference conditions to more accurately reflect the new

ecological characteristics. Expert judgement is consulted, the present status of the resource is assessed and a new reference condition is set according to the new ecological characteristics.

For groundwater, reference conditions are assumed to include:

- water levels
- water quality
- structure and composition of the aquifer
- biota and habitat

Step 4:

4a: Assess the present status of the resource units
This step entails a full present status assessment of resource units in terms of the degree of modification from the reference conditions looking at ecological status and resource quality, water uses, land uses as well as socio-economic conditions

Step 4b. Assess the importance and sensitivity of the resource units

Ecological importance and sensitivity:
Ecological importance of a water resource is an expression of its importance to the maintenance of ecological diversity and functioning on local and wider spatial scales. Ecological sensitivity refers to the system's ability to tolerate disturbance and its capacity to recover from disturbance after it has occurred (resilience) (DWA & Forestry, South Africa, 1999).

Social importance:
Aspects to be included in the assessment of socio/cultural importance are:

- ♦ The extent to which people are dependent on the natural ecological functions of the water resource for basic human needs (sole source of water supply).
- ♦ Dependence on the natural ecological functions of water resources for subsistence agriculture

Economic importance:
Water resources are usually important from an economic point of view. The economic value of a water resource is traditionally assessed in terms of the amount,

which can be abstracted for offstream use. Typical indicators include the number and value of jobs generated by the use of water, or the amount of revenue generated.

Determination of reference conditions, assessment of the present environmental status and sensitivity of the aquifers (steps 3 and 4) were studied in detail and are presented in the following chapters.

CHAPTER 2: GROUNDWATER DYNAMICS OF THE KUISEB RIVER

2.1 Introduction

The Kuiseb catchment, situated in the western region of Namibia, has an arid climate associated with low and variable rainfall. The catchment has a steep and well-defined drainage system that allows for substantial runoff. The Kuiseb River, which is dry throughout the year and flows only after good summer rains, maintains narrow but dense riparian forests and groups of wildlife, which mostly feed on trees. The only source of water for the vegetation throughout the dry periods is groundwater that is stored within the sandy and gravel alluvium of the river. The coastal towns such as Walvis Bay and Swakopmund also depend on the groundwater from the Kuiseb River mainly from the lower parts of the Kuiseb.

The catchment has low, variable and unpredictable rainfall. The dependence of the vegetation, commercial farmers, Topnaars and their livestock and the coastal towns on aquifers for this study may have negative impacts on the groundwater bodies in the long run. Therefore, the need to study the water dynamics of the Kuiseb River was of utmost importance.

The term groundwater dynamics as applied to the ephemeral Kuiseb river catchment describes the quantity and quality of water and the factors that produce any change in the groundwater components.

Groundwater differs from surface water, in the following respects:

1) Groundwater movement cannot be seen so it requires indirect methods of measurements and quantification (R.D.M, D.W.A, and Forestry, South Africa, 1999).

2) Groundwater moves at slow rates measured in meters/year.

Therefore, management of the resources and proper monitoring are essential as they provide information about groundwater responses to natural and human induced factors.

In this chapter we attempt to test the following statement: Groundwater is sufficient to supply present domestic, environmental, livestock and industrial water demands. We approached this hypothesis by answering the following research questions:

- Is rainfall received in the upper Kuiseb adequate to maintain the water balance in the Kuiseb?
- How do the influences of evaporation, evapo-transpiration and groundwater abstraction impact the groundwater level?

2.2 Model Of Inputs Versus Outputs In The Kuiseb Catchment Area

The following figure is a conceptual illustration of the inputs and outputs from each of the three compartments of the Kuiseb River. It also shows the relationship in water inputs and outputs of the three compartments as identified by this study.

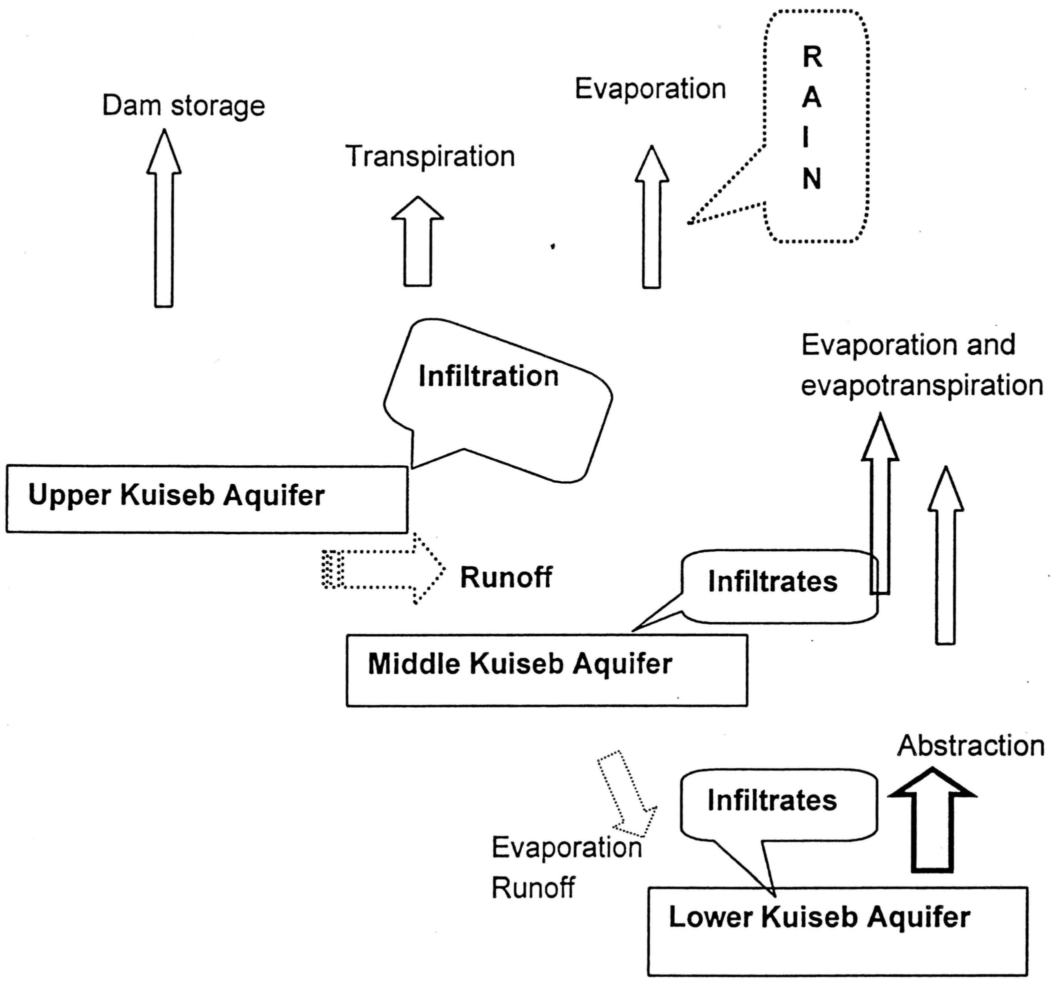

Figure 2.1 Water inputs and outputs from the Kuiseb River Catchment

Based on the above illustration a hydrological model of the catchment, including the upper, middle and lower compartments was established. The aim was to determine the inflow and outflow processes for each compartment in order to better understand water inputs and outputs into the catchment.

a) Upper catchment

The following is a balance equation of water inflow and outflow in the upper Kuiseb (see appendix 2.1):

Q (lu) = Q (em) = Rain -evaporation -evapotranspiration -infiltration -storage -losses.

Where Q(lu) is the surface discharge (leaving upper) from the upper Kuiseb and Q(em) is the surface discharge entering (entering middle) the middle Kuiseb. (Assuming no other abstraction except storage in farm dams). The loss is an unknown factor in this equation and it is estimated by calibrating the model with observed data and establishing a loss coefficient).

b) Middle catchment

Assuming no subsurface flow enters the middle from the upper compartment, the following equation is set up(see appendix 2.2);

Recharge =Rain+[Q (em) - Q (lm)]-evaporation-evapotranspiration-losses-abstraction.

In this case abstraction is made up of abstraction by the Topnaars and abstraction by Namwater. For the reference conditions (natural unimpacted conditions), abstraction is assumed to be zero.

c) Lower catchment

Under the assumption that no subsurface flow from middle to the lower catchment occurs the following equation is set up (see appendix 2.4);

Recharge = Rain+Q (el) - Q (ll)-evaporation-evapotranspiration-losses-abstraction

Where Q(ll) is surface discharge from the lower Kuiseb.

For reference conditions abstraction in the lower Kuiseb is assumed to be zero.

The key assumptions used in this hydrological model are the following

1) There is no subsurface flow from upper to middle catchment, or from middle to lower catchment.
2) Recharge is instantaneous, i.e. the soil porosity of the aquifer is not taken into account.

3) Antecedent conditions are not considered, i.e. water is not stored in the aquifer from year to year.
4) The size of the aquifer is effectively infinite, since this is a one-dimensional model. In case of large floods we need to set the Q(II) (runoff to the sea) >0.

2.2.1 Water quantity

There is a correlation between the water inputs and outputs of the three compartments of the Kuiseb River catchment as can be seen from fig 2.1. Activities occurring in one part of the catchment thus have an influence on other parts of the catchment. The entire catchment relies almost entirely on rain falling in the upper catchment as the source of water input. The middle Kuiseb receives low rainfall, e.g. for the period between 1986 and 1999 the recorded mean annual rainfall for this part of the catchment was approximately 65 mm^3 (Appendix 2.2). The lower Kuiseb rarely receives rain, therefore water recharging the aquifers in the lower Kuiseb is almost entirely runoff from the upper Kuiseb catchment.

On average in Namibia, a great percentage of the rain received is lost, 83% through evaporation and 14% through evapotranspiration (DWA, 1991). The remaining 3% either recharges groundwater locally or runs off to the lower parts of the catchment.

Using the hydrological model it was estimated that not all the "runoff" reaches the lower parts of the catchment. In the upper Kuiseb, about 20% of the runoff is taken up by the farm dams. Sixty-seven per cent is unaccounted-for (probably taken up by the plants, wildlife, lost through evaporation, evapotranspiration and recharge of local aquifers in the upper catchment) and only 13% enters the middle Kuiseb (see appendix 2.3) as surface runoff.

Surface runoff reaching the middle Kuiseb and, together with the little rainfall occurring in this compartment, recharges the aquifers. Apart from the natural losses, i.e. evaporation and evapotranspiration, water is lost through abstraction in the middle Kuiseb. Abstraction from the aquifers in the middle Kuiseb was lower than recharge between 1986 and 1996 (hydrological model for the middle Kuiseb, appendix 2.2).

Over the same time period, water abstraction in the lower Kuiseb was greater than recharge (appendix 2.4). This indicates unsustainable utilisation of the aquifer of the lower Kuiseb.

The lower Kuiseb aquifers supply Walvis Bay and Swakopmund with water. The combined safe yield for the lower Kuiseb aquifers is currently 3.16Mm^3/a abstraction but the total abstraction for Walvis Bay is 4.722Mm^3/a (Walvis Bay Municipality, 2000). Therefore there is no way that water demand for these towns will be met without over abstraction of the aquifers. Thus alternative water sources have to be sought.

Information from national level stakeholders workshops and two Topnaar workshops indicated that the groundwater levels of the Kuiseb river catchment are dropping. The participants of the workshops explained the decline in the groundwater table as a result of excessive water abstraction from the aquifers and reduced surface runoff. Surface runoff is dependent on rainfall; during low rainfall years the surface runoff is reduced and vice versa. The Topnaars argued that farm dams in the upper Kuiseb reduce runoff.

2.2.2 Water quality along the Kuiseb Catchment

Quality of alluvial groundwater throughout the Kuiseb River Catchment appears to be good and acceptable for direct human consumption (Upper and Middle reaches of the River Catchment) or with minimal treatment (Lower reaches) (Results from the workshops). Groundwater of the Lower Kuiseb varies between 600 and 1000 parts per million (ppm) Total Dissolved Solids (TDS).

