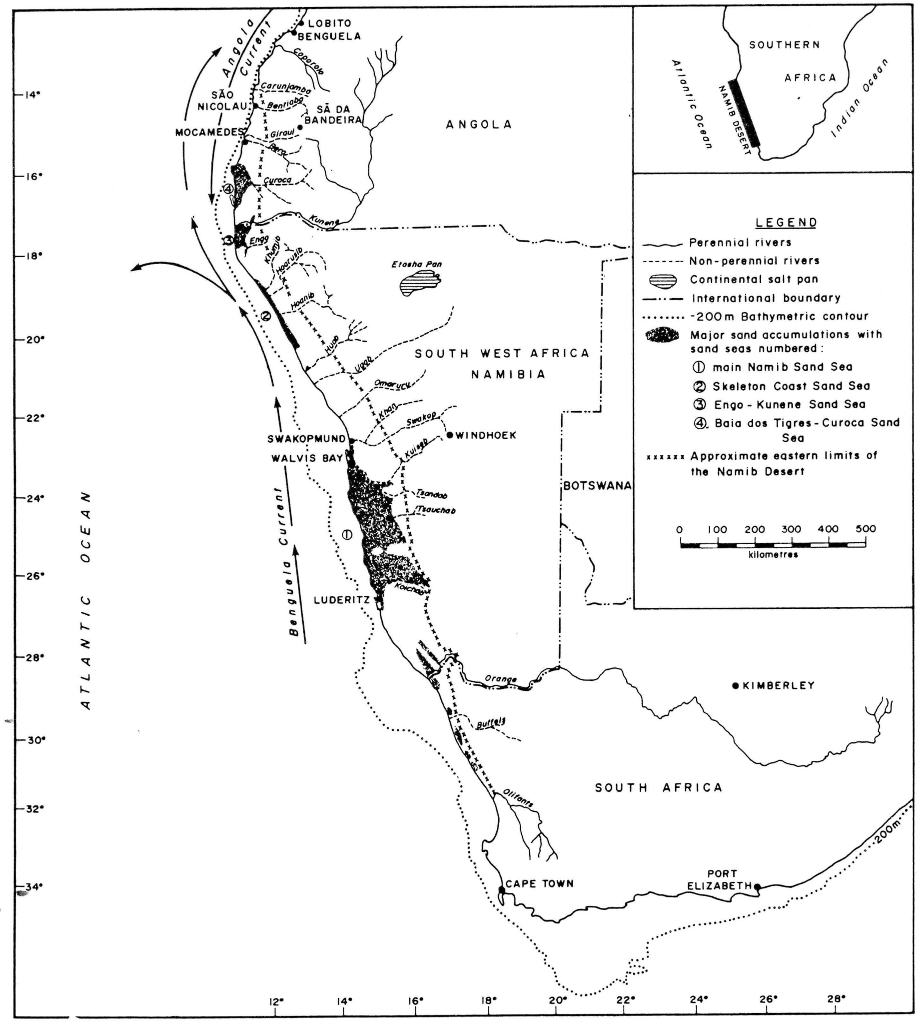

Figure 1. Map of the Namib Desert and environs.

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2. THE KUISEB ENVIRONMENT

B J Huntley, CSIR

The Namib comprises the relatively narrow tract of land, some 2000 km long and mostly less than 200 km wide, lying west of the Great Escarpment between the Olifants River, Cape Province, South Africa and Sao Nicolau, Mocamedes District, Angola (Figure 1). The climate is mostly arid to extreme-arid, with the area north of the Kunene River receiving a summer rainfall maximum and the area south of the Orange River receiving a winter rainfall maximum. The desertic conditions are closely linked to the interacting, aridifying effects of the South Atlantic anticyclone, the cold northward-flowing Benguela Current, with associated upwelling and with the divergence of the South East Trades along the coast. Although the present desert can be considered a geologically youthful feature, the sedimentary history records the prevalence of desertic conditions during much of the Cenozoic (the last 65 million years) for this narrow tract of land. The geological history of the Central Namib is outlined by Ward (this volume, Chapter 3).

