SOUTH WEST AFRICA ADMINSTRATION

Water Affairs Branch

OVAMBOLAND MASTER WATER PLAN

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September 1968

OVAMBOLAND

MASTER PLAN FOR WATER DEVELOPMENT

INDEX

INTERLEAVED DRAWINGS AND TABLES

OVAMBOLAND

MASTER PLAN FOR WATER DEVELOPMENT

CHAPTER 1

PREAMBLE

Ovamboland, the most densely populated region of South West Africa, is being geared for ultimate self-development as expressed in recent policy statements. Because water is basic to all forms of human activity and development, it is probable that adequate and permanent water supplies form the cornerstone of this future development. Recurring droughts and lack of adequate supplies have been inhibiting factors in the past.

The earliest supplies were obtained purely by exploitation of the surface waters and from open wells. The continuity of such supplies was always in doubt and drought was an ever-present fear. In 1954 an intensive programme of expanding the local storage works and development of underground supplies was started. Some measure of security was provided through the construction of a flood water collecting canal between Ombalantu and Oshakati. This work, although planned to fit into eventual requirements of water expansion, was largely of an ad hoc nature, meeting needs as they arose.

From the beginning it had been realised that the local water resources, being of an intermittent and undependable nature, would never suffice for large scale expansion to provide a self-supporting economy. Since 1926, arising from an Agreement with the Portuguese Government, the promise of bringing in permanent supplies from the Cunene river had been held. The manner, however, in which this was to be achieved remained unresolved until 1964 when a further Agreement was signed, paving the way for pumping of water from Calueque. Final approval of this scheme is now approaching reality.

In recent years much investigation has been conducted into the principles and practical aspects of water development in Ovamboland. The stage has now been set for laying down the objectives and mode of execution of the various hydraulic engineering works necessary for placing water supplies on a sound co-ordinated footing, commensurate with eventual expansion. This report presents an overall view of the situation in respect of water requirements and a plan for ultimate development, together with possible phasing in association with expansion of other services in the region.

CHAPTER 2

REFERENCE REPORTS

For convenience the various reports and writings on individual and general aspects of development in Ovamboland are listed below as a form of reference. The information, findings and proposals are largely consolidated in the present report and direct reference should be unnecessary except where it is desired to study a particular aspect in detail. Short explanatory notes are added where appropriate.

1) Various Water Supply Brochures issued by the Water Affairs Branch, South West Africa Administration, in particular Nos. 1 (1955), 2 (1957/58), 6, 7, 8 and 9 (1959), 11 (1960/61) and 13 (1961) - dealing with several aspects of storage works and the flow of the Cuvelai.

2) Reports dealing with development in Angola:

   (a) Southern Angola Report. Dr. O. Wipplinger.

   (b) Abastecimento De Agua Ao Baixo Cunene Relativio Dos Trebalhos Efectuados Em. Carlos A. Neves Ferrão, 1954.

   (c) Groundwater in the Inner Cunene Area. L.C. Halfpenny, 1955.

   (d) Development of Groundwater in parts of Angola, Portuguese West Africa. L.C. Halfpenny, 1957.

   (e) A hidrogeologia e o problema do abestecimento de agua ao Baixo Cunene. Carlos A. Neves Ferrão, Lisboa 1961.

   (f) Cattle breeding development in the Cunene basin. Appendix I(a) to Scheme of Hydraulic Development for Cunene Basin. Portuguese Study Group, 1966.

   (g) Slaughter cattle husbandry in zones of extensive management. Appendix I (b) as in (f) above.

3) Waterwese in S.W.A. H.W. Stengel, Kreisdrukkers, Windhoek 1963.

4) Ovamboland Canal Scheme:

(a) Ondersoek van die Bestaande Oshakati -Ombalantukanaal. Hydroconsults, Sept. 1967.

(b) Planning of Canal System from Calueque to Ombalantu. Hydroconsults, Nov. 1967.

(c) Voorkoming en Bestryding van Bilharzia op die Ovamboland Kanaalskema. Annexure N to report (b).

(d) Addendum Report (Nov. 1967) on Planning of Canal System: Alternative Development Proposals. Annexure O to report (b) - dealing with canal and pipeline alternatives.

(e) Investigation of Soils for Canal Construction. Van Gruting, Comninos and Partners in association with Hydroconsults, Feb. 1968. Annexure Q to report (b).

5) Reports on soils surveys by A.O.C. Technical Services forming Annexures to 4(b) above.

(a) Reconnaissance survey of Soils in Mahanene Area for initial irrigation from lower Cunene river. Nov. 1965, Annexure H.

(b) Reconnaissance survey of Ovamboland Soils for irrigation from lower Cunene river. Nov. 1966, Annexure I.

(c) An Economic Assessment of the proposed 4000 hectares irrigation project. March 1967, Annexure K.

(d) Report on the Detailed Reconnaissance Soil Survey of the proposed first phase irrigation areas, Ovamboland. May 1967, Annexure L.

(e) Report on an Agronomic and Management Study of the proposed first phase irrigation areas in Ovamboland. July 1967, Annexure M.

(f) A proposal for an Irrigation Reserach Scheme in the vicinity of the canal route in the region east of the Oshana Olushandja, Ovamboland. Dec. 1967, Annexure P.

6) A preliminary survey of the Natural Environment and the Agricultural Resources of Ovamboland. A.O.C. Technical Services, April 1967, undertaken for the Department of Bantu Administration and Development.

7) Reports dealing with preliminary planning of alternative and replacement schemes to the Calueque Pumping Scheme:-

   (a) Ovamboland Water Supply: Ruacana Pumping Schemes. Hydroconsults, Jan. 1968.

   (b) Verslag oor samesprekings te Pretoria op 29 November 1967 en Alternatiewe Kunene Pompskema op Suidwes Grondgebied. Director of Water Affairs, S.W.A. Administration, Feb. 1968.

8) Report of the Commission of Enquiry into South West Africa Affairs, 1962-63 (Govt. Printer, Pretoria).

9) Ovamboland - met besondere verwysing na die ontginning van sy waterbronne. H.W. Stengel, in preparation.

10) Ovamboland: Meester-watervoorsieningsplan. In preparation by Water Affairs Branch, South West Africa Administration.

11) A Five Year Plan for the development of the native areas, South West Africa. Department of Bantu Administration and Development. Pretoria 1965. (Restricted).

12) The Planning and Development of the Bantu Homelands. H.H. Harvey, S.A.I.C.E. Convention, July 1968.

CHAPTER 3

FEATURES OF OVAMBOLAND

The provision of water supplies in Ovamboland is intimately bound up with the physical and hydrological nature of the region which in many respects is unique. A brief description is given in this chapter of various salient features which have a strong influence on development. For convenience hydro-meteorological data is presented in seasons beginning in July.

3.1 Topography

Originally 42,010 sq. km in extent, Ovamboland, with the amended boundaries proposed by the Odendaal Commission, covers an area of 56,070 sq. km.* The territory is approx. 120 km wide north-south and stretches over some 400 km from Ruacana in the west towards the Okavango river in the east (Map 1).

Except for some rugged terrain in the north-west corner near Ruacana, the relief of Ovamboland is extremely flat, in the form of a shallow trough tilted towards the Etosha pan. The trough runs in a south-easterly direction and may be considered as the land lying below El. 1110 metres with ruling gradients of the order of 1:10,000, gently undulating internally with local depressions known as oshanas separated by ridges generally only 2 to 3 metres higher than the oshana beds. Outside the trough the land rises quite uniformly about 100 m to the western Kaokoveld divide and only some 50 m to the north-eastern boundary with Angola. In the east an extensive zone of stable dunes extends into Okavangoland.

3.2 Geology

The geology of Ovamboland is also quite simple. Except for dolomite with limestone outcrops on the western edge and a shale zone in the Andoni region (Map 1), the whole area is covered by fine sands and clays

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*Although this proposal has not as yet received final confirmation, the extended area is adopted throughout this report as a basis for describing water services.

to depths of up to 600 metres in the central area. The underlying bedrock of the Damara System with Karroo formation remnants, is again in the form of a dish but rather more pronounced. The inference is that central Ovamboland is the residual delta resulting from the original flow southwards of the Cunene river into the Etosha depression, before river diversion by carving through of the rock barrier east of Ruacana. The alluvial plain has been much altered by aeolian movement such that few distinct channels can be traced. All that remain are the numerous locally depressed oshanas with certain more continuous courses such as the Oshana Etaka and perhaps the Cuvelai.

The geological origin of the soils has a pronounced influence on their utilisation. A long history of deposition of fine material in the delta and evaporation resulted in accumulation of salts which with continued inundation have generally moved down into the soil leaving a highly sodic condition which does not permit ready cultivation. However, local wind deflation created ridges of soil having a degree of colloidal material and from which salts have been leached. The soils are described more fully in Section 3.6.

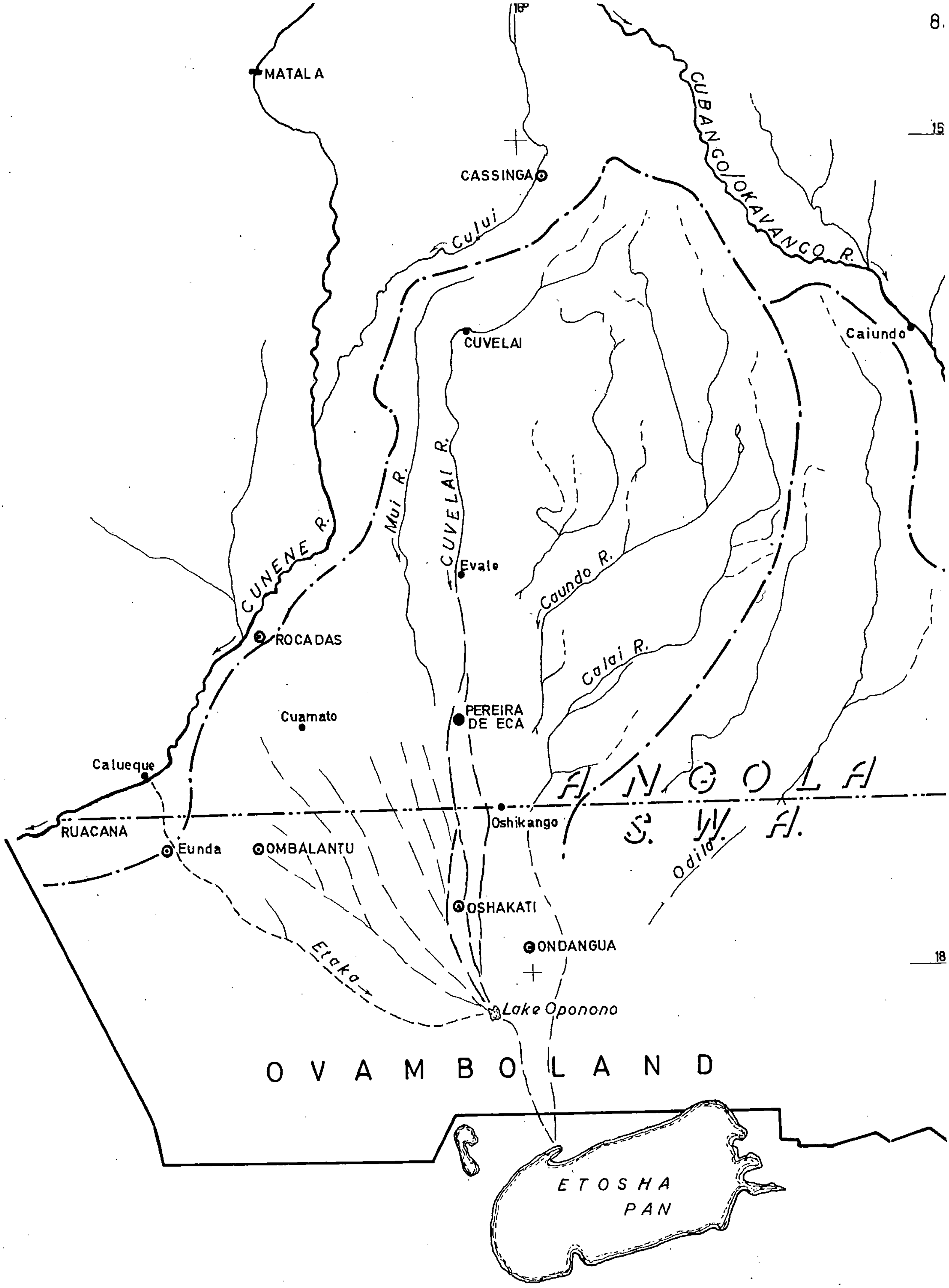
The sand becomes clayey with depth and some calcareous inclusions are encountered. In the trough a saline water table is present a few metres below the surface. No underground fresh water aquifers have been traced in the central zone despite intensive search. The salinity of the underground water increases with depth from 15,000 to 90,000 ppm (c.f. sea water 35,000 ppm). To the west and east of the trough, however, fresh underground water is encountered at varying depths and drilling for water has been quite successful with reasonable though low yields. Presumably this is largely infiltered water and tested yields should be maintained even with more intensive drilling.

3.3 Drainage System (Maps 1 and 2)

As intimated above, the drainage system in Ovamboland is extremely weak. There are no fully defined water courses although certain more continuous flow paths within the delta can be traced. The most prominent of these is the Oshana Etaka on the south-western edge of the alluvial plain. At its maximum this channel is depressed about 8 metres below the plain but elsewhere the definition is very much less and the bed gradient is by no means continuous, with intermittent depressions forming local basins. The Etaka has a water divide (El.. 1102.5) just east of Eunda and the northern leg which drains into the Cunene river is known as the Oshana Olushandja. The south-easterly course drains into Lake Oponono which at its higher level has an outlet into the Etosha Pan known as the Ekuma.

The balance of the alluvial plain is fed through water courses rising in Angola from as far north as Cassinga. This catchment (Map 2) is sandwiched between the Cunene and Cubango (Okavango) rivers and consists largely of Kalahari sand flats in which the water courses take the form of oshanas (chanas in Angola) or wide grassed spillways. The several tributaries tend to come together in one main course known as the Cuvelai passing the Angolan village of Pereira de Eça. Up to this stage the Cuvelai is said to be fairly perennial in character but thereafter the stream is dissipated and flows through the southern continuation past Oshakati into Lake Oponono only after heavy rainfall. This type of spilling flood, known as the "efundja", occurs also in the numerous other oshanas crossing the border. The local depressions are seldom continuous, the isolated elongated basin having first to be filled before spilling over to the next. Apart from the Cuvelai, mention can be made of two other major oshanas, namely the Oshigambo to the east and the Nakangali to the west passing Orongo. The oshana system westwards of Orongo towards Ombalantu is weaker and flows are largely the result of local downpours. Beyond Ombalantu almost no flow occurs from the Angola side.

This whole Cuvelai delta system peculiar to Ovamboland is underlain by a shallow water table. Whereas in the north across in Angola the water is still relatively fresh, the salinity increases progressively southwards. Th fresh surface runoff as it collects in the numerous oshanas and pans is not immediately affected, tending to be "perched" on the almost impervious



MAP 2

CUVELAI DRAINAGE SYSTEM

Scale 1: 2 000 000

20 0 20 40 60 80 100 km

soils, but with evaporation becomes brackish. While in certain oshanas clear water is encountered, the runoff generally picks up fine colloidal material which remains in suspension giving the water a limey appearance After heavy downpours and particularly when the efundja occurs, vast areas of the alluvial plain are inundated, the dune ridges standing out as islands. South of the line Ongandjera-Ondangua the water courses taper into Lake Oponono, creating a zone where the water table is generally high and relatively saline.

West of the Etaka, despite the steeper gradient, there are no continuous water courses. The runoff is dissipated into the sand mantle, finding its way underground or seeping into the many individual pans present in this rolling terrain.

The alluvial plain may be accepted as terminating about midway between Oshikango and Eenana, passing some 20 kilometres east of Ondangua and then following a south-east line towards Andoni at the north-eastern corner of the Etosha Pan. In the eastern region a few flow paths in the deep and loose sands are traceable, such as the Odila, but the definition is poor and can hardly be termed water courses. The area is dotted with numerous small pans and no runoff occurs even with heavy rainfall. The surface gradient is south-westward from the original eastern boundary but in the extended zone the fall is more towards Okavangoland and the Omuramba Ombongola is a minor feature.

3.4 Climate

Although Ovamboland enjoys some of the highest rainfall in S.W.A., second only to Okavangoland, the climate is nevertheless classed as semi-arid.

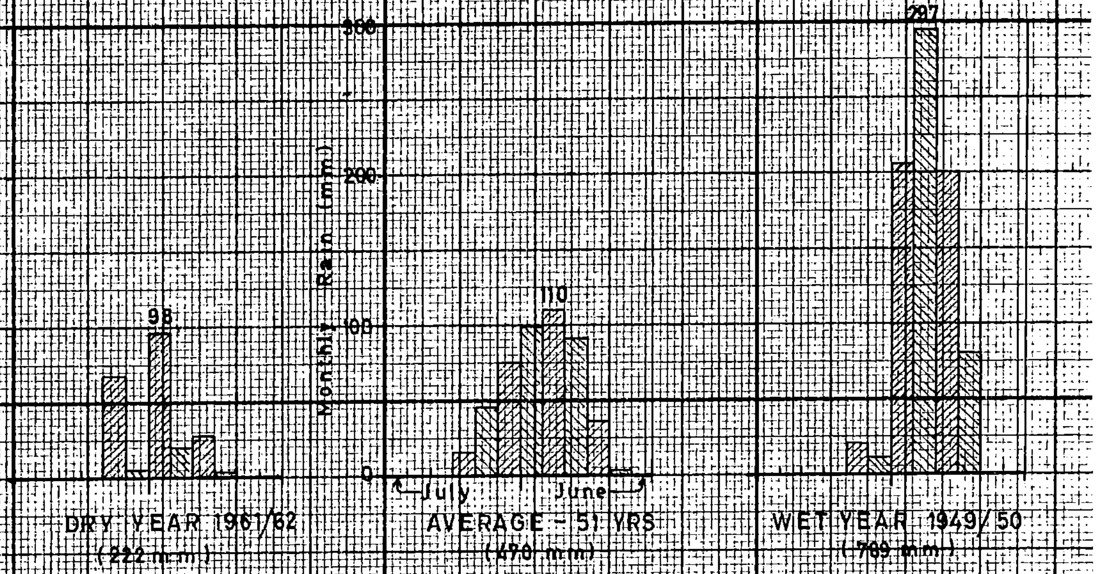
3.4.1. Rainfall

The average annual rainfall increases diagonally north-eastwards from 350 mm along the Kaokoveld divide to about 550 mm in the NE Okavango river corner. Along the line Ondangua-Ombalantu the average is 450-500 mm (18-20 inches), occurring over some 50 rain days. Rainfall is most frequently of the convective type although frontal storms lasting several days contribute appreciable amounts.