Floodwater contains low TDS, typically 197 ppm (Blom in Huntley 1985). Stengel (1964 in Braune 1991) recorded qualities of 70-80 ppm TDS in flood waters sampled at the Schlesien gauging station at the Kuiseb Bridge and 260 ppm TDS near Rooibank in a low flow event in 1957. In contrast, floodwaters from Namib tributaries in the Middle and Lower Catchment are highly mineralized. A sample taken after heavy desert flooding in 1976 showed a TDS of 5375-ppm (Blom in Huntley 1985). As a result, highly mineralized groundwater in the Kuiseb aquifer occurs mainly along the northern bank. Variation in quality of groundwater abstracted at Gobabeb (pers. obs.) is thought to be caused by variation in the proportion of recharge related to the local runoff. A similar process of reduction in water quality is occurring in the lower Kuiseb.

2.3 Chapter summary

This chapter concludes that rainfall in the upper Kuiseb is the only source of sufficient water input for the entire catchment. The dams in the upper parts of the catchment reduce the amount of water reaching the lower parts. In addition to the dams there is a great percentage of the runoff unaccounted for. In the lower Kuiseb, abstraction is greater than the rate of recharge. As a result, it is concluded that current use is unsustainable and high abstraction causes the dropping of the water table. A large proportion of rain water is lost through evaporation and evapotranspiration but little can be done as these are natural occurrences.

It has been noticed that the quality of alluvial groundwater throughout the Kuiseb River appears to be good and acceptable for direct consumption or with minimal treatment.

CHAPTER 3: THE STATE OF ENVIRONMENT IN THE UPPER KUISEB

3.1 Introduction

Several studies have been done in the area on water usage, the hydrology, vegetation in the lower parts and the possibilities of constructing dams in the upper parts of the catchment that would supply water to Windhoek. However these dams will reduce runoff to the lower Kuiseb aquifers which supply water to Walvis Bay and Swakopmund.

If a dam is built at the Donkersan site it will reduce total run-off by 70%. This will cause major problems for farmers living downstream who are dependent on the Kuiseb for most of their water needs (Jacobson, 1993)

3.2 The status of the environment in the upper Kuiseb:

Geology:

The geology of the upper Kuiseb is mainly composed of an extensive mica schist plateau in the north-east near Windhoek (Huntley 1995). Other geological features present are granite, marble, quartzite and conglomerate (Appendix 3.1). This area is characterised by shallow stony soils and hard surfaces. It is mountainous and hilly with a well developed drainage system which leads water to the lower parts of the Kuiseb . (Assessing vulnerability to drought and possible effects of climate change on water resources in a semi-arid country;A. Mostert)

Rainfall:

The area receives from 100 to 400mm rainfall per annum which is the only water input supporting the entire catchment and the coastal towns (Huntley 1985)
The upper catchment is divided into five rainfall zones with variable rainfall. Highest rainfall occurs in the east and becoming less towards the west (Appendix 3.2). However 83% of the rainfall received evaporates and the remainder is used by the vegetation (14%) in the upper Kuiseb, 1-% infiltrates and 2% runoff (SDP, 1993). Part of the runoff fills the dams in the upper catchment before it reaches the lower parts. The soil surface and the 'passage' formed by the canyon enable runoff from the Khomas Hochland to the middle and lower catchments.

Vegetation:

The vegetation in the upper Kuiseb is characterised by highland savannah dominated by *Acacia hereroensis, Combretum apiculatum and Ziziphus mucronata (*Huntley 1985). Perennial and annual grasses occur on the escarpment zones. Succulent species such *Euphorbia* species appear in this area (Huntley 1995).

Land use:

The Upper Kuiseb is a commercial farming area with approximately 109 farms. The farmers in the area mainly keep livestock particularly cattle, sheep and poultry. Livestock are the main water consumers (90% of the available water) (SDP 2, 1993). Other land use types in the area are game farming and guest farms. Wildlife found here include kudu, oryx, zebra and springbok (Huntley 1995). A conservancy is being developed to add to the land use types. There is also a recreational dam, the Friedenau dam.

Objective:

As the whole Kuiseb catchment relies mainly on water input in the upper part, it is essential to understand water supply and demand in this area because it has an influence on the lower parts of the catchment i.e. the recharge to downstream aquifers, supporting the riparian vegetation, wildlife and livestock.

This chapter focuses on the influence rain has on the state of the environment and the following working hypotheses will be tested:

Ho: rainfall is not the only variable that influences the state of the environment in the upper Kuiseb.

Ha: Rainfall is the only variable that influences the state of the environment.

3.3 Groundwater model for the upper Kuiseb

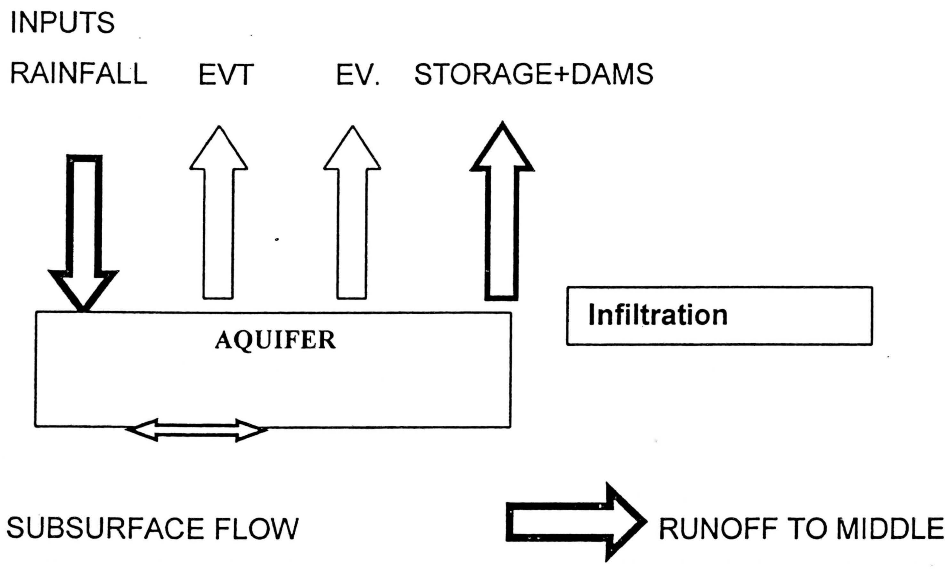

Figure 3.1

Inputs-outputs = Qem

Therefore rainfall-evaporation-evapotranspiration-infiltration-storage =runoff

The equation at work here is a mass equation but we cannot account for all the factors in this equation because of our limited knowledge about the hydrological aspects of the study. It is for the same reason that we have to make certain assumption to fit our model. The relevant assumptions for the upper Kuiseb are no subsurface flow to the other compartments of the catchment.

Evaporation, evapotranspiration and runoff are estimated to 83%, 14% and 2% respectively of the total rainfall in the upper catchment

3.4 Materials and methods

Information for this study was mainly gathered through a stakeholders' workshop held in Windhoek 2nd December 1999. Commercial farmers, representatives from Namwater, an extension officer from the MAWRD and representative from DWA took part in the workshop. Additional information was also obtained from Namwater after the workshop. Existing literature was searched for data not obtained through the above.

3.5 Results

Qualitative data from stakeholders workshop:

Table 3.1 Land use types in the upper Kuiseb

LANDUSE TYPES	PAST	PRESENT	FUTURE
Stock (large+small)	Decrease	Stable	Depends on rain
Game harvesting	Decrease	Stable	Increase (will depend on rain)
Conservancies	Increase	Increase	Increase
Guest farms	Increase	Increase	Increase
Level of diversification			
1.	Medium	High	High
2.	High	High	High

1-Level of diversification on farm

2-Level of diversification off farm

Note;The past refers to ten years back (1988-1998), the present as the last rainy season 1998/99 and the future as 2000 and beyond.

Table 3.2 Water quality and usage patterns in the upper Kuiseb

WATER	PAST	PRESENT	FUTURE
Groundwater salinity	Detectable	High	High
Groundwater quantity	Decrease	Decrease	Decrease
Economic consequences of quality or quantity	Yes	Yes	Yes
Number of boreholes	A6 D36	A6 D40	A6 D40
Springs and fountains	0	0	0
Earth dams> 20000cm3	7	7	7
Large trees:riverside	Decrease	Decrease	Decrease
Largetrees;veld	Decrease	Decrease	decrease

A: active boreholes

D: dry boreholes

Note; number of boreholes is only for one farm.

Table3.3 Management practice in the upper Kuiseb

Management		Past	Present	Future
Level of management	Resting, absence and rotation Adjustment of stock	Yes b) Yes	Yes b) Yes	Yes b) Yes
Fire	Veldt fire as management tool	No	No	No
Bush encroachment	Combating of bush encroachment	No	No	No
Drought	Economic cost of serious drought	Yes	Yes	Yes

LINE PLOT FOR ANNUAL RAINFALL IN THE UK

y=785.12-0.221*x+eps

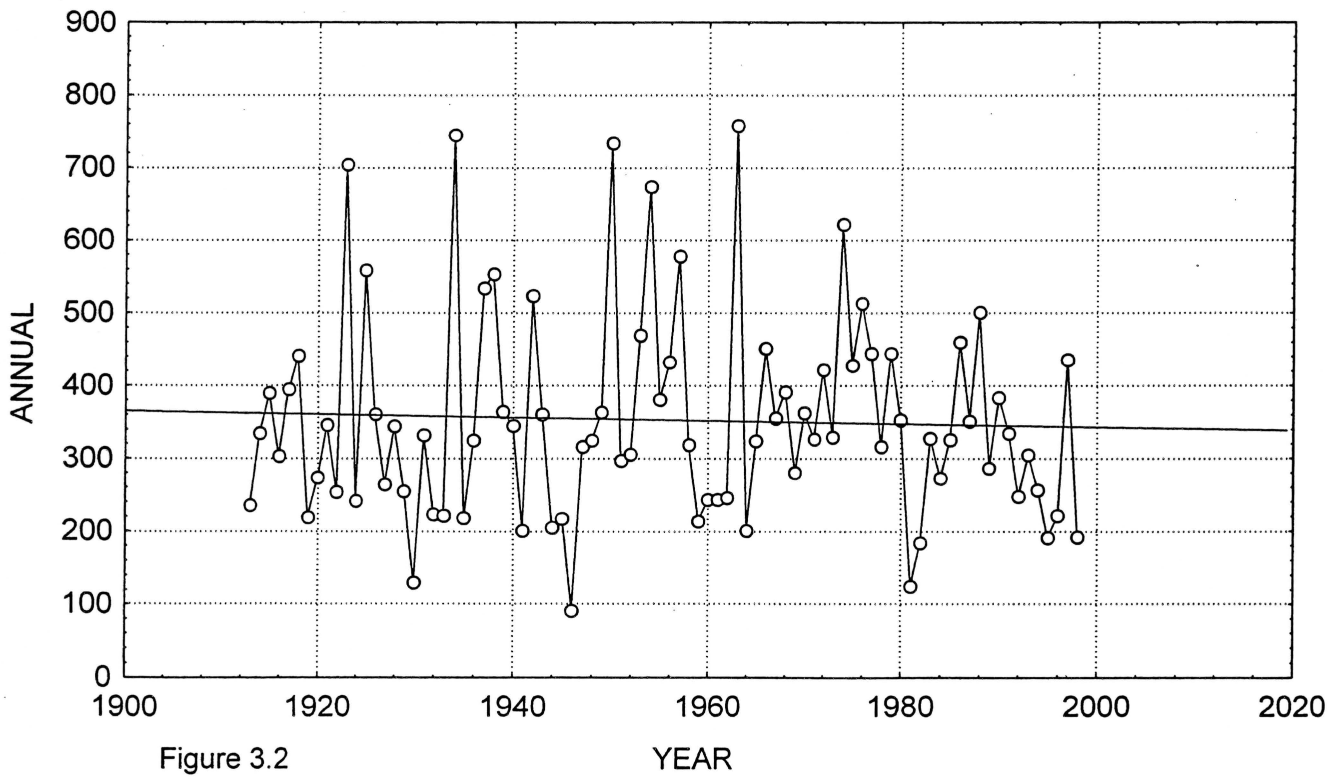

Figure 3.2

The average annual rainfall for the upper Kuiseb was 350mm per year during the period 1913 to 1998. The straight line appearing in the graph is the linear best fit for the data. It shows a slight decrease in average rainfall over the whole rainfall years. The best fitline also runs quite close to the average, above and below the mean. The rainfall is highly variable.

3.6 Discussion

Vegetation and Soil:

Most participants at the workshop described the change in the state of the environment as a consequence of low rainfall. As indicated in Table 3.2, there is a trend of large trees along and in the veld decreasing, particularly *Faidherbia albida*, which are dying. The cover density of grasses was reported to have been better 20 years ago compared to the present, because grass composition has changed from perennial to annual grasses. The building of the Friedenau dam has had major impacts on the veld conditions (Stakeholders).

