WATER AVAILABILITY AND CHEMICAL WATER QUALITY AS IMPORTANT FACTORS FOR SUSTAINABLE WILDLIFE MANAGEMENT IN THE ETOSHA NATIONAL PARK AND FOR DOMESTIC STOCK IN FARMING AREAS OF NAMIBIA

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Abstract

This study deals with the role of water availability and chemical water quality for the game species Springbok *Antidorcas marsupialis*, Blue wildebeest *Connochaetes taurinus*, Burchell's zebra *Equus burchelli* and Gemsbok *Oryx gazella*, in order to gain knowledge of how the adapted wildlife utilises water. In detail, the study investigates the changes of the water availability and chemical quality of water at perennial and seasonal waterholes within a study area of the Etosha National Park, Northern Namibia, throughout the year 1995. It further examines how the animals react to these seasonal changes i.e. in their drinking frequency, their utilisation of perennial and seasonal waterholes, their utilisation of different chemical qualities of water, their 'acceptance limits' of high salinities of water, their daily and seasonal movements and their utilisation of grazing areas. Highly and lowly utilised areas are identified and the reasons analysed. The study concludes with recommendations for the Park Management of Etosha and for decision makers in other national parks, conservancies and farming areas with reference to the Four Os region of Namibia.

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1.0   INTRODUCTION

1.1   Rationale and aim of the study

In arid and semi-arid areas water availability and the chemical quality of water are of vital importance for the utilisation of pasture by game and domestic stock. An optimum number and distribution of waterholes as well as adequate chemical qualities of the water are a prerequisite for demographically vigorous and healthy game populations, for healthy and economically viable domestic stock and for a sustainable park or farm management without over- or under-utilisation of the pasture, especially around waterholes.

Many areas in Namibia where domestic stock, mainly cattle, goats and sheep, are farmed with experience environmental problems, such as pasture degradation, soil erosion and bush encroachment. These phenomena can be summarised as 'desertification', which is understood as "a combination of processes of land degradation occurring in arid and semi-arid environments, whereby the productive potential of the land and its ability to support populations is severely impaired or destroyed" (Quan, Barton & Conroy 1994).

Before vast areas of Namibia were turned into farming land the savannah and desert was roamed by millions of game animals, which had adapted to the harsh climatic conditions of this predominantly semi-arid country over tens of thousands of years. The game left today, which is mainly confined to national parks, such as the Etosha National Park, and other conservation areas and commercial farms, has inherited the ability to cope with semi-arid and arid conditions. Its survival strategies can be a prime and useful example to learn from for Namibia's present farming practices in order to prevent further desertification.

Therefore, this study focuses on the role of water availability and chemical quality for the game species springbok *Antidorcas marsupialis*, Blue wildebeest *Connochaetes taurinus*, Burchell's zebra *Equus burchelli* and gemsbok *Oryx gazella*, in order to gain knowledge of how the adapted wildlife utilises water and waterholes. This will be useful for the wildlife management in the Etosha National Park and for other conservation and farming areas in Namibia, and hopefully give the impetus and necessary ecological information for changing common farming practices which lead to degradation and for adapting them to the more natural and sustainable way in which wildlife utilises water and pasture.

1.2   Study area within the Etosha National Park

The Etosha National Park (hereafter also referred to as Etosha) is situated in Northern Namibia and is one of the largest game parks in Southern Africa with a size of 22 915 sqkm. The study area of this project lies within Etosha and stretches west-east between the waterholes Sonderkop and Halali Seepage and north-south between Okondeka and Ombika (Figure 1). This area was chosen as study area because it was considered to be the preferred habitat of the study animal species. Most of the study activities were confined to roads (see 'travelled roads' in Figure 1) which criss-cross the park. A 2.5km x 2.5km grid was overlaid covering the travelled roads and adjacent areas. In this way the size of the study area was calculated as 1587.5 sqkm. However, wildlife continually moves into and out of the study area, which is an open system.
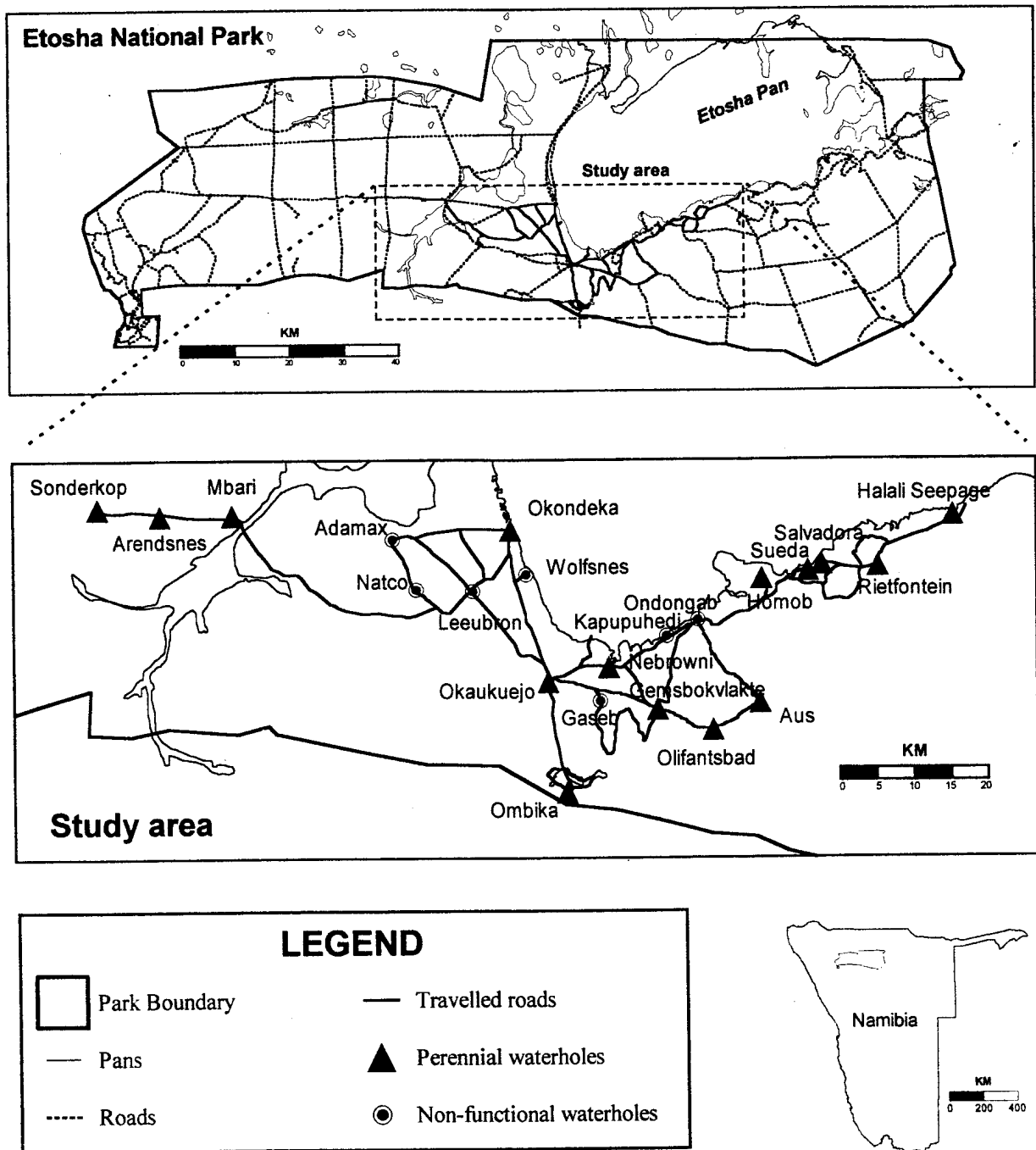
Figure 1: The study area within the Etosha National Park, Northern Namibia

The study area receives a mean annual rainfall of 250 mm to 350 mm (10-year-mean for 1983/4 to 1993/4 calculated from a network of field raingauges all over the park) with an increasing gradient from west to east. The variability (coefficient of variation) of the rain decreases in the same direction from 40 % to 20 %.

In 1995 the rainy season lasted from February until April. The dry season prevailed in January and from May until December, but local rains occurred in September, November and December. February was the month with the highest rainfall, in March and April the monthly amount of rain continuously decreased (Table 1). Summarised, five months had significant amounts of rain of more than 20 mm during 1995. However, these rainfall figures recorded at the three weather

stations can only provide a generalised picture for the study area, because of a high spatial variability of rainfall.

Table 1: Monthly rainfall (in mm) recorded at the weather stations at Okaukuejo, Ombika and Halali during 1995

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total
Okaukuejo	2.4	209.4	25.0	12.2	0.0	0.0	0.0	0.0	41.2	0.0	48.0	1.1	339.3
Ombika	0.0	187.3	51.5	22.0	0.0	0.0	0.0	0.0	22.5	0.0	76.0	0.0	359.3
Halali	1.0	169.0	58.0	36.8	7.0	0.0	0.0	0.0	2.6	0.0	29.6	40.7	344.7
average	1.1	188.6	44.8	23.7	2.3	0.0	0.0	0.0	22.1	0.0	51.2	14.0	347.8

Grassland, steppe (grassland with dwarf shrubs), grass savannah (grassland with few trees and/or shrubs), shrub savannah and tree savannah of various cover densities occur in the study area. Various grass species are found within the study area, shrub and tree savannah mostly consist of *Colophospermum mopane*, but also of *Acacia nebrownii* and *Catophractes alexandri*. For detail refer to Du Plessis 1992 and Sannier 1992.

Population size estimates based on an aerial census undertaken in 1995 suggest that the entire Etosha National Park is home to more than 40 000 big game animals (Erb 1996). The population estimates for the study animal species are listed in Table 2.

Table 2: Population estimates for the study animal species in Etosha (Erb 1996)

Animal species	Scientific name (abbreviation)	Population estimates
Springbok	*Antidorcas marsupialis* (AM)	13 412
Blue wildebeest	*Connochaetes taurinus* (CT)	3 081
Burchell's zebra	*Equus burchelli* (EB)	8 912
Gemsbok	*Oryx gazella* (OG)	7 638

1.3   Study methods

All data for this study were collected throughout 1995 and in October and November 1996.

The water availability and quality at perennial waterholes (2.1) was monitored at the beginning of each month during 1995. At boreholes the water availability was described in general (Yes, No) for the different drinking points (trough, mudhole, pool) separately, at springs it was monitored objectively by measuring the straight distance from a marking (red mark on a rock) to the edge of the water. Seasonal waterholes (2.2), comprising gravel pits, depressions, seasonal springs and dams, were located and mapped at the beginning of the study. Sixty-seven seasonal waterholes were selected and regularly monitored. Their water availability was described in general (Yes, No) twice per month (beginning and middle of the month) during the rainy season and once per month (beginning of the month) during the dry season of 1995. Water samples at both perennial and seasonal waterholes were taken and the electrical conductivity was measured (in mS/m at 25 degrees Celsius) as an indication of the chemical quality of the water. The electrical conductivity is acknowledged as a quick and reliable measure to indicate the general chemical quality of water (Hem 1982, Auer 1993, Gammer 1993, Auer 1998).

The drinking behaviour of the three study animal species springbok, Blue wildebeest and Burchell's zebra (3.1), as well as their preference for certain chemical qualities of water, the moisture content of the plants they utilised, the distances they travelled daily and the areas they utilised (4.1) were studied by following individual collared animals (one collared animal per species plus herd) for two to four consecutive days in the middle or at the end of each month in 1995 from sunrise until sunset. The feeding of the focal animal was recorded on two days per month following the 'instantaneous spot method', during which the focal animal was observed every ten minutes closely with binoculars for a period of two minutes, and the activity (Feeding, Not feeding) and the utilised plant species (if feeding) were noted in ten-second-intervals. Samples were taken of the observed utilised plant species and the moisture content examined by weighing, drying and repeated weighing.

The effect of the chemical quality of water on the waterhole utilisation (3.2) was studied by measuring the electrical conductivity at all waterholes at which the collared animals drank on days of observation, and by carrying out several simultaneous animal counts (sunrise to sunset) at pairs of neighbouring waterholes with contrasting chemical qualities, namely at Sonderkop and Arendsnes in the west and at Salvadora and Sueda in the east of the study area. The water quality 'acceptance limits' of the four study animal species were tested during an experiment between 9.10.1996 and 2.11.1996 at Sonderkop waterhole. By adding natural pan salt to the reservoir, the salinity of the trough water was gradually worsened over a three week period in four phases. The animals' reactions were tested by carrying out animal counts and by noting detailed observations of the drinking behaviour.