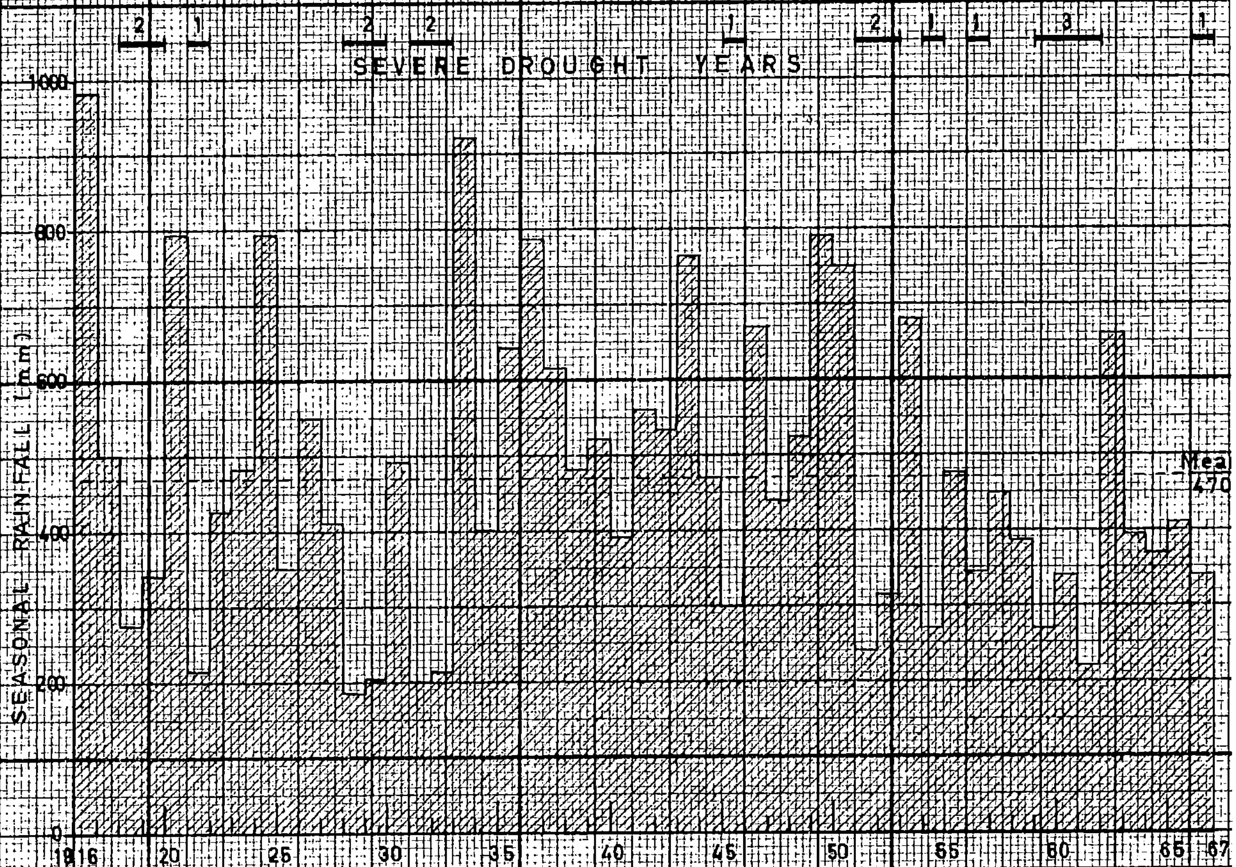
Average monthly distribution is shown below for Ondangua (51 year record), indicating virtual absence of rain from May to October, effective rain beginning usually only in December and heaviest falls from January to March with a peak in February.

July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	Year
0	0	0	13	44	75	98	110	91	35	4	0	470

The shortness of the rain period contributes to the difficulty of maintaining continuity of water supplies. However, it is the variability of seasonal rainfall which has the most pronounced effect on reliability, both for dryland farming and for domestic supplies. This is illustrated in Fig. 1. Taking seasonal rainfall less than 75% of the mean (350 mm) as representing drought conditions it is to be seen that 16 out of 51 seasons (30%) were potential famine years. Five of these seasons were isolated cases which would probably not have had severe repercussions, reducing the incidence of famine to some 20% when two or more consecutive seasons were sub-normal. The well-remembered drought of 1928-33 stands out, when for 4 out of 5 years the rainfall was only of the order of 200 mm broken only partially by one normal year. This situation had a near-repeat in the 3 year period 1959-62 when the average was 277 mm, preceded by 5 relatively dry seasons. The pattern is a familiar one over the whole of S.W.A. and even in the Republic. For Ovamboland with dependence solely on local runoff to replenish water holes and other storage works, these long drought periods can only spell disaster. The aim in any water development policy must therefore be to provide security against extended dry seasons, apart from adequacy of supplies.



TYPICAL MONTHLY DISTRIBUTIONS



SEASONAL VARIATION (51 year record)

FIGURE 1

RAINFALL VARIATION

- ONDANGUA -

3.4.2 Temperature and Humidity

The mean annual temperature in Ovamboland is 22.5°C (72.5°F), with minor variations from year to year. Monthly means of the daily air temperatures (°C) are shown below - indicating hot summers and mild winters, with diurnal variations of 20°C in mid-summer and 15°C in mid-winter. The incidence of frost is negligible.

Month	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Max	26.5	29.4	32.9	34.4	33.3	32.0	32.4	31.2	30.7	31.0	29.1	26.3
Min	6.2	8.3	12.8	16.3	18.0	18.7	19.2	18.8	18.4	16.7	13.0	7.2
Mean	16.4	18.8	22.9	25.3	25.7	25.3	25.5	25.0	24.6	24.1	20.3	16.7

Humidity values are not directly available for Ovamboland but, based on recordings at Pereira de Eça across the border, the annual average is assessed at 50%, rising from 30% in September to 70% in March Wind speeds are generally low but windstorms occur, generally confined to one or two months.

3.4.3 Evaporation

The rate of evaporation is an important factor in the planning of water schemes in Ovamboland. Two main items have to be considered:

(a) direct losses from the free water surfaces of pans, storage basins and canals. Because the surfaces are confined, the loss rate is taken as equivalent to Class A pan evaporation.

(b) evapo-transpiration losses from saturated soil adjacent to water retaining structures or a water table close to the surface after heavy rainfall and from irrigated crops. These can be related to A-pan evaporation by means of appropriate experience coefficients.

No direct recording of A-pan evaporation is available in Ovamboland. However, from analyses of evaporation data for southern Angola and central South West Africa, correlated with humidity, an assessment of a loss rate of 2100 mm per annum was made (Ref. 4b). This value is strongly supported by analyses of the decrease in water depth of several storage dams (Refs. 3, 9) which show annual losses in the range 2060 to 2400 mm, averaging 2200 mm. Isolated losses up to 2600 mm have been analysed but this order of variation from the mear is to be expected in dry years and the particular incident may contain an element of loss by seepage from the storage dam.

Accepting 2200 mm/a as the mean, monthly evaporation rates are:

July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
140	205	268	284	234	190	173	134	133	147	156	136

Peak daily evaporation during October is expected to attain 9 mm, confirmed by observations on a canal where a short-term depletion of 7 mm/day was experienced. Canal losses and crop water requirements are evaluated under the relevant sections.

3.5 Hydrology

In the nature of the drainage system, hydrological measurements and assessments are difficult in the extreme. However, it is of interest to mention certain assessments of the flow of the Cuvelai at Oshakati during the past 27 seasons. Prior to 1955 these were purely estimated orders of flow, but subsequently actual measurement has been attempted. The flow categories and respective occurrences are tabulated below:

Flow category	Order in cubic metres per annum	Number of Occurrences
Nil	0	10
Very Weak	100,000	2
Weak	500,000	3
Normal	5,000,000	4
Good	15,000,000	3
Very Good	50,000,000	3
Exceptional	100,000,000	2

In view of the wide range in seasonal flow any assessment of a mean annual runoff has little significance. Of considerable importance, however, is the fact that in nearly 40% of the seasons no flow whatsoever was registered. The "very weak" category represents occasions when only local runoff occurred. Excluding also certain weak "efundja" seasons, it is apparent that throughflow of the Cuvelai system can be relied on only 50% of the time. Seasons of copious rainfall resulting in good to exception al flow, while contributing a mass of water inundating vast areas, seldom have regular occurrence and, in the absence of effective storage and adequate means of bridging intervening poor seasons, most of this water goes to waste.

Of particular relevance is the recording that for three consecutive seasons (1941/42 to 1943/44) there was no flow. This order of extended drought is by no means uncommon, as was seen in the three seasons 1957/58 to 1959/60 when only minor local flow occurred in 1958/59. In recent years (since 1962) the Cuvelai flows have been above normal and the present system of collecting flood water (see Chapter 6) has not been tested in full. However, it has been the experience that very often, due to localization of rain storms, one or more oshanas will flow whereas the others remain dry.

Depressions filled by the oshana flows remain standing for some while but after two or three months, evaporation takes its toll of the shallow areas and only the few water holes retain water. As described earlier the oshanas are seldom continuous water courses and in normal years only part of the oshana system may be filled, other depressions remaining dry. When viewed from the air or in travelling along particular roads, the appearance of large bodies of water may lead to a false impression of the water resources of Ovamboland. Factors to be taken into account are the intermittency, impermenancy and maldistribution of water.

3.6 Soils

As indicated in Chapter 2, References 5(a) to (f), considerable investigation has been conducted on the soils of Ovamboland and as summarised in Reference 6. From reconnaissance surveys using photo-interpretation techniques a quite intensive patterning and classification of soil types was determined. However, in this section only the four broad groups are described (Map 3).

The common parent material of the alluvial plain is a remarkably uniform, medium-textured sand, relatively unweathered, varying essentially only by virtue of the colloid content (influencing colour and structure) and salinity, and as sorted by local deflation of the surface. Other parent materials are the extensive aeolian sand mantles occurring in the eastern and western zones.

(a) Aeolian Sands are present in several phases, largely outside the central trough but also as seif dunes oriented south-eastward within the delta zone. The youngest deposits are commonly associated with major pans and oshanas, occurring on the leeward (east) side and indicating accumulations of materials from local deflation. Clay content is relatively low, varying between 2 and 8% according to sand type and locality, but the soils are generally non-saline.

Grey Sands occupy the whole of the eastern zone, parts of the southern alluvial plain, sections of the Ruacana plateau and are also found on the lower slopes of seif dunes. Clay content is commonly less than 3%.

Red and Brown Sands are characteristic of the gentle relief of the western plateau area and of the crest and mid slopes respectively of the dunes, the clay content increasing upslope and often with depth. The greater area of these reddish soils occur in the more-arid south west where the low rainfall prohibits normal dryland farming. However, the local dunes in the alluvial plain are preferentially cultivated, in particular where there are complexes of greyish-brown Gradational Soils with clay contents increasing from loamy sand to sandy loam with depth, usually with good drainage. Ridges having these characteristics occur to the west of the Etaka (Eunda area), south-east of Onanime towards Tshandi, south of Ombafi and around Orongo, but no further east than this.

(b) Solonetz Soils are characterized by a bleached upper surface with an abrupt separation to a compacted solonetz horizon having a prismatic structure of low permeability and high sodium activity. The profile is typical of the form developed in saline parent materials, usually in flat areas with poor drainage and associated with tall Mopane growth. Soil types vary from Brown to the more-severely developed Grey occurring in depressed relief. Often the upper surface is shallow but certain "mound" cultivation is practised. These soils occupy virtually the whole of the alluvial plain except for the inclusions of locally derived aeolian materials and certain black clays. Complexes with Grey Sands occur in the south.

(c) Non-solonetz Soils associated with calcrete are found in the western area bordering on the Kaokoveld and appear to be considerably older than the soils of the alluvial plain. The typical soil is a brown sandy loam, non-saline and non-sodic with high inherent fertility and included fragments of calcrete increasing with depth.

(d) Black Clays occur in scattered locations not demarcated on the map but associated with the lowest beds of pans and oshanas, usually having clay contents above 25% and being highly expansive. A typical "black turf" is found in the western non-solonetz area and in the Oshana Olushandja. These clays are non-saline and non-sodic due to satisfactory drainage. An upland black clay type is ubiquitous in occurrence on the alluvial plain, particularly west of Ombalantu, in poorly-drained depressed areas with surfaces sometimes non-saline but salinity increasing at depth. A dark grey sandy loam type is associated with the perimeters of the upland black clay, certain phases of which are known to be non-saline.

3.7 Vegetation

The vegetation is shown on Map 4 in five broad classifications.

(a) Mixed Woodland - Vaalboom and Wild Seringa as main species, with Mukushi (Rhod. Teak), Kiaat and Manketti - occupies the entire eastern zone and the plateau south of Ruacana airport, both areas associated with deep aeolian sands. Few of the trees are exploitable apart from the occasional kiaat and tambootie. Grass in the eastern zone tends to be less palatable than elsewhere (Ref. 11, p28).

(b) Palm Savanna with secondary growth of acacia and mopane scrub occurs in the north-central portion in the environs of Otshikuku-Ondangua and as an isolated area along the Oshana Etaka near Ongandjera. Scattered communities occurring on the perimeters of the oshanas are a feature of the landscape.

(c) Mopane Woodland and Savanna is characteristic of the area west of Otshikuku extending across the Etaka. The denser stands occupy the ridges, while the more open savanna is associated with the depressions having poor drainage. To a large extent this area has been denuded due to the use of timber for pallisades and firewood, as well as to clearing for cultivation.

(d) The whole southern-central and western zones carry a short Tree-Scrub Savanna of various Mopane - Acacia species. The central area north of the Etosha Pan is largely grass flats with some scrub, progressing to bush and tree-bush westwards. Grass cover is sparse and of low nutritive value except in the west where sweet veld is encountered.

(e) In the environs of Lake Oponono, trees and scrub are absent. Open grassland has developed on this seasonally inundated landscape.

(f) A sixth class Sclerocarya-Ficus Savanna dominantly Maroela and with Palms, Baobab and Manketti is not differentiated on the map, occuring as isolated but often extensive communities within the Mopane Woodland on locally derived aeolian soils.

3.8 Communications (Map 1)

A first class all-weather road is nearly completed from Tsumeb, the railhead, through to Ruacana, linking the main administrative centres at Ondangua, Oshakati and Ombalantu. An all-weather road extends from Ondangua to Oshikango on the border with Angola, providing the main route to the north. Secondary roads connect with other centres, and although gradually improved in recent years, the system is still largely rudimentary particularly in wet weather with numerous oshanas to be crossed in the central zone.

Major airports have been built at Ruacana and Ondangua and a landing field at Ombalantu has been improved. Other landing strips such as at Oshakati and Oshikango are available.

3.9 Population

The Ovambo people at present number about 280,000 of whom some 30,000 find employment and living outside of Ovamboland. They comprise eight related but distinct tribes each with its own tribal area. The Onkolonkathi and Eunda tribes are administered together. Based on the 1960 census the distribution is approximately as follows:

Tribe	Percentage	Derived 1968 Population
Ukuanyama	36	100,000
Ondonga	29	80,000
Ukuambi	12	34,000
Ongandjera	8	23,000
Ombalantu	7	20,000
Ukualuthi	5	14,000
Onkolonkathi) Eunda)	3	9,000
	100	280,000

Estimated at 80,000 in 1910 and from various census data, the population growth rate has averaged 2.3%, indicating a doubling of the populatio every 30 years. Subject to no inhibiting or accelerating factors, the Ovambo peoples could well exceed 500,000 by the year 2000, rising to a potential 1,000,000 or more by 2030.

The tribal boundaries and the present concentration of people is portrayed on Map 5. While as an average the population density over the whole of Ovamboland is about 4 persons per sq km, the actual area occupied is less than one-third of the whole and the density rises to 15 persons per sq km, with even greater concentrations around the main centres.

3.10 Agriculture

Pre-eminently the Ovambo are tillers of the soil but hold a large stock population as a measure of wealth rather than for meat and dairy products. The system is based largely on kraal units, each with its own area of cultivated land surrounded by thorn stockade and with herded cattle and goats sharing common grazing. Outworn fields are left fallow and new areas are developed as the need arises. Some nomadic grazing is practise(particular by the tribes in the westand south during wet seasons.

3.10.1 Dryland Farming

The average area cultivated per kraal unit is about 2 hectare. Under the system of reliance on periods of bush fallow to recoup fertility, it appears than not more than one third of the total area of lands is cultivated in any one year, though this varies from place to place (Ref. 6).

The favourable arable soils occur as small isolated entities which are under nearly permanent cultivation, with shifting cultivation extending out into the fringing poorer soils. On the shallower soils such as the solonetz -type, a unique form of mound cultivation is practised. This is also applied on the lower dune slopes subject to inundation. Limited amounts of kraal manure are applied.

Millet (Mohango/Omuhango) is the most important crop and forms the staple food of the Ovambo. Subsidiary crops are sorghum

(kaffircorn), some maize, beans, pumpkins, watermelons and groundnuts. Rice has been grown quite successfully in the Ukuanjama area since 1959 on an experimental basis (Ref. 10).
Fruits such as oranges, pawpaws and guavas are grown in certain kraals and the natural fruits of the Maroela, Mangetti, Wild Fig, and Baobab are harvested.

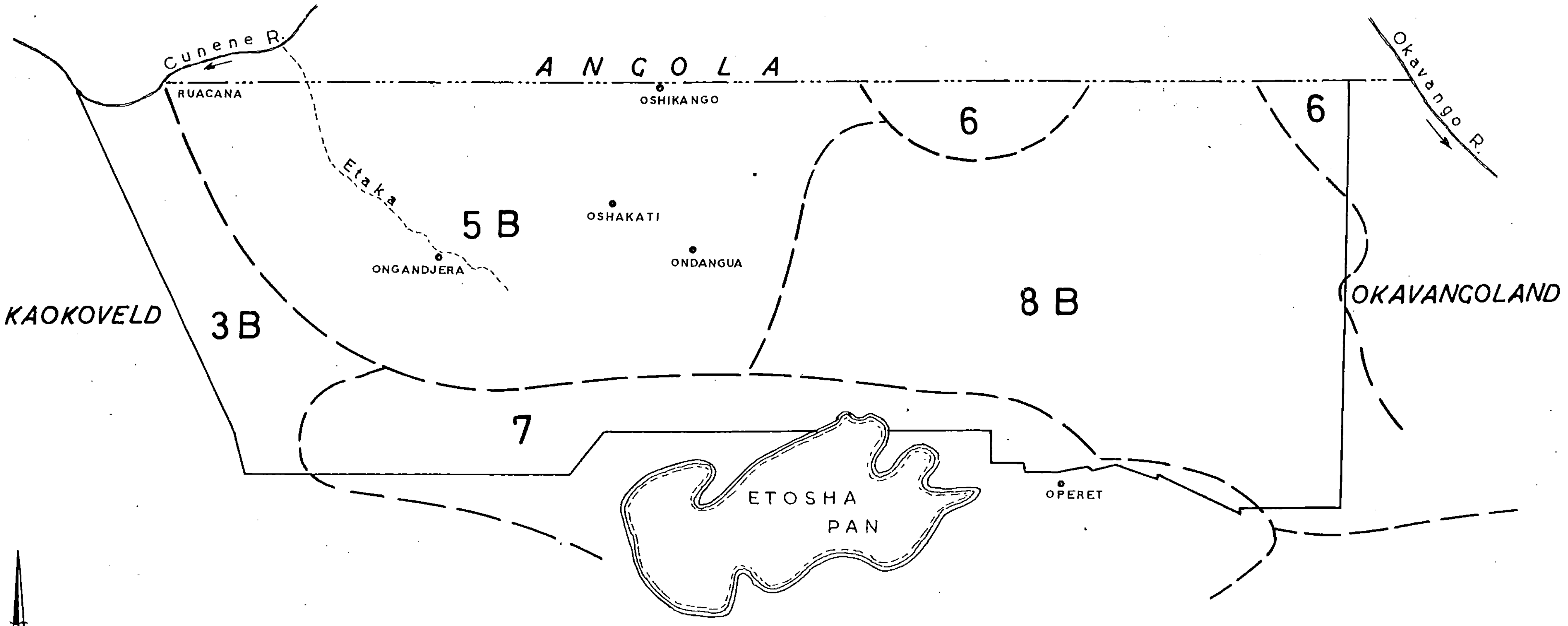
Crop farming is, in the main, confined to the northern half of the Etaka-Cuvelai drainage basin (Map 5). A very low intensity of cultivation is also centred around major pans found along the north-eastern sector. Outside of these areas only isolated settlements occur. Based on a detailed photo-interpretation the total extent of lands (including fallow) is estimated at 170,000 hectare (Map 4 of Ref. 6). Assuming one-third actually cultivated this accords well with another assessment (Ref. 11) that an area of approx. 65,000 ha is annually planted to crops. The ploughed portion represents 3% of the total area of Ovamboland ~~and~~ about 10% of the inhabited zone. Considering that some 25 to 33% of the latter zone is subject to frequent inundation, the actual arable land utilization within the zone rises to 15%.

On the strength of the recent soils investigations and based on practical experience, the potential for expanding arable farming is low except in the poorly watered areas to the west. Soil structure and fertility is an inhibiting factor in most parts and as viewed at present the future for economical improvement of such soils seems remote, unless the people are educated to improved agricultural practices including the use of fertilisation and higher yielding seed varieties.