Average rainfall in this compartment for the past ten years (1988-1998) was calculated to be 305mm/annum and the median 287mm/annum (Appendix 5).The rainfall during the past ten years has been substantially lower than the overall mean rainfall. This does correlate with the information given by the stakeholders that the dying trees and change in grass composition are as a result of a decrease in rainfall.

Water:

Low rainfall in the area has also led to the decrease in quantity and increased salinity of the water at the beginning of the 20th century. To support the decline in water levels Mr Ahlert (a farmer) revealed that there had been seven springs on his farm that all went dry. This took place over the last 30 to 40 years. The rainfall graph (Appendix 4) indicates that the rainfall during the early 1960s was low (below the mean). In 1963 the area received heavy rains but soon thereafter there was a decline in the rainfall. This together with the high evaporation rates (between 2800-2999 mm/year) could be the cause of the drying up of the springs. At the beginning of the last century serious damage on springs was caused by people who tried to improve them(Jacobson and Seely 1995). Which could also be a possible cause for the drying up of the springs.

Mr Ahlert indicated that the number of dry boreholes on his farm increased from 35 to 40. These boreholes were built to support the seven earth dams he has on the farm. Due to variability in rainfall, dams are unreliable sources that only supply water for 8-10 months (SDP 2, 1993). The drying up of boreholes is caused by a drop in the groundwater table which is a result of excess abstraction at the expense of the rate of recharge.

Boreholes prolong the period of water use as the water table continues to decline(Jacobson and Seely 1995). According to the stakeholders, less rainfall and the heavy abstraction of ground water is the cause of increased water salinity. The rainfall data shows a high variability instead of a decrease. Salinity in the water has become detectable in the past (ten years ago) and is increasing. The underlying mica schist bedrock in the Kuiseb (Appendix 4) is extremely salty and soluble, therefore increasing salinity (Stakeholders).

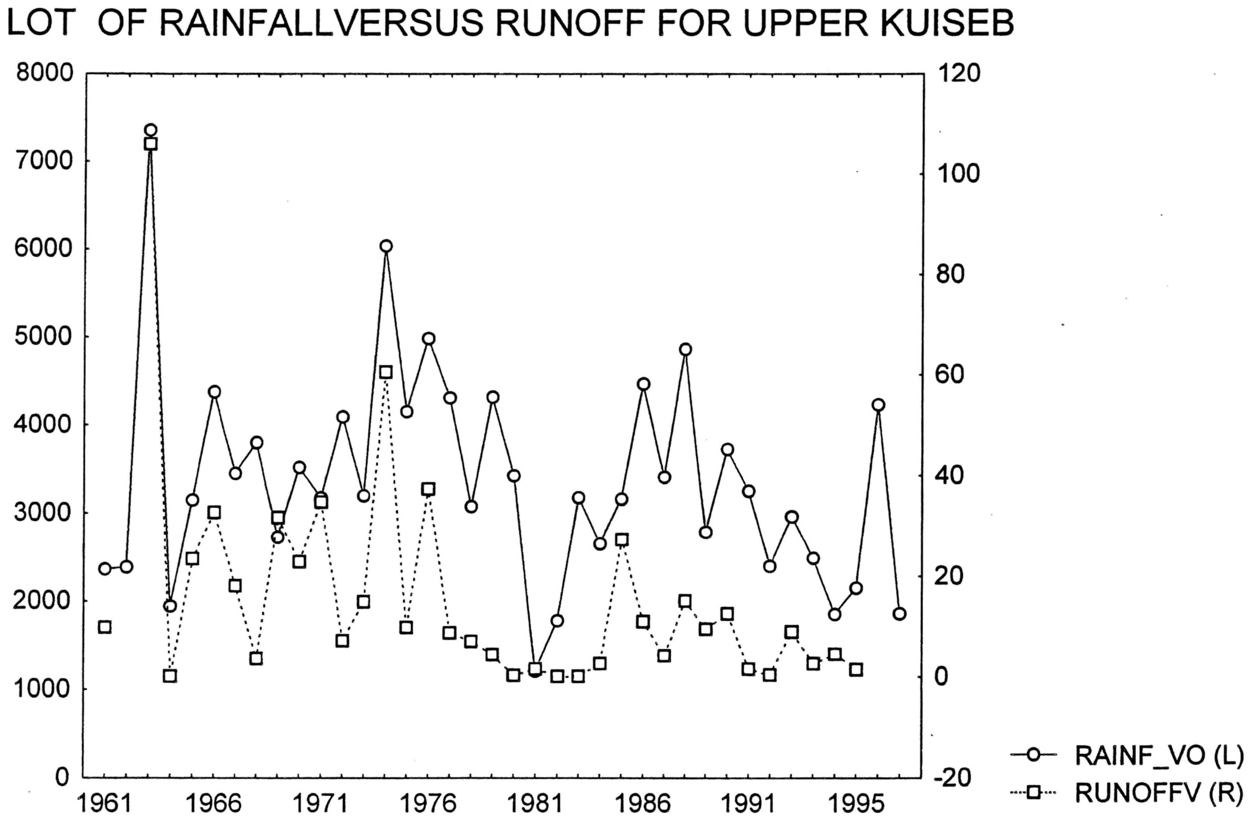

Figure 3.3

Water Input versus Output in the Catchment:

The graph of runoff against rainfall (figure 3.3) shows a trend 69% of the time. i.e: an increase in rainfall causes an increase in runoff and vice versa. During the 1970's no trend between increase and runoff was noticeable. This is the time when:

1) the number of dams increased or

2) a significant change in rainfall patterns, particularly a decrease, in rainfall.

After thorough investigation we derived the following information.

- The average rainfall before 1970 was 361mm and after 1970 it was 300mm. This shows a decrease of 16.8%.
- The runoff before and after 1970 also decreased, but the decrease in this case was 60%.

If we assume that rainfall and runoff are more in trends then both parameters should decrease by the same percentage, Which is not the case in this study, therefore the number of dams substantially decreased the amount of runoff.

Land use types and management:

The farmers at the workshop, whose future will rely on the rainfall (Table 3. 1), reported that land use in the upper Kuiseb depends on the rain just as the other factors that constitute the state of the environment. At present, commercial farmers in the area mainly farm with cattle and a few small stock. There are between 700 and 800 dams in the upper Kuiseb that store water for animals and domestic use. If the rainfall trend continues there will be a decrease in the number of livestock in the upper Kuiseb. The same argument was given for game farming. There is an expectation of an increase in the numbers of conservancies and guest farms due to economic pressure and development. Presently the development of the first conservancy is underway. Diversification (guest farms and tourism) has advantages as they possibly can allow the recovery of the land by lowering the pressure on water recharge and grazing. Tourism and guest farms are also more independent of variable rainfall (Jacobson and Seely 1995).

The farmers indicated that they had always applied management practices on the farms such as rotational grazing and therefore did not contribute much to the changes in the state of the environment especially land degradation. Bush encroachment is not a problem in the upper Kuiseb therefore fire is not used as a management tool. In their view changes in the environment were caused by variable rainfall.

Erosion caused by rain is much more severe than wind erosion. The dominant sign of erosion is sheet erosion and this leads to siltation in the dams and the river downstream. According to the farmers every management decision they take, takes into account the past rainfall season.

3.7 Conclusion

Given the conditions that prevail in the upper Kuiseb the following can be concluded; rainfall is the main variable that influences the state of the environment in the upper catchment. This is due to rainfall variability and semi aridity in Namibia. The increase in the number of dams during the 70s is a clear-cut factor that points to the importance of rain for the farmers upstream.

The Fredenau dam in particular does cause a significant decrease in the amount of runoff, especially in low rainfall years.

3.8 Recommendations

- The number of dams and boreholes per farm should be registered with the MAWRD.
- MAWRD should set up a limited number of dams and storage capacity per farm and/or evaluate the existing 20 000 m^3.
- Assessment of the demand that the dam satisfies and the effects it has on the downstream flow need to be done.
- The role of Friedenau dam needs to be reviewed.

CHAPTER 4: THE STATE OF THE ENVIRONMENT IN THE MIDDLE AND LOWER KUISEB

4.1 Introduction

The Kuiseb River is a linear oasis that supports the desert fauna as a food and water source but also extends their range into the true desert (Seely et al 1981). This explains the vital importance of the Kuiseb to the central Namib (middle and lower Kuiseb river). The water table below the riverbed and floodplain, which is usually replenished by the annual floods, is a precondition for the growth of the riparian forest. The latter is composed of several woody species whose roots are able to reach the groundwater. In the middle and lower Kuiseb, the most important woody plant species are *Faidherbia albida*, *Acacia erioloba, Tamarix usneoides*, *Euclea pseudebenus and Salvadora persica*. In addition the !Nara, A*canthosicyos horridus* can be found at some localities, as well as individual; specimens of *Acacia tortilis*, *Ficus sycomorus and Maerua schinzii* (Van Wyk et al. 1985).

The Topnaars have inhabited the banks of the middle and lower Kuiseb river for at least 300 years (Budack, 1977). Their numerous settlements originally were scattered along the banks of the river, while the riverine habitat provided nearly everything they required to meet their daily needs. Today they still live along the Kuiseb but since coming into contact with the modern economy of Walvis Bay, many of them have given up their traditional way of life. As a result the total number of settlements has deceased, with the permanent residents now living on a semi-permanent basis at the remaining localities (Seely, 1981).

The state of the environment, or the actual condition in which the vegetation cover and the soil is to be found, is an important determinant of how people use the habitat and what benefits it provides. In this chapter, the focus is mainly on state of the environment as an overall umbrella, looking particularly at two specific aspects. These are the human induced effects on the environment and, secondly, those imposed by natural changes. This chapter focuses in particular on Soutrivier and Rooibank in relation to the water reserve. A study was done in the middle and lower Kuiseb areas to investigate the vegetation cover, water availability and types of land uses that are being practiced.

4.2 Objectives

The main objective of this chapter is to determine the state of the environment of the middle and lower Kuiseb with reference to the vegetation, soil and water with emphasis on the following:

1. Change in vegetation, particularly death and regeneration of trees
2. Soil types and infiltration rates
3. Availability of water to the Topnaar community and their livestock.

4.3 Results and discussion

a) Vegetation

There are domestic stock present in every Topnaar village (Topnaar workshops, 1999 & 2000). These include donkeys, goats, sheep and cattle. Along stretches of the middle and lower Kuiseb, which are visited regularly by stock, there are signs of intensive use. This is indicated by the visible browseline on all the four species of trees studied (*F.albida, T. usneoides, E. pseudebenus* and *S.persica*). The usually strong silt-crust in the riverbed has been crushed to fine dust and the herb layer has been largely destroyed. Although all the tree species studied showed evidence of being browsed upon, *F.albida* is the most highly browsed species (appendix 4.2). *S. persica* was the second most preferred species on which the livestock browsed followed by *T. usneoides*. *E. pseudebenus* in most cases was not browsed upon.

The browsing impact on the three woody plant species (*F. albida, T. usneoides* and *S. persica*) showed the following:

- In general, all species tended to be grazed more around the villages and further away from the villages the impact differs slightly for the respective species.
- Near any waterpoint, vegetation is heavily grazed and all the new seedlings and pods are eliminated. New trees cannot grow and the ecosystem may be disturbed beyond its threshold and may not return to its previous equilibrium.

- The vegetation study at Gobabeb and at villages east and west of Gobabeb indicated that the further away one goes from the settlement the more vigorous the vegetation. Away from settlements, browse line levels were lower and not clearly visible.

Of the trees studied, 68% had pods on the branches or on the ground, and 32% had no pods at all (figure 4.3). Only 30% of the trees with pods had extensive pod cover on the ground (figure 4.4). Livestock, particularly goats, eats the pods of *F.albida*. The absence of pods on the ground results from goats and other livestock feeding on the fallen pods. This indicates the importance of *F. albida* as fodder for the animals in the catchment.

The trees' vigour was better east of Gobabeb (average of 3.68, appendix 4.4) and as one moves from Gobabeb towards the lower Kuiseb the trees' vigour decreased to an average of 2.54. This indicated that land degradation is more severe in the lower parts of the Kuiseb than in the middle Kuiseb. Several factors contribute to this but the degree of each factor is not determined. There is heavier water abstraction in the lower Kuiseb, the flood only reaches this part of the Kuiseb in heavy rain years and from the workshops it appeared that people keep more stock there compared to the middle Kuiseb and even have gardens in this part.