The Kuiseb River drains a catchment of approximately 14 700 km^2, rising in the Khomas Hochland and flowing 440 km through the Namib Desert to the Atlantic at Walvis Bay (Figure 2). Stengel (1964) provides a detailed account of the Kuiseb and its recent history, while Hattle (this volume, Chapter 4) details the catchment's surface water hydrology.

Long-term records of precipitation within the Kuiseb catchment range from 400 mm per annum in the upper catchment to less than 20 mm at the coast. Much of the moisture input in the Khomas Hochland is lost to the atmosphere by evapo-transpiration and by utilization in agriculture and mining, with a meagre 1 to 1,5 percent of the upland catchment water yield reaching the Lower Kuiseb, mainly by periodic flooding and a small amount of sub-surface flow. Very little surface water reaches the coast, being absorbed by the deep sands of the lower river bed, adjoining dunes and the delta area.

The regional vegetation of the Namib is outlined by Giess (1971) in his account of the vegetation of South West Africa. The Kuiseb catchment includes his vegetation types: 2 Central Namib, 3 Southern Namib, 4 Semi-desert and Escarpment Zone and 8 Highland Savanna. Aspects of these vegetation types are briefly described here-under and in Chapters 7, 8, 10, 11, 12 and 13.

The Kuiseb Environmental Project developed principally around the need to understand the role played by the water resources of the Kuiseb catchment in the region's ecological structure and dynamics. As noted in Chapter 1,

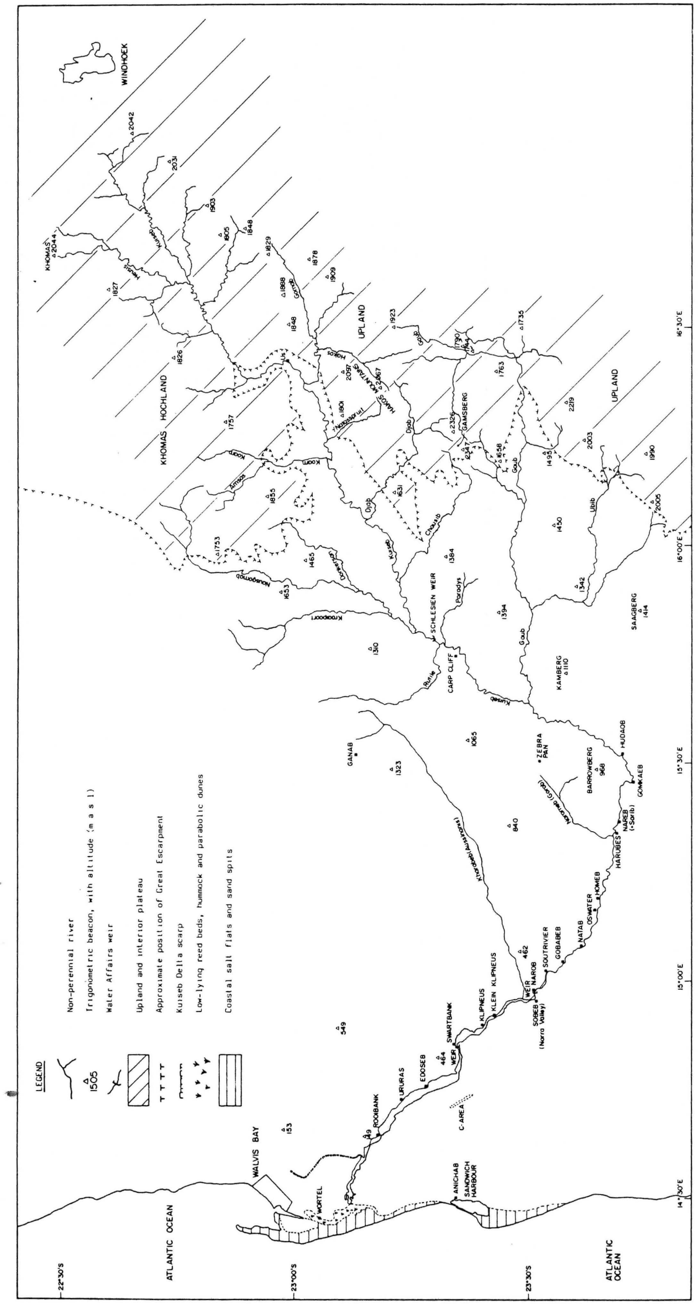

Figure 2. The Kuiseb River basin, indicating the major physiographic regions and study area sub-divisions. Prepared by J D Ward.