3.10.2 **Stockfarming**

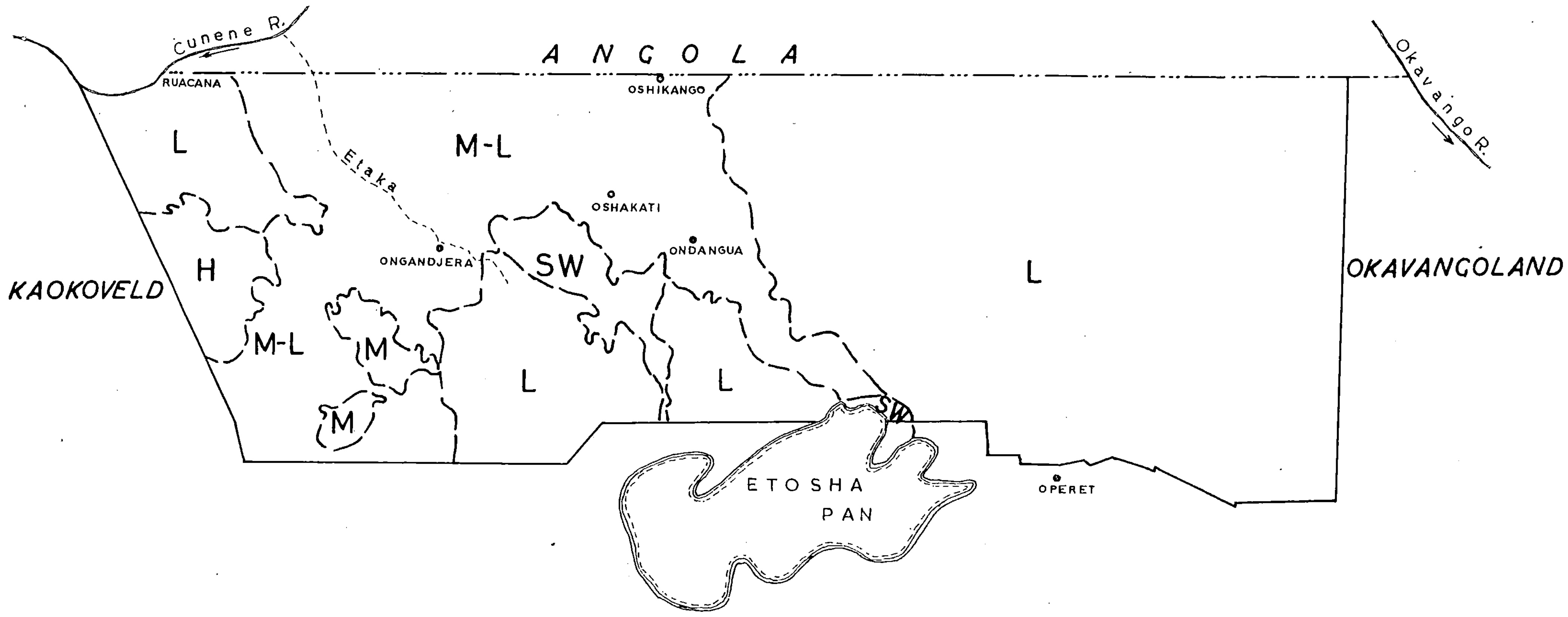
Statistics for livestock are available for 1962:

Cattle	379,542
Goats	420,198
Non-wooled sheep	4,542
Horses and Mules	939
Donkeys	23,713
Pigs	4,096
Poultry	43,858



REGION	CARRYING CAPACITY
3 B	12 ha/L.S.U.
5 B	9
6	7
7	10
8 B	9

(a) CARRYING CAPACITY BASED ON AGRO-ECOLOGICAL STUDIES
(as submitted in evidence to Odendaal Commission)



ZONE	POTENTIAL
H	High
M	Moderate
M-L	Moderate to Low
L	Low
SW	Restricted use due to seasonal wetness

(b) GENERAL CLASSIFICATION OF GRAZING POTENTIAL
(A.O.C. Technical Services – reproduced from Map 3 Ref. 6)

OVAMBOLAND WATER PLAN
MAP 6
GRAZING CONDITIONS

Considered in terms of grazing and water requirements (5 small stock = 1 large stock) the above figures represent about 490,000 large stock units (L.S.U.), giving a ratio of 2 L.S.U. per head of population in 1962 and indicating a possible growth to some 550,000 L.S.U. at present (1968). In this event the density of stock is 10 ha per unit overall but probably attaining 5 ha per unit for the actual utilized area. The typical carrying capacity of the veld as derived from agro-ecological studies has been assessed at a requirement of 9 ha per L.S.U., indicating extreme overstocking at present and the urgen necessity to provide water supplies so as to realise the unused grazin potential. A factor to be considered in these relative figures is that the local Sanga cattle are small in build and generally not of a high quality, the value of the herd being assessed in numbers and not quality.

The potential for grazing as derived from soil and vegetation studies (Map 3 of Ref. 6) is illustrated on Map 6B. Related to previous agro-ecological studies (Map 6A) the carrying capacity range is possibly 12ha/L.S.U. for low potential to 7 ha/L.S.U. for high potential. Grazing represents one of the chief agricultural assets. The stated carrying capacities are considered as conservative and account for the fact that better distribution of water and camps has yet to be made (Ref 11, p45). The capacity may improve with sound management but regard must be had to preventing deterioration of the soil and vegetation cover. Creation of dust bowl conditions must be guarded against. Full utilization of the veld is entirely dependent on the provision of suitable water supplies. A further shortcoming is that the grazing deteriorates in field value during the dry season and supplementation by fodder is desirable (Ref 11, p31).

CHAPTER 4

URBAN AND AGRICULTURAL DEVELOPMENT

The future requirements for water in Ovamboland are intimately bound up with the potential for development in the urban and agricultural sectors. In this chapter a brief review is given of the indications as presently known.

4.1 Urban Expansion

The region is only on the brink of urban development. Earlier concentrations were largely around the various mission stations. Recent improvements brought about by the authorities have been mainly in such centres as Oshakati, Ondangua and Oshikango, based on satisfying the more-immediate needs of administrative, health and social functions. Thus a township of 150 houses has been established at Oshakati along wi the first large state hospital. Similar township development is taking place at Ondangua and a teachers training college for an ultimate 900 students is being built at Onguediva. Several of the earlier-established mission schools and hospitals are to be converted to fully-fledged state institutions, improving the standard and range of services.

At the present juncture it is difficult to forecast with any degree of certainty just how far and how rapidly urban expansion will take place. The need for conversion from an almost wholly subsistance economy to a reasonably high proportion of monetary or exchange economy is fully recognized (Ref. 11, p66, 190).

The present work is regarded merely as a start of a considerably larger programme of which the following Phase I expansion due for completion over 5 years may be detailed:

- (a) Ten nuclei for townships
- (b) Establishment of six tribal community centres along with other sub centres (see Map 5)
- (c) Additional schools - 530 classrooms being envisaged for the immediate future
- (d) Conversion of 7 mission hospitals

(e) Erection of a leper hospital at Ovudhia

(f) Building of 34 clinics and a number of social welfare services.

(g) Development of an agricultural college initially for 100 students at Orongo.

Industrial expansion will be subject to restrictions by the available natura resources but stimulation in this sector is considered of cardinal importance (Ref 11, p82-84). The immediate programme envisages the following:

(a) Expansion of the existing furniture factory at Oshakati for the manufacture of school furniture.

(b) Creation of mobile saw mills to exploit the indigenous timbers

(c) Establishment of meat canning factories at salient points to allow effective marketing of animal products. Associated industries will be skins, tanning and local leatherware processing.

(d) A wholesalers trading centre is to be founded at Ondangua along with training facilities for dealers.

(e) Clothing manufacture for local consumption is envisaged.

(f) To meet the needs of housing construction a brick-manufacturing industry is to be encouraged. Sand-cement brick units are in existence and prospects for burnt-clay brick making appear good, with a potential for export in the absence of suitable material elsewhere in the Territory.

In addition the following possible industries are to be explored:

(g) Soda ash and commercial salt

(h) Tourism

(i) Fishing from natural and artifical basins.

Regarding industry as the secondary sector, a tertiary sector of commercial interests will grow alongside it.

It has been suggested that the exchange economy sector should be stimulated to absorb some 40-50% of the population (Ref 11, p190). This undoubtedly should take into account that for many years to come, as at present, a high proportion of labour will be gainfully employed outside the tribal borders and Ovamboland must continue to look to this form of export as a means of building up its wealth. In 1960 the number so occupied formed 12% of the total Ovambo population and a doubling of this percentage can readily be envisaged.

Nevertheless, expansion in the urban sector, possibly to 25% of the population, will place a heavy responsibility on agriculture for the local production of foodstuffs for sustaining the urban workers and their families. Some relief might be obtained through a form of peri-urban development but in view of the limited arable areas close to townships the prospects of significant smallholding settlement may not be outstanding.

4.2 Agricultural Expansion

As noted in Chapter 3 expansion of existing agricultural practices is hedged with difficulties due to virtual saturation and as encumbered by the limitations of the natural environment. However, the prospects of reorganisation of certain aspects are not to be denied.

Dryland cropping is presently restricted to some 65,000 ha while as indicated in Section 3.9.1 about twice this area lies fallow. Encouragement of the use of fertilizers may well result in the greater utilization of available arable soil. Associated with this would be the use of higher-yielding crops (e.g. groundnuts) and improvement of actual farming operations such as crop rotation. Nevertheless, it must be realized that dryland farming under the particular climatic conditions is inherently unstable. Recurrent droughts cause extensive crop failures and as in the past subsidization may be needed, e.g. 1960/61 when maize purchases were subsidized at R1 per bag and again in 1962 when large quantities were brought in (Ref 8, p285). There is little that can be done about this phenomenon since it is recognized that intermittent supply of water to extensive arable areas can never be economic.

Within the present inhabited zone the prospect of increasing the cultivated area is rather slight (Ref 11, p106; Ref 6, p23). A present restriction applying to arable cultivation in the western zone is the lack of suitable or adequate domestic water supplies, inclusive of stock-watering. It is foreseen that the provision of water supplies would enable an expansion perhaps to the extent of 25%[10]. It appears dubious for the near future that dryland farming can be successfully extended on the loose sand soils of the eastern zone beyond the existing low intensity farming, and for the present it would be conservative to rely on not more than about 100 000 hectare as being available for crop production without irrigation. Such arable production will be needed essentially for self-support of the rural population. Surpluses available for urban use are likely to be restricted to seasons of good yield. The potential for irrigation development as a means of satisfying urban and other requirements is described in Chapter 5.

Regarding stockfarming the indication (Section 3.10.2) is that Ovamboland is probably already overstocked in terms of carrying capacities commensurate with effective use of the available grazing (Refs 8, 11). Much, however, remains to be done in this direction, the foremost factors being:

(a) A change in the attitude of the people from regarding stock as a symbol of wealth and social standing to that of production. This may involve improvement of the cattle breed and new market outlets in addition to the existing one at Oshakati will have to be created, along with the necessary veterinary services to control diseases.

(b) The provision of secure water supplies for stockwatering, particularly in the outlying zones at present extremely sparsely inhabited or only sporadically grazed due to the lack of water except in abnormal rainfall years and then only during the summer months.

Adopting the agro-economic assessments submitted in evidence to the Odendaal Commission, the carrying capacity of Ovamboland, allowing for the suggested extended boundaries and for the factors above, would be some 610 000 L.S.U. (Table XIV of Ref 11). In comparison the present holding of livestock (possibly 550 000 L.S.U. on a much restricted area) is already approaching this figure so that no more than about a 10-15% expansion can be contemplated if stockfarming is to play its full role in the development of Ovamboland as a self-supporting nation.

The rural population associated with the above assessment, inclusive of the utilization of 100 000 hectare of arable land, is 25 600 Economic Farming Units of 5 persons per family (Ref 11, p 67) or about 130 000 people. The actual number already on the land far exceeds this "ideal" figure for the primary agricultural sector. It is therefore obvious that considerable stimulation of a diversified economy will be required before a desirable standard of living and a suitable occupational distribution can be achieved.

The above figures are based on a farming unit producing a gross family income of R450 per annum (Ref 11, p 193) derived as follows for the main agro-ecological regions in Ovamboland:

Pastoral unit of 30 L.S.U. with an annual income of R15 per cattle unit regarded as reasonable.

Mixed unit of 20 L.S.U. plus 7 hectare of arable ground with an average yield of 10 bags of grain per hectare valued at R2.50 per bag.

While a gross family income of R450 may be deemed desirable, this standard should perhaps be reconsidered in relation to the development of the community (Ref 11, p 48), in particular for the existing density of population in Ovamboland and the restricted opportunity for migration to urban activity. At present in the Republic economic units are said to be designed to yield R120 per year under existing farming practice (based on the 1955 Tomlinson Report - Ref 12, p 5), having a potential with improved farming to rise to about R400 a year (Sunday Times survey, 21 July, 1968). It would therefore seem necessary, as a basis for assessing the rural population capacity for many years to come, to accept that income standards (allowing for inflation since 1955) will have to be roughly half the ideal figure of R450.

Thus, in determining future population distribution (Section 4.3) and water requirements (Chapter 7), the size of a pastoral unit is halved to provide grazing for 15 L.S.U. occupying some 140 hectare. For the mixed farming units which would surround the urban centres, a slightly higher standard of income is perhaps necessary. Also, in order to reconcile available land areas for grazing and cultivation within the mixed farming zone, a unit consisting of 6 hectare arable land plus grazing for 6 L.S.U. occupying about 60 hectare is deemed appropriate. The relative incomes would then be R240 per annum for a mixed unit, compared with R225 for a pastoral unit.

4.3 Future Population Distribution

While more intensive studies will undoubtedly be undertaken following on the subdivision into physiographic regions and the recommendation of farming systems according to inherent agricultural potential (Maps 6 and 7 of Ref 6), it suffices for the present examination to adopt a simple classification into ranching and mixed farming regions as illustrated on Map 9(p 412). All evidence points to restriction of intensive mixed farming to the northern central zone, with possible isolated arable production along the north-eastern border. The extent of such land is roughly 1 000 000 hectare and the balance of 4 600 000 hectare is regarded as entirely pastoral. Accordingly the future rural situation, subject to satisfactory provision of water supplies as the most essential service, can be tabulated as follows:

Farming Unit	Area(ha)	Economic Unit		Population	Livestock (L.S.U.)	Arable land (ha)
		Size (ha)	No. Units			
Mixed	1 000 000	60	17 000	85 000	100 000	100 000
Pastoral	4 600 000	140	33 000	165 000	500 000	-
Totals	5 600 000		50 000	250 000	600 000	100 000

In the absence of other more definite indications and predictions, the expected future urban population is necessarily derived from the above assessment of the supportable rural community. If, as suggested (Ref 11, p 190) the agricultural sector should constitute some 54% of the total, then an Ovambo population of about 450 000 can be envisaged. According to past growth trends (Section 3.9) this order of population could be reached by 1990 and it would be realistic to plan for this far ahead. The growth rate must be expected to reduce due to restraining factors and the suggested order of population may only be attained about the end of the century. After that time future growh is beyond present comprehension and cannot reasonably be treated now.

The prospect is that roughly 200 000 Ovambos must necessarily be independent of the agricultural sector (except for foodstuffs). Of this total it can be envisaged that approximately half, or 100 000 compared with 30 000 at present, will find their living outside of Ovamboland itself. This would leave 100,000 as a potential urban population, dependent either on industry and commerce as well as tertiary activities within the townships or on support by the external workers. No differentiation of the two categories is necessary in respect of water requirements and other services, but an approximation would be about half each. Whether a 50 000 industrial population can be developed remains conjectural. The expediency of conversion to an exchange economy is self-evident but it is not to be denied that Ovamboland does not yet offer much opportunity for a diversified economy (Ref 11, p 82). Investigations have indicated that administrative centres for ethnic groups can, with diversification, grow into cities with populations equal to 25 per cent of the total population (Ref 12, p 4). It is therefore necessary to ensure that adequate supplies of water will be available for the growth of the various centres. Food supplies are equally important.

CHAPTER 5

PROSPECTIVE IRRIGATION

As revealed in the foregoing chapter the problem of providing self-support for a growing population in Ovamboland is most unlikely to be solved simply by increasing the productivity in the present agricultural sector, nor can the envisaged exchange sector be expected to provide a living for a high proportion of the population, even with maximum expansion. Some relief has to be found, firstly to provide a measure of stability to agriculture against recurring drought conditions and secondly to produce sufficient food for the population engaged in the secondary and tertiary sectors. For these reasons alone it will be necessary to look to irrigation as a future activity.

Irrigation development in Ovamboland has long been foreseen, ever since the right to divert water from the Cunene river was upheld in the 1926 Agreement with Portugal. Serious investigation of the irrigation potential was started in 1964 with the undertaking of a reconnaissance survey of the lands in the Mahanene area (Ref 5a). Certain complexities arose from the finding that only particular soils were readily suitable for normal irrigation. Other potential soils demand special and probably expensive precautions in the preparation of the land as well as in application of water.

At the particular juncture in negotiations on the joint international Cunene project concerning comprehensive storage regulation, it was contemplated that free diversion of surplus flood water might possibly be arranged and that it would be necessary to secure the rights to future abstraction in terms of available irrigation potential. A rapid survey of the whole of Ovamboland was undertaken (Ref 5b) which indicated that while the irrigation potential of certain more-isolated dune ridge zones was high, other soils in particular the solonetz types should be regarded as marginal, involving a lesser degree of utilization as well as special techniques. The grey sand areas in the east could not be recommended for irrigation. The general description and classification of the soils which followed from this investigation is given in Section 3.6.

Subsequent to this overall reconnaissance survey and as part of the more-specific planning for a canal from Calueque to Ombalantu to link up with the existing floodwater collecting canal through to Oshakati, a detailed but still general survey was made of the soils along the canal route and certain possible branch canals (Ref 5d). This closer examination of the soils, in both occurrence and characteristics, formed the foundation for planning of a canal system to serve central Ovamboland as more fully described in later chapters.

In review, it was accepted that, failing to secure free diversion rights from a storage dam on the Cunene at Calueque and with a limited amount of water available from the proposed pumping scheme, it was expedient to select only the best classes of soil for initial irrigation. It was the desire at the time to consider a scheme for 4000 hectare and to distribute this equitably among the various tribes. However, this did not prove feasible. It was shown conclusively that, apart from isolated patches in the Ondangua area, the soils east of Orongo are unsuited to irrigation even on a quite long-term basis (e.g. the grey sands).

West of Orongo, excluding from present considerations all solenetz types of low permeability and high sodic activity, the better class soils are to be found on the dune ridges and are essentially the locally derived materials. The criteria adopted included acceptable clay content not less than 4% and adequate depth, drainage and surface slope, as well as suitable texture and structure of the soil. The grey and red gradational soils, such as are preferentially cultivated by the Ovambos, can be recommended for irrigation without reserve. These soils with high clay contents are generally located on the upper slopes and crest of the ridges and drainage is seldom a problem. Certain large areas of shallow soils such as around Ombalantu were necessarily eliminated for initial irrigation.

Red and brown sands which occur on the mid slopes, forming a band around the highly-graded crest materials, were found to have a marginal but still-acceptable clay content. In character these soils can be equated to the Kalahari sand type developed on the Vaal Hartz irrigation scheme. To be conservative it was assumed that only 60% of such areas of more-exacting soils could be readily developed.

The survey coverage was by no means exhaustive and using photo-interpretation guided by field experience it was possible to delineate other potential sites. It was assumed that only 40% of such areas would be usable.

The results of this survey regarding occurrence of irrigable soils in the zone east of the Oshana Etaka are depicted on Map 7. Four dune lines lend themselves to exploitation, namely the ridge between Onanime and Tshandi, a zone NW of Orupaka, a ridge south of Ombafi and the Orongo strip just east of the Oshana Nakangali. These would generally be served by branch canals or feeders running parallel to the ridges. In total, excluding certain potential sites which are considered too isolated for inclusion at present, the propsective net irrigation area after allowing for the abovementioned reduction factors is some 3000 hectare of which 1700 hectare is highly graded soil. This assessment is to be regarded as conservative and applying only to initial intensive irrigation.

Up to the present no survey has been conducted of minor patches of soil which lie in close proximity to the main and branch canals which might profitably be considered for extensive irrigation, in particular as a means of providing a form of supplementary irrigation (part cropping) on normal dryland farming units. The extent of such practice may admittedly not be very large (as affecting canal capacity) but its significance in drought years could be great. Mention can be made of the possibility of using the non-sodic oshanas for rice production, fish culture and improvement of grazing (Ref 4b, Section 4), particularly as an interim use for water from any canal scheme. These productive factors need further investigation on a pilot scale.