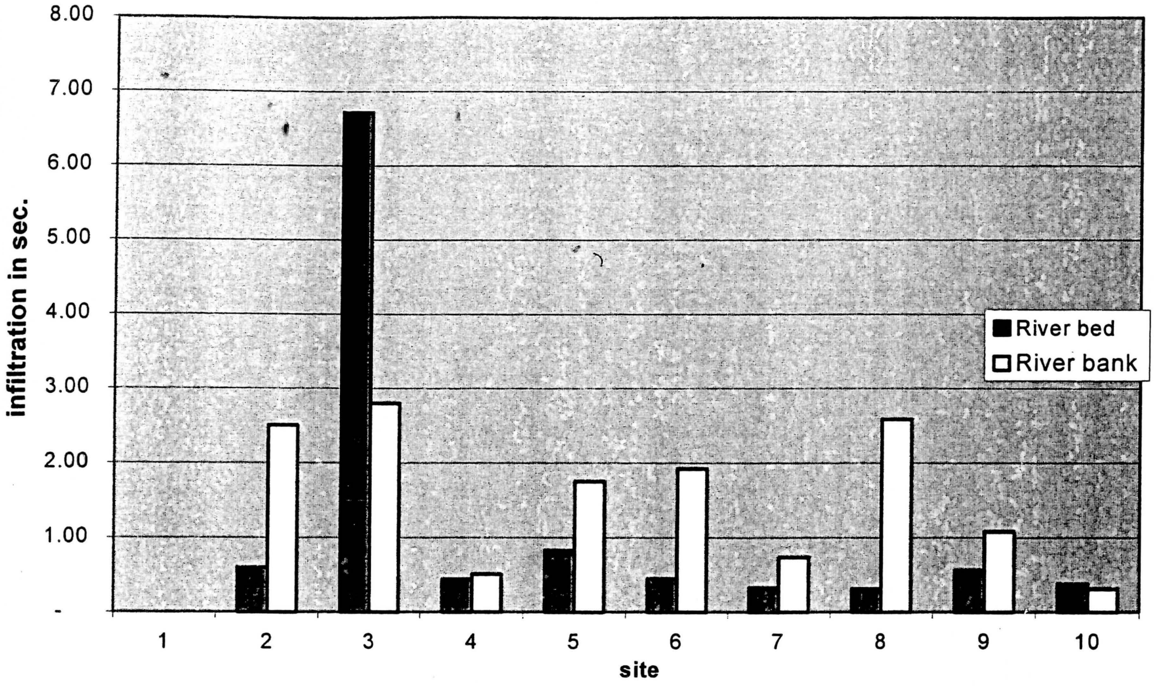

Figure 4.1: Infiltration rates in the middle Kuiseb

b) Soil

From the two workshops held at Soutrivier and Rooibank respectively, the local people said that the soil type has changed from clay to sandy soil over the past 10 years.

From the above graph, it is clearly shown that on average the infiltration rate is higher in the riverbed than on the riverbank. This correlates with the information from the soil particle size data that shows that more silt on the riverbank than in the riverbed. More silt on the riverbank means that this area can hold more water and there is a longer time for the trees to grow. The high percentage of coarse sand in the riverbed also shows that there is more water infiltration in the riverbed than on the riverbank.

According to Paulus Nande, a Rooibank resident for 48 years and David, the soil type in and around Rooibank has changed from clay soil to sandy soil. He said this is due to changes along the Kuiseb River- trees are dying and the sand from the sand dunes is easily blown by the wind into the river and the silt in the river is easily washed away by the slight floods.

According to the Topnaars who were part of the ecological walk (see materials and methods section), erosion removes the little humus in the topsoil and compaction impedes the infiltration of rainwater to recharge the aquifer and the germination or growth of plants. In the past, water could usually be found in the dry season by digging below the surface in many part of the watercourse. The Topnaar people feel that there is a change in the soil type around their communities.

Desert sand is found in areas that once were said to be highly productive, for instance at Rooibank. The majority of these deposits are permeable and permit a rapid infiltration of floodwater. With a low average annual precipitation and high evapotranspiration, a fresh groundwater reservoir is an important resource.

It is expected that under natural conditions, an overall equilibrium is needed between groundwater recharge and discharge. This hydrologic balance results in a stable interface between fresh and salty water as is situated either at the coast or offshore depending on the nature of the underlying surface deposits (Johnson1995). In addition, the lowering of land levels usually associated with pumping of groundwater can result in poorly consolidated sediments. The removal of the liquid from the sediments subtracts an integral part of the sediment mass. This causes a decrease in the buoyant pressure that the liquid had contributed to the sediments. As a result, the sediments can no longer support the pressure resulting from the overburden and they begin to compact. Once compaction occurs, the land cannot return to its former condition, even if an effort is made.

c) Water availability for the Topnaars

According the Topnaars living at Soutrivier and Rooibank, they used to dig wells by hand to a depth of 3m, which provided them with good quality water for both animals and humans. But that was until the late nineteen seventies and early eighties. In the early 80s the government had to install boreholes, as people could no longer find water even up to a depth of 18m. The state of their animals has remained the same, despite changing availability of water, and changing vegetation cover.

d) Water use from the lower Kuiseb

Walvis Bay and Swakopmund towns are situated on the west coast of Namibia in the dry Namib desert. One of the challenges for Namibia is to meet the increasing water demands for these towns. The lower Kuiseb aquifers are important water sources for the two towns. The dependence of these towns on the Kuiseb aquifers dates back to the early 1920s. Presently water demand in Walvis Bay and Swakopmund exceeds the supply potential of the Kuiseb aquifers. For this reason, the Omdel aquifer in the Swakop River was included in the scheme to supply Swakopmund with water.

4.4 Conclusion

This chapter shows that land degradation occurs in the Kuiseb catchment particularly in the lower Kuiseb. The vegetation of the lower Kuiseb is in a bad condition and a number of trees observed are dying. In the middle part of the catchment the condition is not severe and the environment seem to be in its natural dynamic state. There are three main factors causing changes in the vegetation but the one with the greatest effect was not identified. The factors are water abstraction, agricultural practices and variable rainfall all of which have a role to play.

Change in the soil type is mainly as a result of erosion that blows away the topsoil that can contain higher levels of nutrients. The communal farmers do not appear to contribute to changes in the soil. Water availability in both the lower and the middle Kuiseb has changed. Water was more abundant in the past. There is a definite drop in the water table that causes changes in the vegetation.

4.5 Recommendations

Middle Kuiseb catchment

- The effects of reduced flood rates on recharge and the environment should be monitored.
- Abstraction should remain limited for local usage (Topnaar and GTRC)

Lower Kuiseb catchment

- Namwater should review their assessment of "sustainable yield" considering that the a preliminary water reserve value determined by SDP is almost 30% lower than their value.
- The effects of reduced flooding, abstraction and other factors on the environment need be studied in detail and monitored.

- A cost-benefit study on the impacts of abstraction on the aquifer and environment need to be done.

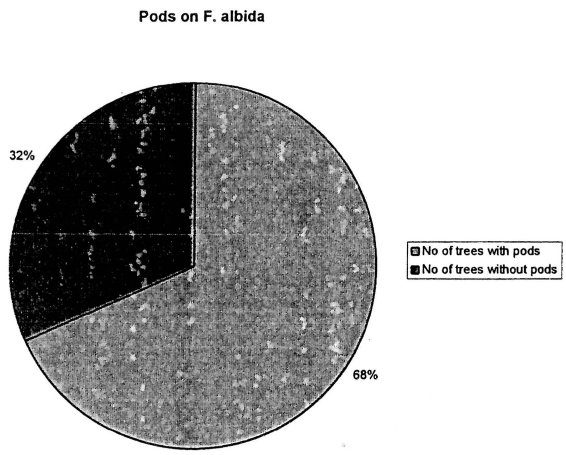

Figure 4.1

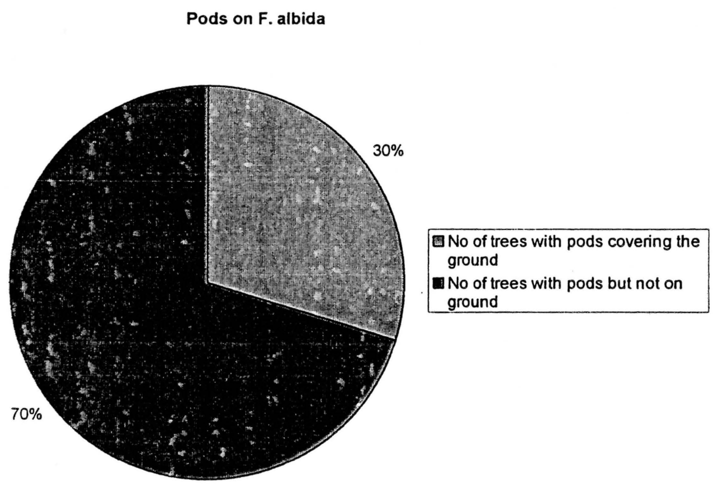

Figure 4.2

Table 4.1: Vigour of *F. albida*

East of Gobabeb		West of Gobabeb	
Site	**Vigour**	**Site**	**Vigour**
1	5	1	2.6
2	4	2	2.2
3	4.8	3	3.4
4	4.8	4	3.2
5	3.8	5	3
6	2.8	6	3.2
7	3.4	7	1.8
8	3	8	2.1
9	2	9	1.4
10	3.2	**Mean**	**2.544444**
Mean	**3.68**		

CHAPTER 5: NATURAL RESOURCE ECONOMICS

Case study: Urban area attached to the Kuiseb catchment area

5.1 Introduction

5.1.1 Background

The coastal zone of Namibia is predominantly urban because of the unique character of the landscape, which precludes agriculture. The population is concentrated in the urban areas of Walvis Bay, Swakopmund, Arandis and Henties Bay and a few small settlements such as Langstrand and Wlotzkasbaken. The main coastal towns are Walvis Bay and Swakopmund with an estimated population of roughly 42608 and 30 557 people respectively and estimated growth rates for Walvis Bay 6.5% and 3.38 % for Swakopmund. The population is expected to increase enormously. The rural population in the coastal area includes a group of Topnaar (approximately 250 – 350 persons) living along the Kuiseb river. All of the above, with the exception of the residents of Henties Bay and Wlotzkasbaken use Kuiseb water for at least some of their needs.

A number of people have moved to the coastal towns in search of employment opportunities. Only 26 % of the population of Swakopmund (CSO,1991) and 30 % of the Walvis Bay residents (TRP,1999) were born in the towns. According to the TRP Survey the main sources of migrants over the past ten years were from the Omusati, Oshana, Ohangwena and Oshikoto regions which account for 53%; while Khomas and Erongo regions were 10% and 12% respectively (TRP, 1997). High rates of population growth in the rural areas will continue to put pressure on natural resources and will support the current high level of rural immigration to urban areas. Although economic development in the northern towns may have a significant effect on limiting the flow of urban immigrants to Walvis Bay, the general rate of urbanisation is not expected to decrease significantly (ICZMP, 1999).

The fishing as well as the tourism industries in these towns form the main backbone of the Namibian economy and employ around 19 964 people (1998). Walvis Bay alone has an economically active population of 14 298 people, 72% of the total employed in the coastal zone. The remaining 28% are employed elsewhere along the coast.

Statement of the problem

The increasing demands for water in the coastal zone, largely driven by a high immigration rate in addition to the natural growth rate, means that over-abstraction of the available water sources, namely the Kuiseb and Omaruru aquifers, will continue. This has led to a severe drop in the groundwater level with accompanying negative ecological and socio-economic impacts on the surrounding environment. Economic growth will support this trend as more and more development takes place around the EPZ and the harbour as well as the fishing industry.

Given that the recharge of the Kuiseb aquifers is slow and other supply options such as desalination are relatively expensive, water availability is the most critical factor determining the future development of the coastal zone. The cost of supplying water and sanitation services affects consumption only to the degree that costs are reflected in the price. If for whatever reason, the unit price is less than the financial or economic costs of the unit of water provided by the utility, more water will be used (subject only to physical restrictions) than if the price were set at the level of these costs. The fact that water is so cheap and still subsidised in Namibia, especially in Walvis Bay, makes it lose its true value to the consumers, creating loopholes for its wastage and strangling any reasons for conservation.