limited funds and manpower led to the adoption of a system analysis approach to the study and the definition of interrelated hydrological/ ecological compartments within the catchment. The first approximation model of the system (Chapter 1, Figure 1) identified 11 main compartments. A brief outline of some of their main characteristics is provided as a background to the more detailed accounts of some of the key topics studied in the project.

KHOMAS HOCHLAND AND ESCARPMENT ZONE

The sources of the Kuiseb River rise to the west of Windhoek on the Khomas Hochland. The Hochland is an extensive mica schist plateau of 800 to 2033 m (Figure 3), with well preserved remnants of the original planation surface. The area receives from 100 to 400 mm rainfall per annum, 70 percent of which falls in the months of January to March (see histograms, Chapter 4).

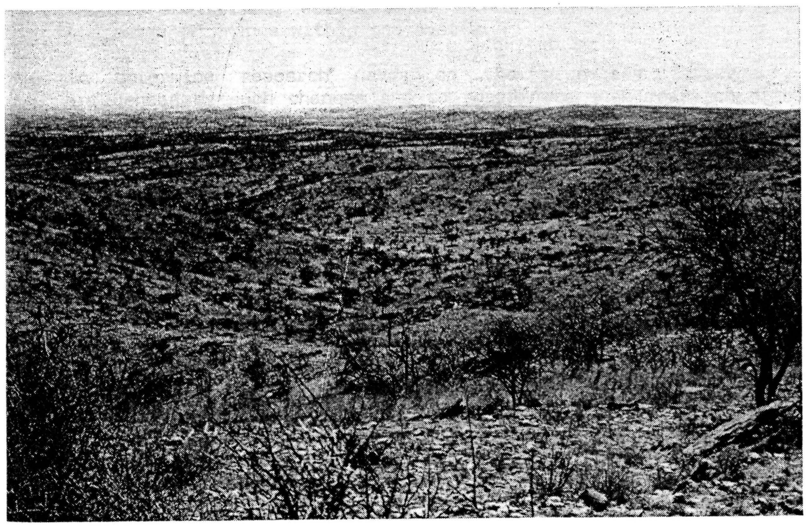

Figure 3. Rolling mica-schist hills of the Khomas Hochland (Photo: J D Ward).

The vegetation of the Hochland has been described in detail by Joubert (1973) and Giess (1971, 1974). The major area of the plateau is occupied by Highland Savanna (Giess 1971) which comprises an open low tree savanna dominated by 3 to 5 m tall Acacia hereroensis, Combretum apiculatum and

Ziziphus mucronata. The herb stratum includes the perennial grasses *Aristida meridionalis*, *Eragrostis nindensis*, *Anthephora pubescens* and *Brachiaria nigropedata* and the annuals *Aristida adscensionis*, *Pogonarthria squarrosa*, etc. The escarpment zone falls within the Semi-desert and Savanna transition of Giess (1971). The terrain is extremely rugged, soils are shallow and precipitation generally much lower (50 to 150 mm) than on the more gently undulating plateau. With the exception of *A hereroensis*, all the species already mentioned occur on the escarpment slopes, with a wide variety of *Acacia* spp and in particular *Commiphora* spp. Succulent *Euphorbia* spp and other arid savanna/desert transition types such as *Sterculia africana*, *Parkinsonia africana*, *Maerua* spp, *Boscia* spp, etc make their appearance.

The unpredictable and widely fluctuating rainfall received in the Khomas Hochland and the escarpment, the shallow stony soils and scarcity of perennial surface waters account for the low agricultural productivity of the region. The upper Kuiseb catchment is occupied by 109 farms (of an average area of 7618 ha) which were estimated to carry a total of 35 567 cattle, 71 075 sheep and 3025 goats in the mid 1970's (Huyser 1979). A more recent estimate, based on the carrying capacity of the area (which ranges from 8 to 30 ha per large stock unit), indicates that the area's potential stock carrying capacity would be in the order of 76 230 cattle and 102 224 small stock - sheep and goats (Loubser pers comm 1983). The game population was estimated at 3000 kudu, 3200 oryx, 2000 Hartmann's zebra and 1200 springbok.