The numbers, densities and distribution of the four study animal species (4.2) as well as lowly and highly utilised areas (4.3) were investigated by animal road counts carried out on two consecutive days (start approximately at 8.00 h) at the beginning of each month during 1995. The count data were summarised per 2.5 km x 2.5 km grid block over the study area.

2.0   WATER AVAILABLE TO WILDLIFE

2.1   Perennial waterholes

In the study area are 15 perennial waterholes (Figure 1) of which nine are artificial boreholes, namely Sonderkop, Arendsnes, Mbari, Okaukuejo, Ombika, Nebrowni, Gemsbokvlakte, Olifantsbad, Aus, and six are natural springs, namely Okondeka, Homob, Sueda, Salvadora, Rietfontein, Halali Seepage[1].

The distance between perennial waterholes ranges between 2.0 km and 21.3 km and averages 8.6 km (+/- S.D. 4.6km). The average density of perennial waterholes in the study area (size: 1587.5 sqkm) is one perennial waterhole per 105.8 sqkm. The waterholes are mostly evenly distributed within the study area, with the exception of one large waterless area in the Mbari-Okondeka-Okaukuejo triangle and another smaller area between Nebrowni, Homob and Aus.

At most boreholes and all perennial springs water was available throughout the year at least at one drinking point (trough, pool, mudhole). However, at three boreholes there was no water available during some time, namely at Sonderkop in December, when both trough and mudhole were dry, and at Aus in March and at Ombika in May and June, when the pool fell dry. For game which

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[1] Several, mostly nameless perennial seepages occur along the Etosha Pan's edge in the Salvadora area, but were excluded from the waterhole investigations due to the inaccessibility of the terrain in the rainy season.

came for a drink this meant either going without drinking or walking to the closest neighbouring waterhole, an average distance of 8.6 km in the dry season.

Quantitative changes of the water availability were monitored at perennial springs and were found to be closely related to rainfall, as is shown for the waterhole Homob in Figure 2. At both pools the lowest water availability of the year (measured as the longest distance between water edge and mark) was recorded at the beginning of January before the rainy season started, when both animal pressure and evaporation were very high. The highest water availability was found in March after high rainfall in February and was caused by local recharge (direct input of rain water, infiltration and run-off). The water availability continuously decreased during March and April (months with less rainfall), but increased again during May and June. This increase can only be interpreted as the delayed effect of ground water recharge in the distant recharge areas. The general trend of a decreasing water availability during the dry season (July until December) was halted (pool north) and reversed (pool south) by rains in November.
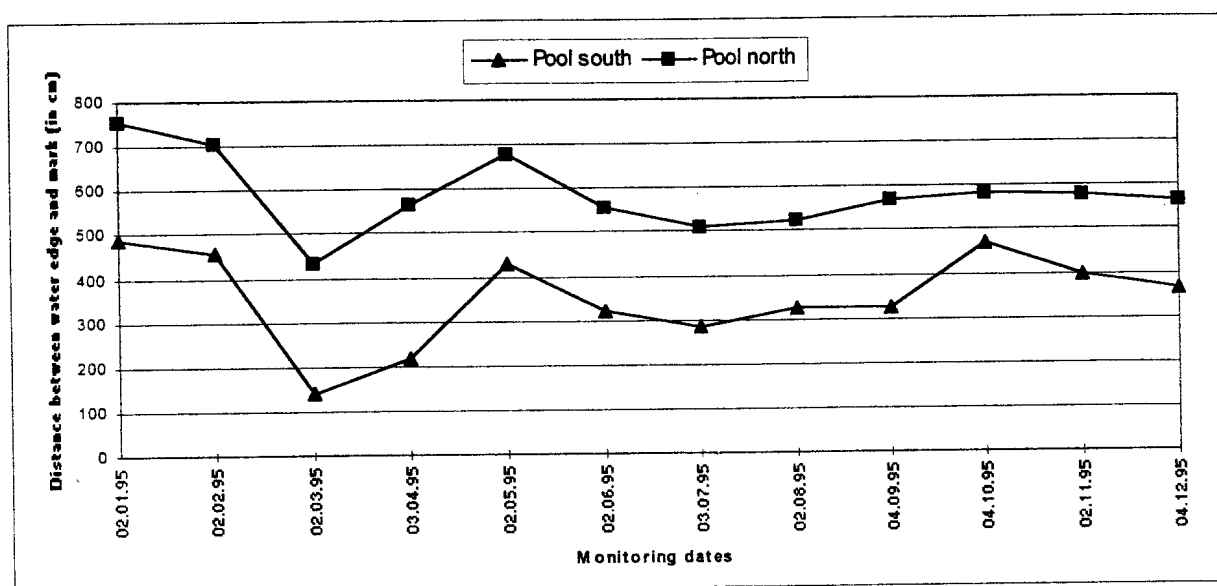
Figure 2: Water availability at Homob spring during 1995

All monitored perennial waterholes, except for Arendsnes and Sueda, have water of acceptable water quality. During 1995 their average electrical conductivity lay under the recommended maximum guideline of 900 mS/m for stockwatering (Department of Water Affairs, 1991). On contrast, the borehole Arendsnes and the spring Sueda supplied highly saline water of over 5000 mS/m (trough) and 3000 mS/m (mudhole), and 1500 mS/m (pool) respectively.

Similar to the water availability, the water quality (indicated by the electrical conductivity) showed a seasonal pattern which was closely related to the rainfall (Figure 3). In general, the worst water quality was measured in January and February before the start of the rainy season. A low availability of water and the consequent relative concentration of salts was responsible for the relative high salinity of the water. The best water quality was measured in March, April and November after significant rain, as a result of the diluting effect of pure rain water.

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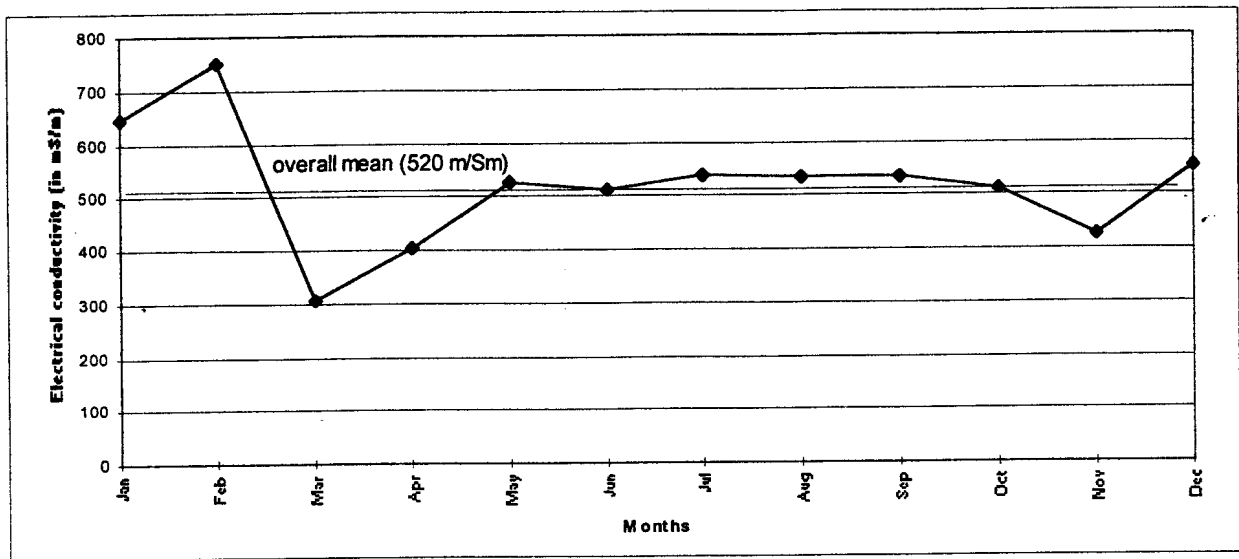
Figure 3: The mean electrical conductivity at various water points (n=19) at perennial waterholes (n=13) in 1995

2.2. Seasonal waterholes

In the study area 217 seasonal waterholes were identified and mapped (166 gravel pits, 49 natural depressions, one seasonal spring and one dam) of which 67 (60 gravel pits, five depressions, one dam and one seasonal spring) were selected for regular monitoring (Figure 4), aiming at an even coverage over the study area. The density of all mapped seasonal waterholes in the study area was calculated as one seasonal waterhole per 7.3 sqkm.
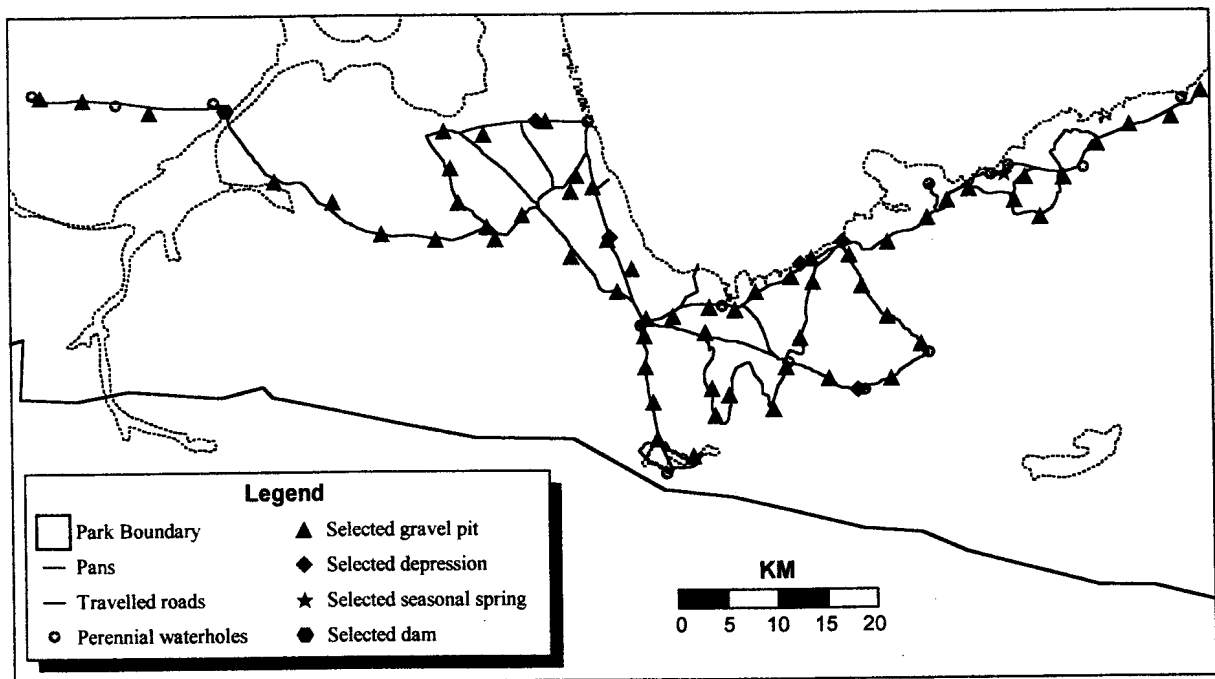
Figure 4: Seasonal waterholes in the study area

At gravel pits water was available between February and May and again between October and December for an average duration of 2.2 months (0.5 to 4.5 months). Depressions held water

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from February until April for an average duration of 1.3 months (0.5 to 2.5 months). This indicates a higher water holding capacity of gravel pits compared to depressions. The single monitored dam held water between March and August for 5.5 months, the single monitored seasonal spring between February and October for 8 months.