5.1.3 Objective of the study

The main objective of this chapter is to determine whether costing and pricing reflect the scarcity of water and to suggest means for improving aspects such as pricing policies.

5.1.4 Working Hypothesis

The null hypothesis (Ho) states as follows: The costing and pricing reflect the scarcity of water.

The alternative Hypothesis (H_A): The costing and pricing do not reflect the scarcity of water.

5.1.5 Significance of the study

This study will help us to determine a water reserve that will enable policy makers to create policies leading to sustainable development that will raise the quality of life of our people. In the long term it can serve as a tool for poverty reduction. It is the first study in this area looking at water reserve determination so it can serve as a basis for more research in this field.

5.2 Literature review

5.2.1 Water Demand

The determination of demand

If water demand is to be managed effectively, it is essential to understand the major factors influencing it. The interpretation of the term demand and what determines it is probably the source of most confusion and disagreement of the relative weight to be given to supply and demand management. To facilitate understanding two ways to determine the demand will be discussed below.

a) The Conventional Determination of Demand

The two main ideas which drive the definition of demand, as it is used in practice, are requirements and need.

Although it is recognised that quantity and quality parameters differ from type of user and, to some extent, within user categories, the current demand for water is assumed to be mostly determined by the number of users of different types. The future demand is estimated, based on the projected rates of growth of each user group, while allowing for increase in per capita use. The usage requirements are then derived from these estimates. In practice, the estimated capacity requirements for the supply organisation include an additional allowance for water that is not accounted for in sales or other recognised deliveries to users (Garn, 1993). The resulting total is described as the aggregate demand for water.

The weakness of this approach is as follows: The demand estimate using this procedure very frequently exceeds the actual pace of growth of sales plus unaccounted for water (UFW) for a much longer period than expected. This becomes serious as water becomes relatively more scarce, as supply expansion costs rise, and as available water is more completely allocated to particular users (Garn, 1993).

Research by the World Bank has shown that these overestimates can be substantial; if investment is closely tied to accurate demand forecasts the investment cost saving could be about 20 per cent (Garn, 1993). If new investments are more closely tied to effective UFW reduction programs the investment cost savings could be in the range of 25 to 30 per cent. The legitimate need for advance planning and the likelihood of periods of excess capacity due to the lumpiness of investment should be taken into account. The revenues expected on the basis of the overestimated demands do not materialise, which leaves many utilities short of the necessary funds to meet their financial obligations without increased subsidy support.

b) An alternative way of viewing Demand

The International conference on water and the environment held in Ireland, in January 1997, has endorsed an important idea which is that: Water is an economic, as well as social good and should be managed as such: The statement reads as follows:

> *"Water has an economic value in all its competing uses and should be recognized as an economic good...Past failure to recognize the economic value of water has led to wasteful and environmentally damaging use of the resource. Managing water as an economic good is an important way of achieving conservation and protection of water resources" (Garn, 1993).*

Thus water demand is based primarily (1) on the value of water to the users, (2) the price of water to be paid by the user, (3) the users' income, and (4) the availability and price of water from other sources.

1. The more valuable the water is to the users the more will be purchased.
2. The higher the price the less will be purchased.
3. The greater the income the more will be purchased.
4. The effect of the availability and price of water from other sources depends on the relative values. If water is equally accessible, but lower in price from the utilities than from an alternative source, the more water will be purchased from the utilities.

The results are usually expressed as price and income elasticity. The likely magnitudes of these effects have to be taken individually, because these tend to vary between countries, among user groups and within user groups. The interpretation of elasticity is the percentage change in quantity used for a one- percent change in the price (for price elasticity) or income (for income elasticity).

The Price Elasticity

$$E = \frac{\Delta Q * P}{\Delta P * Q}$$

Where: ΔQ = change in quantity demand of water

ΔP = change in price of water

P = price of water

Q = quantity of water

This method is useful in the case of Walvis Bay, where the demand for water is increasing in the face of water scarcity.

From the above discussions it would be useful to look at the demands over the years from the coastal area.

5.2.2 Water pricing

Water as a Merit Good

A merit "good" is a good that harbors wider social benefits than might be reflected by the benefits that accrue purely to individuals. Education is considered to be a merit good since a well educated society will harbor wider social benefits than the benefits that occur privately to educated individuals: reduction in crime, innovative population etc. In the same breath, clean water supply is often considered to be merit good. The reduction of water related diseases as a result of clean water supply infers wider social benefits upon society than those that occur alone for example:

- a healthier workforce may be more productive
- medical costs are reduced

In cases of education and water it is speculated that the benefit to the economy as a whole is greater than the sum of private users. Economic theory states that merit goods justify some sort of subsidisation since the market in which private individuals make their preferences known will not reflect the wider significance of the provision of the good. However, there is some debate as to the extent to which water fulfils the role of merit good. It is clear that some level of water consumption is required for survival and various guidelines are stipulated for this required daily consumption: The World Health Organisation recommend between 25 – 30 litres per capita per day. It could be stated that these minimum levels of water consumption should be encouraged through subsidisation. Accepting that the recommended 30 litres per day is a socially desirable level of consumption, and recognising that certain water consumers may not be able to afford this level of consumption, implementation of cross subsidisation through increasing block tariffs has occurred within several municipalities (Boois; 1999).

An example to be considered is the cross subsidisation in Swakopmund where the first $30m^3$ per month consumed are subsidised. The tariff for the first $8m^3$ (considered the lifeline level of consumption for a household of 8) is free, and units consumed between 9 and $30m^3$/month are charged at N$ 4.25.

5.2.3 Cost of supply

The current cost of supply

The criteria currently used to relate price to cost in the sector are primarily financial, not economic. Although there are many differences between the two, the most significant for present purposes are that financial costs are based on historic costs, i.e. average costs, while the relevant economic costs, i.e. marginal costs, are future oriented.

5.3 Results and discussion

5.3.1 Water demand

From the table below, it is clear that the unaccounted for water figure (UFW) in Walvis Bay is far above the desirable level, which is 10% in a world wide context and which is considered to be a reasonable target for good management. Unaccounted for water can occur for the following reasons: leaks, inaccurate meters, illegal connections and administrative errors. In general UFW has been associated with urban water use, however similar losses can occur in all sectors, particularly in large irrigation schemes (Boois, 1999). According to Brummer 2000, the high unaccounted for water figure in the case of Walvis Bay is due to inaccurate meters accompanied with administrative errors. The management of Walvis Bay municipality is working on this to see how they can come up with water management techniques. This loss should be seen as a financial loss, since water is used and no one accounts for it, rather than to be viewed as water wastage (Brummer, 2000).

Table 5.1: Unaccounted for water (UFW) – Walvis Bay

Years	Total H_2O production m^3	UFW In %
94/95	4668488	14.6
95/96	4728067	14.3
96/97	4571496	16.6
97/98	4436786	13.9
98/99	4651386	18.2
99 /00	4722425	15.3

Source: Municipality of Walvis Bay, 2000

The water demand and consumption in the coastal area has been increasing since 1992 due to the increase in the population number as well as the increase in industries.

Table 5.2: Water consumption in Walvis Bay – cubic meters

	1992	1993	1994	1995	1996	1997	1998	1999
Total Water Demand	3906310	4192449	4668488	4728067	4571496	4436786	4651386	4722425
% change	2.7	3.2	4.0	3.8	3.1	2.7	2.8	2.73

Source: Municipality of Walvis Bay, 2000

<u>5.3.2 Pricing</u>

Current system of Pricing

Water tariffs:

The price of water in the coastal towns has been increasing over the years, as can be seen from the example of Walvis Bay in the table below.

Table 5.3: The cost of water for Walvis Bay.

Years	Increase	0-15m^3	16-25m^3	25-85m^3	+85m^3	Business	Average
93 / 94		0.58	0.70	1.04	2.20	1.32	1.17
94 / 95	45%	0.85	1.14	1.51	2.92	1.81	1.65
95 / 96	32%	1.11	1.50	1.99	3.85	2.38	2.17
96 / 97	40%	1.33	1.89	2.77	5.87	3.14	3.12
97 / 98	54%	2.16	2.80	4.27	8.54	4.27	4.41
98 / 99	25%	2.70	3.50	5.34	10.68	5.34	5.51
99 / 00	30%	3.51	4.55	6.94	13.88	6.94	7.16

Source: Municipality pers. comm. 1993

According to the table, domestic price increases with the amount of water used per month due to the implementation of the scaled water tariff system (a conservation system). On average water increased from N$ 1.17 in 1993 to N$ 7.16 per m^3 in 1999. With price increasing, water is currently priced only for its production cost and subsidised for domestic use. For the water budget to break even, a 65 % increase in tariffs is required for this current year (Brummer, 2000).

5.3.3 Cost of supply

Principles for cost of water

Water cost is determined by how much it costs to distribute the bulk water (presently N$ 2.79/m^3) and how much it costs the Municipality to purchase the water from Namwater (presently N$2.70/m^3).

According to the municipality of Walvis Bay the purchase price of water increased from N$18 505 million in 1998/99 to N$22 242 million in 1999/00, an increase of 120 %. As stated above, for the water vote to break even, a 65% increase in tariffs is required, which means the municipality will only be able to cover its supply cost. (Section 1 in the figure below)

But in addition to supply costs, there are other costs known as external costs. These may include costs to the environment when a river is dammed and the downstream ecosystems suffer. And opportunity costs, which are carried by people who forgo the opportunity to do something because the water has been used somewhere else. This forms section 2 of the cost involved, in the figure below, since these costs are not taken care of by the existing operation given that the Municipality can only break even and thus no profit is made. NamWater is also not driven by profit motive but rather by social responsibility which is the one of supplying water. Other costs, such as the environmental and economic externalities costs are paid by the tax payers, who are affected by the ecological changes, and by the economy of the country in general.

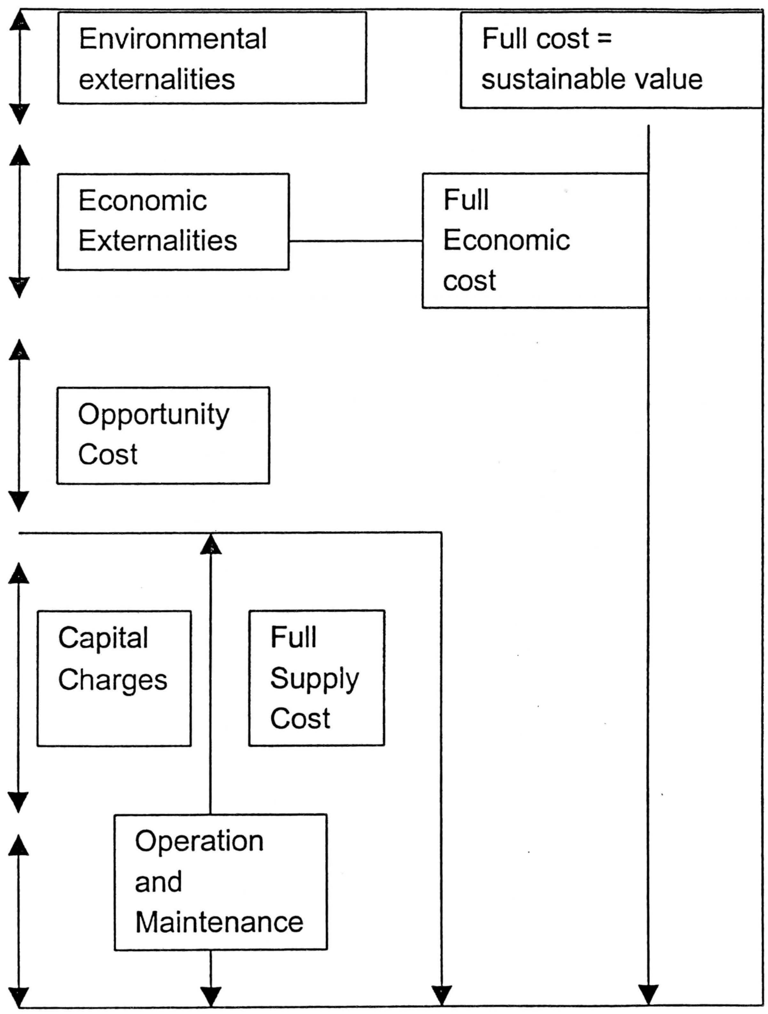

Figure: 5.1 Different cost involved in the Supply of Water

5.4 Conclusion and Recommendations

1) Demand Management

Demand management refers to a strategy to create incentives for water to be used more efficiently and less wastefully, so that instead of trying to meet the growing demand for water, one tries to manage the demand.