The water resources of the Kuiseb catchment were surveyed in detail by the National Institute for Water Research as a contribution to the Kuiseb Environmental Project (Huyser 1979). Of 591 sub-surface water sources examined, 90 percent comprised boreholes, 8 percent wells and 2 percent natural springs. The median depth of boreholes was 75,2 m, with the water table lying at a median of 18,9 m delivering an average of 1,6 $m^3\ hr^{-1}$. Open water supplies (from dams and standing pools in riverbeds) accounted for 34 percent of the total water use (2694 $m^3\ d^{-1}$) in the catchment. A survey of farm dams of the Khomas Hochland (Anon 1974) indicated that 407 dams occurred in the area, of which about half were built in the last twenty years. Their total potential storage capacity approximates 19,9 million m^3, which has been reduced to approximately 15,8 million m^3, due to siltation. Average dam capacity (excluding two large dams of 1,7 and 6,9 million m^3) was 27 600 m^3. The average annual runoff from the Khomas Hochland and Escarpment of ca 39,8 million m^3 has been reduced by ca 21 percent by the construction of farm dams.

An evaluation of the viability of the farms of the Kuiseb basin was undertaken early in the project (Joubert et al 1976). The farms were classified according to their current or potential economic viability: 72 were found to be viable, 11 were currently inappropriately managed but could be brought to viability, 12 (on the lower margin of the escarpment/desert transition) were considered totally unsuited to any farming practices, while the remainder suffered from a range of problems preventing their rapid attainment of viability. Logan (1977) provided guidelines for the possible reorganization of some of these latter farms.

Industrial developments in the Khomas Hochland catchment of the Kuiseb are extremely limited. A single copper mine (Matchless, owned by the Tsumeb Corporation) annually produces approximately 20 000 tonne of copper and pyrite concentrates from a reserve of 900 000 tonne ore of 2,37 percent copper and 15,01 percent silver.

KUISEB CANYON

From the foot of the escarpment (Figure 4) to the Nausgomab confluence the Kuiseb is moderately incised whereafter it flows through a deep (ca 100 to 200 m) canyon (Figure 5) to Natab. The canyon unit normally receives very little rainfall and little runoff from the surrounding plains and hills: it acts mainly as a passageway for the runoff from the Khomas Hochland to the Lower Kuiseb. The upper canyon floor is almost entirely rocky, with a few isolated pools which persist late into the dry season, and scattered patches of sparse vegetation on local sandbanks.

Figure 4. The deeply dissected Khomas Hochland escarpment zone (Photo: J D Ward).

UPPER RIVERINE WOODLAND (HARUBES TO THE GAUGING WEIR AT GOBABEB)

A key feature of the Central Namib environment is the linear oasis which crosses it from the base of the escarpment to the coast at Walvis Bay. This oasis is formed by a dense woodland which is supported by the periodic flood recharge of underground water supplies along the course of the

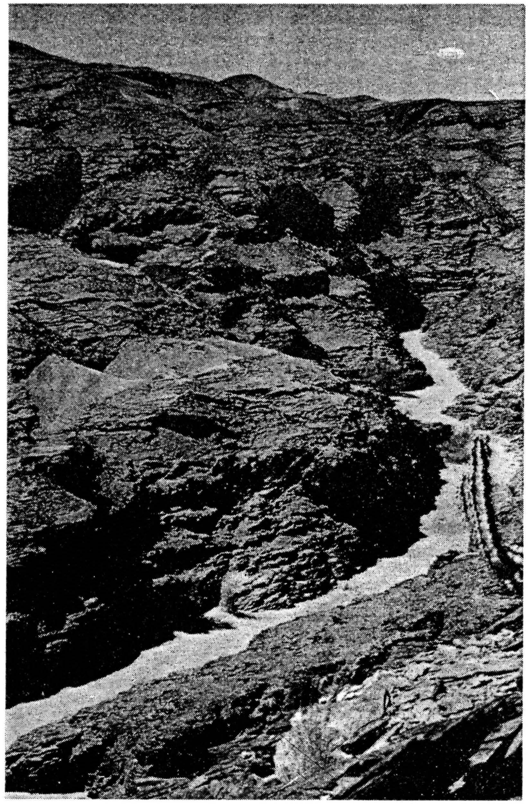

Figure 5. The deep canyon of the Kuiseb River near Hudaob (Photo: J D Ward).