A comparison of the percentage of monitored gravel pits and depressions holding water (Figure 5) with the rainfall figures (Figure 1) indicates that the water availability at gravel pits closely relates to the months with rainfall. Unlike gravel pits, depressions were not refilled by the rain in the late dry season. Whereas nearly all gravel pits and depressions had water available during the rainy season, very localised rainstorms at the end of the dry season filled only a few gravel pits (north of Okaukuejo and in the Okaukuejo-Ombika-Aus-Nebrowni area).
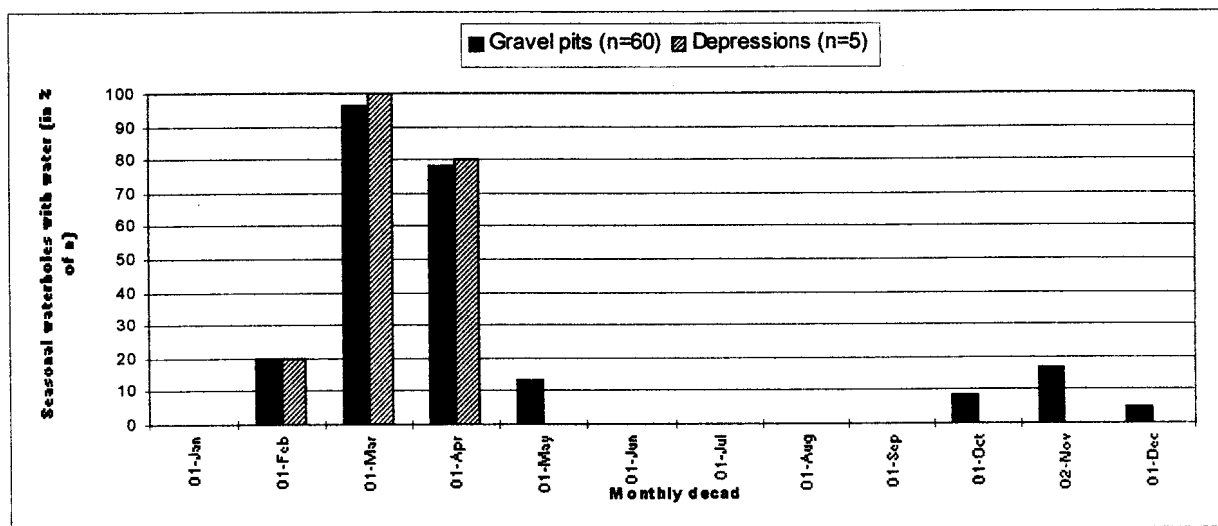
Figure 5: Percentage of monitored gravel pits and depressions holding water during 1995

Gravel pits and depressions can be considered as good quality seasonal waterholes. Seventy-five percent of all electrical conductivity (EC) measurements at gravel pits and depressions lay under 150 mS/m, which is considered as very good quality water, chemically suitable even for human consumption (Department of Water Affairs, 1991). Ninety-six percent of all EC measurements at gravel pits and 94% at depressions lay within the recommended guideline for stockwatering of 900 mS/m (Department of Water Affairs, 1991).

The chemical water quality at gravel pits showed some temporal variability. It was generally best shortly after the start of the rainy season (mean electrical conductivity (xEC): 35 mS/m; n=15) and deteriorated towards the end of the rainy season (xEC: 205 mS/m; n=15). The reason for this is that less rain water input caused the water body to shrink due to evaporation and infiltration, and resulted in a relative concentration of the soluble salts. Local rainstorms at the end of the dry season in general produced less good quality water at seasonal waterholes compared to the rainy season (xEC: 550 mS/m; n=19). This can be explained by the rains having mainly been single events, which dissolved the salts (evaporation residues) left from the rainy season and thus caused the high salinity. Further rain, which would have caused consecutive dilution, did not occur.

3.0   WATER UTILISED BY WILDLIFE

3.1   Drinking behaviour observed in collared study animals

The drinking frequency (number of days with drinking in % of total number of observation days) shows differences between the three animal species springbok, wildebeest and zebra. On avérage, the springbok was the least dependent on water and drank about every fourth to fifth day (mean drinking frequency of 23 %). The wildebeest drank about every second to every third day (mean drinking frequency of 42 %). The zebra drank on two out of three days (mean drinking frequency of 76 %) and therefore proved to be the most water dependent of the three study animal species.

Springbok and wildebeest showed seasonal differences in their drinking frequencies, the zebra did not. The springbok's drinking frequency (Figure 6) was mainly influenced by and negatively related to the moisture content of its feed. In months with/after rain and consequently with high plant moisture content, the springbok drank least frequent or not at all, in the dry season months, when the plant moisture was low, the springbok drank most frequent. Unlike the wildebeest, the springbok did not make use of seasonal waterholes when they were abundant.
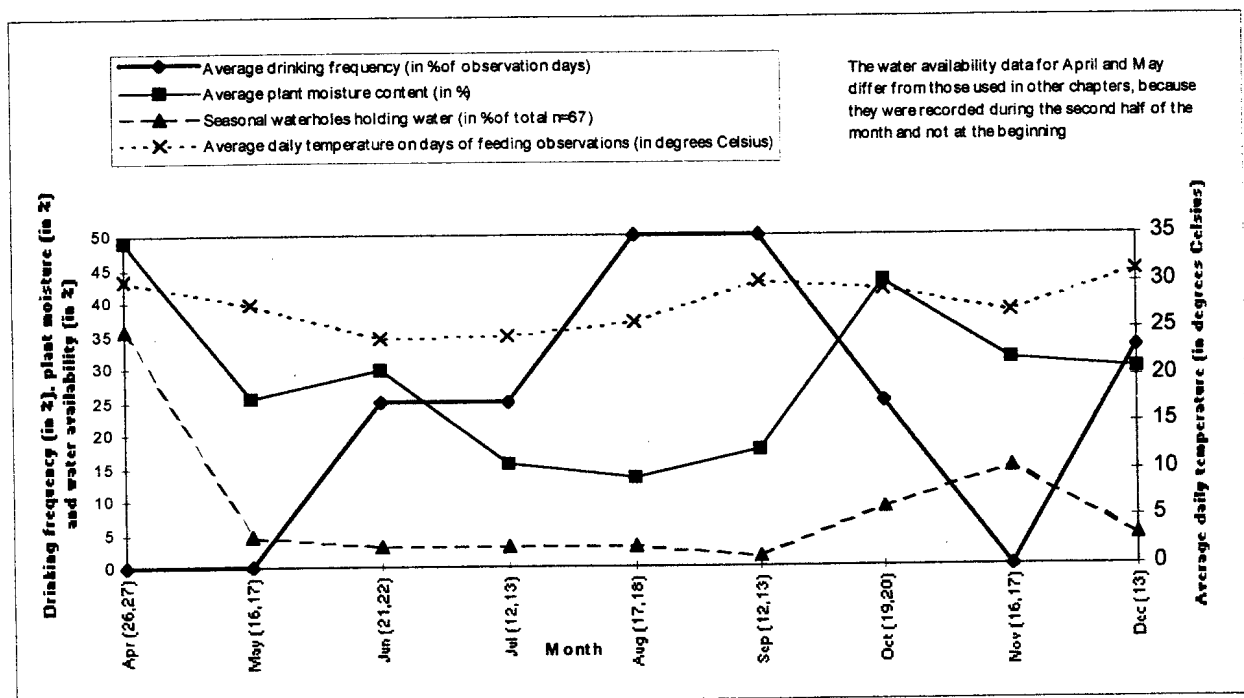
Figure 6:   Drinking frequency of the collared springbok compared to the plant moisture of the utilised plants, the water availability at seasonal waterholes and the air temperatures

The collared wildebeest's drinking frequency was influenced by different factors during the year (Figure 7). In the rainy season, when both plant moisture and water availability at seasonal waterholes were high, the wildebeest made use of this over-abundance of water and drank frequently and opportunistically. In the dry season and late dry season the drinking frequency was found negatively related to the moisture content of the wildebeest's feed and positively related to the air temperatures. A generally low plant moisture content and increasing air temperatures were responsible for an increase of the drinking frequency. When temperatures dropped and the

moisture content increased after rains in the late dry season, the drinking frequency decrease as well.
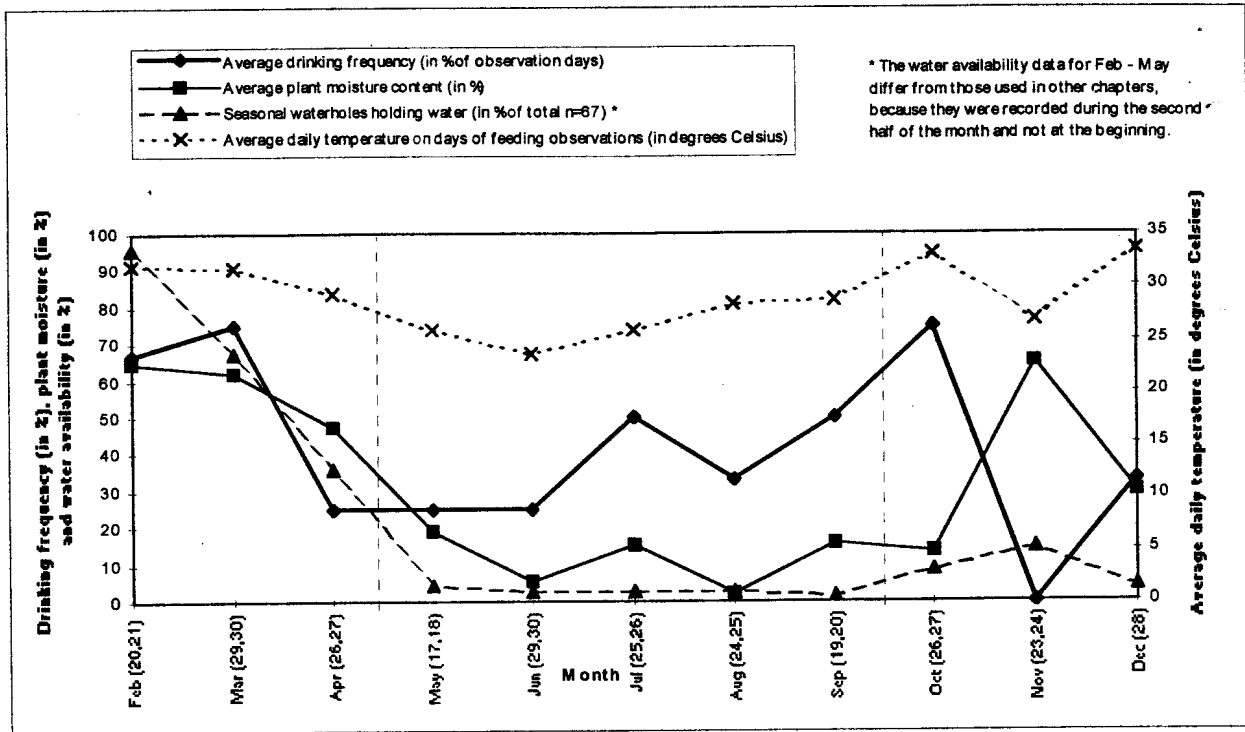
Figure 7: Drinking frequency of the collared wildebeest compared to the plant moisture of the utilised plants, the water availability at seasonal waterholes and the air temperatures[2]

All study animal species were preferably morning drinkers. Most drinking events of the collared springbok occurred between 10:00 and 12:00. The study wildebeest drank mostly between 9:00 to 10:00 and 11:00 to 12:00. The collared zebra drank mainly between 10:00 and 11:00.

The general chemical quality at waterholes utilised by the collared animals was good (EC between 13 mS/m and 135 mS/m) during the rainy season (February to April), when wildebeest and zebra drank exclusively at seasonal waterholes. The springbok was not observed drinking in these months. During the rest of the year, when all collared animals exclusively utilised perennial waterholes, they consumed moderately saline water (EC between 309 mS/m and 754 mS/m). Summarised, the collared animals utilised chemical qualities of water between 13 mS/m and 754 mS/m during the year.

3.2   Chemical quality of water and its effect on waterhole utilisation

Animal counts at neighbouring waterholes with 'long-term' contrasting water qualities, namely at Sonderkop (moderately saline) and Arendsnes (highly saline) as well as at Salvadora (moderately saline) and Sueda (highly saline) revealed that animals showed a clear preference for the moderately saline waterholes (Table 3). In total, Arendsnes was utilised only by 10.5 % of the

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[2] The month May is part of the dry season here - and not part of the rainy season as stated in Point 2.3 - because the wildebeest was observed in the middle of May, on 17th and 18th May, when the majority of the seasonal waterholes were dry. The observation period in middle September was taken as part of the dry season - and not as part of the dry season with local rain - because no rain had fallen in the area the wildebeest utilised.

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numbers of the four study species (Total4spp) which drank at Sonderkop, Sueda only by 0.2 % of the animal numbers counted drinking at Salvadora. As for the individual study species the preference for moderately saline water was statistically confirmed for springbok, zebra and gemsbok. Although wildebeest also utilised the moderately saline waterholes in higher numbers compared to the highly saline waterholes, the differences could not be found statistically significant due to generally low wildebeest numbers.