2) Water policy as an alternative

Because consumption for all users is somewhat sensitive to price, pricing policy should be considered as an important element of water demand management. Water pricing policy relies on improving water resource management and conservation. In many studies it has been found that water consumers respond to price changes (Garn, 1993).

3) Adjusting of water tariffs:

- We need to think of criteria that should be employed in setting prices, and get consumers' responses to setting the price.
- Water tariffs are an important tool to curb excessive water consumption, yet few municipalities in Namibia adhere to the tariff principles as set out in the Water Supply and Sanitation Sector Policy (WASP).
- Water should rather be priced at its replacement cost in order to stress its true value and reflect the scarcity of water in a desert town like Walvis Bay.

4) Removing subsidies:

- Subsidies to consumers are now on the decline and it is a common opinion that, for production purposes and for those sections of the population that can afford to pay for water, charges should adequately cover the cost of supply. In fact prices should be charged for the water itself as well as the cost of the infrastructure to provide it. An example is from Botswana where government subsidies for major supplies are supposed to drop from 76% in 1990 to 40% in 2000.

CHAPTER 6: THE SOCIO ECONOMICS OF THE TOPNAAR COMMUNITY LIVING ALONG THE KUISEB CATCHMENT AREA.

6.1 Introduction

Historical background of the villages and the people:

The Topnaars' history is not complete, but archaeological evidence suggests that a hunter gatherer community has inhabited the lower Kuiseb catchment area and it's adjacent coastline for well over two thousand years (Kinahan, 1991). Some of the early dwellers inhabited the coastal dunes, drank from fresh water springs and survived on available marine species and vegetation. Others moved and settled within the upper parts of the Kuiseb catchment area, depending on the availability of water, vegetation and wildlife. Over the last thousand years, the economy of these early inhabitants diversified from being based on hunting and gathering to include domestic farming (Kinahan, 1991).

By the mid 19th century, the Kuiseb delta people were documented as the Topnaar: A Dutch-Afrikaans translation of a Nama name #Aonin – meaning people of a marginal area (Budack, 1983). These people traded their cattle, sheep and oxen with European ocean crews for glass beads, tobacco, and alcohol. While the Europeans were eager to trade for domestic stock with the Topnaar, they expressed little economic interest in the indigenous !Nara melon. A few accounts however, describe the !Nara melon as an essential source of food and water for the Topnaar (Budack, 1983).

This chapter attempts to outline the socio economic situation of the Topnaar community living along the Kuiseb River in the Namib. How the Topnaar people use the available resources to meet their basic daily needs was investigated with particular reference to the availability of water. Since the Topnaar people depend exclusively on the Kuiseb river and it can be assumed that a drop in the ground water level could have a direct impact on them, their use of water from the aquifer was studied. It was also hypothisised that the Topnaars' use of water does not have great effects on the ground water level of the aquifer. It was felt that the socio economic situation in these areas with particular reference to the Topnaar people should be investigated with an emphasis on four main aspects with water as a cross-cutting issue.

(i) Demographics

(ii) The agricultural practices, mainly livestock.

(iii) An overview of the natural resources (i.e. !Nara, important trees and wildlife).

(iv) An overview of other resources, for example: pensions and employment.

6.2 Results and discussion

6.2.1 Demographics

Although the Topnaars today seem to have merged with the urban population of Walvis Bay, a number of them are found resident in the thirteen separate rural settlements scattered along the middle and lower portion of the Kuiseb, within and outside the boundaries of Namib Naukluft Park. The urban population is estimated to be between one thousand and three thousand Topnaars, according to the current Topnaar chief Seth Kooitjie and his counselor Rudolf Dausab. The number of Topnaars living in the Kuiseb catchment, the focus area of this study, is estimated to range between 350 and 450 (Kooitjie, 1994, Namibia census, 1991).

In March 1966, researchers at Gobabeb estimated the total population of the lower Kuiseb to be about 130 people in eight settlements as reflected in table 1. The 1991 Namibian population and Housing Census recorded a total of 313 people living in the 9 villages inside the Walvis enclave which was administered by South Africa. Taking the 1966 estimates of 130 people in 8 villages by Jenkins and Brian in comparison to (1994) estimates of 428 people in 13 villages, the net population of the lower Kuiseb has indeed more than doubled over the past 28 years. However, it was not possible to calculate the annual growth rate as no stable or average population has ever been measured and there are no data available on population mobility, birth rate or mortality rate.

Table 6.1: Topnaar population and number of settlements over a period of 28 years.

Years	Number of people	Number of settlements
1966	130	8
1991	313	9
1994	428	13

Contrary to other places in rural Namibia which show gender imbalances (i.e. more females than males), there are more males than females living along the lower Kuiseb especially between the ages of 20 and 45 (55% of males versus 45% of females) (Jenkins and Brian, 1966). The age structure is typical for that of a developing country, skewed towards a younger generation – 43% less than 15 years of age, 52% adults aged 15-59 and 5% are pensioners aged 60+ (Jenkins and Brian, 1967).

Table 6.2: Age and gender of the Topnaar

Age group	Percentages
Less than 15 years of age	43%
15-59 years	52%
60+	5%

The 1994 study shows that the thirteen settlements are spaced between two and 15 kilometers apart and line the northern bank of the river for about 130 kilometers. Within villages, dwelling areas and kraals are relocated, intermingled and overlain on the same spot. Homes are constructed from second hand and scrap building materials, flattened metal oil drums, corrugated iron sheeting, old signs, cardboard boxes, timber, wire, bark and disused cars and buses i.e. anything people can find.

In 1991, the total population of Gobabeb was 21, of which 16 were Topnaars and 5 were foreign researchers. Of the 188 Topnaar living in Etuseb, 117 were school children at the local primary school and 71 were residents. In addition, most of the twenty teaching staff originated outside the lower Kuiseb, from Walvis Bay and from southern Namibia. The Etuseb School has grown since 1991. Of the 40 to 50 residents living in the Department of Water Affairs (DWA) housing complex at Rooibank, one family of five were Topnaars and the rest originated from other parts of Namibia. In summary, from tables 1 and 2 one can deduce that the number of people has increased over the last 28 years.

Table 6.3: Number of people in three different settlements.

Settlements	Number of people
Gobabeb	21
Etuseb	188
Department of Water Affairs, Rooibank	50

1991 census survey

To relate this to our findings from the workshop held with the Topnaars at Soutrivier, it was discovered that the number of people in the village had decreased. The reason given was that people, especially the young, moved to Walvis Bay to search for job opportunities. However this is not representative of the entire middle and lower Kuiseb.

6.2.2 Use of agricultural and natural resources

As in all other rural areas in Namibia, the Topnaar communities within the Kuiseb river catchment depend on natural resources for their livelihoods. Livestock farming also plays an important role in their lives. Table 6. 4 below shows the ranking of these resources based on the importance of each resource. The text thereafter gives a more detailed explanation about each resource.

Table 6.4: Resource ranking for Soutrivier and Rooibank as indicated by workshop participants.

Resource	Soutrivier	Rooibank
!Nara	2	2
Livestock	3	1
Water	1	1
Wood/ trees	4	3
Pension	4	4
Maize meal	1	1

Explanation for resource ranking:

1= High reliance, important source of life

2= Medium reliance, important only when available

3= Medium to low reliance, occasionally used

4= Lowest reliance, only if no alternatives

Although the order of importance of the resources varied for the two Topnaar villages, Rooibank and Soutrivier, it is clear that the same resources are used to sustain life at both places and probably the same applies to all other Topnaar villages. Water and maize meal are the most important resources in these two villages. It was stated that water is life and without it Topnaars would have no life. Their animals depend on water and people use water for drinking, cooking and bathing. It was indicated at the workshops that maize meal was the stable food for the Topnaars, not !Nara as many people believe.

!Nara is of second rank importance to many Topnaars. However, to a few, !Nara is still the most important resource. One resident of Rooibank at the workshop maintained that !Nara is still of importance to him as he generates income by selling them in Walvis Bay. "I sell 10 bags of !Nara and get N$3 500 for them" reckoned Nickey. To those living at Rooibank, livestock are of great importance. Wood and pension are of approximately the same importance at both Rooibank and Soutrivier. The ranking of resources was said to differ from season to season.

A Agricultural practices

(a) Livestock farming

Although !Nara was ranked second in importance overall, it appeared to have a high qualitative importance to the Topnaars we interviewed. Particularly at Rooibank, it has declined in importance and households have shifted their time and effort into stock farming. For some Topnaars, stock farming is the most important land use practice. With boreholes installed in all settlements many households, particularly the ones headed by wealthy farmers, have been able to increase their herds (Budack, 1994). Table 5 shows that the main livestock kept by the Topnaars are goats. Though the numbers of goats fluctuate over the years, there are more goats than any other livestock. Goats are considered to be drought resistant by the Topnaars. That is why they are preferred over other types of livestock. Compared to goats, cattle consume a lot of water. At Soutrivier, the residents do not keep cattle as they are expensive to maintain. They indicated that cattle were kept only during periods of heavy rains. Table 6.5 indicates that the number of cattle and donkeys is increasing though at a slow pace. Horses were introduced into the area in 1989 and from the table it can be seen that they are not doing well.

Table 6.5. Number of livestock kept by Topnaars over a period of six years.

Type of stock	1988	1989	1990	1991	1992	1993
Cattle	78	105	123	160	161	163
Goats	1442	1615	2413	2507	2231	2374
Donkeys	63	64	90	118	116	120
Horses	0	215	7	9	7	6
Sheep	0	0	2	22	24	30
Pigs	0	0	0	0	5	7

(Source: Mr. Burger, Veterinary Services, Windhoek)

Information gathered from the two workshops reveal that Topnaars depend on their goats for meat, milk and income. For example, they use goat skins to make mats and belts that they sell in Walvis Bay. The donkeys are used to pull donkey carts that are the basic mode of transport. According to the residents, pigs were brought into the area for the first time in 1992. From the Rooibank workshop it was discovered that some villagers farm with chickens and sheep in addition to the other livestock, although on a small scale. In general, livestock farming has become important for the Topnaars as the use of !Nara declines.

(b) Crop farming:

Crop farming is not practised at Soutrivier and the reason given by the villagers at this place was that it requires a lot of water to maintain fields or gardens. They referred back to the times when water was abundant, when they used to have hand dug wells and revealed that they cultivated crops then. Contrary to what was found at Soutrivier, participants of the Rooibank workshop indicated that they cultivated crops.

B Natural resources

a) The !Nara

The !Nara as an indigenous plant has been used for many years by the Topnaar people in many different ways. A study by Budack in 1983 revealed that the harvesting of !Nara was no longer of subsistence throughout the year for the majority of Topnaar families due to its inaccessibility. Presently only a handful of individuals move to the Kuiseb delta each summer and are driven by the cash incomes earned from selling the pips in Walvis Bay. According to Budack, during his excursion to the !Nara fields in February 1983, five groups were found harvesting the !Nara. This implies that today there is only a small number of households depending on the !Nara for their economic livelihood. Virtually all Topnaar families have abandoned the seasonal practices of moving to the delta to harvest !Nara. Instead, a new trend has emerged where a few individuals, mostly men, travel to the !Nara fields for a few weeks each season and collect just enough !Nara melons to make a few hundred dollars that are used in different ways (i.e. pay hostel fees or buy provisions for their families, and even buy a few goats). Similar to what Budack found in his 1983 study, a workshop conducted by SDP8 with the Topnaar people living at Soutrivier revealed that although !Nara has been the main reliable resource for the Topnaars for centuries, its value has declined over the years. A study on !Nara plants by the DRFN and Topnaars in 1996, revealed that one cause for decline in the use of !Nara could be that the !Nara fields are moving further away from people.

"We need research on the amount of water used from the Kuiseb, as this influences the prominence of the !Nara plants along the Kuiseb" Mr Dauseb was quoted. According to the Topnaars, before groundwater was abstracted from the Kuiseb to supply Walvis Bay, Nara fields were big enough for people to make a living from.

b) Trees

The same species of trees are used for the same reasons at both settlements where the workshops were held. *Euclea pseudebenus* was reported to be the main species used for firewood. Other trees such as *Faidherbia albida*, *Acacia erioloba and Salvadora persica* are also used for firewood but are not preferred as they produce a lot of smoke. *Faidherbia albida* and *Acacia erioloba* are important for livestock grazing.