Regarding the zone to the west of the Oshana Etaka no detailed surveys have as yet been undertaken. However, the general reconnaissance has revealed extensive prospective areas suitable for irrigation (Refs 5b; 6). Apart from the ridge of locally-derived material running SSE of Eunda with the potential of developing several thousand hectare, there are considerable zones to the south and west of non-solonetz class soils associated with calcrete (Map 3), which are reported to have high fertility. Other intervening vast areas of red and brown sands would also come up for consideration. The planning of irrigation in this western zone is regarded as a long-term project, dependent on detailed surveys both of topography and soils and furthermore on satisfactory arrangements for water allocation. Nevertheless it would be very conservative to assume that at least two irrigation schemes of comparable size to the one envisaged for the central zone could be brought about.

The success and practicability of irrigation in Ovamboland is admittedly a rather unknown factor. The only irrigation that has been attempted was a 3 ha plot at Oshakati using water from the flood collecting canal. This plot unfortunately was sited on poor soils, namely the grey sands which have since been shown to be unacceptable in terms of present-day knowledge of suitable practices. Nevertheless the results were not unpromising. Five varieties of wheat were sown, yielding an average of 16 x 90 kg bags per hectare - probably at least 8 times the yield of millet on dryland cultivation. Lucern and vegetables were also grown with marked success. Indeed, for the amount of water applied (420 mm in the 1st year and 890 mm in the 2nd year, over 8 months) this preliminary attempt holds much promise for the extensive type of irrigation. Regretfully the experiments had to be abandoned when increasing domestic demand cut short the supply of water for irrigation use in the third year.

Complementary studies have been made of the various factors involved in irrigation as a new venture in Ovamboland, guided by the knowledge accumulated from schemes elsewhere. An agronomic and management study (Ref 5e) considered four basic alternatives of estate or individual holding in combination with cash cropping (export) and crops for local consumption (supplementary). Although too early to come to a definite decision, it would seem that in the initial stage estate management oriented largely to cash cropping should be practised, with progressive change-over to individual holding as irrigation experience is gained. A three-year crop rotation system is considered desirable, with cereals occupying about two-thirds of the land. The main crops envisaged are shown in the table below, together with estimated water requirements, yields and fertilisation levels.

Crop	Water demand (mm)	Yield potential (bags/ha)	Fertiliser recommendation kg/ha
SUMMER			
Maize	410-630	50	150
Sorghum	380-430	30-40	125
Millet	430-510	20-24	95
SUPPLEMENTARY			
Soya beans	510-560	10-12	50
Cow peas	460-510	15-20	50
Sweet potatoes	630-760	30 tons	175
Groundnuts	510-630	35	75
WINTER			
Wheat	510	30	115
Beans	300-350	20-24	120
Vegetables	300-380	20 tons	220

(1 ton = 2000 lb)

Millet has been included essentially as a useful means of introducing the change over to higher-yielding crops from the present practice of dryland millet production. Other prestige crops such as cotton (2.5 tons/ha), lucerne (20 tons/ha) and possibly rice and tobacco can be introduced at an opportune time. Citrus and sub-tropical fruits should prove worthwhile. Irrigated pastures are not recommended but the obvious production of fodder to enhance ranching on contiguous areas would need to be considered.

Regarding irrigation methods the present inclination, based on the permeable character of the upper soils and the general flat surface gradients, is towards the use of sprinkler systems. While this method of application of water would fit in well with probable pumping systems for distribution from branch canals and would reduce drainage problems, the ability of irrigators to adapt to mechanised farming will have to be considered and the most suitable method evolved by trial. This applies to several other aspects and proposals have been drawn up for pilot schemes and irrigation research (Ref 5e). Convenient sites on the east bank of the Oshana Olushandja have been indicated for testing different soils but it is envisaged that essential research on techniques would be carried out largely at the new agricultural station at Orongo (Ref 11, p 102).

The training of irrigators is regarded as very essential but there is every reason to believe that, as in the Republic (Ref 11, p 100), the Ovambo would make very effective use of holdings under irrigation and provide a good living on economic farming units. The specific size of an individual holding has not been determined. Initial considerations indicate a plot of about 2 hectare when linked with some grazing as possibly being adequate for income return, although a 3 hectare holding is regarded as being manageable by an average family unit in respect of labour requirements (Ref 5c).

The economics of irrigation in Ovamboland has been studied in as far as present knowledge allows (Ref 5c). Actual productivity will be governed to a large extent by suitable management and the nature of crops applied. The economic viability of any scheme is moreover affected by a number of factors, not the least of which is the assumption as to allocation of the cost of the various works necessary to irrigation when shared in part by other services and as may be subsidized by the state as a matter of accepted policy. Furthermore, the success of irrigation must be measured in terms of the human resources and the demand for the products which, as suggested earlier, may dominate the need for development.

Adopting a family unit size of 2 ha and the simplest double cropping system of summer maize and winter wheat with legumes, the gross value of production can be assessed at over R 700 per unit based on sales values given in Ref 5c. This disregards the retentions for home consumption. The net value after deducting all direct costs except family labour is not less than R 300 per unit, comparing favourably with the R 240 gross value associated with a mixed (dryland) farming unit as given in Section 4.2. Actual cash return would depend on any charge made for water.

An initial development of 3 000 ha under irrigation would add 1 500 economic farming units to the number available. Gross production value would be over R1 000 000 per annum. For eventual irrigation development of some 10 000 ha, the 5 000 economic farming units would support a further agricultural population of 25 000, increasing the total by 10%, and gross production value would rise to R3 500 000 per annum as a minimum without regard to cultivation of higher-value crops such as cotton, lucerne, groundnuts and vegetables.

These conservative estimates when viewed in the light of policies adopted in the Republic indicate that irrigation in Ovamboland would be well worthwhile. It has been stated (Ref 12, p 6) that, due to the very much smaller area taken up by an irrigation farming unit (2 ha) compared with the 140 ha for the pastoral farmer, "it is thus essential that the irrigation potential be fully exploited". The proposal for the initial irrigation scheme and aspects of water demand are dealt with in later chapters.

CHAPTER 6

HISTORY OF WATER SUPPLY DEVELOPMENT

The development of water supplies in Ovamboland has evolved gradually, making use of every natural feature. Starting from the available water holes and pans, as water became scarcer it was found expedient to dig wells. These were normally open excavations, keeping pace with the water table as it receded in the dry months. Subsequent flooding caused the sides to slough in and fill with silt so that repeated excavation was necessary. Some use of timbered wells with raised banks was attempted but this construction was not lasting and fell into disuse.

In the drought of the late1920's the first excavated dams were constructed by the Administration using hand labour.Many of these simple storage units having capacities of 3-6,000 m^3 are still in use to-day and pointed the way to providing carry-over water not only for the winter months but also for a succession of dry seasons.

6.1. Excavation Dam Development

In 1954 intensive development of water supplies was started. This was aimed at providing adequate supplies to local communities and various urban growth centres. The principle of the "excavation dam", open on at least one side to the local oshana,was retained. Seasonal flow filled the depression and normally this sufficed. Using earth-moving machinery the capacity could be made very much larger than before (20-30,000 m^3). Pallisades were erected to prevent cattle from tramping in the sides. To provide suitable drinking water simple sand-filter construction leading to a well fitted with a hand pump was arranged. The fine local sand, however, has a very slow rate of percolation and these filters were not always satisfactory.

The depth of excavation is limited by the local saline water table. In parts this is as shallow as 2m but generally the more favourable ground is sought and depths of 5m have been used. Subject to this condition being observed, little problem of salt penetration has been encountered. The location of such storage works was naturally restricted to the oshanas where the soil is dumped on two sides allowing throughflow and to certain pans where the dams are constructed on the edge with one side open to the pan. Side slopes are generally 1:2 or 1:3 depending on the soil, but where the dam is not fenced off a flatter slope of 1:6 is required to allow direct stockdrinking.

This principle of creating storage was extended in the case of road construction to advantageous siting of borrow pits and the use of causeways to dam up the oshanas. Some capacities are small, but an extreme example is the Oshakati Lake where a gross storage of 3 000 000 m^3 was obtained. In the period 1954-56, 23 dams with sand-filters were constructed. To date the number of all types of dams has risen to over 300. About one-third of these are in the 6-15,000 m^3 class but, including certain large works, a total storage of about 7 000 000 m^3 has been achieved. The aim has generally been to provide a 2 year supply including for evaporation losses.

These excavation dams are naturally restricted to places where local runoff can be tapped and so the vast majority are in the northern half of the Etaka - Cuvelai delta, with some spread along the northern sector of the eastern zone towards Nkongo (Map 8).

6.2 Pump Storage Works

As conditioned by the limitation on depth of excavation and by evaporation losses, the next logical step in securing storage was the construction of pump storage dams. The excavated material is banked around the depression to form a fully enclosed dam with the wall raised several metres above the oshana bed. An adjacent open sump is created to catch the local flow and to allow pumping into the dam. Initially portable tractor-operated pumping plant was used but this has been superseded by fixed machinery having typical pumping capacity of 250-300 m^3/hr, several units being used for the larger schemes.

Water depths of up to 10m have been obtained in this way, which apart from more than doubling the capacity of the normal excavation dam has also kept down evaporation losses. Seepage through the raised banks of compacted fine clayey sand has proved to be insignificant except for some problems with termites. Wave erosion is prevented by the use of precast concrete facing slabs on the upper slopes. Evaporation losses have effectively been reduced by 40-50% through the use of floating sheets of an expanded concrete. Experiments are still proceeding.

Some 40 pump storage dams have already been built (Map 8). About half are equipped with complete filter plants for supplying purified and sterilized water to hospitals, schools and community centres. Basically, slow sand filtration has been applied, although some difficulty has been experienced with the fine local sand and coarser graded material is obtained from Ruacana. Coagulation and pre-settling in a sedimentation unit has been found advantageous in increasing throughput capacities. Filtered water is stored in a balancing reservoir and where necessary elevated tanks are used.

This type of installation has been fundamental to the development of various centres in recent years. A large unit employing rapid gravity filters and having a capacity of 1 million m^3/a (600 000 gall/day) is scheduled for construction to serve the needs of the Oshakati-Ondangua complex. Since 1955 the pump storage works have eminently served their purpose and only one failure due to neglect of the pumping arrangements is known.

The cost of water supplies from pump storage schemes is approximately 30 cents/m^3 for unfiltered water and 45 cents/m^3 when purified. These costs are 2 to 4 times as high as those ruling in the European zones of the Territory and indicate the pressing need for a cheaper and more efficient water supply system.

6.3 Collecting Furrow and Canal Development

Local runoff as trapped by the excavation dams and the pump sumps is sometimes inadequate and is also highly unreliable. As a cure for the former situation local furrows leading water into the dams have been constructed. This has resulted in some improvement but does not solve the problem of failure in dry years of flow to occur in the local oshana. Likewise with expanding requirements the flow may be inadequate. Nearby oshanas on the other hand may have higher runoff and the situation is often experienced whereby a local downpour causes one oshana to flow and not others. Thus the principle of constructing collecting furrows was evolved to provide greater security and capacity of supplies. An example of this is the construction at Ondangua where furrows 7 km from the west and 5 km from the east supplement the locally available flow.

The next stage in this development was to consider the difficulties which arise in drought period when the oshanas in the district fail to flow altogether. In the meantime other districts may well experience runoff. The solution lay in the construction of a flood water collecting canal tapping a whole system of oshanas. The first of these was the Oshakati canal which from commencement in 1960 has been extended westwards from the low point at Oshakati to as far as Ombalantu at present - a distance of 100 km. This canal was designed to fit in with an eventual system of bringing in Cunene river water and has a nominal capacity of 1 cubic metre per second. Initially it has been constructed as an unlined channel although certain portions have been lined with concrete and it was envisaged that eventually full lining would be required. At each oshana only the southern side is banked up and a spillway provided such that initial runoff is diverted into the canal but surplus flow is released down the oshana. The system has worked exceptionally well. Despite the relative dryness of recent times (Fig 1), there has been flow in the canal, every season, several years at full capacity, distributing life-giving water to the full reach of the canal between Ombalantu and Oshakati. A 10 km branch canal was constructed to Elim.

A second main canal also 100 km long has been constructed to the west of the Etaka between Eunda via Tshandi to Ongandjera. The system, with its bridges, sluices, pump storage dams and bailiff's houses at selected intervals, is not yet in full use but provides for potential growth development in the more sparsely populated west.

Including collecting furrows, the total canal length constructed to date is 250 km. Other flood water collecting canals are in the planning stage, in particular one to serve the Oshikango complex.

6.4 Supplemental Pumping Systems

To supplement supplies in centres less-advantageously sited in relation to natural runoff it has been necessary to lay pipelines and to pump water to higher elevations or to places of insecure supply. Thus a 37 km long 10 inch dia pipeline has been constructed from Oshakati via Onguediva to Ondangua, forming a logical extension of the canal to overcome the slight reverse gradient of the land. Extension pipelines lead to Onandjokwe and from there to Oshigambo (north) and Olukonda (south), with another to Onanjena (east) proposed.

Together with other pumping systems at Ombalantu and Oshikango the total pipeline length to date is 88 km. Every use is made of local supplies first before resorting to pumping with attendant high operating costs.

6.5 Wells and Cisterns

In the past few years the erection of small schools and clinics in rural areas away from the main supplies has been facilitated by the construction of concrete or cement-brick lined wells. These rely almost entirely on groundwater. The poor infiltration capacity of the soils and high salinity (particularly in the Ukuambi area) has resulted in only about half the wells being successful. Some 50 wells equipped with handpumps are now in operation, while others are under construction. In the same category of small supplies is the development of artificial runoff surfaces, using primarily the roofs of buildings, and storage in cisterns.

6.6 Boreholes

Seven holes were drilled in the central area in 1927/28. The results were discouraging as only saline water was encountered. Further drilling was undertaken in the period 1948 to 1953, again without success in the central zone but with promise in the Omboloka area on the northern edge of the eastern zone. Backed by the findings of the Odendaal Commission an intensive drilling programme has been undertaken since 1962. Altogether some 250 boreholes have been sunk (Map 8). The majority are in the 50-150 m depth range, others up to 250 m deep and there are 5 deep exploratory holes drilled to as much as 650 m. Considerable difficulties have been experienced in drilling in the fine sand due to falling in, clogging of filters and damage to pumps. Special methods were developed to overcome these problems.

The efficacy of drilling may be described under the three districts indicated on Map 9. In the central alluvial plain there has been no success whatsoever largely due to the high salinity and further drilling for water in this zone has had to be abandoned.

On the other hand boreholes in the eastern district (the majority of which are in the Omboloka-Nkongo area) have generally been successful (85%), although deep (70-90 m to water table) and the yields (averaging about $2m^3$/hr) are not remarkable but nevertheless satisfactory. Boreholes drilled in the south-eastern area proposed for addition to Ovamboland have a higher watertable (about 10-25 m) and yields of up to $15m^3$/hr. The total dissolved solids (T.D.S.) in the eastern district is about 500 ppm and few holes have failed on account of this factor.

In the western district drilling results have been rather variable in respect of both yield and salinity. Successful holes near Ruacana airport in the north have yields averaging $2m^3$/hr while others in the centre and south commonly yield about $5m^3$/hr. However, rather more than half the holes drilled are weak. The water table is usually relatively shallow (10 - 30m) except on the Ruacana plateau (about 50m). Salinity is satisfactory in the north (400 ppm) and south (1000 ppm) but in the centre T.D.S. values up to 5 000 ppm are encountered, rendering the water suitable only for stock watering and not human consumption.

The more successful boreholes have been equipped with wind driven pumps but the infrequency of winds is a problem.

6.7 Present Situation

The present framework of water supply arrangements can be said to have brought about a satisfactory improvement. However, the various works have generally been placed and sized solely to meet the immediate requirements. These will soon be fully utilized and become inadequate. Other areas have hardly been touched so that large-scale expansion of existing services and development of new sources is becoming a dire necessity for the future of Ovamboland.

CHAPTER 7

FUTURE WATER REQUIREMENTS

Before considering possible schemes for extending existing works and augmenting with new supplies to provide security and expansion development, the potential future requirements for water are examined. This is done both on a unit basis and for the total future demand so as to allow ready application to various schemes and as a means of appreciating what can and should be done eventually.

It is convenient to examine the respective requirements individually according to the nature of consumption. Logically there are three main categories of demand, viz. stockwatering, domestic supply and irrigation use, but various sub-divisions need to be applied to cater for differing unit rates and combinations of supply.

The anticipated occupation of the land, apart from prospective irrigation is as described in Section 4.3 The manner in which the various demands can be met is discussed in subsequent chapters.

For consistency water requirements are generally quoted in terms of cubic metres per annum (m^3/a), with the prefix M used to denote millions. Average daily rates are indicated where necessary in the more familiar values of gallons per day (gpd), the conversion being 1 gpd = 1.66 m^3/a. A further unit used is the cumec (cubic metres per second) equivalent to 35.3 cubic feet per second (cusec) or 19 million gallons per day (mgd).

7.1 Stockwatering in Extensive Areas

Arising out of the proposals described in Section 4.2, an average pastoral unit is taken as consisting of 15 L.S.U. requiring 140 hectare of grazing. Although the present livestock breeds are adapted to low water consumption, it is considered that the supply should provide for improved breeds. Accordingly the normal drinking requirement of 20 m^3/a (12 gpd) per head of large stock is adopted in assessing future requirements. This is the net value to which must be added about 25% to allow for wastage, giving a gross rate of 25 m^3/a per L.S.U.

A further addition must be made for the domestic supply for the herdsman and his family. For this type of existence a consumption rate of up to 25 m^3/a (15 gpd) per capita would be a reasonable allowance in the foreseeable future.

Thus the total demand per pastoral farm would be 500 m^3/a or a unit rate of 3.5 m^3/a per hectare. This of course represents an average demand, to be varied by such factors as higher or lower grazing potential (Map 6). Peak seasonal rates would be about 50% above average. For the extensive ranching area as a whole (4 500 000 ha) the total consumption can be placed at 16 Mm^3 per annum.

7.2 Rural Demand in the Delta Zone

On the mixed farming areas the demand for water is assessed on the basis of a unit of 60 hectare, comprising stockdrinking for 6 L.S.U. (150 m^3/a) and domestic water for 5 humans. The more settled existence could lead to a higher domestic use of say 30 m^3/a (18 gpd) per capita and the combined demand per farm would be 300 m^3/a at a unit rate of 5 m^3/a per hectare, giving rise to a total consumption of 5 Mm^3 per annum for the mixed farms in the northern half of the delta zone covering 1 000 000 hectare.

7.3 Domestic Demand in Urban Areas

The future demand for domestic water in urban areas (including industrial use) can at best only be hazarded since urban development is very recent. The only statistics available are for Oshakati and Ondangua (Ref 10) which taken together have increased their consumption over the past 7 years from virtually nothing to the order of 150 000 m^3/a (1967/68). Much of the increase has occurred in the past two years. Extrapolation to 20 years hence would be very precarious.

The future urban demand must therefore be decided purely on the basis of expected population (Section 4.3 - 100 000) and unit consumption. Accepting that urban dwellers will be accommodated in houses and enjoy a higher standard of living than the rural population, and including for industrial needs as also for a high degree of public institution usage, the overall water requirements might reasonably be set at 100 m^3/a (60 gpd) per capita. In this event the future urban demand would total 10 Mm^3/a (6 mgd). While admittedly a very rough estimate, this order of demand as a foreseeable requirement is considered quite acceptable as a basis for determining supply arrangements.

As a rough approximation the distribution of future urban supplies in the main centres might be as follows:

Oshakati-Ondangua complex	3 Mm^3/a
Oshikango complex	1.5
Nkongo	0.5
Ukuambi-Otshikuku	1
Ongandjera	1
Ombalantu	1
Ukualuthi-Tshandi	1
Eunda-Onesi	1
	10 Mm^3/a

In the case of urban supplies a peaking factor of about 3 might apply, resulting in an early summer daily demand of some 30 Mm^3/a equivalent to a rate of 1 cumec (19 mgd) overall for Ovamboland. The supply for the Oshakati-Ondangua complex can be expected to peak at up to 0.3 cumecs (6 mgd). Sustained peaks would be about half these values.