Kuiseb. Over a distance of approximately 150 km, from Harubes to Rooibank, the groundwater supplies and soil conditions permit the maintenance of dense tall woodlands of Acacia albida, A erioloba, Tamarix usneoides and Euclea pseudebenus. These woodlands are of great importance to the downstream migration of both animals and plants, and provide food and shelter to plains game during critical periods. The plant communities of this oasis are described by Theron et al (1980), (and in Chapters 7 and 8, this volume) while valuable details of the river's flooding periodicity and the structure and general ecology of the woodlands are provided by Seely et al (1981). The latter paper draws attention to the constant fluctuations in the woodland structure brought about by variations in the frequency, intensity and duration of floods. (See also Ward, Chapter 9, this volume). For the purpose of the Kuiseb Environmental Project, the riverine

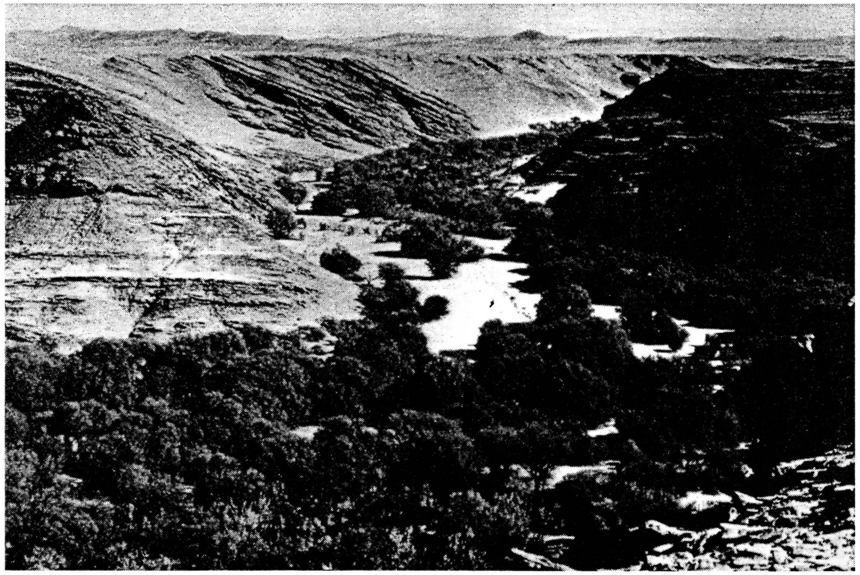

Figure 6. Upper Riverine Woodland (Photo: J D Ward).

woodlands were divided into three sectors in terms of their main hydrological and ecological characteristics.

The Upper Riverine Woodland sector extends downstream from Harubes, where the Kuiseb aggrades and has a wide sandy floor with low stream terraces occurring occasionally along the main channel. The river course continues to flow within the steeply sided walls of the Canyon (Figure 6) until Natab, whereafter the height and slope of the river margins is less severe.

In common with the Canyon area and all areas downstream, the Upper Riverine Woodland division receives very little water input either from rain or lateral runoff, the only meaningful supply being the input from floods rising in the Khomas Hochland and from sub-surface flow.

