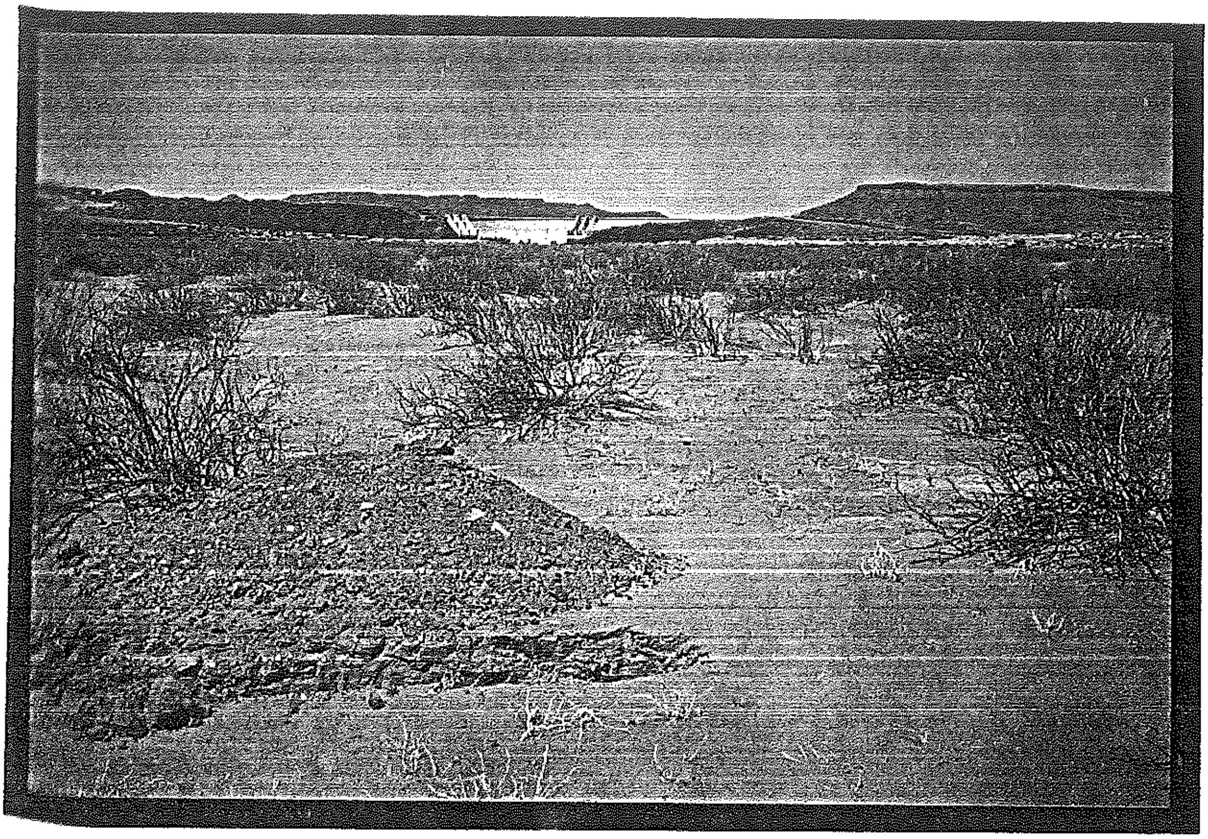
REPORT ON A SOIL SURVEY IN AREAS WHICH COULD BE IRRIGATED FROM THE PROPOSED NECKARTAL DAM ON THE FISH RIVER

VOLUME I.

Text and diagrams

JUNE 1987



FRONTISPIECE: View of the Naute Dam with, in the foreground, one of the test pits excavated in the course of the soil survey for proposed pilot irrigation area A.

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1. TERMS OF REFERENCE

In terms of a letter Reference 13/11/2/64 of 5th January 1987, T.C. Partridge, Consultant in the Earth Sciences, was appointed by the Secretary of Water Affairs of South West Africa to undertake a soil survey in areas which could be irrigated from the proposed Neckartal Dam on the Fish River. Detailed terms of reference for this work were contained in Appendix "B" of the Memorandum of Agreement drawn up in connection with this survey, and the salient requirements are summarized below:

(a) The preparation of soil maps of some 5000 ha comprising the larger blocks of potentially irrigable soil identified in the course of a reconnaissance survey of the area carried out in 1968. A mapping scale of 1:10000 was requested for the entire area.

(b) The identification of an area of some 250 ha downstream of the Naute Dam suitable for development as a pilot scheme. For this area soil maps at 1:2500 scale were requested.

(c) The mapping programme was to comprise interpretation of available aerial photographs of the mapping areas to delineate soil boundaries, the excavation, description and sampling of test pits, and the execution of field tests to determine soil infiltration rates and conductivities.

(d) Laboratory analyses of representative soil samples were to be carried out in order to determine the salient physical and chemical properties of the soils for classification purposes, crop selection and the determination of the most suitable irrigation systems.

(e) Classification of the soils was to be carried out in accordance with the Binomial System of the South African Soil and Irrigation Research Institute, with cross-correlation to classes in the U.S. Department of Soil Conservation Service Taxonomic Soil Classification System. In addition, the soils were to be classified for irrigated agriculture in terms of such factors as rooting depth, slope, texture, structure and internal drainage and the presence of, or susceptibility to the build up of, salinity and alkalinity.