Table 3: Total numbers of animals which drank at neighbouring waterholes with contrasting chemical water qualities between sunrise and sunset

(xEC: mean electrical conductivity in mS/m) (Total all: total of all mammals and ostriches counted)
(Total 4spp: total number of springbok, wildebeest, zebra and gemsbok counted) (xTotal4spp: daily average of Total4spp)

Date	Sonderkop xEC trough: 525 xEC mudhole: 552	Arendsnes xEC trough: 5598 xEC mudhole: 3772	Date	Salvadora xEC pool South: 482 xEC pool North: 605	Sueda xEC pool: 1548
20.01.95	324	16	27.01.95	768	15
21.07.95	418	5	21.06.95	261	8
18.08.95	487	58	19.07.95	545	12
27.09.95	744	156	23.08.95	490	3
17.10.95	600	15	30.10.95	423	4
			2.12.95	133	14
Total all:	2573	250	Total all:	2620	56
Total4spp:	2301	242	Total 4spp:	2548	5
xTotal4spp:	460	48	xTotal 4spp:	425	1

Similar results were found during a water quality experiment at the waterhole Sonderkop, during which the salinity of the trough water was gradually increased over three weeks in four phases (from EC: 520 mS/m to 2306 mS/m) (Figure 8). A comparison of the total numbers of the four study species (total 4spp) confirms a trend of decreasing utilisation as the water's salinity increases. This accounts mainly for springbok and zebra which drank in significantly less numbers when salinities increased above 1900 mS/m. Wildebeest, because of generally low numbers, and gemsbok did not show any significant difference in numbers utilising the water.
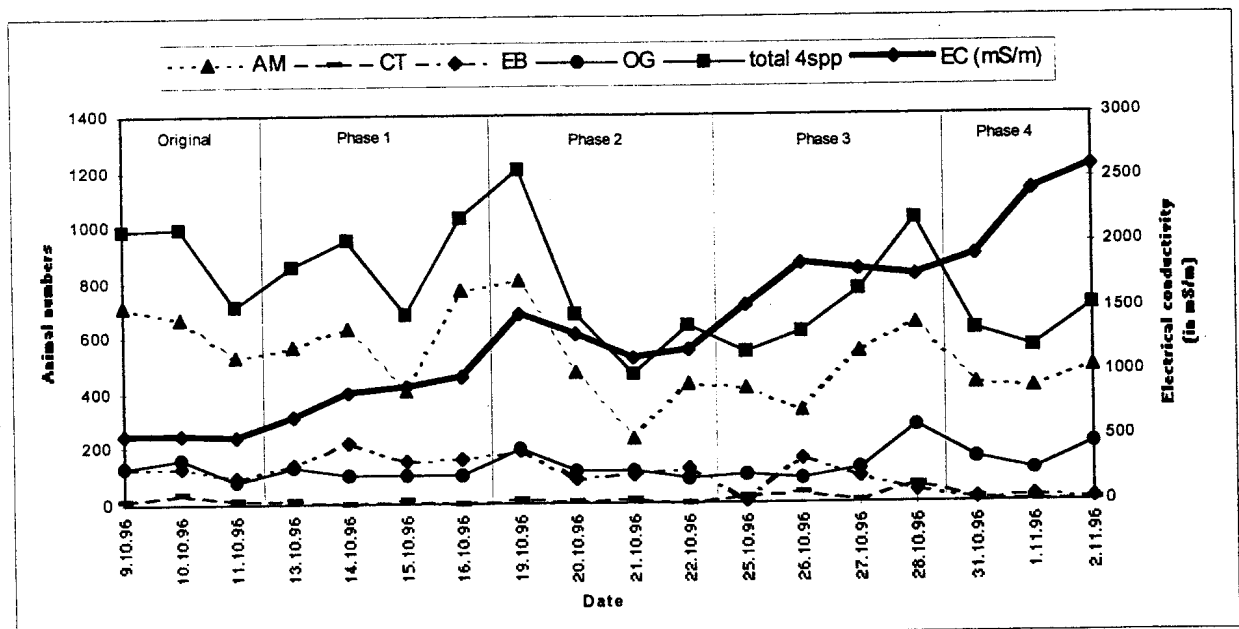
Figure 8: Animal numbers and water quality at Sonderkop during the water quality experiment

Compared to the 'long term' high salinities at Arendsnes and Sueda which resulted in extremely low utilisation, the 'short term' high salinities at Sonderkop were still used by over 70 % of the animal numbers (total 4spp) counted before the salinity was increased. However, it is expected that a further decrease in animals numbers utilising the water would have occurred if the salinity had been increased further or stayed very high for several months.

In addition to a decrease in numbers, a change in the animals' drinking behaviour was observed with the increase of the water's salinity at Sonderkop. Whereas animals usually approach the water and drink nearly immediately (Class 1 = 'Normal drinking behaviour'), animals were observed sniffing and tasting the water extensively and trying many positions at the water before their drank or even left without drinking (Class 2 = 'Disturbed drinking behaviour').

At the moderately saline waterholes Duiwelsvuur and Mbari, which served as control waterholes (reference behaviour) 98 % of the observed animals drank normally and 2 % drank abnormally (Figure 9). On contrast, significantly more animals, namely between 18 % and 43 % of the observed animals, drank abnormally at Sonderkop during the experiment. At salinities between 900 mS/m and 1500 mS/m (Phase 1 and 2) 18 % to 24 % of animals drank abnormally, at salinities between 1500 mS/m and 2600 mS/m (Phase 3 and 4) even 39 % to 43 % of the animals showed disturbed drinking behaviour.

Generalised, the occurrence of abnormal drinking behaviour in the four study species set in at ('short term') salinities of about 900 mS/m, and the percentage of animals which drank normally decreased with the increase of the water's salinity.
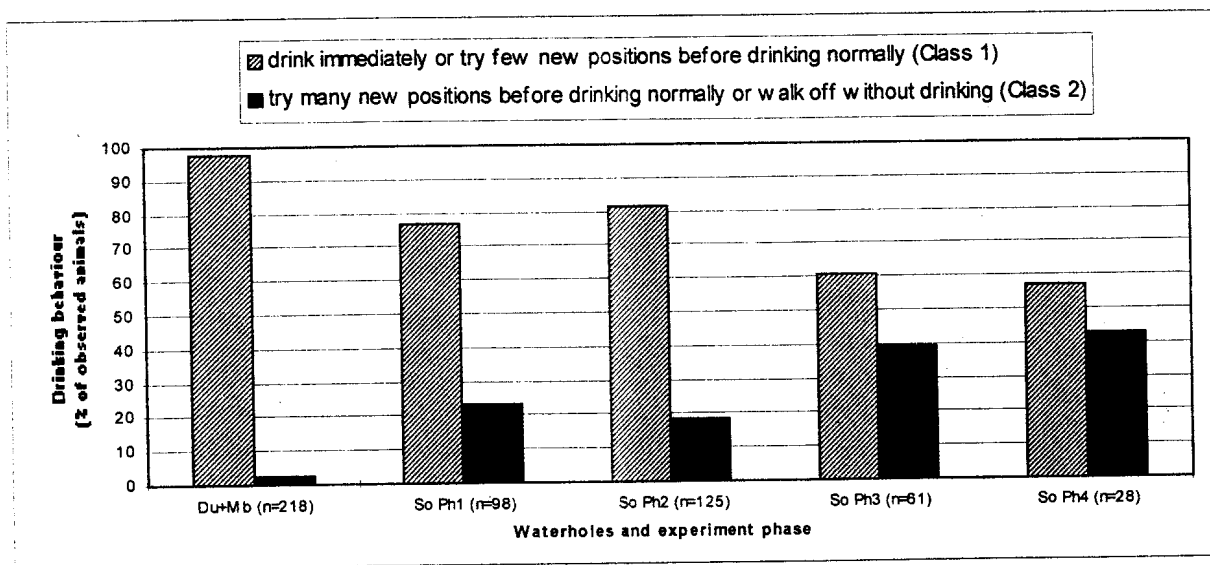
Figure 9: Drinking behaviour of the four study species (AM, CT, EB, OG) (% of observed animals) at Duiwelsvuur and Mbari (Du+Mb), and at Sonderkop (So) during the four phases of the water quality experiment

The drinking behaviour of the individual study species showed deviations from the above described picture for the total of the observed animals, and revealed interspecific differences (Figure 10).

Springbok revealed a dislike to the increased salinity during the entire experiment and drank abnormally in 28 % to 56 % of the observations. However, the fact that springbok also showed

some disturbed drinking behaviour at Duiwelsvuur and Mbari (8 %), suggests that other factors besides the salinity might have induced abnormal drinking.

Wildebeest were more tolerant but also showed an increase in abnormal drinking behaviour with the salinity's increase. At above 1500 mS/m over 20 % of the wildebeest drank abnormally.

Zebra were found to be the most tolerant to increasing salinities and only drank abnormally (50 %) at salinities over 1900 mS/m.

Gemsbok showed the least tolerance of the four animal species to increasing salinities. Whereas about 20 % of the observed gemsbok drank abnormally at salinities between 900 mS/m and 1500 mS/m, the majority of gemsbok (67 % to 71 %) were observed drinking abnormally when the salinity increased to between 1500 mS/m and 2600 mS/m. In addition, many gemsbok showed behavioural changes. They stayed in the vicinity of the trough or even in the trough over most of the day unlike their usual behaviour of coming to the water, drinking and moving off again. In addition, they showed high intra- and interspecific aggression at the waterhole.

Summarised, zebra were found to be the most tolerant towards increased salinities judged by the drinking behaviour, followed by wildebeest, springbok and gemsbok, the latter being the least tolerant.
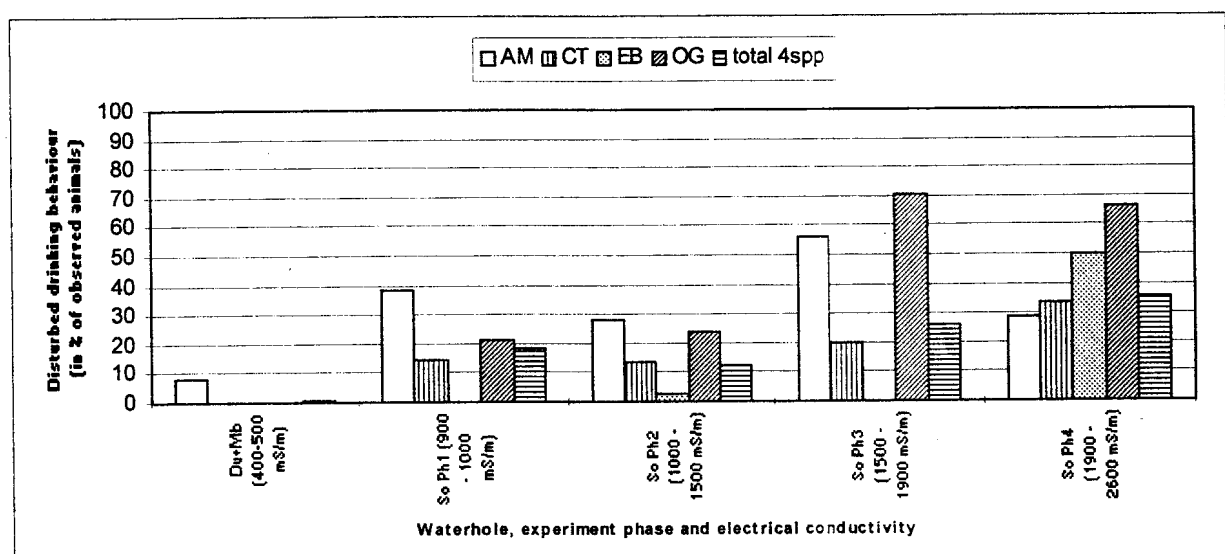
Figure 10: Disturbed drinking behaviour of the four study species (AM, CT, EB, OG) (% of observed animals) at Duiwelsvuur and Mbari (Du+Mb), and at Sonderkop (So) during the four phases of the water quality experiment

4.0 ANIMAL MOVEMENTS AND AREA UTILISATION IN RELATION TO WATER AVAILABILITY

4.1 Daily distances travelled and areas utilised by collared animals

The mean daily distance walked by the collared animals (on days of more than six hours of observation) were 4.1 km for the springbok, 4.8 km for the wildebeest and 5.7 km for the zebra. The minimum distances each species walked on one day lay under one kilometre, the maximum distances amounted to 9.4 km for the springbok, 12.1 km for the zebra and 16.2 km for the

wildebeest. For all three collared animals the mean daily distance walked on days with drinking (6.2 km to 7.1 km) was double the distance walked on days without drinking (3.1 km to 3.5 km).