MIDDLE RIVERINE WOODLAND (GOBABEB TO SWARTBANK)

The lower sandy river bed of the Kuiseb is divided into several compartments by bedrock barriers which traverse the bed from the gravel plains in the northeast to the Sand Sea in the southwest. These barriers occur at Narob (gauging weir), Swartbank, Rooibank and at Mile 16. Each compartment comprises an elongated basin filled with sand and alluvium deposited by the river during floods. The compartments are bounded on the northern side by impervious bedrock. On the southern side they are bound by the Sand Sea which is underlain by pervious sediments into which considerable leakage of underground water from the sandy river beds may take place. The sand basins support Acacia spp woodlands which differ in

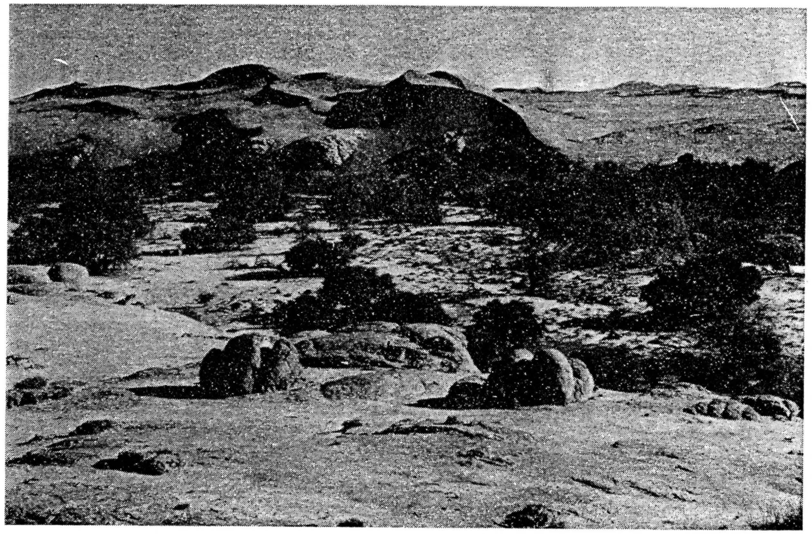

Figure 7. Middle Riverine Woodland at Gobabeb (Photo: J D Ward).

their structure from those of the Upper Riverine Woodland (see Theron et al, this volume, Chapters 7 and 8) (Figure 7). The Middle Riverine Woodland occurs in a reach of the river characterized by rock outcrops and generally thin (2 to 3 metres) alluvium in contrast to the Lower Riverine Woodland. No abstraction occurs within this section.

LOWER RIVERINE WOODLAND (SWARTBANK TO ROOIBANK)

This section is characterized by the absence of rock outcrops in the river bed along the left bank and by deeper alluvium. Water abstraction has occurred from the upper reaches of this compartment since 1976 and from the lower reaches since 1925.

KUISEB DELTA

Five km below Rooibank, at the rock barrier at Mile 16, the Kuiseb bed widens rapidly to form an extensive delta. The northern arm of the delta used to open into the sea at Walvis Bay, but is now diverted to the south by a flood protection wall. The indistinct southern arm comprises a mosaic of the previous river surface interspersed with the northern ends of several linear dunes, as well as mobile crescentic dunes and partly-vegetated hummock and parabolic dunes. Sub-surface flow of water from the Rooibank compartment is limited by the solid rock barrier at Mile 16, which crosses the river and extends more than a kilometre into the dunes. The groundwater level lies at 35 to 40 metres below the surface. Woody plants are represented by shrub forms of *Acacia erioloba*, less frequently *A albida*

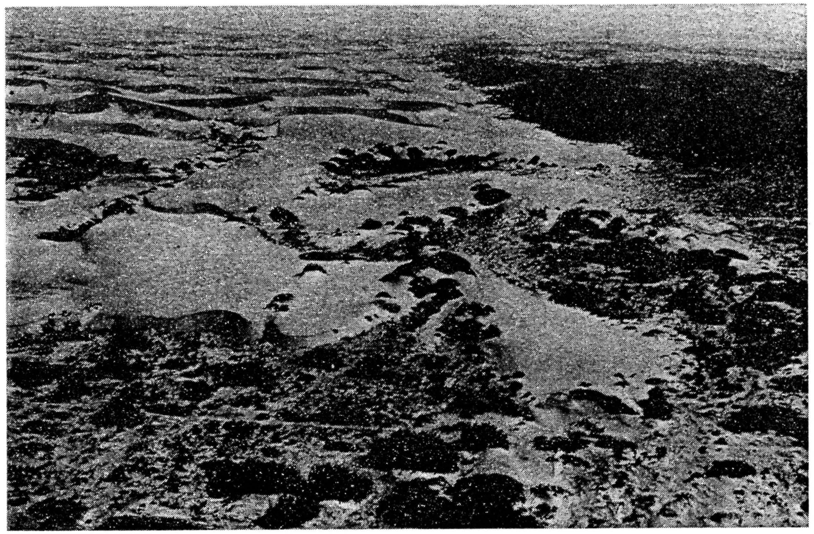

Figure 8. Kuiseb Delta, at the edge of reed beds and saline marshes (Photo: J D Ward).