7.4 Irrigation Demand

For the lack of direct experience in Ovamboland, water requirements of crops under irrigation have been derived from evapotranspiration analyses. This approach is deemed quite satisfactory since various methods taking into account different factors in water demand for optimum production result in a fairly narrow range of values for selected crops.

The detailed analysis carried out as part of the irrigation management study (Ref 5e) gives the actual crop requirements (expressed as a depth of water) as follows:

Maize	:	677 mm (27 ins)
Wheat	:	585 mm (23 ins)
Summer Legumes	:	510 mm (20 ins)
Winter Legumes	:	380 mm (15 ins)

Based on the suggested cropping system of two-thirds under grain and allowing for minimum rainfall only, the maximum annual net water usage as an average over a plot would be 907 mm (36 ins). Irrigation efficiency, including all losses from field edge to plant and evaporation from furrows or sprays, is taken at 60% so that the annual requirement for the particular crops considered can be set at 1.5 metres (about 60 ins) as a maximum.

In average rainfall years water requirements might be 0.3m lower, i.e. 1.2 m, but when considering the ultimate use of water, provision should be made for probable later conversion to crops such as lucerne, vegetables and possibly sub-tropical fruits having a higher consumptive use. In this event the average annual field edge duty can acceptably be set at 1.5m.

The total water requirements for 3 000 hectare under irrigation would then amount to 45 Mm^3/a. Canal losses in the case of the proposed eastern canal through Ombalantu (as discussed later) would in total over the growing season boost the gross annual consumption of water by about 20% (Ref 4b, p 24) to 54 Mm3. Canals serving potential irrigation schemes in western Ovamboland, which as indicated in Chapter 5 might consist of two similar size schemes, would possibly involve slightly higher needs because of more adverse climatic conditions.

Assuming for present purposes that in total some 10 000 hectare is eventually developed, the irrigation demand would be about 190 Mm^3/a, requiring a continuous flow of 6 cubic metres per second (cumec).

Peak daily demand for irrigation water has been calculated according to the growing season to be a possible maximum of 7.6 mm (0.30 ins) for summer crops occurring in January or February in drought years. The normal maximum for winter crops is 6.9 mm (0.28 ins) occurring in August or September. Heavier individual duties will be needed for other crops with high growth rate in early summer (e.g. 12 mm/day for lucern in October) but this would be counterbalanced by requirements for winter crops about to be reaped on the rest of the area being low at this time. Thus for canal design purposes a peak field edge duty of 7.6 mm/day is satisfactory. The corresponding canal duty, allowing for 10% header distribution losses and a diversity factor on irrigation demand of 85%, is 1 200 hectare/cumec (40 morgen/cusec) at the distribution points.

7.5 Summary of Potential Demand

As enumerated above the gross requirements for water in Ovamboland in the foreseeable future could amount to:

Stockwatering on pastoral units	16 Mm^3/a
Mixed farm usage	5
Urban demand	10
Irrigation: Initial 3 000 ha	54
Future 7 000 ha	135
Total	220 Mm^3/a

While in normal years portion of this potential demand would be met from natural runoff, even with storage the fraction must necessarily be small. Moreover, as brought out in previous chapters, prevailing prolonged and frequent drought conditions render reliance on runoff completely insecure. Thus, water supply schemes must be based on the gross requirements and the total shown above is equivalent to the continuous supply of 7 cumecs. The peak demand rate neglecting balancing storage would be approximately double this at 14 cumecs, of which expected urban demand is 1 cumec.

CHAPTER 8

SCHEMES FOR WATER DEVELOPMENT

Having determined the potential future requirements for water we turn now to the means of satisfying the expected demand. This is done without regard to actual timing; the costs and implementation in phased development being dealt with largely in the next chapter, although some reference is made here to these matters particularly where alternative methods of supply are involved.

Proposals for future schemes must necessarily take into account the successful development of supplies in the past (Chapter 6), but at the outset and in view of the volume of water needed, it is to be emphasized that dependence on local sources as permenant supplies (with the exception of boreholes) cannot be countenanced. Existing supplies for urban and rural use garnered from excavation and pump storage dams and as enhanced by various flood water collecting systems have enable certain initial development and brought about an immense improvement to the situation in Ovamboland. However, as noted from the records of oshana flow (Section 3. 5) and depicted for seasonal rainfall variation (Fig 1), the system developed in recent years has not gone through a thorough testing under full drought conditions. Moreover, as has been mentioned, many of the existing schemes are reaching full utilization. Expansion on existing lines could perhaps cater for say a doubling or possible trebling of present water use but expected demand goes far beyond this. Furthermore irrigation development, seen as a salient feature in creating a self-supporting economy for Ovamboland, cannot be brought about using local sources.

It is recognized by all concerned (Ref 11, p 108) that bringing in Cunene river water (by pumping at Calueque, earlier known as Eriksonsdrift) is the most urgent part of the scheme for supplying Ovamboland with its needs for man and beast, as well as initial irrigation. Indeed the Calueque Pumping Scheme and its extension into the interior of Ovamboland forms the very foundation for comprehensive satisfaction of water demand.

This cannot be done completely disregarding cost and it is encumbent upon planning to develop local low-cost sources to their utmost, particularly for areas that cannot readily or economically be served from a canal system however wide-tentacled. Also, local sources in certain instances could possibly be adequate for the normal requirements of the particular settlement envisaged. The first consideration then is for successful development of the more-minor localized supplies such as boreholes and oshana diversion and storage works.

Experience has shown that local water services can be divided into two distinct types. On the sandy outlying districts in the west and east, except in isolated places, runoff is almost non-existent and supplies can be obtained only through the drilling of boreholes. In the alluvial plain on the other hand boreholes are completely unsuccessful due to the high salinity of the underground water and reliance is entirely on runoff in the oshanas and to the scattered pans.

8.1 Borehole Supplies

For present purposes the rural water requirements in the outlying zones will, for the lack of detailed evaluation, be taken as the average demand, although a varying grazing potential would be applicable in practice. The anticipated ideal occupation would be a pastoral unit of 140 hectare requiring a supply of 500 m^3/a.

In the poorer northern areas such as on the Ruacana plateau and around Omboloka, yields from successful boreholes are about 2m^3/hr (440 gph). Southward the yields improve and 5m^3/hr is quite common. However, the higher yields may not be effectively utilized due to the restraint placed on distance of grazing from the watering point and carrying capacity of the veld.

Briefly, adopting the suggested maximum walking distance from the furtherest grazing of 4 kilometres (2.5 miles) with boreholes 7 km apart, the corresponding area to be served would be 4200 hectare. For a water demand of 3.5 m^3/a/ha, as analysed in Section 7.1, the annual output of the borehole would need to be 15 000 m^3. Applying a peaking factor of 1.5, the corresponding demand for 24 hour operation is 2.5 m^3/hr. Allowing further for part-time operation of the borehole, a minimum acceptable yield for stockwatering purposes would be of the order of 3.5 m^3/hr.

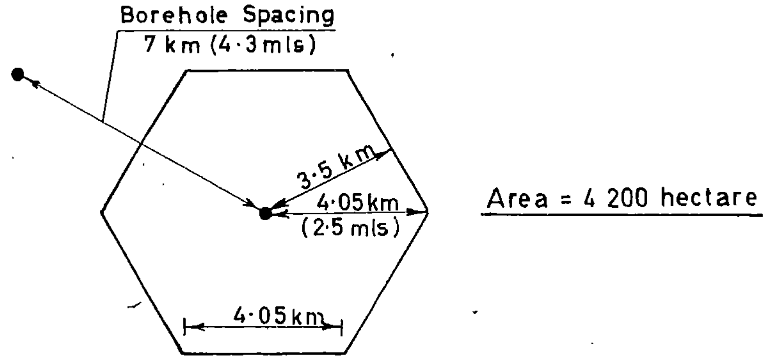
Thus borehole yields much larger than about 4 m^3/hr (900 gph) cannot be effectively used unless resort is had to piping the water to points away from the borehole (possibly economic in difficult drilling areas) or accepting a longer grazing distance. An alternative use for surplus water would be to allow minor irrigation where suitable soil lies adjacent to the borehole. Such possibilities, however, are best left for field application.

The present need is to determine the number of boreholes that would be required to allow full exploitation of the grazing potential of the sandy zones which lack surface water. Account must be taken of indications that bordering on the delta zone certain portions of the sandy zones are poor in respect of borehole yield and sometimes quality (Ref 10). In particular this condition is likely to prevail for about 80 km into the eastern zone and to a lesser extent in the western zone so that the approximate areas in which drilling for water should be applied as shown on Map 9 (p 41a) are:

Western District	:	800 000	hectare
Eastern District	:	1 800 000	hectare
Total	:	2 600 000	hectare

Circular or square shaped areas served by a central borehole are wasteful due to overlapping of adjacent zones. For optimum use the area should be hexagonal in form with boreholes spaced on an equilateral triangle pattern (Fig 2). A convenient maximum distance from watering point to furthest boundary for grazing is 4.05 km (2.5 mls) given by a borehole spacing of 7 km (4.3 mls). The area enclosed by the hexagon is 4200 hectare and the borehole would then serve 30 pastoral units of 140 hectare, having a water demand of 15 000 m^3/a at a peak continuous rate of 2.5 m^3/hr.

The concept of, or even restriction to, physical pastoral units need not necessarily apply, particularly as intensive subdivision and fencing may not be a practical proposition. Indeed economic ranching management demands large-scale herding and undoubtably this could be adapted to tribal customs. However, the spacing of boreholes is not affected by such policy matters and eventual placing on an equilateral triangle pattern with sides of 7 km, adapted according to field conditions, is proposed.



HEXAGONAL GRAZING CAMP

(Ideal Ultimate Pastoral Unit)

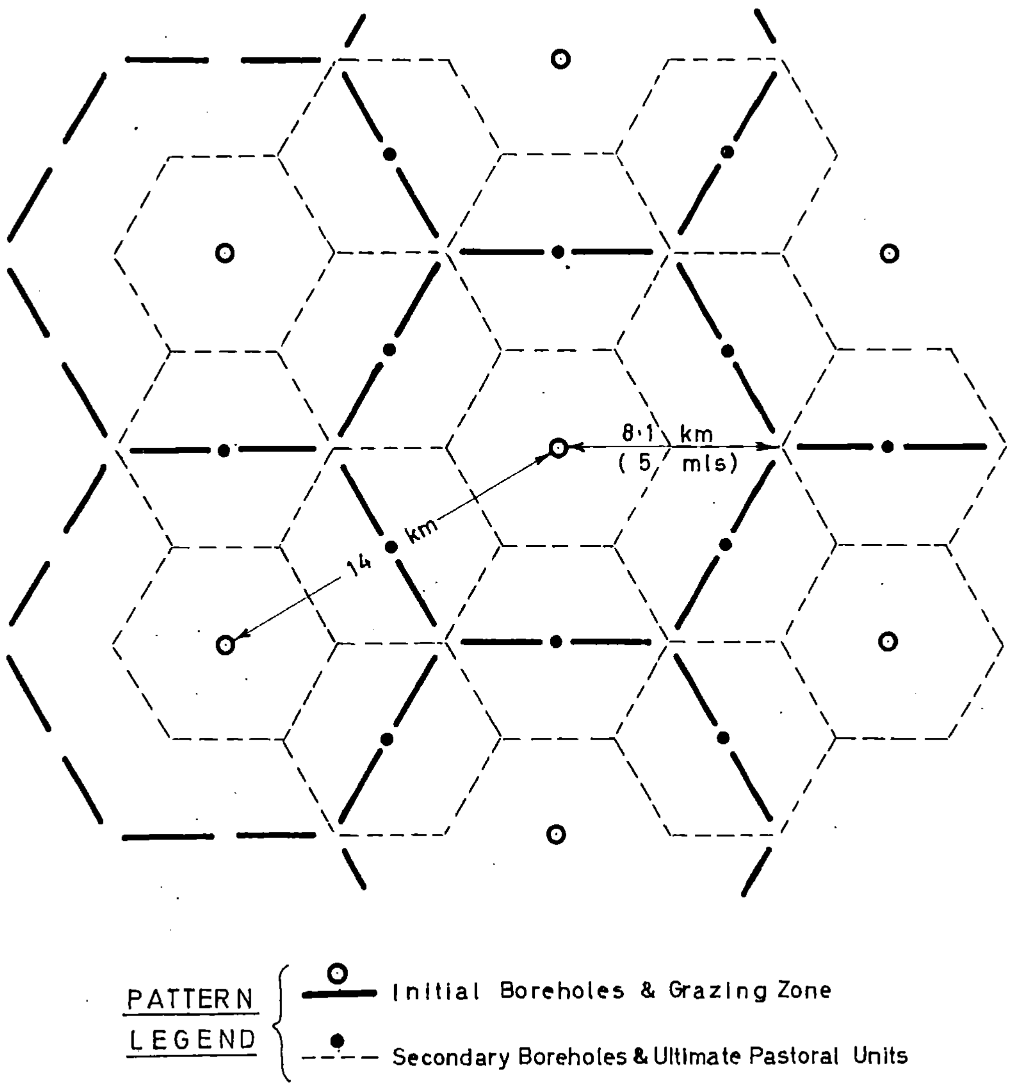


FIGURE 2

BOREHOLE PATTERN

The number of boreholes needed in the outlying zones is therefore assessed at 620. Existing successful boreholes number about 70 for effective use on the above pattern leaving some 550 to be undertaken. This immense task cannot be contemplated immediately and initially drilling might be restricted to every alternate borehole with a spacing of 14 km, each borehole serving an area of 17 000 hectare. The ideal pattern is illustrated on Fig 2 and the desired siting shown on Map 10. The total number of boreholes required for the initial phase would be 155, reduced by effective existing boreholes to some 110 as a new drilling requirement for successful boreholes.

The number of actual boreholes for the initial programme based on past experience of success is determined as follows:

District	Western	Eastern	Totals
Area (ha)	800 000	1 800 000	2 600 000
Total boreholes required in initial phase	48	107	155
Existing effective holes	20	22	42
New successful drilling	28	85	113
Past drilling success	50%	85%	
Total new drilling	56	100	156

It is to be remarked that this initial programme will place some restriction on the occupation and utilization of the sandy areas because of the long distance between furthest grazing and watering point of 8.1 km. However, the pattern (Map 10) allows for filling in with secondary boreholes as the need arises. Of course the actual placing of boreholes will depend on the local conditions and this adaptation would be done in the field. It might also be considered advisable to develop areas of higher grazing potential on the intensive pattern initially rather than to attempt full coverage on the extensive basis. Such a policy decision can be taken as the work proceeds.

The tempo of drilling during the past 6 years has been 30 boreholes/annum so that the initial phase of 156 holes could be completed readily in 5 years.*

*Note that in the 5-year Plan previously considered, allowance was made for drilling of 200 holes over 4 years (Ref 11, p 109).

For succeeding phases the number of boreholes required would increase due to the lesser availability of existing successful boreholes fitting in the pattern. The full requirements for new drilling are :

	Western District	Eastern District	Total
Phase 1 :	56	100	156
Phase 2 :	88	112	200
Phase 3 :	92	118	210
Phase 4 :	96	124	220
Total	332	454	786

The resulting system of boreholes would give a main framework for occupation of the undeveloped areas. Further subdivision in grazing camps with individual watering points is regarded as a future task and is not treated here.

8.2 Excavation and Pump Storage Dams

The precise boundary between zones in which boreholes will be successful and the central region where surface water supplies will be needed cannot be defined at present, but it would appear that some 3 000 000 hectare in central Ovamboland must necessarily depend either on local storage works or on supplies from a canal and pipeline system (Map 10). As mentioned in the introduction to this chapter it is considered highly desirable to develop local storage to the utmost.

While excavation dams and their development to pump storage works have proved highly successful in normal years, the runoff conditions during drought are a critical factor. Nevertheless for certain rural areas dams may be the only salvation since piped supplies due to the distance involved would be wholly uneconomic. In this situation the capacity of the dam must be sufficient to carry over for at least 2 and preferably 3 years if the supply is to be regarded as permanent, even with restriction on consumption during drought.

The continued construction of local storage in areas which could eventually be served from a canal system with branch pipelines or other feeders is to be encouraged because, apart from their function as balancing storage, the dams in this situation need not have a high carry-over capacity. Possibly one-year storage would be adequate and the low cost will render such dams worthwhile.

Envisaging such dams as essentially for rural use, the pattern of development automatically follows that proposed for boreholes. However, since over several months of the year there will normally be other surface supplies for stockwatering (e.g. along the oshanas in waterholes, or in pans), the restriction on grazing distance need not be as severe. It would only be in drought years that the cattle would suffer through longer-distance grazing. Accordingly the spacing of dams could be increased to about 11 km when the furthest grazing would be 6.2 km (3.8 miles) and the area served 10 000 ha. This, however, brings about the difficulty of size of dam which would need to be about 30 000m^3 where no carry-over is involved. The spacing and size would have to be varied according to the local circumstances regarding runoff and for present purposes an average grazing distance of 5 km (spacing 8.66 km) with each dam serving 6 500 ha is adopted for deciding the number required.

On the basis of dams being required throughout the 3 000 000 hectare of the central region including those parts of the eastern and western zones indicated as unsuitable for boreholes, the total number of dams needed is 460. Of the existing 320 dams of all types roughly half would be effective in the ideal distribution, leaving some 300 dams still to be constructed for complete coverage. A tentative siting of new dams is shown on Map 10.

It is proposed that construction of the dams follow the development which has been found successful in the past, namely an initial excavation dam open to the local runoff, followed by building up to a pump storage work as the consumption rises and by local diversion furrows when required to improve the supply. Filtration units would be introduced at an appropriate stage to provide clear domestic supplies.

The capacity for the individual dams would need to be decided on the basis of the population to be served (whether pastoral or mixed farming with different unit rates as determined in Section 7) and the degree of carry over storage needed for the local circumstances as discussed above. In the zone covered by the proposed canal and pipeline system little carry-over will be required since the supply would be supplemented by release from the canal down the relevant oshana or by pumping when needed. Such dams could perhaps be limited in eventual capacity to about 20 000 m^3 when serving a full area of 6500 ha under mixed farming. On the other hand dams serving pastoral units which are solely dependent on runoff would need to have capacities of the order of 50 000m^3 to be adequate against prolonged drought; even higher capacity is advisable where possible, particularly for mixed farming areas. It may be expedient to consider constructing only part of the storage at the start and duplicating at a later stage when the demand justifies this, thereby providing for the situation in which immediate unit consumption is not as high as postulated.

A further case which requires attention is the construction of dams in the grassflats of the southern delta region where the depth of excavation will be limited to about 2 metres due to the shallow water table. Here, as well as in outlying districts poor in underground supplies, difficulties must also be expected in regard to adequacy of runoff. Full exploitation of these areas may not be feasible. Conversely an extension of piped supplies will be required. The area concerned comprises about one-quarter the total central region (700 000 ha). Actual development will need to proceed by trial to find the best solution.

As indicated earlier, about half the existing dams will fit into the proposed spacing for full coverage. Not all these dams are adequate and a programme of improvement must be contemplated. In particular it will be necessary to increase the supply by constructing diversion furrows and enlarging the capacity so that more people and cattle can be served from such points.

8.3 Wells and Cisterns

For small rural schools and clinics the system of wells and cisterns has proved suitable. However, certain improvements to existing works are necessary to bring them up to the required standard. This should be carried out at an early stage.

With intensification of development in the present inhabited zone and on exploitation of remote areas it can be anticipated that new rural services will be founded. Provision must therefore be made for additional water supplies of the well type and of cisterns fed from artificial runoff surfaces. Some 60 wells and 140 cisterns are contemplated, spread over a reasonable period.

8.4 Canal and Pipeline Systems in General

In recognition of the urgent need for bringing in water from the Cunene river, detailed studies were undertaken of the necessary main system of pumping from Calueque and conveyance of water to connect up with the end of the existing flood water collecting canal at Ombalantu. In anticipation of future irrigation the basic planning (Ref 4b) was done on the basis of a canal having substantial capacity and adequate to meet all demands in the supply zone along the route. Improvements to the existing canal between Ombalantu and Oshakati as may be required in the eventual system have also been investigated (Ref 4a). Because the actual implementation date for irrigation development is uncertain, due attention was given to the alternative proposition of initial use of a pipeline with pumping to meet urban needs (Ref 4d - see Section 8.8). The proposals resulting from the several investigations are discussed in subsequent sections along with the branch canals required for irrigation.