The mean daily area size utilised by the collared animals (on days of more than six hours of observation) was 0.9 sqkm for the springbok, 2.0 sqkm for the wildebeest and 2.8 sqkm for the zebra. The minimum area size each species covered on one day lay under 0.1 sqkm. The maximum area size utilised was 2.9 sqkm for the springbok, 13.3 sqkm for the wildebeest and 12.4 sqkm for the zebra. All three collared animals utilised larger areas on days with drinking compared to days without drinking. On days with drinking the springbok covered an area double the size, the wildebeest four times the size and the zebra three times the size of the area utilised on days without drinking.

During all months of observation (April to December 1995), the collared springbok stayed in the close vicinity of Okaukuejo. The furthest distance it was ever recorded from Okaukuejo waterhole was 4.3 km. It is concluded, that the springbok was able to obtain all needed food quantity and quality from an area less than 57.4 sqkm around the centre point of Okaukuejo, otherwise it would have utilised a larger area or have migrated to other areas.

The collared wildebeest, on contrast, was located and observed in various areas west and south of the Etosha Pan. During the rainy season months (February to April) the wildebeest utilised areas between 10 km to 20 km south-west and west of Okondeka, where numerous seasonal waterholes were available. In the dry season (June to September) it stayed in the vicinity of Okondeka, no further than 12 km from the waterhole, and drank exclusively there. During the late dry season, the collared wildebeest[3] migrated extensively. In October it was located near Halali Seepage and in November it was found about 60 km westwards between Gemsbokvlakte and Ombika, were fresh grass had sprouted after local rainfall. In December it was found back in the east, 70 km from November's grazing area.

The collared zebra was located in different areas west and south of the Etosha Pan. During the rainy season months (February to April) the zebra utilised areas between 6 km to 14 km south-west and west of Okondeka, where seasonal waterholes were abundant. In May it moved more than 60 km eastwards to the plains areas south of Salvadora. Between June and October it stayed in the vicinity of the perennial waterhole Goas (outside the study area) no further than 7.5 km from the waterhole.

4.2   Numbers, densities and distribution of the four study animal species

Monthly animal road counts in the study area recorded between 3000 and 5000 animals (total of the four study species: Total4spp) for the dry season months and between 7000 and over 9000 animals for the rainy season months (March to May) (Figure 11). In general, the majority of animal species counted were springbok and zebra, wildebeest and gemsbok occurred in low numbers of under 600 and 400 respectively. The high animal numbers counted in the rainy season are the result of an influx of migrating springbok and zebra from other park areas, mainly the east, into the study area.

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[3] After the death of the collared wildebeest at the beginning of October 1995, another female wildebeest was collared on 20.10.1995 near Halali Seepage and followed until the end of the year.
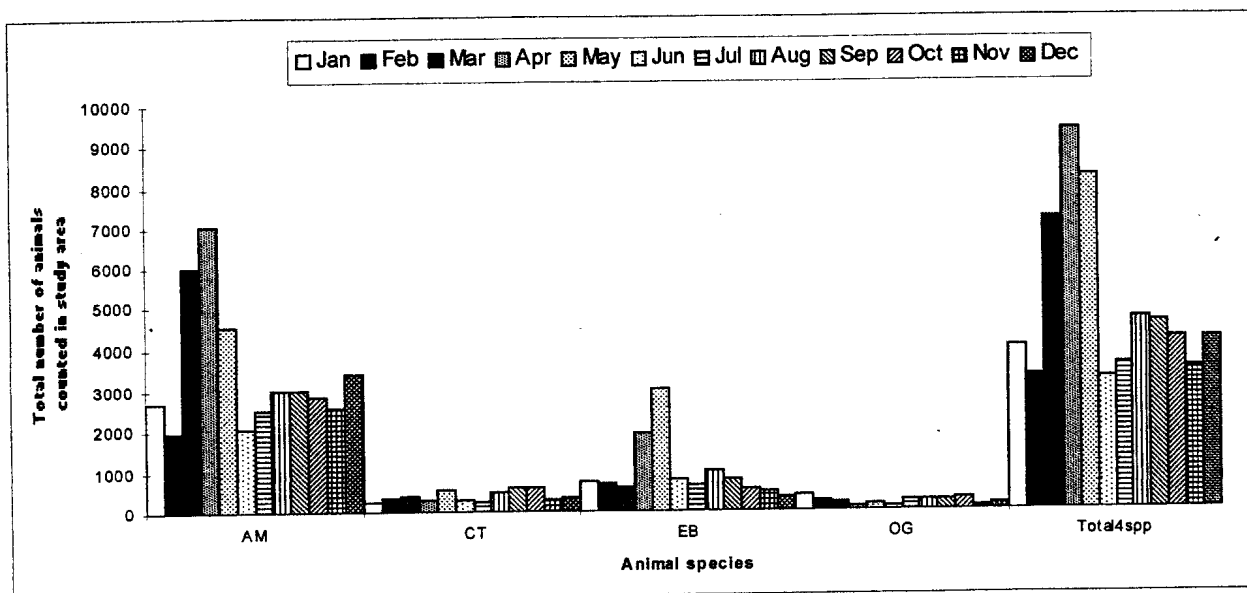
Figure 11: Numbers of study animal species counted during monthly road counts

Springbok were counted in numbers of between 2000 and 7000 during the year. In the dry season months 2000 to 3000 springbok were generally found dispersed over the study area and concentrated around some perennial waterholes. In the rainy season (March to May) the monthly number of springbok doubled to between 4000 and 7000 animals mainly due to an influx of migrating springbok into the study area. Most springbok were found concentrated in the Okaukuejo-Adamax-Okondeka area, which traditionally is a favoured plains system when both food and water are abundant. Local rains between October and December drew concentrations of springbok into areas north of Okaukuejo and between Okaukuejo-Ombika-Aus-Nebrowni.

Wildebeest were only recorded in relatively low monthly numbers between 200 and 600. In the dry season wildebeest concentrated around perennial waterholes and mainly utilised the central and eastern parts of the study area. In the rainy season months March and April wildebeest preferred the Okaukuejo-Adamax-Okondeka plains system, but were found dispersed rather than in high concentrations over the area. In October concentrations of wildebeest were recorded north of Okaukuejo were fresh grass was abundant after local rain. On contrast, no considerable wildebeest numbers were recorded in November and December in the Okaukuejo-Ombika-Aus-Nebrowni-area, which had received considerable rain in November.

The monthly numbers of zebra counted varied between 350 and 3000 during the year. The monthly numbers recorded in the dry season of 350 to 1000 zebra tripled in the rainy season months April and May to 1800 and 3000 zebra respectively, due to an influx of migrating zebra mainly from the east of the park. Concentrations of zebra were then found on in the Okaukuejo-Adamax-Okondeka area. In the dry season, on contrast, zebra occurred dispersed mainly in the east of the study area but also concentrated around some perennial waterholes. Fresh grass growth north of Okaukuejo and in the Okaukuejo-Ombika-Aus-Nebrowni-area in the late dry season, attracted moderate concentrations of zebra to the former area but none to the latter.

Gemsbok were generally counted in low numbers and varied between 100 to 400 animals. However, due to gemsbok not being true plains ungulates but also utilising bush extensively, the count results are regarded as under-counts. In addition, the monthly fluctuations of gemsbok numbers are considered to rather reflect seasonal differences in habitat (plains - bush) than

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differences in true gemsbok numbers in the study area. Gemsbok occurred in all regions of the study area during the year.

4.3   Lowly and highly utilised areas within the study area

The yearly totals of animals counted per block during monthly road counts are given in Figure 12. The majority of blocks were extremely lowly to very lowly utilised with yearly totals of under 482 animals. Although this might reflect the true picture, many of these blocks just bordered the travelled roads and/or could not be entirely overlooked because of dense vegetation.

The reason for the low utilisation of the area between Sonderkop and Mbari is considered to lie in the high salinity of the waterhole Arendsnes. A lack of perennial waterholes is thought to be the main reason for the low utilisation of the areas between Mbari and Adamax, and between Nebrowni and Homob along the Pan's edge. The low animal numbers in the Okaukuejo-Ombika-Gemsbokvlakte triangle may be caused by the low water availability at Ombika waterhole and the fact that the water lies in a depression, which increases the risk for animals to be surprised and caught by predators. The low count results of other areas (e.g. Gemsbokvlakte-Aus-Ondongab triangle) are partly a result of dense vegetation and consecutively poor visibility.

Moderately high, high and very high yearly animal numbers were found around perennial waterholes, such as at Mbari, Okondeka, Okaukuejo, Gemsbokvlakte, Salvadora, Rietfontein, Halali turnoff and Halali Seepage, which are concentration areas in the dry season. The high animal numbers between Adamax and Okondeka, and ten kilometres north of Okaukuejo were favoured grazing areas in the rainy season. The area five kilometres north-west of Okaukuejo received rains in the late dry season and consecutively attracted high numbers of game. The largest area within the study area of generally high utilisation (moderate to very high) was identified between Adamax and Okondeka.
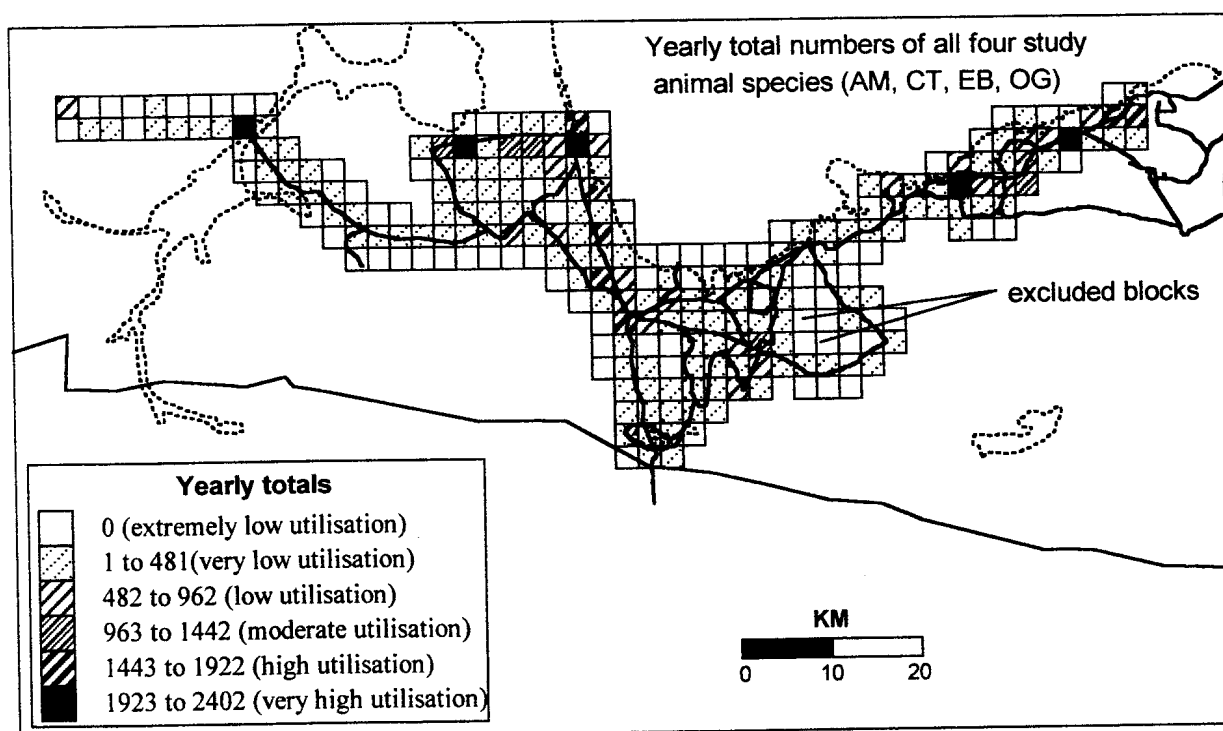

Figure 12: Total numbers of all four study animal species counted per block during the year within the study area

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5.0   __CONCLUSION__

1.   The study animal species experienced three different periods of water availability during 1995, which affected their movements and drinking habits. These periods correspond to the three 'hydrological seasons': the "Rainy season" (February to May), the "Dry season" (January and June to September) and the "Late dry season with local rain" (October to December).[4]

1 a.   *Period 1: "Rainy season" - High water availability and good water quality*
The rainy season months had relatively high estimated waterhole densities[5] of one waterhole in 7 - 34 sqkm. It was a time of water abundance during which water-dependent game species were not restricted in their movements and could graze freely. During this period the majority of water points were seasonal waterholes, which the game preferred to perennial waterholes. Due to the low utilisation of perennial waterholes the rainy season allowed the vegetation in these areas to recover. In addition, the water available was mostly of good quality. Most seasonal waterholes held fresh rain water with an electrical conductivity (EC) of under 150 mS/m, and at perennial waterholes chemical qualities were the best of the year (mean electrical conductivity (xEC) under 530 mS/m).