C: Other resources

The middle and lower parts of the lower Kuiseb where the Topnaar villages are situated is located within the Namib-Naukluft Park. During the workshops, residents indicated that they would like to live with game as did their forefathers. This has been made difficult by proclamation of the park and implementation of the Odendaal Plan.

Rudolf Dauseb, counselor of the area, was quoted "As history has proven, in the past we were living freely in this area as other Namibians are living in the rest of the country. Unfortunately, this area was proclaimed as a national park, and from there on our traditional way of life was completely changed. We had to adapt to the park regulations, which was so insulting and discriminating against the people, because it forced this community to change its way of life completely.

While this view of the situation is held by the Topnaars, it was learnt from an interview with Mr. Maketo, Chief Warden of the Erongo Region in the Ministry of Environment and Tourism, that the park regulations did not apply to the Topnaars as they were found living there before its proclamation. The Topnaars are allowed to do everything in the park except hunt.

In a sociological survey of the lower Kuiseb in 1992, it was discovered that tourism in this area was beneficial to the people. In a number of ways, people could provide guides for tourists who visit the area, donkey cart rides, information and tours to the !Nara fields (Jones, 1992). While this viewpoint represented both the middle and lower Kuiseb areas, our workshops at Soutrivier and Rooibank showed that although people knew about tourism, they were not ready to opt for this option as they did not know much about it.

Another way in which Topnaars generate income is through formal employment. The Gobabeb Training and Research Center and the NamWater facility at Rooibank provide job opportunities for these people. A number of Topnaars are employed in Walvis Bay and they send remittances to relatives remaining in the villages.

6.3 Conclusion

The socio economic situation of the Topnaar community, shows that they have been depending on natural resources for a long time, particularly the !Nara, *E. pseudebenus* and wildilfe. As !Nara fields became less productive and people could no longer rely on wildlife (because now they lived in a park), they diverted their dependence from these resources to livestock farming and seeking other alternatives to making a living. The decline in the groundwater table of the Kuiseb affects them because !Nara no longer produces fruit as abundantly as in the past. To many, !Nara was the most important natural resource from which they made a living. Although many have shifted to livestock farming as an alternative, they farm mainly with goats because they do not require a lot of water. Overall, the Topnaars use little water, less than 0.1% of the water abstracted from the lower Kuiseb. Therefore they do not have a significant effect on the groundwater levels.

CHAPTER 7: SUMMARY

7.1 Lower Kuiseb:

7.1.1 Vegetation

Based on the Rooibank workshop and own observation, the riparian vegetation seems to be under stress. This might be due to natural causes, even though abstraction of water from this area could be an aggravation. The virtual absence of rainfall on the other hand has a direct effect on the production of grasses in this area. Slabbert 1991 stated that vegetation stress was observed to be worse in 1991 compared to the 1978 study.

7.1.2 Land uses

Abstraction of water from the Kuiseb is of vital importance to the Topnaar community. Apart from the Kuiseb River, there is no other place to keep their livestock (cattle, goats, donkeys and chicken). !Nara fields occur in the northern regions close to the Rooibank area. These however are not productive and are not used optimally any more because of lack of water (Rooibank Workshop, 2000). The !Nara plant is sensitive to competition from other plants and to a lower quality of water (Slabbert, 1991). Cultivation also exists in the lower Kuiseb where maize, carrots and onions are planted in Rooibank villages. Because people in the lower Kuiseb do not stay in the park, they have more freedom to carry out different land uses. As many of the trees are dying, people make money from selling wood.

Vegetation types such as *Acacia erioloba* and *Faidherbia albida* and their pods are a primary food source for the Topnaars' livestock, although other vegetation types in the Kuiseb ecosystem also contribute to the livestock's diet.

7.1.3 Water abstraction

The town of Walvis Bay with a population of 37 565 people (projected to be 45 804 in the year 2000) uses 4.4 Mm^3 water per year from the Kuiseb aquifer. This water is used for domestic (72%) and industrial (28%) purposes. Of the town's entire water consumption, 36% is used for gardening (SDP, 1994). The town of Swakopmund with a population of 24 000 people uses 2.9 Mm^3 water per year, for domestic purposes (96%) and light industry (4%).

The rate of recharge, sustainable yield and water levels of the aquifers was compared to abstraction and the following was observed.

Recharge vs. abstraction

Recharge to the lower Kuiseb aquifers is predominantly from runoff events and some subsurface flow. A good indicator of recharge to the aquifers is based on the estimated runoff losses that occur over the whole aquifer domain (Namwater, 1998). The current rate of abstraction from the lower Kuiseb aquifers is exceeding the rate of recharge (Fig 1.2).

Sustainable yield vs. abstraction

The lower Kuiseb aquifer provides water to the west coastal towns and to the Topnaar community living along the river. Sustainable utilisation of the aquifer requires achievement of a balance between an acceptable rate of abstraction and the sustainable yield. Total abstraction from the Kuiseb River has varied considerably over the years (Chapter 2).

The estimated sustainable yield for the lower Kuiseb aquifer that was set by the Department of Water Affairs is given in the table below

Table 7.1: Estimated existing groundwater & sustainable yield (DWA, 1993 & Namwater, 1998)

Aquifer	serve Mm^3	cy yield Mm^3	Sustainable Yield m3	Remarks
k		2.0	2.0	0 Mm^3 in dead storage
A		1.2	1.2	6 Mm^3 in dead storage
B		0.8	0.8	
Dorop		5.0	1.0	From mining reserves

Comparing the sustainable yield of the aquifers with the actual abstraction for each year (1986-1998), it is visible that abstraction exceeds sustainable yield.

fields exist, which don't seem to fruit any more (Soutrivier Workshop). Although the Topnaars in the middle Kuiseb also sell wood, they do it less frequently compared to those living in the lower Kuiseb areas. As in the lower catchment, riverine vegetation supports the Topnaars' livestock.

7.2.3 Water uses

About 400 Topnaar communal farmers in 10 villages use about 0.006 Mm^3 per year from Kuiseb groundwater. This water is used for livestock (58%) and domestic (42%) purposes (SDP, 1994). Groundwater also supports the vegetation on which the livestock browse and the !Nara plants which are income generators and a source of food. About 0.007 Mm^3 water per year is used by researchers and educators living at Gobabeb (SDP, 1994). This compared with 7.3Mm^3 used by Walvis Bay and Swakopmund are negligable.

Water used by Walvis Bay and Swakopmund from the Kuiseb aquifer is not sustainable. Exhaustion of the reserve can be predicted if current rates of abstraction continue. Based on the state of the environment presented during the above discussion, it is not really clear whether the vegetation is dying because of over-abstraction from the Kuiseb River or whether there are other contributing factors. However, the state of environment has changed considerably during the past few years.

7.3 Upper Kuiseb

More than 750 farm dams with a total storage capacity of about 12.3 Mm^3 are spread over the upper Kuiseb catchment. It was estimated that the combined effect of these dams amounted to a reduction of the average flow of the Kuiseb River by 21% (Slabbert, 1991). Runoff from the upper Kuiseb catchment is highly variable, with a high of 105.9 Mm^3/a and a low of 0.0065 Mm^3/a as recorded at Schleisen Weir (SDP, 1994). Of the total water entering the KCA annually as rain, 83% evaporates immediately, 14% is used by vegetation and only 3% is potentially available for consumption (SDP, 1994). Evaporation from open water storage surfaces on farm dams and reservoirs was identified as a large avenue for water loss in the upper and middle catchment.

Recharge to the lower Kuiseb aquifer is dependent on runoff events and subsurface base flow. After the 1997 floods, recharge to all aquifers was recorded. Water levels in the Swartbank and Rooibank A areas increased by an average of 2.23 m and in Dorop South and Rooibank B areas by 0.41 m and 0.5 m respectively (DWA, 1993).

CHAPTER 8: SETTING THE RESERVE

8.1 Introduction

An environmental reserve for an ephemeral and a perennial river can be set according to different criteria. We can decide whether we want to set a reserve according to its reference conditions or whether we want to set a new standard to which the newly defined reserve must conform. In trying to do so we have to know the reference conditions and the present status of the reserve, only then can we decide on the conditions the reserve will be based on. In setting a reserve in this study, we tried to strike a balance between the environment on one hand and development on the other, so that neither of the two suffered at the expense of the other, but rather so that they could complement one another.

8.2 Reference conditions for the Kuiseb catchment groundwater resource

Since the abstraction of water from the lower Kuiseb River started in 1923, it is assumed that the groundwater resource has been modified. Thus the reference conditions are set according to the information that was collected from the workshops. This information is presented in table 8.1 below. The water level and fauna of the upper catchment could not be determined because of inadequate information.

8.3 Present status assessment of the resource

Table 8.1: Reference Conditions

Resource quality	Lower	Middle	Upper
Water level (below surface)	0-4m	0-3m	Unknown
Water quality	Good	Good	Good
Flora	♦ Figs ♦ F. albida ♦ A. erioloba ♦ E. pseudebenus ♦ P. salvadora	♦ Figs ♦ F. albida ♦ A. erioloba ♦ E. pseudebenus ♦ P. salvadora	Perennial grassland, narrow riparian vegetation, woody forest
Fauna	♦ Reptiles ♦ Amphibians ♦ Wildlife ♦ Livestock	♦ Reptiles ♦ Amphibians ♦ Wildlife ♦ Livestock	Livestock, wildlife, other unknown
Inhabitants	Semi-nomadic Topnaars	Semi-nomadic Topnaars	Commercial farmers

8.3.1 Structure and composition of the aquifer:

Rooibank A

This aquifer is made up of varying proportions of reworked aeolian and fluvial sands, gravel and silts. There are narrow channels in the bedrock that provide conduits linking with the up-stream Swartbank and other areas (Wierenga, 1989). The maximum capacity of this aquifer is estimated to be $20Mm^{3.}$ (DWA, 1991)

Rooibank B

The aquifer is composed predominantly of aeolian sand with extensive intercollations of impermeable fluvial silts (Wierenga, 1989). The maximum capacity of this aquifer is estimated to be $126Mm^3$ (DWA, Slabbert, 1991).

8.3.2 Resource quality and ecological status

Table 8.2: The present resource quality of the Kuiseb catchment

Resource quality	Lower Kuiseb	Middle Kuiseb	Upper Kuiseb
Water level (below surface)	5.0	9.6	Unknown
Water quality	Good	Good	Increase in salinity
Flora	Riparian	Riparian, palms	Unknown
Fauna	Livestock	Livestock	Livestock
Water treatment for basic human needs	Minimum treatment	Minimum treatment	Minimum treatment

Source: DWA, 1993 & The Stakeholders workshop (Windhoek, Dec1999)

Table 8.3: Water quality evaluation of the different aquifers (DWA, 1993)

Water quality	Rooibank A	Rooibank B	Swartbank	Dorop
TDS value (mg/l)	900	800	-	128 1375
Comment on quality	good	good	good	Bad, contamination might have occurred during drilling

Although water quality in the Middle Kuiseb is generally good, fluctuations from class A to class D (S.A.B.S for drinking water) were recorded.

Table 8.4: Assessment of the resource in terms of land use, water use and socio-economic conditions

RESOURCE	UPPER KUISEB	MIDDLE KUISEB	LOWER KUISEB
Land use	Livestock farming, Guest or tourist lodges, small scale cropping	Livestock, Nauklift National Park, Gobabeb Training and Research centre	Livestock
Water use	Domestic use including livestock, small scale irrigation	Domestic use including livestock	Domestic use including livestock
Socio-economic condition	Productivity of farms is decreasing leading to a reduction in the employment of the local inhabitants of the area	Mainly dependant on !Nara sales, goat sales, pension, Gobabeb jobs and money coming from jobs outside the catchment	No other sources of income apart from goat sales, !Nara sales, pension, Namwater jobs and money from the coastal towns.

8.4 Present importance of the groundwater resource

8.4.1 Ecological importance and sensitivity

The aquifers are ecologically very important and only the Dorop aquifer is sensitive (Stakeholders workshop, Windhoek 1999

8.4.2 Social importance

The aquifers are the only source (Stakeholders workshop, Windhoek 1999) of water supply and subsistence agriculture is very dependent upon them.

8.4.3 Economic importance

The aquifers have a high degree of economic importance because all jobs and activities in Walvis Bay are centred on them. (Stakeholders workshop, Windhoek 1999)

8.5 Major findings for the reserve

The aquifer at Rooibank is a bowl-like sand and gravel filled depression with a broad lip. For this reason as abstraction continues the rate of decline of the groundwater subsidence accelerates.