The above system provides a main artery reaching to Oshakati. Development on the western edge of the alluvial plain and in the southern delta region would depend on the Etaka canal. Connecting up from a bifurcation point on the main canal near Mahanene or from the inlet to the siphon across the Oshana Olushandja to the existing Etaka canal would be relatively straight forward. For its ultimate function as a second artery the Etaka canal will require certain improvements and the elongation of both arteries from Oshakati and Ongandjera as far as Lake Oponono is suggested (Ref 10). Further, the need for piping supplies to other urban centres and farming regions and the provision of purification works is to be considered.

8.5 Calueque Pumping Scheme

The portion of the scheme lying within Angola for pumping from Calueque has been made the responsibility of the S.W.A. Water and Electricity Corporation. Known as the Calueque Pumping Scheme it is to consist of a pump station on the south bank of the Cunene opposite Calueque village, using direct diversion until such time as a regulating dam needed for hydro-electric power generation at Ruacana is built. Power will be supplied from an interim station at the Falls. The pumps will lift the water 22m through a 2500m long rising main to a ridge along which the supply can be taken in a 12 km long concrete-lined canal to the S.W.A. border near Mahanene (see Map 7).

As agreed the maximum abstraction rate is limited at present to 6 cumecs. This could be increased only by further negotiation but a rate of 12 cumecs has tentatively been proposed as a future value in discussions already conducted. Pumps are to be installed in units of 2 cumecs capacity of which there would be two initially, one as standby. Additional plant would be ordered as the demand requires. Complete plans and tender documents have been submitted to the Portuguese Authorities and final approval is imminent. The scheme excluding overheads is estimated to cost R3 300 000 but does not form a charge on Ovamboland development.

At one stage, anticipating certain difficulties, consideration was given to a possible replacement scheme involving pumping from Ruacana (Ref 7). This was shown conclusively to be very costly and the idea has subsequently been abandonded. The Calueque scheme has been accepted as the only economic solution.

8.6 Mahanene - Ombalantu Canal

The extension of the conveyance system from the border to connect up with the existing canal at Ombalantu - a distance of 47 km (Map 7) - has been studied in considerable detail (Ref 4b). Accepting that ultimate irrigation is essential to Ovamboland development, a canal is deemed the only satisfactory structure (Ref 4d - as also reviewed in Section 8.8). Even if irrigation should be deferred for many years the immediate construction of a canal to full capacity would provide interim benefits other than the satisfaction of urban needs along the route. As has been demonstrated, runoff in the oshanas is highly insecure even with an extended flood water collecting system. Thus it must be foreseen that a permanent supply for the numerous stockwatering dams in the delta zone can only be secured by drawing water from the canal, either by direct release down the oshanas or by pumping.

This interim use of the water pending irrigation development can be extended by releasing surplus flow for improvement of grazing in the oshanas, creation of fish farms in artificial open water bodies and the leaching of slightly saline areas to a state where crops such as cotton and rice might be grown on clayey soils.

Based on serving 3000 hectare under irrigation and at the canal duty derived in Section 7.4, a carrying capacity of 3.2 cumecs is required at the head of the eastern canal. This includes for all losses in the main and branch canals as determined from detailed studies (Ref 4b, Section 9). Largely the losses consist of evapo-transpiration from the free surface and adjacent soil strips, taken conservatively high. Seepage is inconsequencial due to the very low permeability of the soil in combination with negligible gradient on account of flat cross-fall and a high natural water table.

The initial section of canal from the border as far as the Oshana Olushandja is designed to take the full authorized flow of 6 cumecs and is to be fully lined. Provision along this section is made for a bifurcation which will be used subsequently to supply the Etaka canal as well as any future demand for water to the south when taken out in a high level canal. In the meantime surplus flow has to be carried into the Oshana Olushandja where it will be stored and released down the Oshana Etaka over the divide.

Balancing storage in the Oshana Olushandja of the order of $40Mm^3$ can be provided by construction of a relatively low embankment in the north. At the southern end partial excavation of a shallow trench through the divide and installation of control sluices will enable release of surges as far as the Etosha Pan where at the infall of the Ekuma (Map 10) it is possible to enclose a bay of fresh water to enhance the attractions of the game reserve. The body of fresh water in the Olushandja itself is expected to become an important facility for fish production and recreation. Similar bodies of water can be encouraged down the length of the Etaka. The dams in Ovamboland have proved themselves eminently suitable for the breeding of fresh water fish (Ref 11, p 115 - see also Annexure E of the Cunene River Feasibility Report).

The canal crossing of the Olushandja at 9 km from the border is to be accomplished by means of an 1.8 km long inverted siphon 2.2 m in diameter. An outlet in the bed will be capable of releasing the full 6 cumecs but the siphon when passing canal flow will have a capacity of 3.2 cumecs as needed to the east (Map 7). At Onanime 15 km from the siphon outlet a branch canal would take off to the south-east to serve 1300 ha and the main canal capacity is reduced to 1.9 cumecs. Further reduction to 1.5 cumecs takes place near Orupaka and from Ombalantu to Ombafi a capacity of 1.3 cumecs is required in the existing canal. The furthest point for intensive irrigation is at Orongo, a canal distance of 100 km from the stilling basin at Calueque.

In the design of the canal full account was taken of the hazard to health by bilharzia although its presence in Ovamboland or in the Cunene river is not known. Nevertheless full preventative measures are considered desirable and following comprehensive investigation (Ref 4c) it is proposed to fence the canal throughout. This measure will also reduce preventative maintenance of the canal banks considerably. Movement across the canal will be provided by suitable road and cattle bridges at frequent intervals.

A further measure strongly recommended in respect of bilharzia is lining of the canal. Apart from the prevention of weed growth serving as a source of food and cover for snails, there are other advantages such as higher hydraulic efficiency and reduced canal maintenance. Taking all these factors into account and comparing various lining types, the conclusion was reached (Ref 4b, Section 12.7) that concrete lining would be the most economical and acceptable solution. It is permissible for only the sides to be lined initially, the invert being left to later construction should it be deemed necessary to reduce capital expenditure.

Because of the consistency of natural ground slope, an automatic general gradient for the canal is 1 : 10 000. The alignment both in plan and elevation, as well as bed width, was optimised using computer analyses. This was applied to the complete canal from Calueque, including the sizing of the Olushandja siphon and the respective control levels at inlet and outlet. Preliminary investigation of distribution systems for branch canals had indicated that due to the particular topography no advantage could be gained by a high level canal serving irrigation under gravity, as discussed more fully in Section 8.9. It is proposed that the minor oshanas east of the Olushandja also be crossed by means of siphons, thereby allowing a free passage for oshana flow which it is not necessary to divert into the new main canal, and also providing unrestricted movement in the dry season.

Construction of the canal is envisaged in two sections. Because of its character as a national scheme for supplying water to S.W.A. and being a counterpart of the works across the border, the section of canal from Mahanene to the outlet end of the Olushandja siphon is to form part of a State Water Scheme. It will therefore be constructed out of loan funds as an Odendaal project for which the S.W.A. Administration assumes responsibility. The planning of the Mahanene - Olushandja Canal section has been completed and tenders have been invited for its construction pending final approval of the works across the border.

By agreement between the S.W.A. Administration and the Department of Bantu Administration and Development, the latter assumes financial responsibility for the Ovamboland Canals east of the Olushandja siphon outlet, this part of the works being considered as directly necessary for the internal water supply to Ovamboland.

8.7 Existing Ombalantu -Oshakati Canal

The existing canal from Oshakati as extended over the years to Ombalantu (Map 10) was conceived as a flood water collector. Although planned to fit in with eventual connection to the Calueque Pumping Scheme, it was expedient at the time to keep canal construction as simple as possible. Thus, only selected difficult portions of the canal were lined (about 10% of the 100 km length); in general a stable side slope of the unlined excavation was not attempted; and protective banks and drains against surface runoff into the canal were not provided. The whole canal was built at low cost (R 1 000 000 or R10/metre) and has eminently served its purpose.

The above features however, have led to certain maintenance problems, in particular the erosion of the banks and the washing in of silt from overland flow, as brought out in recent studies (Ref 4a). Furthermore, the bedwidth was purposely made large so as to provide storage within the canal itself through the use of control sluices. If operated in future at low flow rates, losses would be high from evaporation despite negligible seepage in the highly impervious soil. A further problem of the unlined and unfenced canal is that the risk of bilharzia would be increased with more permanent operation of the canal.

In view of the foregoing it must be accepted that the canal will require a number of improvements to bring it up to an acceptable standard for its future combined function of flood water collecting and conveying Cunene river water. Whether the former function should gradually be dispensed with is still being studied, but it is quite clear that future growth of townships along the route of the canal will demand ever increasing quantities of Cunene water and during extreme drought will be wholly dependent on it.

The most urgent improvements are considered to be complete fencing and bridging and the construction of siphon crossings at the oshanas with control structures to effect satisfactory cross drainage at these points. Certain canal sections in deep cut requiring heavy maintenance should be provided with side drains to control overland flow into the canal. Little work is envisaged by way of increasing the carrying capacity as the present nominal 1 cumec rate is probably adequate for all intended flows. The lining of the canal sides and invert, although a factor in maintenance, is less urgent regarding bilharzia since probably for at least the next decade the demand should be such that the canal can be operated in surges, with periods of drying in between to prevent snail infestation.

8.8 Pipeline Alternatives to Canal System

It was shown (Ref. 4b, Section 13) that the use of a pipeline for pumping of the total supplies as an alternative to the canal in the section between the Olushandja and Ombalantu would not be economic. The comparative cost would be more than double that for a canal, involving an extra expenditure of some R1 500 000.

Should irrigation development be deferred for any considerable period, however, the possibility existed that initial use of small diameter pipelines supplying only the domestic demand, followed at the appropriate time by construction of an irrigation canal carrying the larger quantities needed, might be acceptable. This alternative form of development was analysed in detail (Ref. 4d) for the Olushandja - Ombalantu Canal as well as for possible replacement of the existing Ombalantu - Oshakati section.

Assuming that all peaks in demand would be met from existing or future storage works at each major draw-off centre and that normally about 3 Mm^3/a would be available from local supplies to meet urban and stock-watering demand, the pumping capacity at the Olushandja as a continuous rate would be 0.4 cumecs. This would reduce in stages along the pipeline to about 0.25 cumecs at Orongo.

In the comparison of alternative systems, pipeline and pumping requirements were optimised for the relevant stages within each canal section and a number of possible development situations were examined. These included, in particular, the deferment of pipelines beyond Ombalantu by the continued use of the existing canal for various periods over the different sections, and also for phased development of irrigation. The comprehensive analysis shown in Table 1 provided for possible delay in the start of irrigation by as much as 10 years, to an extreme of 20 years.

The full comparison is made on the basis of effective present-worth costs in the case of deferred actual capital expenditure and includes where appropriate for special maintenance on the existing canal and for the capitalized cost of power which is a significant feature in the case of pipeline systems. For pump stations west of Ombalantu a unit power rate of 0.75 cents/kWh was adopted, increased to 1.25 cents/kWh east of

Ombalantu to allow for additional transmission costs. It should be mentioned that as yet no decision has been taken by SWAWEK on the charge for power; it may be as much as 1.5 cents/kWh and the adopted lower rates tend to favour pipeline construction. A further factor in this regard is that the power requirements (1250 kW and 2050 kW west and east respectively of Ombalantu) cannot be met from the interim power station at Ruacana; depending on the timing for main Ruacana power it would be necessary to double up the interim station if a full pumping system should be adopted.

Table 1 shows the comparison for individual reaches of canal or pipeline alternatives but because the relationships are similar only the main sections need be considered here. For the Olushandja - Ombalantu section the comparative costs are:

Canal, with invert lining deferred for 10 years:	R1 550 000
Pipeline System, with irrigation deferred for	
(a) 10 years:	R2 250 000
(b) 20 years:	R2 120 000

Earlier irrigation development is seen to increase the comparative cost for the pipeline, while deferment beyond 20 years will not effect a substantial reduction. In fact due to continued pumping expenses, the comparative cost eventually begins to rise with extended period. On this account even complete abondonment of irrigation will be more costly in respect of effective costs and, of course, the direct comparison of a limited pumping system with the canal proposal is then odious in regard to benefits. Interim use of water from the canal is an immediate benefit which cannot be neglected, but the large saving on effective costs is of more direct concern.

For the Ombalantu-Oshakati section the very existence of the flood water collecting canal renders the suggestion of replacement by a pipeline very disadvantageous in respect of comparative values. The extreme and most favourable case considered was deferment of pipeline sections to Ombafi by 10 years, to Orongo by 15 years and the eventual Oshakati reach by 20 years. Maintenance costs on the existing canal then become a factor. Certain immediate improvements to the canal are desirable, but complete lining can be deferred for periods corresponding to those above for permanent use of the canal. If a pipeline was laid, any work on the canal for subsequent irrigation use (intensive and extensive) was assumed to be delayed a further 10 years, i.e. up to 30 years on the Oshakati end. The effective costs in this situation are:

Betterment of existing canal:	R1 250 000
Pipeline system :	R2 320 000

The comparison for the Ombalantu-Oshakati section is therefore very heavily in favour of continued use of the existing canal, with improvements being carried out as needed. Even for the reach beyond Orongo where major irrigation is not contemplated, it has been shown that in first costs alone the pipeline (R1 420 000) is more expensive than full betterment of the canal (R1 200 000).

The conclusion reached is that, with any period of deferred irrigation, conveyance of water by canal is far superior to the pipeline alternative in the economic comparison. For this reason development requiring pumping of water cannot be recommended whenever the use of gravity flow canals is possible. Direct construction of canals - apart from interim benefits - also holds the advantage that no restraint would be placed on commencement of irrigation at an opportune time. This would most definitely be the case for heavy initial capital expenditure on a pipeline system carrying only domestic supplies.

8.9 Branch Canals for Irrigation

The semi-detailed surveys have shown that the soils acceptable for initial irrigation in the region east of the Oshana Etaka lie on the ridges having a south-eastward trend (Map 7). The main canal in its general eastward course will intersect these ridges and it is therefore necessary to construct branch canals roughly parallel to the dunes to provide distribution of irrigation water (Ref 4b, Section 11).

Detailed topographic surveys are presently being made which will allow planning of branch canals, but the preliminary arrangement for distribution as decided on the basis of available information can be described in general. The best soils lie on the crest of the ridges. Usually the ridges are at least 2-4 m above the grade line of the Oshana beds and gravity command is out of the question since the cost for a high level-main canal would be enormous. Moreover, the ridges themselves are not continuous so that branch canals along the crests are not practical.

The most appropriate solution would be to run the branch canals along the lower edge of the "marginal" soils, part way up the slope, thus not taking up valuable soil in the servitude. A suitable location is on the western side between the irrigable soils and the adjacent Oshana. In consideration of the optimum invert grade elevation for the main canal which will be about 0.5 m below the Oshana beds, gravity diversion into branch canals is not feasible and low head pumping will be required. Further distribution from the branches would be by individual pumping units serving local areas through a reservoir-cum-furrow system or by pressure pipelines for spray irrigation practice. The branch canals would incorporate the necessary balancing storage works which may be integrated with the excavation dam system outlined in Section 8.2.

8.10 Etaka Canal

The 100 km length of the Etaka canal constructed between Eunda and Ongandjera as a flood water collecting system forms the base for a second artery to carry Cunene river water into Ovamboland. The essential purpose of this canal (Map 10) will be to convey water to urban and farming development along the zone which has been restricted in the past due to insecurity and inadequacy of supplies. A secondary function will be to provide a modicum of irrigation on suitable soils which are more readily served from this artery than from the eastern canal. Final planning awaits detailed surveys of both topography and soil but it is anticipated that the nominal capacity to which the Etaka canal is built will be adequate.

The most urgent construction required is the linking up of the present head of the canal with the bifurcation on the Mahanene - Olushandja over a distance of 20 km. Thereafter the canal should be brought up to the same standard proposed for the eastern canal. This will include complete fencing, additional bridges, new abstraction points, improvement of drainage crossings and eventual lining of the canal throughout.

8.11 Canal Extensions

It is only logical that the main arteries should be extended to serve a greater area. In the case of the Oshakati canal the extension is necessarily southwards and it is contemplated that this should end up in Lake Oponono. The Etaka canal extension must follow along the bank of the Oshana and would also terminate in the lake. The respective distances are 40 and 75 km (Map 10). Relatively simple canal construction can be envisaged since the essential purpose is to serve a series of stockwatering points and such minor urban and irrigation development as may be possible with the opening up of the areas concerned.

Release of water from the eastern canal down the oshanas is foreseen for interim use of water as well as a means of serving excavation dams in time of need. To accomplish this and to reduce waste by evaporation in the wide basins, it is proposed that drainage trenches be excavated down the length of suitable watercourses, cutting through the slight rises which presently inhibit continuous flow and spill over only with heavy inundation. Simple excavation is proposed and structures need only be provided at access roads and occasional flow control points. Diversion furrows would tap off water to adjacent oshanas and other storage dams.

To facilitate development in areas north of the eastern canal and particularly for the Oshikango complex it will be necessary to construct a flood water collecting canal on the same principle that has been shown to be successful in the past. Security for such supplies is described in the next section.

The extension of a canal system in the western zone to serve potential irrigation schemes is not envisaged for the near future. Planning will have to await mapping and further investigation of the soils, as well as obtaining additional abstraction rights.

8.12 Piped Supplies

To provide a measure of permenancy to supplies for the Oshikango complex the only solution would be to construct a pipeline with pumping from the eastern canal in the vicinity of Oshakati. This would serve as an emergency supply to be operated initially only during prolonged droughts. With development in the district, however, more continuous pumping might be required for adequacy of supply. The pipeline length is 45 km and a 12 inch pipe reducing to 10 inch diameter half way to Engela is indicated (Ref 10). From Engela smaller branch pipes would be taken to various parts of the complex. Other branches along the route would be laid for emergency supplies to rural storage works (Map 10).

Piped supplies could be taken from the eastern canal to stockwatering points along the route. A limiting distance of 10 km is suggested. The present 10 inch pipeline between Oshakati and Ondangua will serve for a long period. However, extension of a branch pipe system into the less-watered eastern area is desirable to allow occupation on a more intensive scale.

Because the region south of the Oshana Etaka lacks adequate runoff for high density settlement, a comprehensive system of piped supplies drawing water from the Etaka Canal extension is contemplated for this area. Other pumping points could be established on Lake Oponono with pipelines radiating to the east.

The various works proposed would then create a zone of permanent supply as depicted on Map 10, covering an area of approximately 1 000 000 hectare.

8.13 Purification Works

For domestic supplies at storage dams serving the rural areas the use of simple filters and handpumps will be adequate in the early stages. Conversion to slow sand filtration works may be justified later.

In the case of developing communities more sophisticated purification works will be required from the start. The output capacity and nature of the works would be geared to the individual requirements, possibly with stage construction to meet demand as it grows. A typical installation would have sedimentation, followed by filtration and chlorination, with low and high level storage of purified water.

CHAPTER 9

COSTS AND PHASED IMPLEMENTATION

Although certain works and proposals have been designed in sufficient detail to allow realistic estimates of costs to be made, other features are yet in the preliminary planning stage and costs are necessarily very approximate. As far as possible known costs for past construction have been applied after suitable adjustment. However, with future price trends uncertain, all values represent the estimated present-day (1968) costs. Because of the globular nature of the estimate, refinement is not attempted and round figures are used.

The planning suggested in the present report covers a period of 20 years which is regarded as a reasonable requirement for development of the facilities concerned and can also be associated with the foreseeable population growth. Four phases each of 5-years duration are considered, which if taken as starting in 1970 would allow implementation of the whole by 1990. The suggestions made should be regarded as tentative and the actual implementation would require to be adjusted to the rate of expansion of other services and the actual settlement of the land in the case of development of uninhabited areas, as well as in the light of circumstances prevailing at different stages.

A complete setting out of costs and phasing is given in Table II (at the end of the chapter). The order followed for the works is that adopted in Chapter 8 but this is not significant in regard to priority. The table also indicates a tentative subdivision of cost responsibility between the S.W.A. Administration (Water Affairs Branch) and the Department of Bantu Administration and Development. As mentioned in Chapter 8, the Water Affairs Branch is to bear financial responsibility for works of a national character such as the canal from the border to the Olushandja and it was further assumed that this responsibility would extend to works or portions thereof designed for domestic water supply. The balance would be to the account of the Department of Bantu Administration and Development. The distribution of cost as shown is necessarily approximate, to be adjusted in more real terms as the planning of each feature proceeds.