In the rainy season thousands of springbok and zebra, and hundreds of wildebeest migrated, also from outside the study area, to a favoured plains system in the Okaukuejo-Adamax- Okondeka-area. Springbok and zebra concentrated in selected areas whilst wildebeest dispersed throughout the entire plains system. Of the collared study species, both wildebeest and zebra followed the migration. The collared springbok, on contrast, stayed in the close vicinity of the perennial waterhole Okaukuejo during the whole year, which contrasted sharply to the migratory behaviour of thousands of springbok.

Although the freshly sprouted grass which was utilised by the game was high in moisture, both the collared wildebeest and zebra drank frequently at seasonal waterholes, which revealed them as opportunistic drinkers. The wildebeest drank on two of three or three of four days at the start of the rainy season, and every fourth day towards the end. The zebra drank every day to twice in three days at the beginning and every third day at the end of the rainy season. On contrast, the collared springbok was not observed drinking in the rainy season, which indicates that it received sufficient moisture from its feed, and was less water-dependent than wildebeest and zebra.

1 b.   *Period 2: 'Dry season' - Low water availability and least good water quality*
In the dry season months the waterhole densities were relatively low with one waterhole in 76 - 88 sqkm. The availability of water was limited to perennial waterholes, which restricted the movements of water-dependent game species and resulted in a high animal pressure around these water points. In addition, the chemical quality of the water available was less good than in Period 1. Especially before the start of the rainy season the highest electrical conductivities of the year were recorded at the perennial waterholes (x EC between 500 mS/m and 750 mS/m).

The drying up of the seasonal waterholes and the very low moisture content of the feed forced the game to leave waterless grazing areas and move closer to perennial waterholes at the beginning of

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[4] The borderline months should be understood as transition periods between the seasons rather than fixed points in time, and are expected to vary from year to year.
[5] The estimated waterhole density was calculated combining perennial and seasonal waterholes, and extrapolating the water availability findings from monitored seasonal waterholes onto the entity of mapped seasonal waterholes.

the dry season. Immigrated game moved back eastwards out of the study area. The collared wildebeest and zebra followed the eastward emigration, the collared springbok on contrast stayed in the vicinity of Okaukuejo. The maximum distances at which the collared animals were found from perennial waterholes during this period were 4.3 km for the springbok, 12 km for the wildebeest and 7.5 km for the zebra.

The low plant moisture of the feed caused all three collared animals to drink frequently. Both the collared springbok and wildebeest drank between every fourth and second day, the collared zebra drank on two of three days or every day.

1 c.   *Period III: 'Late dry season with local rain' - Moderate water availability and moderately good water quality*

The months with localised rainstorms showed moderate waterhole densities of one waterhole in 34 - 69 sqkm. Water was available at about equal numbers of perennial and seasonal waterholes. However, localised rain storms filled seasonal waterholes in parts of the study area only. In these areas the increased water availability at seasonal waterholes caused a reduced animal pressure around perennial waterholes. Slightly better chemical qualities than in Period 2 were recorded at the perennial waterholes (xEC: 425 mS/m - 552 mS/m). The water quality at seasonal waterholes varied from very good to highly saline (EC range: 17 mS/m to 5200 mS/m; xEC: 550 mS/m).

In this period patchy rainstorms fell north of Okaukuejo and in the Okaukuejo-Ombika-Aus-Nebrowni area, which filled seasonal waterholes and caused fresh grass to sprout. With the rest of the study area being dry and providing food with low moisture, these areas attracted substantial numbers of game. However, numerous animals remained around the perennial waterholes in the east. Springbok reacted the most of the study species to these localised rains. Wherever fresh grass growth was found, springbok concentrated in considerable numbers. Wildebeest and zebra on contrast were observed only in October in the areas with fresh green, but not in November and December, whdn they either did not detect or deliberately did not make use of the green grass. Of the collared animals the springbok benefited from the increased moisture of the green grass in its favoured area around Okaukuejo. The collared wildebeest migrated 60 km from Halali Seepage to graze south of Gaseb in November, but was found 70 km back east outside the study area in December. The collared zebra utilised the area around the perennial waterhole Goas in October, but could not be located in November and December.

The drinking frequency of the collared springbok was relatively low. It was not observed drinking in November, when the moisture content of the feed was relatively high, but otherwise drank every fourth or third day. The collared wildebeest also was not recorded drinking in November, but drank on three of four days in October and every third day in December. The collared zebra drank every second day in October, but was not observed later in the season.

2.   The studied wildlife species springbok, wildebeest and zebra showed a high mobility throughout the year which was influenced by the availability of water and food. However, the mean daily distance moved by all three species of four to six kilometres throughout the year was relatively short (AM: 4.1 km, CT: 4.8 km, EB: 5.7 km). Mean area sizes utilised per days were comparatively small with one to three square kilometres for all three collared animals (AM: 0.9 sqkm, CT: 1.9 sqkm, EB: 2.8 sqkm). Whereas both distances walked and area sizes utilised for all three species were significantly higher on days with drinking compared to days without drinking, no changes were observed between the seasons. The maximum distances travelled on a single day

were 9.4 km for the collared springbok, 16.2 km for the collared wildebeest and 12.1 km for the collared zebra.

3.   The collared springbok was found to be the least water dependent of the three study animal species with a mean drinking frequency of every fourth to fifth day during the year. The collared wildebeest drank more frequently, on average every second day. The zebra was found to be the most water dependent and was recorded drinking on two out of three days.

4.   The chemical quality of water utilised by the collared animals ranged from 13 mS/m to 135 mS/m at seasonal waterholes in the rainy season, which is considered as good quality water. In the dry season and late dry season with local rain, the water quality of the utilised perennial waterholes varied between 309 mS/m and 754 mS/m which is regarded as moderately saline water.

The four study animal species (springbok, wildebeest, zebra and gemsbok) utilised waterholes with chemical qualities of above 1500 mS/m in moderately lower numbers compared to waterholes with 500 mS/m to 600 mS/m. At salinities above 1900 mS/m they drank in significantly lower numbers. Generalised, the degree of the utilisation of a waterhole was found to decrease with an increase of the salinity of its water. Differences in this trend were revealed depending on whether the high salinity was permanent or temporal. Waterholes with a permanent high salinity were found to be much less utilised than a good quality waterhole at which the salinity was temporally increased for three weeks. This indicates that the study species do not react quick and drastically to changes in a waterhole's salinity and are able to endure high salinities for a certain period.

However, changes of drinking behaviour were noticed when the salinity was temporally increased from moderate salinities (500 mS/m) to high salinities (2600 mS/m). At a water quality of 500 mS/m the animals 'drank normal', which is immediately or with some testing and sniffing of the water. On contrast, 18 % to 24 % of the animals showed 'abnormal drinking behaviour' at salinities between 900 mS/m and 1500 mS/m, in that they sniffed and tasted the water extensively and at several spots before they drank normally or even moved off without drinking. When the salinity increased further to between 1500 mS/m and 2600 mS/m even more animals, 39 % to 43 %, drank abnormally.

With respect to the individual species, both springbok and zebra reacted with decreasing numbers to increased salinities. On contrast, wildebeest, which occurred generally in low numbers, and gemsbok did not show any significant changes in animal numbers. However, with increasing salinities gemsbok showed the highest percentages of disturbed drinking behaviour of the four species, followed by springbok, wildebeest and zebra, the last of which was the most tolerant to high salinities with regard to the drinking behaviour.

5.   Within the study area several areas were identified as being extremely lowly and very lowly utilised throughout the year, e.g. between Mbari and Adamax and between Nebrowni and Homob. This under-utilisation can mainly be attributed to the absence of perennial waterholes. The low utilisation of the Ombika area is probably caused by the low water availability of the Ombika waterhole and its location in a depression, which increases the risk for animals to be caught by predators. The extremely low and very low utilisation of the area between Sonderkop and Mbari can be attributed to the high salinity of the waterhole Arendsnes.

Moderate, high and very high utilisation was identified around the perennial waterholes Mbari, Okondeka, Okaukuejo, Gemsbokvlakte, Salvadora, Rietfontein, Halali turnoff and Halali Seepage, the main concentration points of animals in the dry season and late dry season with local rain. Besides areas around perennial waterholes, high utilisation was recorded for the area between Adamax and Okondeka, and ten kilometres north of Okaukuejo, the animals' favourite rainy season grazing area, and five kilometres north-west of Okaukuejo, where animals concentrated in the late dry season with local rain because of green grass growth.

6.0   Recommendations for the waterhole management of the Etosha National Park

With respect to the findings of the above documented study and personal observations made during the study the following recommendations are made:

R1.   Seasonal waterholes, i.e. gravel pits proved to increase the water availability drastically in the rainy season. They were found to be good quality waterholes, which allowed water dependent animals to utilise areas which are void of perennial waterholes, and thus increased their ability to utilise areas with the best food available. The water availability at selected gravel pits could be extended even further into the dry season by cementing some gravel pits.

R2.   Troughs at perennial boreholes, into which animals frequently urinate and defecate, should be cleaned more regularly during the year, but especially in the dry season, to improve both the chemical and biological quality of the water.

R3.   The average distance between perennial waterholes within the study area of 8.6 km is considered as being too short. In the future the spacing of waterholes in Etosha should aim at an approximate distance of 15 km (12.3 km to 17.1 km) between perennial waterholes, which is three times the daily travel distance of animals (4.1 km to 5.7 km for the three study species) after Owen-Smith (1996).

R4.   Extremely lowly and very lowly utilised areas where identified in the following areas:

- Sonderkop - Mbari: This area is 'under-utilised' mainly because of the high salinity and the consequent extremely low utilisation of Arendsnes waterhole. It is recommended that Arendsnes waterhole is closed, and a new borehole with better quality is drilled further south of Arendsnes.

- Mbari - Adamax: This area is 'under-utilised' mainly because of the lack of perennial waterholes. However, no perennial waterhole should be installed on the plains systems of Grootvlakte or within the Okaukuejo-Adamax-Okondeka triangle because of the danger of over-utilisation. Instead, a perennial waterhole could be installed south of these plains system at the edge of the tree savannah.

- Okaukuejo-Ombika-Gemsbokvlakte: The low utilisation of this area might be influenced by the low water availability at Ombika waterhole and the fact that the water lies in a two metres deep and small depression. It is suggested that the pipe is moved a few tens of metres further west and the water flow is directed into a larger, only slightly depressed pool area (similar to the set-up at Aus waterhole), and that the water production is increased.

- Nebrowni - Homob: This area is extremely lowly utilised mainly because of the lack of perennial waterholes. The area could be made accessible for animals by opening a waterhole in this area.

Because of the sensitivity of this Pan's edge area, the suggested borehole should only be opened after above-average rainfall, and be closed during the dry season.

R5.   Moderately, highly and very highly utilised areas were identified in the following areas:

- Mbari: The waterhole Mbari is very highly utilised throughout the year because it is the only waterhole within the steppe and shrub savannah area east and south of it. In addition, the high salinity and consequent 'under-utilisation' of Arendsnes waterhole adds game pressure from the west. It is suggested that Mbari is closed for some time so that the vegetation can recover. Instead water could be made available to the game by opening another waterhole south of Arendsnes (as suggested under point R4.)

- Okaukuejo: The Okaukuejo waterhole is highly utilised throughout the year, because it is the only waterhole within a large waterless area west of it. Since the flood-lit Okaukuejo waterhole is a high attraction for tourists visiting the Okaukuejo camp, the closing of the waterhole is not recommended due to economic reasons. In order to reduce the game pressure at Okaukuejo a new waterhole could be installed between Grunewald and Okaukuejo along the track or south of it in the shrub and low tree savannah, as suggested under point R4.

- Gemsbokvlakte: The waterhole Gemsbokvlakte is moderately utilised throughout the year. To relieve the pressure on the area, Gemsbokvlakte could be closed for some time and instead a new waterhole opened south of there in the low tree savannah.