and in silty depressions *Tamarix usneoides* (Figure 8). The vegetation of the delta floodplain includes many ephemerals and short-lived perennials. The saline marshes within the delta are dominated by *Phragmites australis*, *Salsola* spp, *Lycium* spp and *Tamarix usneoides*.

SALT FLATS

Largely vegetationless salt flats lie between the saline marsh/dune hummock section and the sea. Sub-surface recharge to the inland portion of these flats is through groundwater flow from the Kuiseb. Surface flow is of rare occurrence, averaging once every eight years. The last floodwaters to penetrate to the sea occurred in 1934 and 1963. The influence of the development of a large salt works on the hydrology and ecology of the salt flats has not yet been monitored.

GRAVEL PLAINS

The Namib Platform, an extensive, relatively smooth planation surface, is exposed to the northeast of the Lower Kuiseb. This granite and mica schist platform is patchily covered by thin gravels, gypsum and calcrete. Most of these plains receive less than 50 mm rainfall per annum and support a very sparse grassland and dwarf succulent shrubland on which small nomadic populations of gemsbok, springbok, zebra, ostrich, etc subsist (Figure 9). These populations depend to a large measure on the availability of forage and water along the Kuiseb Canyon and Riverine Woodland sectors. Drainage lines and dry riverbeds, which occupy about three percent of the gravel

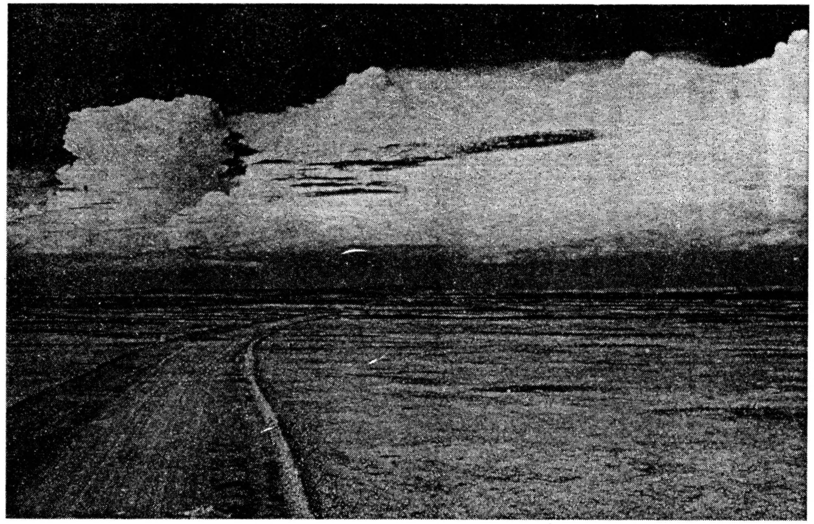

Figure 9. The gravel plains near Gobabeb (Photo: J D Ward).

Figure 10. Dunes and interdune valley near Rooibank (Photo: J D Ward).

plains surface area, contribute substantially to the forage production of the plains. The main woody species include Acacia erioloba, A reficiens, Ziziphus mucronata and Euclea pseudebenus, while important herbs include Stipagrostis ciliata, S uniplumis, S hochstetteriana and various legumes. The plant communities of these plains are described in detail by Robinson (1976) and are outlined by Nel (this volume, Chapter 12). Two minor copper deposits, at Hope and Gorob, have been mined sporadically over the last century. Neither is currently operational, nor is either likely to become active in the immediate future.