9.1 Borehole Drilling

As shown in Chapter 8 complete coverage of the outlying sandy area with boreholes on an eventual pattern spacing of 7 km would require the drilling of 786 holes with the anticipation of obtaining 550 successful boreholes having a yield

Distinction is made between the western and eastern areas both for costing and the anticipated success of drilling. The former area will in general require holes about 50 m deep on the average and past drilling has been carried out at a cost of R 2000. In the eastern area the required depth may be 150 m and the cost rises to about R 4000 on the average.

The total expenditure envisaged for drilling is R 2 400 000. To this must be added the cost of equipping each successful borehole with casing, wind and standby diesel pumps, reservoirs and drinking troughs, assessed at R 2500 per borehole and R 1 400 000 in total, resulting in an overall cost of R 3 800 000. The phasing allows for a gradual rise in tempo as shown in Table II.

9.2 Excavation and Pump Storage Dam Construction

The indications are that some 300 new dams will be required, of which 100 would be restricted to the shallow type in the southern district and 200 could possibly be developed to the full pump storage stage. The respective costs are estimated at R 6000 and R 25 000, resulting in an expenditure of R 5 600 000. In addition provision is to be made for completion of some 60 of the existing dams to the pump storage stage inclusive of small filter units at an anticipated cost of R 400 000 (10). These improvements would be carried out in the first phase when say 100 new dams would also be completed to the simple excavated stage. In succeeding phases these works would be extended to pump storage units and other excavation dams built with a fairly even expenditure spread over the 20 year period. A 15% allocation to domestic water supply works was adopted.

9.3 Well and Cistern Extension

In Phase 1 the improvements to existing small water sources for schools and clinics and construction of 35 new cisterns would cost about R 50 000. Similar expenditure is envisaged in each succeeding phase for putting down new wells and cisterns in line with development of rural services of this nature.

9.4 Mahanene-Olushandja Canal

The cost of the canal from the border to the Oshana Olushandja inclusive of the siphon crossing is estimated at R 920 000 (Ref 4b). This section is scheduled for construction immediately final approval is received for the Calueque Pumping Scheme. The cost is to be borne in full by the Water Affairs Branch.

9.5 Olushandja Balancing Dam

Subject to more detailed planning when full topographical surveys are available and the necessary site explorations have been conducted, the cost of the necessary embankment in the Olushandja and auxiliary works and controls at the Etaka divide is estimated at R 200 000. It is required that the balancing dam construction be carried out in Phase 1, possibly incorporated in the above canal contract, so that the full benefit can be realised from the start. The dam is regarded as part of the State Water Scheme and the cost is allocated to Water Affairs.

9.6 Olushandja-Ombalantu Canal

As described in Section 8.8 the immediate continuation of the canal through to Ombalantu so as to allow conveyance of Cunene river water into the existing canal is fully justified bearing in mind both expansion of demand and the need to provide security in water supply services. For phasing purposes in Table II, it has been assumed that concrete lining of the invert is omitted for the time being, resulting in an initial cost of R 1 380 000 and R 300 000 being spent in Phase 3 to complete the lining. However, the policy in this regard has yet to be formulated depending on financial exigencies at the commencement of construction.

9.7 Improvement of Standard of Existing Oshakati Canal

Pending detailed surveys and design, the cost of immediate fencing of the canal, provision of further access bridges and the reconstruction of Oshana crossings to the standard required for operation with Cunene river water is estimated at R 200 000. This work should be carried out as part of the contract for canal extension to Ombalantu.

Lining of the canal throughout (R 2 000 000) is conveniently phased in the three sections at the following approximate cost, inclusive of a further allowance of R 200 000 for additional control sluices and offtakes along the length of the canal:

Phase 2	Ombalantu-Ombafi	:	R 600 000
Phase 3	Ombafi-Orongo	:	R 400 000
Phase 4	Orongo-Oshakati	:	R 1 200 000

Because protective measures such as fencing are involved, about 20% of these costs have been allocated to the domestic water supply aspect.

9.8 Pilot and Extensive Irrigation

To allow for pilot irrigation at Orongo (or elsewhere) and the supply of pump units for extensive type of irrigation along the main canals, an expenditure of R 500 000 is envisaged in Phase 1 (including experimental station buildings and equipment) and R 100 000 in each succeeding phase (Ref 10, Section 7.6).

9.9 Irrigation Branch Canals and Distribution Layout

The development of 3 000 ha under irrigation is provisionally indicated as taking place after 10 years in the last two phases at the following cost for branch canals and the distribution system including for layout of the plots (assumed at about R 400/ha):

Phase	Branch Canal	Irrigated Area (ha)	Estimated Cost		
			Branches	Layout	Total
3	Onanime 27 km Orupaka 7 km	1300)) 1800 500)	950 000	750 000	1 700 000
4	Ombafi 20 km Orongo 11 km	500)) 1200 700)	550 000	450 000	1 000 000
Total	65 km	3000	1 500 000	1 200 000	2 700 000

Because the branch canals will serve also to carry domestic supplies, 25% of the cost is indicated as being the responsibility of Water Affairs.

9.10 Etaka Canal Connection and Betterments

The 20 km northern link to the bifurcation near Mahanene is estimated to cost R 700 000 and is required in Phase 2 to permit effective use of the Etaka canal. This link is regarded as forming part of the State Water Scheme.

Betterments to the existing canal as detailed in Section 8.10 would require an approximate expenditure of R 2 500 000 spread over the last three phases at a slightly rising rate. This allows for a rather higher lining requirement (95%) than the Oshakati canal (90%), but a reduced number of oshana crossings. Because the canal carries water southwards, 75% of the cost of betterments has been allocated to Water Affairs.

9.11 Canal Extensions and Collecting Furrows

The extension of the Oshakati canal southward to Lake Oponono for a distance tially of a furrow, with a restricted number of access bridges and control structures. A cost of the order of R 100 000 is anticipated and the work is tentatively placed in Phase 1. This canal extension is essentially for agricultural purposes and the cost is allocated accordingly.

Extension of the Etaka canal over 75 km will probably require to be of a higher standard, partly because of the nature of the terrain traversed but more particularly in view of the anticipated future use for pumping to the southern grassflats. The extension, estimated to cost R 300 000, is divided evenly between Phases 3 and 4, two-thirds of the financial responsibility being borne by Water Affairs.

A project assuming some urgency is to provide greater security for supplies in the northern area around Oshikango, for which a flood water collecting canal about 50 km long is being planned. Similar in concept to the existing Oshakati canal, the project is estimated to cost R 500 000, of which R 200 000 is provided under Phase 1 and the balance in Phase 2. The expenditure is split evenly between the two authorities.

In hand with the construction of excavation dams in the central oshana region, a number of diversion furrows will be required. Of similar character will be the drainage trenches down the oshanas leading water from the eastern canal southwards. At this stage a total length of about 400 km is envisaged. The approximate cost of R 400 000 is evenly divided over the four phases and is allocated as shown in Table II.

9.12 Pipeline Construction

The 45 km pipeline for emergency supplies to the Oshikango complex is set down provisionally for Phase 3 and is estimated to cost R 500 000, inclusive of pumping plant.

Branch pipelines from Engela and from Ondangua, as well as the piped supplies from the canals to stockwatering points, are assessed at requiring some 330 km of small diameter pipe at a cost of R 1 800 000 inclusive of low-head pump units. It is proposed that this expenditure be spread evenly over the last three phases.

9.13 Purification Works Cost

Envisaging an eventual urban water demand of 10 Mm^3/a in a number of small plants (Section 7.3) the necessary purification works, inclusive of the new Oshakati Scheme, are estimated to cost R 1 850 000. This is phased for an initial spurt and thereafter on a rising scale over the 20 year period in which the demand is expected to grow progressively.

9.14 Total Expenditure on the Water Plan

The above enumerated costs, the phasing and the division of financial responsibility for comprehensive water services throughout Ovamboland are summarised in Table II. In the final item allowance is made for administration and engineering costs of the order of 10%, bringing the total expenditure on the master plan for water development to R 30 million as a round sum. The expenditure per 5-year phase is indicated as about R 7 million for the first two phases increasing to R 8 million for the last two phases. Annual expenditure would vary between one and two million Rand depending on the particular schemes being tackled and this is considered to be acceptable from the point of view of administering and executing the work. The financial responsibility per phase and in total on the tentative division indicated is close on one-third for the Water Affairs Branch of the S.W.A. Administration and two-thirds for the Department of Bantu Administration and Development.

The expenditure per phase is compatible with the previous amount of R 6 million for water services out of a total of R 30 million for all services envisaged in the 5-year plan (Ref 11, p. 193). Water services are essential to the infrastructure that will have to be created for self-development of Ovamboland. "Economic activities must be brought to the Homelands as far as possible and must where necessary be supplemented by capital expenditure in the development of basic resources".

CHAPTER 10

REVIEW

The ultimate development of Ovamboland to a self-supporting economy is dependent on many factors but the provision of water services in sufficient quantity and security is of paramount importance. Dependable supplies are the only means of bringing about production on a sustained basis in all sectors of the economy.

The extremely flat terrain originating from the delta feeding the Etosha Pan and as disturbed by aeolian movement of the sands, has only a residual of ill-defined water courses known as oshanas. Rainfall, although high for South West Africa, is by other standards very moderate and temperatures are high. The oshanas supplied by floods in Angola carry water only for a restricted period during the year and are frequently without water when droughts occur. Soils are generally sandy and saline in character over most of the alluvial plain which has a shallow water table. Loam soils occur in isolated patches on the ridges separating the numerous oshanas in the delta zone and these provide the only arable cultivation, restricted to a mere 3% of the total land. Other soils are suitable only for stockfarming which is widely practised but largely as a measure of wealth rather than production. Due essentially to lack of water supplies, only about one-third of the land is now inhabited.

The present population numbers about 280 000 of whom some 30 000 are resident outside of Ovamboland. Based on past growth rate, the population by 1990 could attain 450 000. Urban development is in its infancy. Agricultural expansion has definite limits because of the natural environment. Surveys have indicated that, even with provision of full water supplies in areas lacking surface runoff such as in the present uninhabited east and west, no more than about 100 000 hectare can be cultivated continuously, while for a reasonable return the livestock should be limited to some 600 000 large stock units. The corresponding supportable rural population is deemed to be 250 000 at an income standard which is relatively low but still compatible with the development of the community. The prospect is that for self-sufficiency roughly 200 000 Ovambos will need to be engaged in the exchange sector. It can be envisaged that about half might be gainfully employed outside Ovamboland and support a number of dependants, but a future urban population of 50 000 engaged in industry or commerce seems indicated. Thus the secondary and tertiary sectors will need to be stimulated and this will create a further demand for water as well as farm produce.

The prospects for irrigation development have been investigated in fair detail, particularly in the alluvial plain. While many of the soils have a certain potential, the majority would be difficult to work and must be disregarded in any initial consideration. Selected loamy soils and other marginal but acceptable material is limited in occurrence at convenient locations in the central zone to some 3 000 hectare and can be proposed for initial development. Larger areas of suitable soil are known to be present in the western zonebut these should perhaps be reserved for later exploitation.

Early water requirements were obtained from the oshanas and from waterholes as the surface supplies diminished. Wells were dug but were primitive. The water supply problem, accentuated by the growing population and creation of urban communities with various organised services, has been tackled in earnest from 1954. Excavation of dams to create storage in the oshanas was found to be a useful solution, particularly when designed to last over a period of prolonged drought. Evaporation being a problem, the use of pump storage works was initiated and furrows were dug to divert more water as it was needed. However, even in normal years it is a feature that certain oshanas do not flow while others subject to local storms carry appreciable amounts of water. Thus, the principle of a flood water collecting canal was applied, starting from the main centre at Oshakati proceeding westwards as far as Ombalantu, and this proved of immense benefit in providing a measure of security. A second canal of similar concept was constructed along the Oshana Etaka with a view to development in the west. Pipelines have been used for supplementing supplies in certain areas such as Ondangua and filtration works were constructed for purifying domestic water. In the vast sandy areas west and east of the alluvial plain, surface supplies are almost non-existent and dependence is essentially on boreholes which have been moderately successful.

The works so far have been largely of an ad hoc nature attempting to meet the various demands as they arose. Many of the existing water supplies are already approaching full utilisation. Moreover, despite the success in improving local supplies, the fact remains that surface runoff is unreliable in the extreme. Permanency and adequacy of source cannot be assured. For this it will be necessary to look to the Cunene river as a source of water — a promise held from 1926 as a result of an Agreement with Portugal on the use of these waters. This could guarantee supplies to man and beast as well as initial irrigation. The principle of pumping from Calueque across the border in Angolan territory was accepted in 1964 and final approval of the detailed scheme is imminent. At the present juncture it is expedient to consider what form the master plan for water development in Ovamboland should take. Much investigational work has been undertaken and various proposals formulated.

Future water requirements have been assessed on the basis that there is a need for full exploitation of the whole area. From the various surveys of soils and vegetation, specific zones were demarcated regarding the use of the land for extensive ranching and mixed arable and stockfarming. Applying agro-ecological studies, the desirable cattle and human occupation of the land was fixed and using appropriate water needs it was determined that the future rural demand could be 21 million cubic metres per annum. Domestic demand in urban areas could amount to 10 Mm^3/a and initial irrigation of 3000 hectare would require 54 Mm^3/a. In total the water needs would be 85 Mm^3/a and if further irrigation in the western zone is contemplated in the more distant future the eventual consumption could rise to 220 Mm^3/a.

The plan for meeting the above needs with the exception of future irrigation can be divided in two main forms. The first consists of developing local sources to their utmost. For the western and eastern zones where underground supplies are reasonable a complete coverage of boreholes is contemplated. If patterned on the basis of optimum area served, some 550 new successful boreholes would be needed which would probably require nearly 800 actual drillings allowing for failures. The storage provided by excavated dams to trap surface runoff could be expanded in the central zone and some 300 new dams are proposed for rural development, along with a number of wells and cisterns to serve remote schools and clinics.

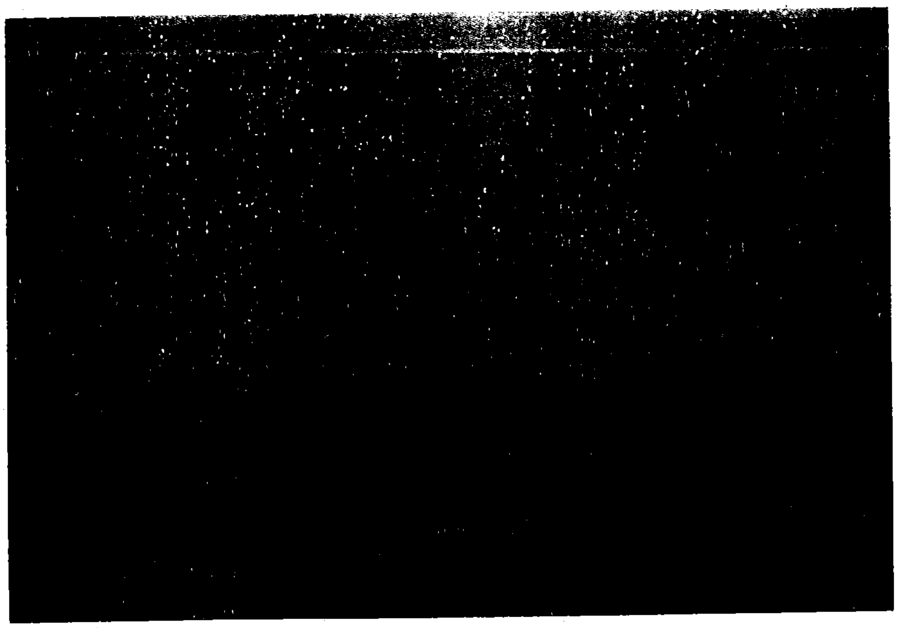
The second form of development is based on bringing in and distributing Cunene river water. The scheme with its various components will cover the heart of Ovamboland and provide security to existing and future local sources in times of drought as well as adequacy for expansion as contemplated. From Calueque in Angola the water will be pumped at a maximum rate of 6 cubic metres per second into a canal which after crossing the border near Mahanene would turn eastward and cross the northern continuation of the Oshana Etaka known as the Olushandja. At this point a balancing storage dam would be created by closing off the Olushandja just south of the border so as to permit surplus water to be released down the Etaka, eventually to reach the Etosha Pan in such quantities as can be utilised. From the Olushandja crossing the canal would continue and connect up with the existing canal at Ombalantu, thus allowing conveyance of water through to Oshakati. Along the way branch canals would take off to serve irrigation in the western section where the soils have been found to be suitable. Detailed analysis has revealed that a canal is more economic than a pipeline with its pumping requirements, even if irrigation is deferred for many years. In the meantime the canal has other benefits and any detractions can be guarded against.

From a bifurcation near Mahanene a link canal would be constructed to connect up the existing Etaka canal and thus provide a second artery having permanent water. Both existing canals would in the course of time be brought up to full standard and also extended into the south-eastern section to feed Lake Oponono, the intermediate terminal of the oshana system before spilling over into the Etosha Pan. The furrow system would be extended wherever it is practical to carry water down the oshanas or to divert the flow so as to widen the zone of supply. From both main canals it is envisaged that piped supplies will radiate out to serve the more sparsely-watered zones. One such pipeline would be taken towards Oshikango on the northern border. Others would supply the southern grass flats which at present can be grazed only very intermittently in exceptionally wet years. To supplement existing domestic water supply plant, new purification works would be constructed as needed in the various urban centres.

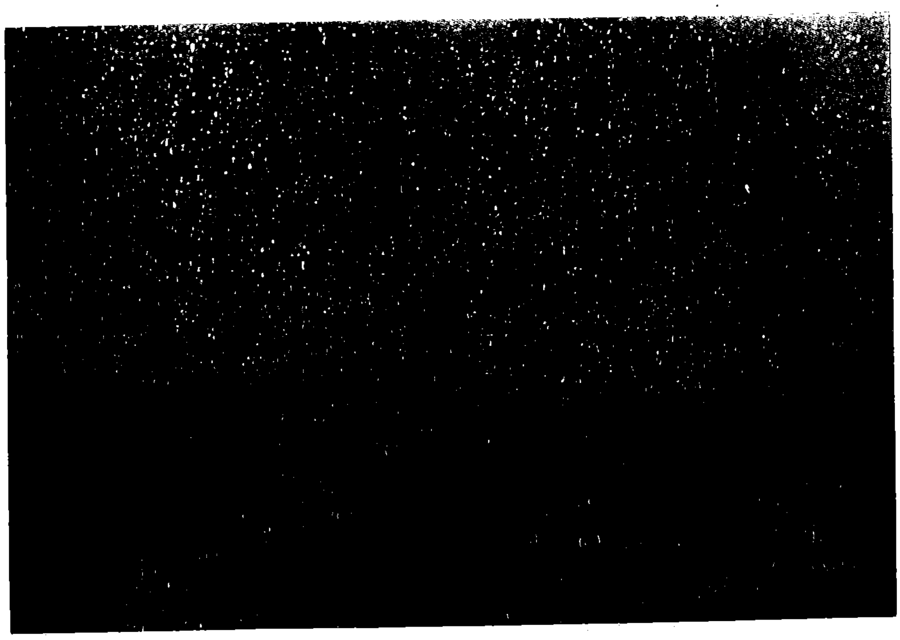
The scheme in its numerous components taken as a whole is estimated to cost R 30 million. The plan provides for the complete development of water supplies in Ovamboland with the exception of future irrigation which would be possible only if an increase in the authorised pumping rate from the Cunene is negotiated. It appears reasonable to consider implementation of the plan over a period of 20 years, corresponding to the anticipated population growth with which it is associated. A programme of phased construction is suggested (Table II) which allows roughly even expenditure in each 5-year period.