R6.   Rotational waterhole management could be practised within the park in order to reduce game pressure on the areas around permanent waterholes. A group of boreholes could be closed for the dry season in areas with extremely low grass biomass so that animals have to move to another group of boreholes and utilise the better grazing areas there.

7.0   **Applications of the study results for decision makers in other national parks, conservancies and farming areas**

7.1   **Important factors of waterhole management in order to prevent desertification**

The high mobility and natural rotational grazing as shown by the studied wildlife species is considered the prime example for sustainable area utilisation which domestic stock holders in commercial and communal areas should return to. Many farms in the commercial areas are using this example and have adopted the camp system which implements rotational grazing with the help of fences. In the past, rotational grazing was also commonly practised in the communal areas, which were mostly not fenced and allowed free movement of people and stock. In the Four Os region (former Owamboland) for example, cattle utilised the oshana area in the rainy season but were moved into dry season grazing areas, mostly east and south when water and grazing became scarce (Marsh & Seely 1992, Pallett 1994). This seasonal cattle movement, called transhumance, allowed the vegetation to regenerate in both rainy and dry season grazing areas.

Today, however, the rotational grazing is practised to a much lesser extent. The main reasons are the introduction of reliable water sources in the form of boreholes, pipeline and canals in areas which were formerly waterless or had hand-dug wells only, and the reduction of traditional grazing areas by fencing. This has the effect that people become sedentary in the vicinity of the water points and that cattle are kept longer near these water points. This frequently results in the

degradation of the mediate area around the water points, such as the decrease of plant species diversity, reduction in the vegetation production and top soil erosion, and a semi-permanent reduction of the production potential (Danckwerts & Teague, 1989).

One of the main keys to sustainable wildlife, stock and veld management is an environmentally sound waterhole management. Since water availability is one of the most important assets for survival in semi-arid areas, people and animals concentrate wherever water is available. What is of most importance for communal areas is the fact that the establishment of reliable water points (such as boreholes, pipeline, canals, etc.) gives the impetus for human settlement and is willingly or unwillingly initiating and directing the development of an area.

Therefore the following recommendations are made:

R1.   <u>Co-ordinated development of water points and environmental impact assessments</u>
        <u>(EIAs)</u>

- *in national parks and conservancies*: The site for a new water point should be selected in co-operation with an experienced ecologist (preferably plant ecologist or soil scientist). The spacing between water points should vary between 10km to 20km, but not be less than 10 km.

- *in commercial and communal farming areas*: In order to avoid the uncoordinated and inappropriate opening of water points, as it is currently happening in many areas, trained governmental co-ordinators should be appointed for each region of Namibia in order to co-ordinate and approve the establishing of water points. A detailed environmental impact assessment (EIA) undertaken by a trained and experienced ecologist for each suggested water point site with respect to the effects and possible negative impacts on the surrounding areas, should be obligatory for the final approval by the governmental co-ordinator.

R2.   <u>(Re-)Implementation of rotational grazing, and control over and co-ordination of</u>
        <u>grazing</u>

- *in national parks and conservancies:* Rotational grazing is mostly practised naturally by adapted wildlife species in areas which are large enough to allow migrations. In smaller areas rotational grazing can be encouraged by the rotational opening and closing of waterholes and of waterhole groups. This will have to be undertaken in consideration of the condition of the veld in order to avoid degradation. Animal movements on the biggest scale possible should be aimed at, so that large areas get an adequate rest.

- in *commercial and communal farming areas:* The use of seasonal waterholes, such as gravel pits, dams and natural depressions, by cattle should be encouraged in the rainy season and late dry season with local rain. Perennial waterholes in the vicinity of seasonal waterholes should then be closed in order to give grazing areas around the perennial waterholes time to recover. In communal areas, today's free grazing of domestic stock has led to over-grazing in many areas. One of many reasons for this is the fact that on communal land there is no sense of ownership or of commitment on the part of the people to utilise the veld sustainably. Awareness should be created amongst livestock owners about the negative impacts their stock has on the land and suggestions should be made about how to avoid or minimise them, such as by practising transhumance. The grazing should be controlled and co-ordinated, e.g. satellite remote sensing could be used to detect the best grazing areas at a certain time of the year for each region, which

could be recommended to the farmers. In general, farmers should be held responsible if they use the land in an unsustainable way.

<u>R3.</u>   <u>Provision of sufficiently good quality water at perennial waterholes</u>

- *in national parks, conservancies, commercial and communal farming areas:* Highly saline waterholes (e.g. >1500 mS/m) should be closed and - if possible - replaced by better quality waterholes in the vicinity. The under-utilisation of a highly saline waterhole can cause an increase in game pressure at the neighbouring better quality waterholes. If the grazing area, which the highly saline waterhole should cover, is thought to be accessible by animals utilising the neighbouring waterholes, the highly saline waterhole should be closed without the opening of a better quality waterhole in this area and the installations of the water point used for a new waterhole in another area.

7.2   Differences in the water requirements and waterhole utilisation patterns between the study wildlife species and domestic stock

In the following a comparison of the water requirements and waterholes utilisation patterns of the study wildlife species springbok *Antidorcas marsupialis*, blue wildebeest *Connochaetes taurinus* and Burchell's zebra *Equus burchelli* will be drawn with domestic stock, i.e. cattle, sheep and goat. The facts on wildlife are taken from the above documented study and from publications of other studies, the details on domestic stock are taken from the literature. No detailed information could be obtained on the special water requirements and waterhole utilisation patterns of Namibian cattle, sheep and goat species. Therefore, the study results of various work undertaken in other semi-arid and arid countries are adopted.

Drinking frequency:

Of the collared study species the springbok was the least water-dependent, with an average drinking frequency of every fourth to fifth day. It was not observed drinking during the rainy season, and drank every second day in the dry season. The wildebeest drank more frequent, on average every second to third day. The zebra proved to be the most water dependent and was recorded drinking on average on two out of three days.

No reference could be found on how often cattle, sheep and goat are watered in Namibia. According to farmers the cattle in the commercial farming area are watered once per day or even twice per day in hot weather. In the communal areas of Namibia cattle, sheep and goat are likely to be watered daily too. However, if grazing becomes scarce around the watering points in the dry season the stock has to move further away and thus may be watered less often. Detailed information is needed on the drinking frequencies of domestic stock in Namibia with respect to the different species. Studies in Australia have reported that Merino sheep drank twice per day to three times in two days and Border Leicester sheep drank twice per day (Squires & Wilson 1971), while consuming a salty diet. Both switched to drinking once per day when walking distances between food and water increased to further than 4.0 km and 4.8 km respectively. Merino sheep foraging on a grassland site drank once daily (Squires 1976).

Comparing wildlife with domestic stock shows that the studied wildlife species need to drink less often than domestic stock. This consequently means less trampling and lower vegetation utilisation around the water points and therefore less degradation.

Amount of water consumed per day:

No data could be obtained during this study on the amount of water utilised by the studied wildlife species. However, Nagy & Knight (1994) have reported that springbok of the Kalahari had a daily water turnover of 3.18 to 4.93 litres per day. The study of Macfarlane et al. (1971) gives a daily water turnover of 9.72 litres for black wildebeest *Connochaetes gnou* and King et al. (1978) found that the fringe-eared oryx *Oryx beisa callotis* has a daily water intake of 1.6 to 3.2 litres per day. All of these studies describe the water intake through drinking and feeding. Summarised they suggest a daily water turnover of less than ten litres per day for these wildlife species.

Namibian cattle have been reported to consume 45 litres per day, and goats to drink 12 litres per day (Forbes Irving 1996). Australian Merino and Border Leicester sheep feeding on saltbush consumed 5-7 litres and 7-11 litres respectively per day (Squires & Wilson 1971). When Merino sheep fed on grassland they consumed between 0.6-3.1 litres per day (Squires 1976). Macfarlane et al. (1971) states that in the summer desert of Australia and northern Kenya, the highest water turnover rates of domestic stock occurred in cattle, with sheep at about half their rate and goats somewhat less. Comparing domestic stock and wildlife they found that eland *Taurotragus oryx* and boran cattle *Bos indicus* were equal in water demands, while wildebeest *Connochaetes gnou* were comparable with sheep and an oryx had a water turnover of less than one-third of cattle.

These figures should be taken as rough guidelines of the water intake of various animal species only, since they are influenced by factors such as age, sex, pregnancy, lactation, climate, vegetation, saltiness of water, etc. However, they indicate that in arid environments domestic stock in general consumes more water than the adapted wildlife.

Distances walked between water points and grazing areas:

During this study the collared springbok walked an mean distance of 4.1 km per day, the collared wildebeest travelled 4.8 km, the collared zebra 5.7 km per observation day. Distances walked were higher on days with drinking compared to days without drinking. Despite the low average distances walked per day, which might be an indication for a high feeding effectiveness, all three study wildlife species are known as migratory animals which may cover remarkable distances.

No details on the daily distances walked could be obtained for Namibian stock. Australian Merino sheep were recorded to move between 8-14 km per day when fed on saltbush, and between 5-6 km per day when they foraged on grassland (Squires 1976). The increased distance travelled when the diet contained increased levels of salt resulted from a higher drinking frequency. Maximum distances of Merinos and Border Leicesters fed on saltbush were recorded as 13.6 km and 17.6 km respectively.

The above information on walking distances of wildlife and domestic stock suggest that the daily distances travelled are similar. However, more detail has to be obtained on this issue. In addition, observations on the condition of the animals are necessary when investigating the travel distances

of animals, as it has been recorded that domestic stock which travels extensively looses condition much quicker than wildlife would.

Water quality tolerance of utilised water:

Observations showed that the wildlife species springbok, wildebeest, zebra and gemsbok utilised highly saline water (electrical conductivity (EC) above 1500 mS/m) in lower numbers than moderately saline water (EC: 500 mS/m to 600 mS/m). The utilisation of a waterhole in general decreased with an increase of the salinity of its water. However, waterholes with a permanent high salinity were found to be much less utilised than a temporary high salinity at a previously good quality waterhole. This indicates that wildlife is willing and able to utilise high salinities for a certain period. Although wildlife was utilising temporary high salinities, a high percentage (39 % to 43 %) of disturbed drinking[6] behaviour was observed.

No guidelines exist yet on the upper limits of the chemical quality of water above which negative physiological effects are to be expected in wildlife. The study results suggest that an electrical conductivity of 1500 mS/m are taken as a guideline for watering wildlife. Long-term use of water with a higher salinity is expected to affect wildlife negatively.

For domestic stock water quality guidelines exist. The Department of Water Affairs, Namibia (1991) water with an electrical conductivity above 900 mS/m should not be used for stock watering. A few studies have been undertaken by various authors in which they tested the effects of saline water on cattle and sheep (Pierce 1957, Weeth et al. 1960, Weeth and Haverland 1961, Wilson 1966, Potter and McIntosh 1974). Cattle showed an increase in the water consumption at an electrical conductivity above 1515 mS/m, a reduced growth rate above 1894 mS/m and a reduced water intake above 2273 mS/m. At salinities above 2662 mS/m weight loss and anorexia were observed, at salinities above 3030 mS/m various symptoms such as weight loss, anorexia, lethargy, anhydremia, mild diarrhoea, weakness, collapse and death were reported. In sheep adverse effects were observed at electrical conductivities of 1515 mS/m when pregnant sheep were found distressed at parturition, and neonatal mortalities occurred. At salinities above 2273 mS/m sheep showed a decreased feed intake and a loss in body weight as well as weakness. No higher salinities than 3030 mS/m were tested on either cattle or sheep.

Although no water quality guidelines based on physiological effects of saline water exist for wildlife, it is believed, that wildlife can tolerate higher salinities than domestic stock. More research is needed on the effects of salinity and also of individual ions, alone or in combination, on wildlife.

Summary:

Overall, wildlife seems to utilise water more efficiently than domestic stock, with a generally lower drinking frequency and daily water consumption. The daily distances covered by wildlife were found similar to domestic stock. However, domestic stock has been reported of loosing body condition after longer distances had been covered, whereas wildlife, especially springbok, wildebeest and zebra, are able to migrate vast distances without losing condition. It is further suggested that wildlife is more tolerant and adapted to high salinities of water.