DUNES

The Namib Platform slopes gently to the southwest, passing under the high mobile dunes of the main Namib Sand Sea south of the Kuiseb River.

Groundwater from the Middle and Lower Riverine Woodlands flows under the dunes and some of this is thought to emerge at Sandvis Lagoon. The local wind patterns result in the dunes moving very slowly in the northeasterly direction, the periodic scouring action of floods retarding this movement across the Kuiseb (see Ward, this volume Chapter 6, and Seely et al 1981).

The dunes are very sparsely vegetated, but arid grasslands cover the inter-dune plains and support small nomadic groups of large mammals (Figure 10), besides their diverse lower vertebrate and invertebrate faunas. A detailed account of the vegetation of the dunes is provided by Robinson (1976) while the structure and dynamics of the dune ecosystems is described by Seely and Louw (1980).

SANDVIS LAGOON

Sandvis Lagoon is a large, generally shallow lagoon lying at the foot of very high dunes on the Atlantic coast approximately 50 km south of Walvis Bay. Also known as Sandwich Harbour, the lagoon is a wetland of international importance as an overwintering stop-over area for palaeoarctic waders. Berry and Berry (1976) record 90 species of birds from Sandvis, including 18 palaeoarctic waders, 20 seabirds, 34 waterbirds and 18 landbirds. Up to 250 000 Cape cormorants use it as a roosting area, while thousands of terns and flamingoes feed in the lagoon.

The lagoon is considered of significance to the Kuiseb Environmental Project due to the belief that the freshwater seepage along its inland margin is derived from the Kuiseb. Geophysical studies suggest that two channels run from approximately Klipneus on the Kuiseb to the northern end of Sandvis Lagoon (Van Zijl and Huyssen 1967). Apparent changes in the water quality along the seepage line of Sandvis Lagoon were interpreted as a consequence of increased water extraction from the Lower Kuiseb (Hellwig 1974). Subsequent studies have not observed the predicted changes in the lagoon fauna and flora (Penrith 1979). Indeed Penrith suggests that the freshwater seepage has only a very limited area of influence in an otherwise marine lagoon. Reedbeds of Phragmites australis (Figure 11), thought to be dying out in the early 1970's, expanded considerably in the mid and late 1970's. Robinson (1976) describes the vegetation of Sandvis Lagoon, which includes Typha latifolia, Arthrocnemum affine, Sporobolus virginicus and Odyssea paucinervis communities.

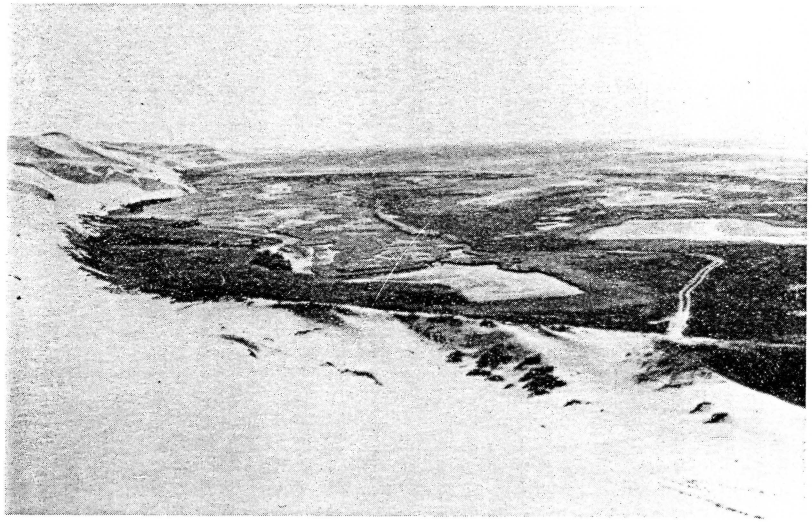

Figure 11. Sandvis Lagoon, viewed from the northern end (Photo: J D Ward).

WALVIS BAY LAGOON

The Walvis Bay Lagoon comprises some 600 - 1000 ha of tidal flats. Tidal scouring has been greatly diminished as a result of road construction and salt works on the south bank and the lagoon is currently threatened by wind-blown sand from the surrounding dunes depositing along its southeastern shores.

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