<u>DIRECTOR OF WATER AFFAIRS.</u>

OSHANA COUNTRY

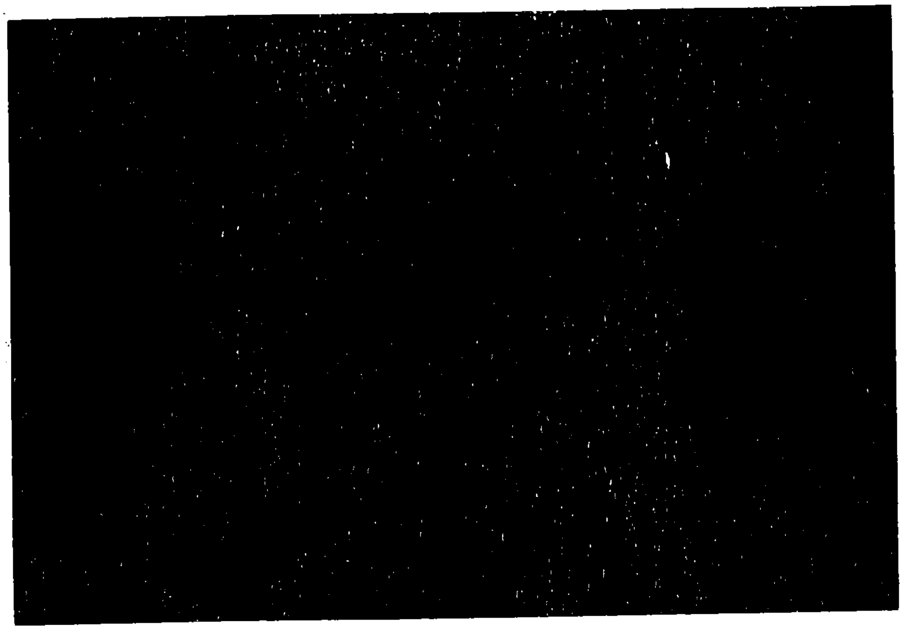


Minor oshanas and basins
with cultivation on elevated land

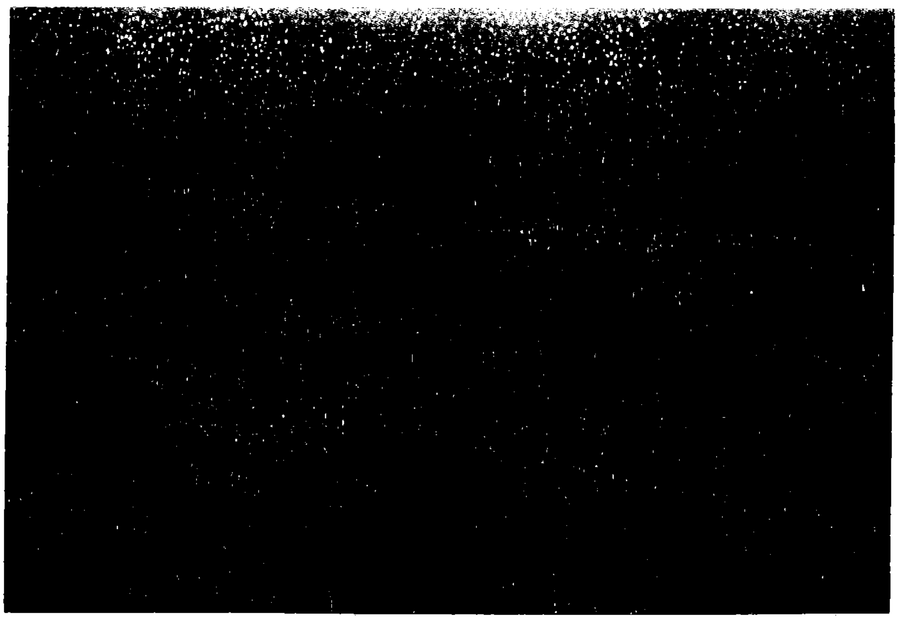


Defined water courses, spilling over
during seasons for normal rainfall

WATER FOR GATHERING

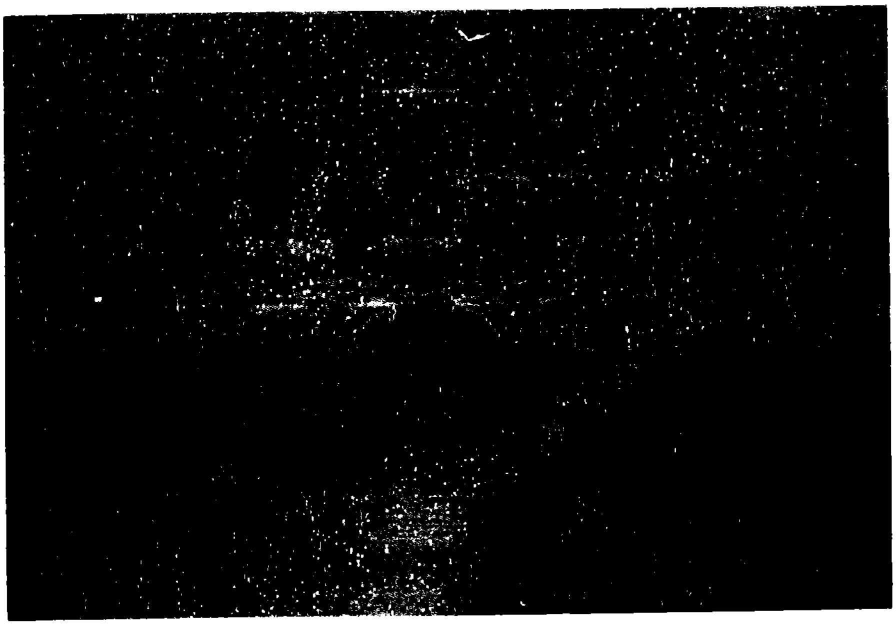


The "efundja"
Causeway crossing of oshana

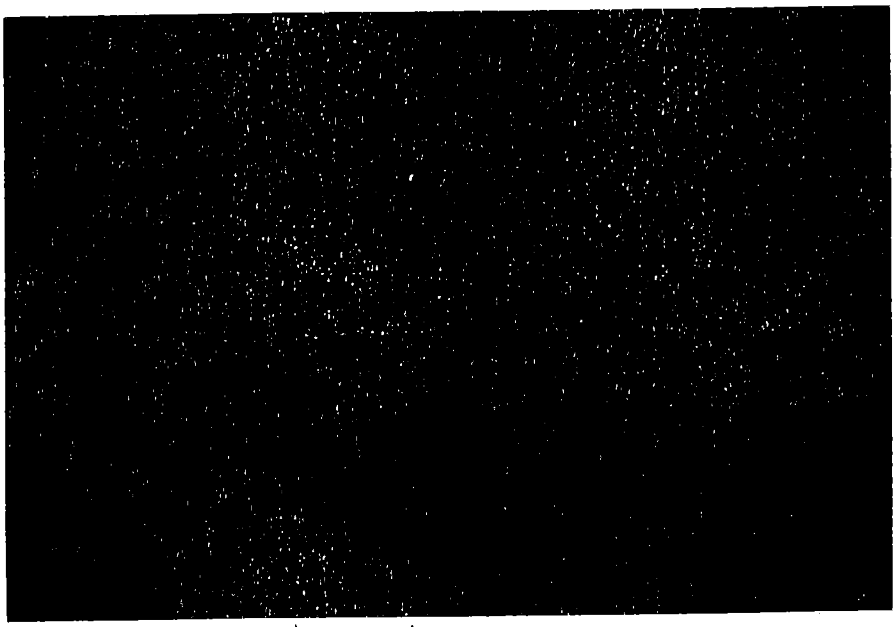


Otshikuku
Floodwater collecting canal between road and secondary oshana in background

OSHAKATI CANAL
The Flood Water Collector



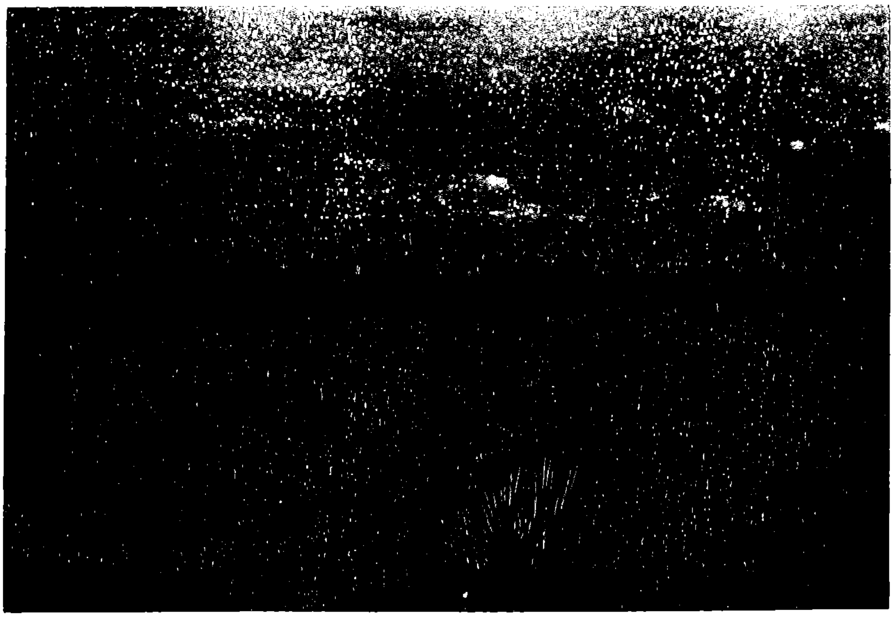
Unlined canal excavation near Oshakati (looking West) carrying flood water (showing also the maintenance problems)



Lined canal near Ombalantu (looking East)
Collected water held in storage

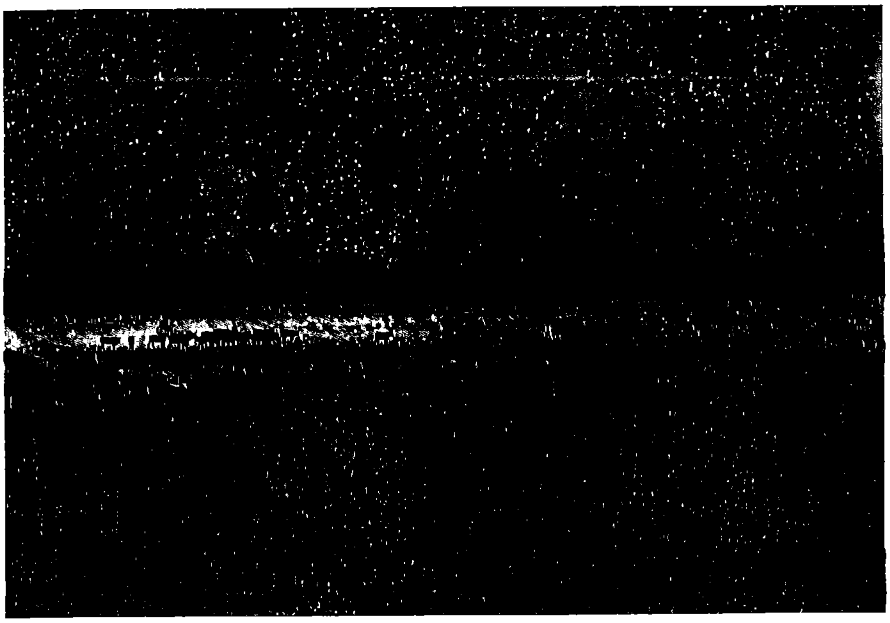
WATER HARVEST

Oshakati Pump Storage Complex
Pump sump in foreground, with pump station (red roof) supplying round dam ($250\ 000m^3$) and two rectangular pump storage dams ($160\ 000m^3$) – left one protected against evaporation by floating plates

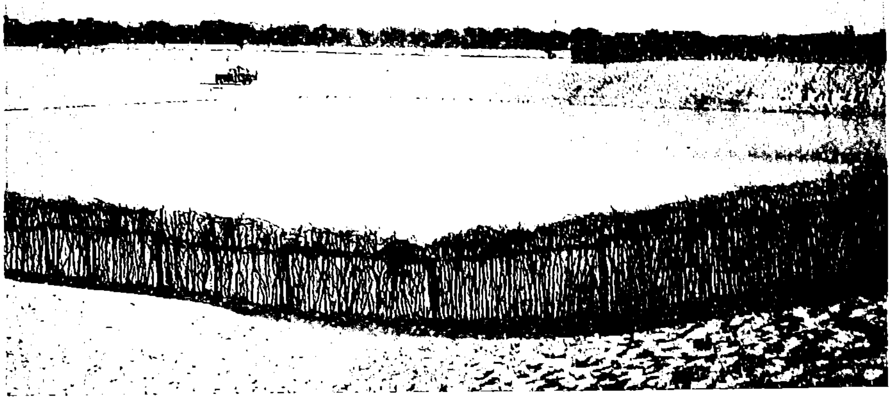


Pump storage dam at Ondangua ($70\ 000m^3$)

EXCAVATION DAMS

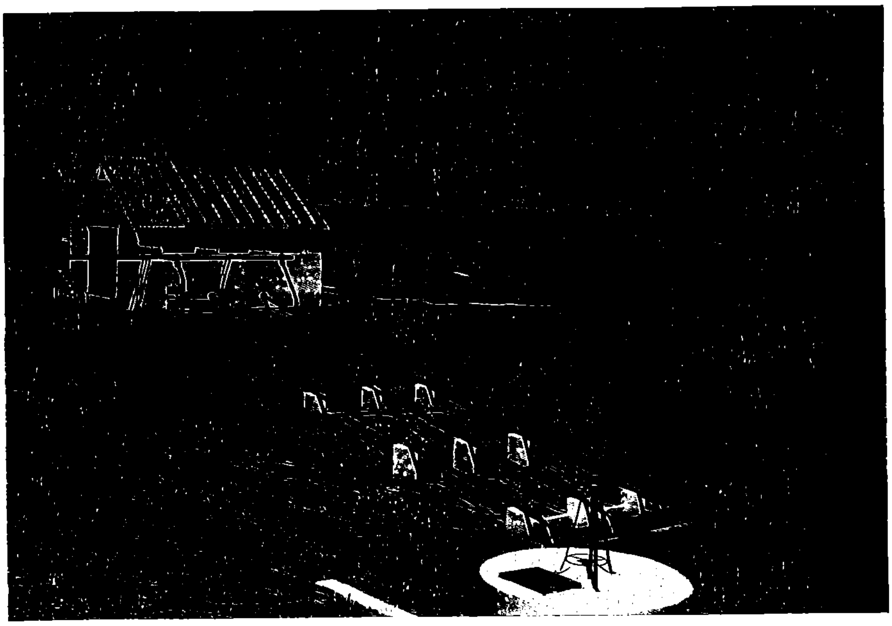


Simple excavation for stockwatering

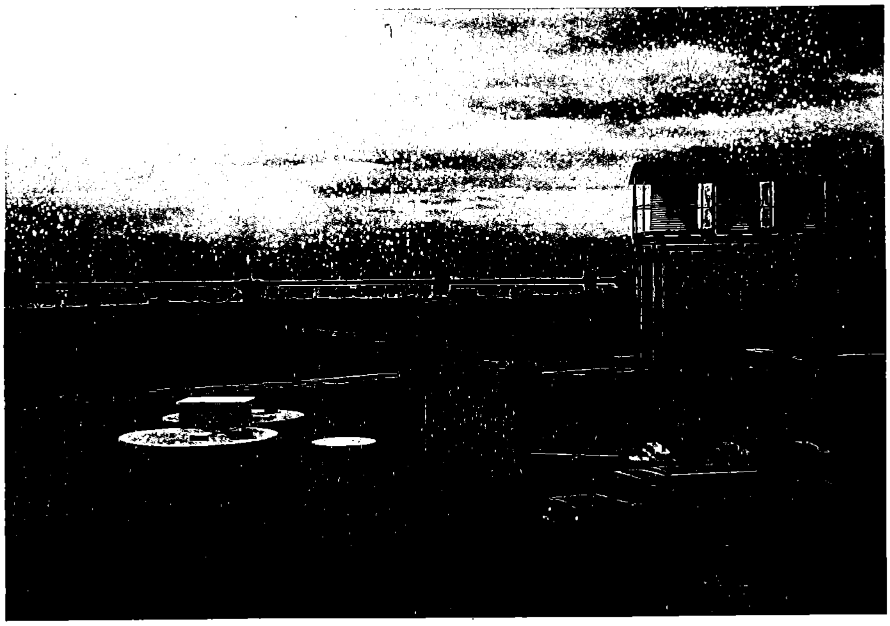


Stage 1 excavation open to oshana on one side and banks protected by stockade

IMPROVED SUPPLIES

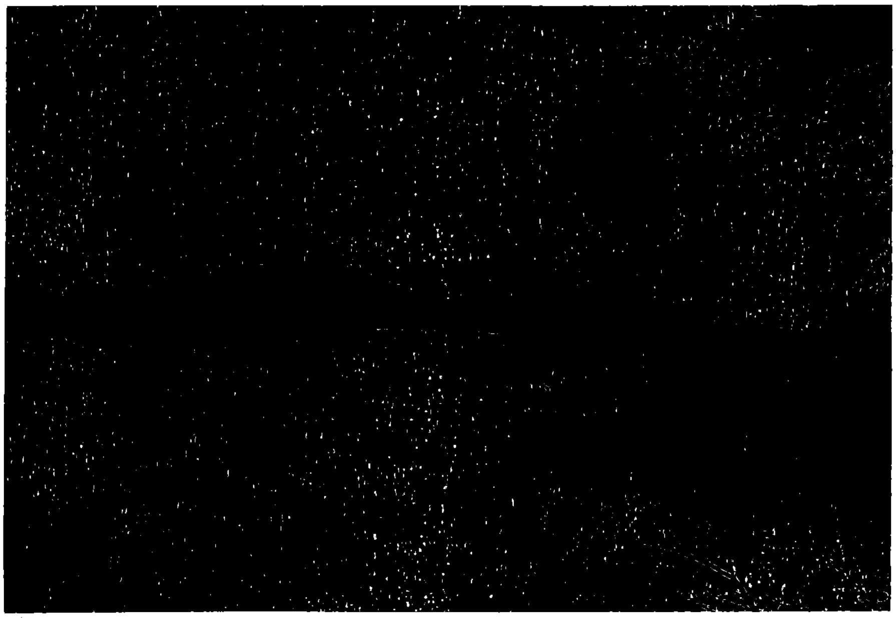


Pump station at Oshakati (see P.4)
drawing water from sump (early stage)

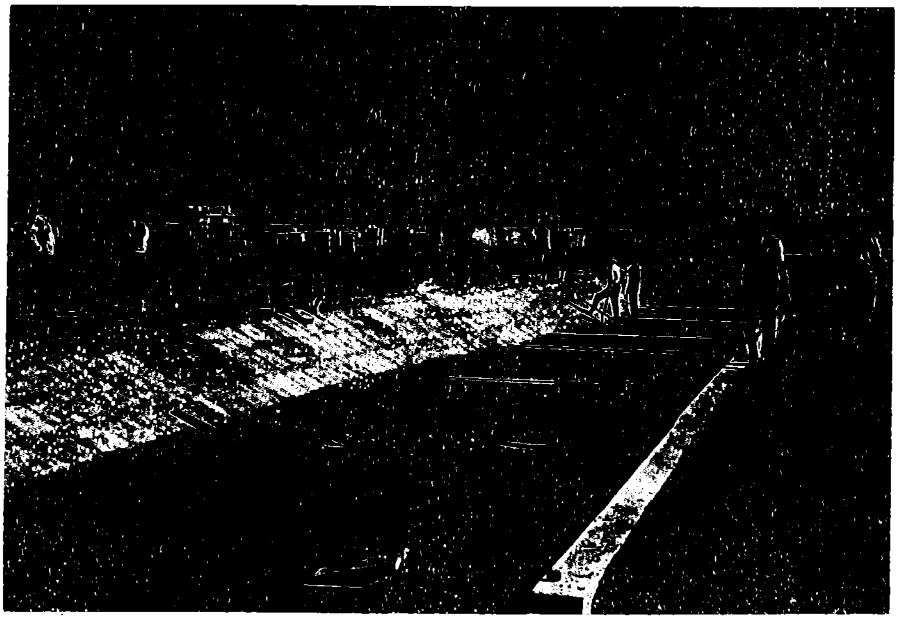


Purification works at Orongo with elevated water tower
(Nakangali in background – taken from bank of pump storage dam)

FUTURE PERMANENT SUPPLIES



Cunene River at Calueque
The site for pumping – Eriksonsdrift in background



Water Artery
Etaka Canal near Tshandi
Fully lined section of canal using precast units