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[6] such as sniffing and tasting the water several times and at several positions before they drank or even left without drinking

The fact that wildlife is generally better adapted to the semi-arid environment than domestic stock has been widely acknowledged. Skinner, Von La Chevallerie & Van Zyl (1971) suggest that springbok have two main biological advantages over domestic animals in Africa, namely a better physiological and behavioural adaptation to a hot semi-arid environment and a higher reproductive rate, and therefore advertise them as ideal farming animals. This has been confirmed in this study by the fact that the collared springbok obtained all its water and food requirements during the entire year from a small and over-utilised area around the Okaukuejo waterhole without losing condition.

7.3   Water availability and chemical quality of water in the Four Os region and its usability

The Four Os region (former Owamboland, now named after the four regions Omusati, Oshana, Ohangwena and Oshikoto) lies north and east of the Etosha National Park. Before the park's boundary fence was established in the 1970s large-scale animal movements occurred throughout the entire northern region and between Etosha and Owamboland. Both the fencing of the park, which stopped the migrations of wildlife (except for elephants, which break the fences), and the human population increase in the Four Os region are responsible for today's extremely low numbers of wildlife in the Four Os region.

In the Four Os region livestock keeping is an important tradition. The Namibia Stock Census (1997) suggests a total number of 476 658 cattle (mostly Sanga cattle), of 230 000 goat and 19 000 sheep. In addition 120 000 donkeys are kept, mainly as draught animals. Whereas cattle are a source of milk, meat, traction and manure, in many cases the herd is the family's stock of wealth and an insurance-cum-investment fund (Marsh & Seely 1992, Tapscott 1990). In the last years, however, herds and herd management have come under great pressure because of several factors. Illegal fencing and a constant increase of the human population caused a reduction of the land available for grazing. In addition, continued low and variable rainfall especially in the 1990s caused a lower grass production in most areas. The increased installation of boreholes in recent years, also as part of the 'drought relief programme', has caused many people and their livestock to become sedentary in the vicinity of the boreholes which increased the pressure on grazing land in the surrounding areas and accelerated the process of each household fencing off a small piece of land. In general, these developments have led to land degradation in many areas.

In semi-arid and arid climates the settlement of people and their livestock is mainly ruled by the availability of water. Also in the Four Os region water is the single most important limiting factor, and therefore the development of the water infrastructure has received considerable attention in recent years. There are different sources of water in the Four Os region (Figure 13):

The *Cuvelai* is a system of oshanas, shallow interconnected channels and pans with very low gradients, which supplies the northern Omusati region, the western Ohangwena region and the northern Oshana region with surface water when an efundja (a major flood) occurs after good rains over its Angolan catchment area. The water flow in the oshanas is highly variable between years and places and ceases when the recharge from rain and floods ends. Water is available for some months but mostly not year-round. Although no water analyses data are available, the water quality is expected to be of good chemical quality which deteriorates with the evaporation of the water (Marsh & Seely 1992).

Throughout the Four Os region people extract water through open *hand-dug wells* which tap a shallow aquifer at a depth of less than 25 meters. Due to the sandy nature of the soils, the sides of the wells often collapse and make laborious re-excavation necessary. The chemical water quality measured at eleven wells in the Uuvudhiya area varied from very good quality water of 40 mS/m to highly saline water of 1760 mS/m (Trippner 1996). This variation in the quality of well water is expected to occur throughout the Four Os regions (Department of Water Affairs 1990, Marsh & Seely 1992).

Numerous *boreholes* have been installed in the Four Os region. Boreholes are found in the south-western half of the Omusati region (the north is covered by the Cuvelai system) and throughout the Ohangwena region (except the far west where the Cuvelai runs). They are sparsely distributed over the northern Oshikoto region but densely located in the southern Oshikoto region, with an estimated average spacing of 5 km to 10 km between boreholes. The Oshana region is generally void of boreholes. The water quality is suitable for human consumption (<400 mS/m) at some boreholes along the western and southern boundary of the Omusati region, throughout the Ohangwena region and at the majority of boreholes in the Oshikoto region. Stockwatering (<900 mS/m) is confined to these areas too. On contrast, the central area of the Four Os region, including the middle and eastern south of the Omusati region, the western Oshikoto region and the entire Oshana region, is underlain by highly saline ground water (Figure 14). The salinities are extremely high in these areas and unsuitable for both human and livestock consumption.
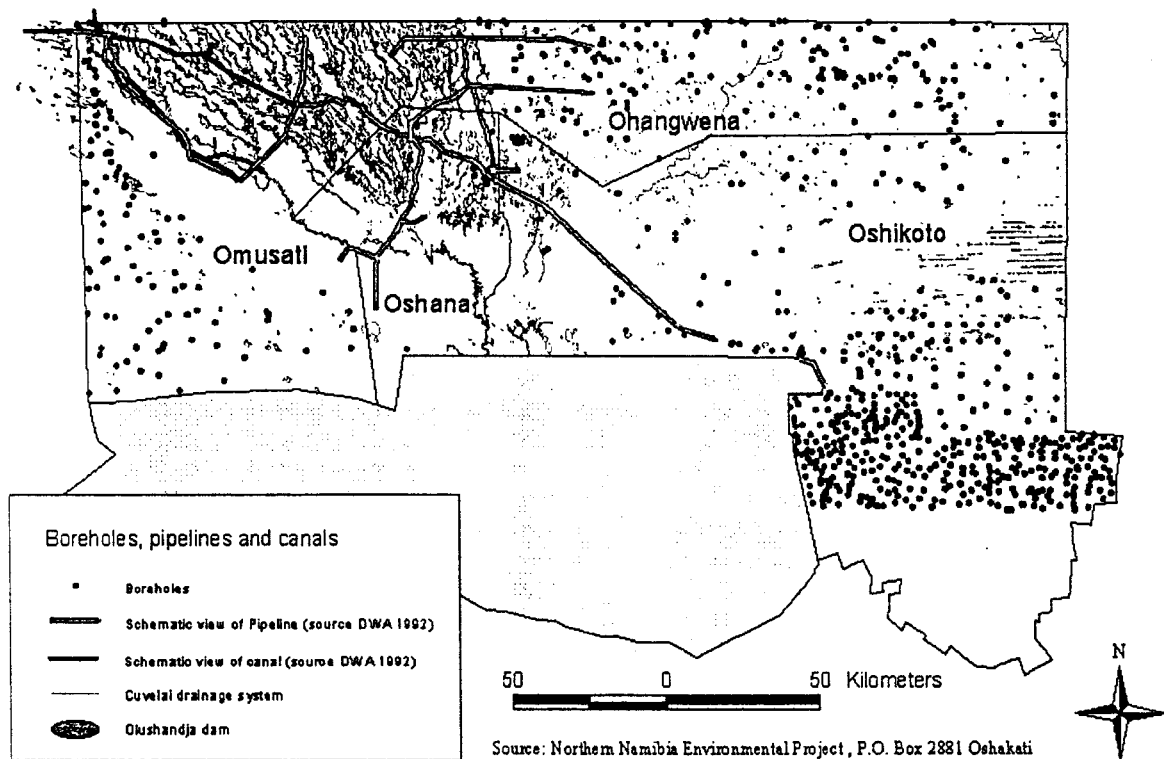

Figure 13: Cuvelai system, boreholes, pipelines and canals in the Four Os region, Namibia
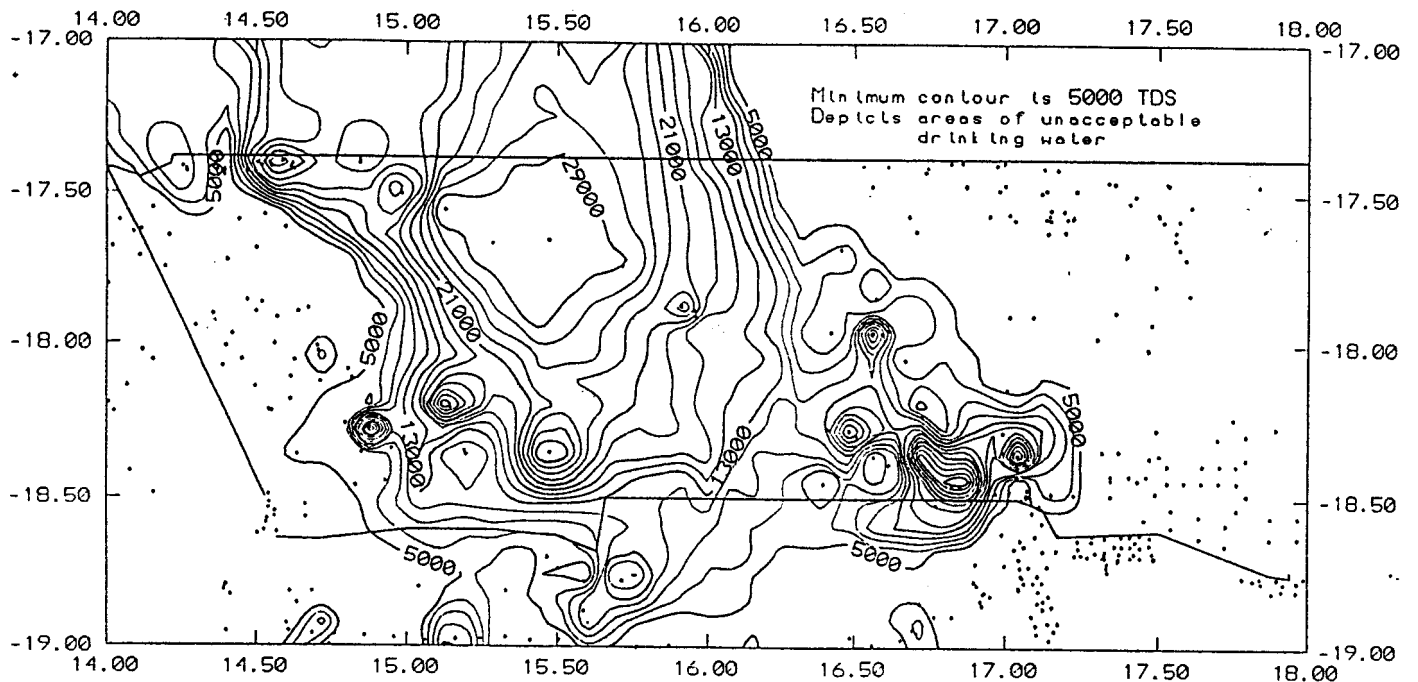
Figure 14: Total dissolved solids (TDS)[7] of groundwater in the former Owamboland (Department of Water Affairs 1993)

In order to provide a reliable water supply to the cuvelai area and to the regions with highly saline groundwater, a bulk water system consisting of a *canal* and *pipeline* was constructed, which brings water from the Cunene River into these areas. Taps and watering points for cattle make water available for people and their livestock. According to Marsh and Seely (1992) the flow of the oshana system has been altered by the construction of the canal, which resulted in a reduced groundwater recharge and vegetation growth in the areas south of the canal, and consequently a lower carrying capacity for people and livestock. No data were available on the water quality of the canal water. However, it is expected to be chemically fit for both human and livestock consumption, but biologically unfit for human consumption due to contamination of this open canal system. The water has to be boiled before consumed by humans. On contrast, the pipeline transports purified water with an excellent chemical quality (mean electrical conductivity 89 mS/m +/- S.D. 6 mS/m at seven sampling sites in the Uuvudhiya and Omapale areas).

Summarised, the Four Os region has limited suitable ground water resources especially in its central area, including the eastern Omusati region, the entire Oshana region and the western Oshikoto region. This area is still lowly populated but is expected to experience an increase in the human population and stock numbers if sufficient and suitable water is made available by extensions of the existing pipeline into these areas. According to Du Plessis (pers. comment 1998) the soils and vegetation in this area are highly sensitive to utilisation and could not sustain high numbers of cattle for a long period.

Since the high seasonal variability of food and water is a natural phenomenon of the semi-arid climate of Namibia and wildlife has shown to be better adapted to this environment than domestic stock, it is suggested that wildlife is re-introduced into these sparsely populated areas in the near future. Conservancies should be established so that communities can benefit from the wildlife in that they are eventually permitted a certain number of yearly off-take and can develop tourist ventures. A simultaneous reduction of stock numbers is recommended in this area to reduce the pressure on the land. This would prevent degradation of the area and diversify the income

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[7] The TDS are directly convertible to the electrical conductivity (EC) using the formula: TDS / 6.6 = EC

structure of communities. Farming with domestic stock and wildlife would be more sustainable in the long term, especially during years of under-average rainfall, which have a high probability of occurrence in the semi-arid Namibia. Conservancies or similar community based natural resource management initiatives would also partly reinstate community control over the area with respect to the settlement, fencing and stocking rates of livestock.

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