The capacity of the Rooibank aquifer for abstraction depends upon recharge. The Swakopmund Municipality identifies 4.2 Mm^3 as a sustainable Kuiseb yield. Nevertheless abstraction increased from 6.7 Mm^3 to 9.9Mm^3 between 1987 and 1998.

The 1996 flood did not saturate the aquifer. It increased extractable reserves to about 42 Mm^3 from 32 Mm^3 but as of 1998 the groundwater level has been declining and below 40 Mm^3.

The total capacity of the Kuiseb aquifer is 280 Mm^3. Of this 150 Mm^3 is Rooibank B and Dorop south. In the year 2000, the abstractable water and the ground water table are again declining and now stand near 38Mm3. At the rate the water was abstracted between 1986 and 1996, the aquifer will be exhausted by 2014 if a recharging flood does not occur. There is a 23% chance that such a flood will not occur.

We recommend a maximum risk of 20% of depletion to failure based upon only major floods. The probability of no flood occurring in 16 years is 20%. This puts the maximum extraction of Swartbank and Rooibank A to 2.3 Mm^3 as a first option. The current sustainable yield of the aquifer as calculated by DWA is 4.2 Mm^3 per year. The current abstraction rate is 7.3 Mm^3 per year, exceeding the sustainable yield by 3.1 Mm^3 per year.

As a second option we recommend that the abstraction rate of 7.3 Mm^3 per year be brought down to 4.2 Mm^3 per year which is the sustainable yield of the aquifer. By this it is hoped to reduce the rate at which the water table is dropping.

8.6 Recommendations

- By reducing the rate of groundwater abstraction and allowing the aquifer to recharge during floods, the impact on the woody vegetation in the Kuiseb catchment could be minimised.
- Alternative sources of supply must be found while the Kuiseb aquifer recharges, such as the desalination plant proposed for Swakopmund.
- Undertake an in depth study of the water reserve. Our results suggest that by reducing abstraction to 40% of the recharge rate, the water level could recover to reference level (5 M below surface).
- A sustainable water use policy should be implemented, suitable to the Kuiseb catchment.
- The Kuiseb directly above Swartbank should be declared a no abstraction zone.
- Establish Water Demand Management Committee with all stakeholders using and managing water from the lower Kuiseb aquifer.
- Cost water according to real "price" (considering its "environmental" value)

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APPENDICES:
APPENDIX 1

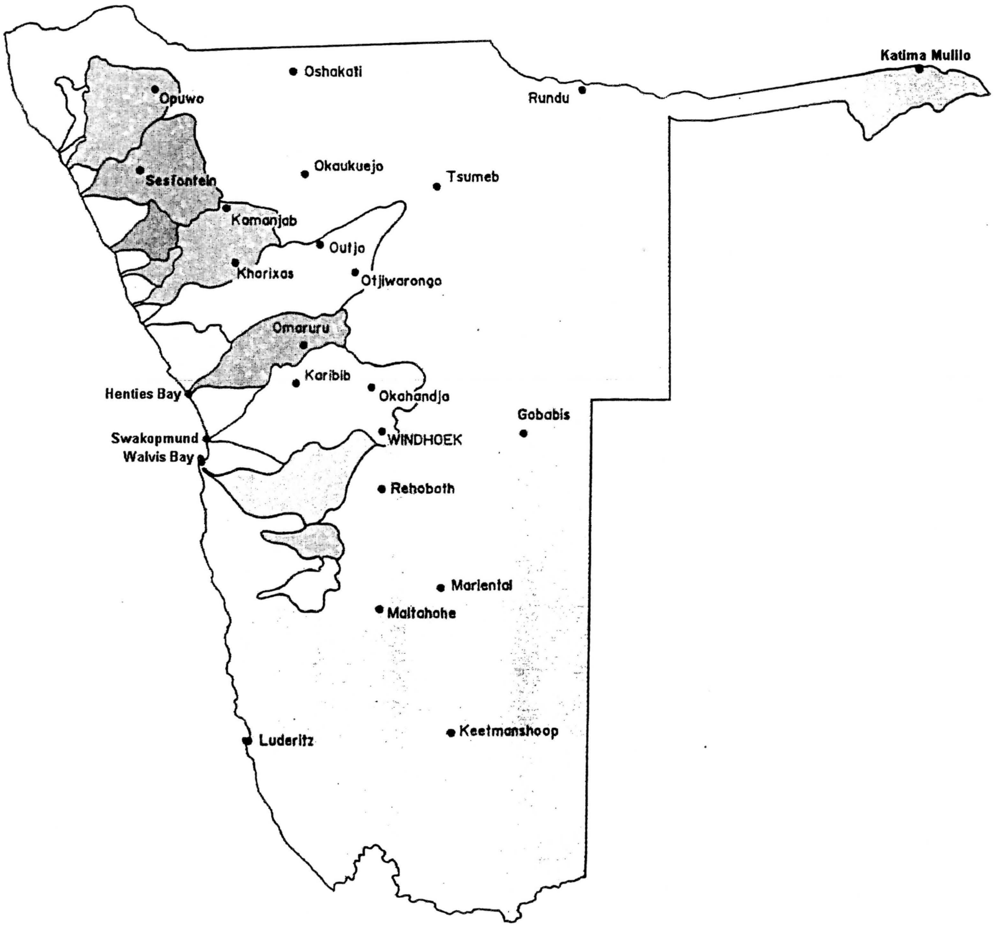
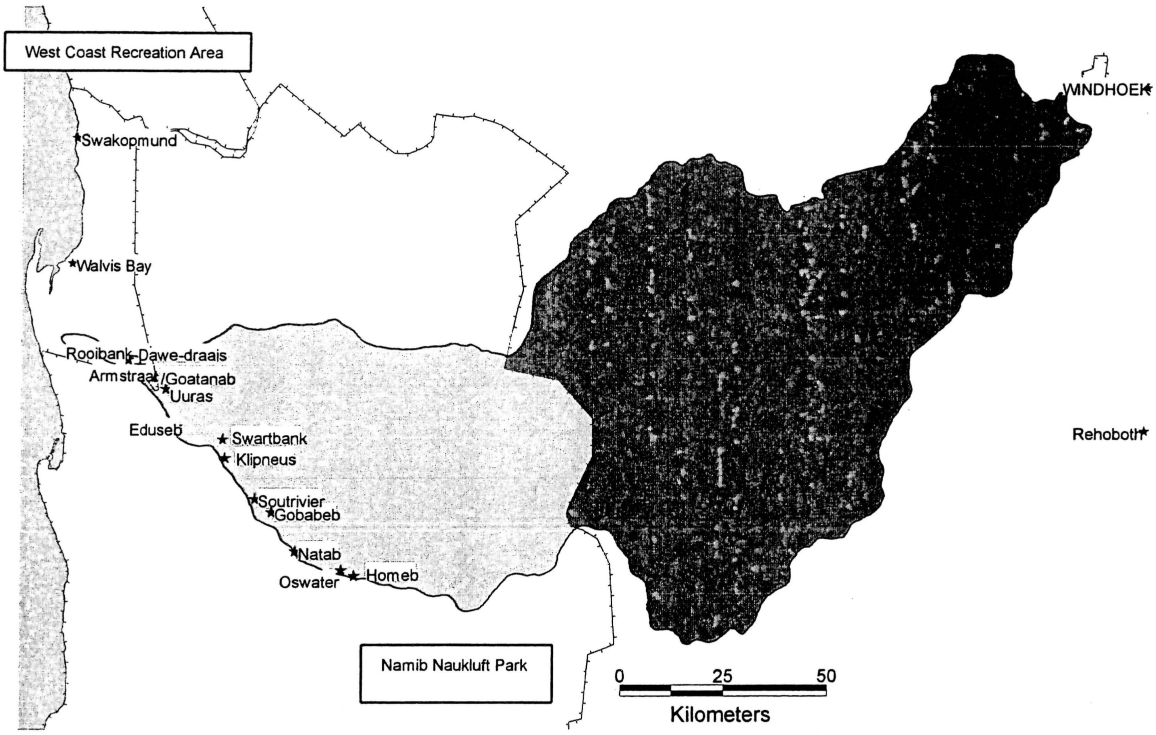


Figure 1.1: Map of the ephemeral river catchments in Namibia

the division of the Kuiseb River catchment. In this study, the term catchment was used to refer to both surface and subsurface water resources.



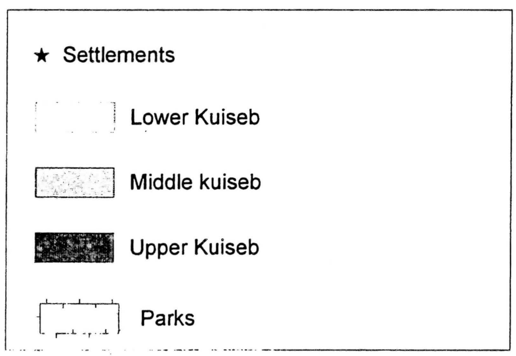


Figure 1.1: Map showing the Kuiseb Catchment River (original map from National Remote Sensing Centre, Ministry of Environment and Tourism, Windhoek)

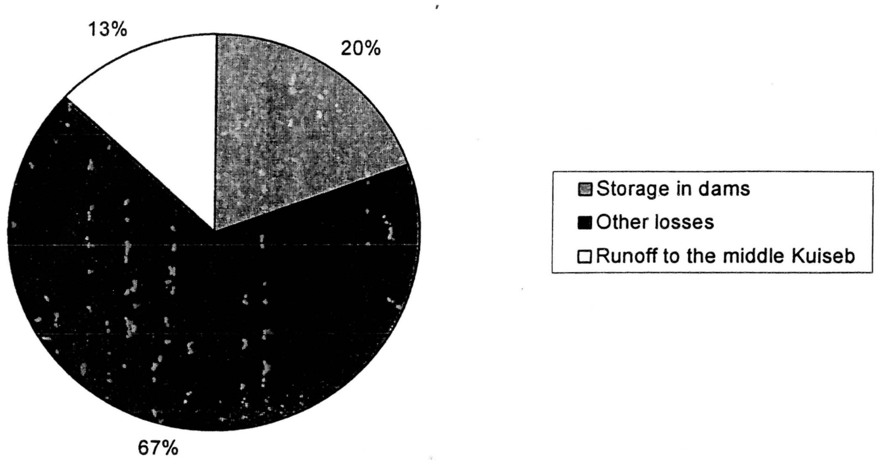


Figure 2.3: Runoff in the Upper Kuiseb

Table 2.4: Hydrological model for the Lower Kuiseb

Year	Qel	Evaporation	ET	Infiltration	Abstraction	Recharge
1986	8.117	6.73711	1.13638	0.08117	7.6	-7.43766
1987	1.96	1.6268	0.2744	0.0196	9.9	-9.8608
1988	16.213	13.45679	2.26982	0.16213	9.7	-9.37574
1990	6.062	5.03146	0.84868	0.06062	9.6	-9.47876
1991	6.807	5.64981	0.95298	0.06807	8.3	-8.16386
1992	0.669	0.55527	0.09366	0.00669	8.2	-8.18662
1993	0.232	0.19256	0.03248	0.00232	8	-7.99536
1994	8.291	6.88153	1.16074	0.08291	7.3	-7.13418
1995	2.301	1.90983	0.32214	0.02301	6.7	-6.65398
1996	6.92	5.7436	0.9688	0.0692	8.2	-8.0616
1997	3.149	2.61367	0.44086	0.03149	6.7	-6.63702
1998						
1999						
Median	6.062	5.03146	0.84868	0.06062	8.2	-8.0616
Mean	5.520090	4.58167545	0.772812	0.055200	8.2	-8.0895981

APPENDIX 3:

Figure 3.1 Geology map of the Kuiseb

Geology of the Kuiseeb catchment

- Gneiss, metasediments, amphibolite
- Granite
- Marble, schist, quartzite, diamictite
- Marble, schist, quartzite, graphitic schist
- Mica schist, minor quartzite, graphitic schist, marble
- Ortho-amphibolite
- Ortho-amphibolite, anorthosite, serpentinite
- Quartzite, schist, conglomerate, quartz porphyry
- Rhyolite, basalt, andesite, ortho-amphibolite
- Sand sea of the Namib Desert

Figure 3.2: Rainfall map of the Kuiseb