(f) A general assessment of crops suitable for cultivation in the area was to be provided together with recommendations concerning the most appropriate irrigation methods. Irrigation scheduling and the water requirements for the crops selected were to be considered, and an assessment of potential problems likely to be encountered was to be included.

(g) An agroclimatic summary of the area was to be compiled.

The above requirements have, to a very large extent, been met in the present report. The only significant departure from them, which has been made with the approval of senior professional staff of the South West Africa Department of Water Affairs, is in respect of map scales. In view of the scales of the aerial photographs supplied to us by the Department (approximately 1:20 000 for the entire area and approximately 1:7500 for the area downstream of the Naute Dam), and in view of the poor quality of the 1:5000 scale base maps supplied to us for this latter area as well as the incorporation of units from the earlier reconnaissance soil survey on them, it was agreed that the soil survey of the entire area should be presented on 1:20 000 scale enlargements of the available 1:50 000 scale topographic maps of the area, while the more detailed survey for the proposed pilot schemes should be presented on re-draughted portions of the 1:5000 base maps supplied. It should be noted that, although the title blocks supplied by the South West Africa Department of Water Affairs describe the soil survey as "detailed", this in fact applies only to the 1:5000 scale mapping for the pilot areas. The remaining mapping at 1:20 000 scale can be regarded as no more than semi-detailed. The areas mapped at 1:20 000 scale will therefore need to be further investigated prior to the final design of any irrigation scheme in the area. We do not believe, however, that any significant benefit would be achieved by the more detailed mapping of soil types; we suggest, rather, that for layout purposes attention should be directed to the detailed mapping of saline areas for exclusion from the irrigated lands. This is a routine operation and could be undertaken by local technical staff at relatively low cost.

Attention is drawn to the fact that, although a total area of some 250 ha was envisaged for the pilot projects, our investigations have revealed the presence of no more than about 200 ha of readily irrigable soil in the areas selected for detailed investigation, owing to the presence of considerable tracts of saline soil. Should additional land be considered necessary for these pilot schemes a potentially suitable area has been indicated on the relevant maps.

The report has been prepared in three volumes: Volume 1 comprises the text and diagrams, Volume 2 includes the soil profile records and laboratory results, and Volume 3 contains the agroclimatic survey. The maps have not been bound in the report in view of their size and number; they include seven 1:20 000 scale A1 sheets covering the entire survey area and two 1:5000 scale A1 sheets covering the proposed pilot schemes.

2. INFORMATION SUPPLIED

The following information was supplied to us by the South West Africa Department of Water Affairs:

(a) Soil maps produced in the course of a reconnaissance survey carried out in the area in 1968 by Messrs. A.O.C. Technical Services (Pty) Ltd. These maps had originally been presented on airphoto mosaics at a scale of approximately 1:25 000, but the data which they contained had subsequently been transferred to the available 1:50 000 scale topographic maps of the area.

(b) Seven photogrammetric contour maps of the southern portion of the survey area, at 1:5000 scale and with a contour interval of 1,0 metre, prepared by the Air Survey Company of South West Africa (Pty) Ltd. The material supplied to us comprised poor quality prints and sepia transparencies which incorporated the soil boundaries of the reconnaissance survey referred to in (a) above. We understand that the originals of these sheets are unavailable.

(c) Three sets of aerial photographs providing stereoscopic cover over different parts of the area. Those covering the northern part of the area comprised prints from Job 505 flown in November and December 1962 at a nominal scale of 1:36 000, enlarged to an approximate scale of 1:20 000. These photographs were generally of poor contrast and quality. Coverage of the remainder of the area comprised photography flown on special contract by Messrs. Aircraft Operating Company (Pty) Ltd. during March and April 1967 at nominal scales of 1:20 000 and 1:7500. The quality of this photography was considerably better than that provided for the northern part of the area.

(d) The results of chemical analyses of water samples from the Naute Dam recovered during the early part of 1987.

(e) General notes on the proposed Neckartal Dam and irrigation scheme prepared by members of staff of the South West Africa Department of Water Affairs.

Since these notes provide a useful introduction to the main proposals encompassed in the Neckartal Project, they are reproduced in full below.

"The Neckertal Dam Development is situated in the southern part of South West Africa/Namibia, to the west of Keetmanshoop. The dam site itself is on the Fish River located in Namaland immediately north of the farm Neckertal. The project lands for irrigation purposes, are located some forty kilometres south of the dam, downstream of the Naute Dam on the Lowen River and also east of Seeheim on the Schaap River.

The Neckertal Dam site has been known since the German colonial period as a potential site. During the planning of the Naute Dam the possibility of building the Neckertal Dam as a second phase specifically to supply additional water for irrigation was investigated.

However, although some physical investigations were carried out, a lack of funds prevented work going ahead and so the project was shelved. Then in 1983 a request was received from the City Council of Keetmanshoop to once again look into the Neckertal Dam and its feasibility. The present work is a result of that initial enquiry and certain other discussions with interested parties that have been held since then.

The purpose of the Neckertal Dam Development would primarily be to stimulate an irrigation development project in the Keetmanshoop District. The dam could also be used and developed to provide tourist facilities in the area. However other uses for the water are unlikely, domestic demand at Keetmanshoop is adequately catered for by the Naute Dam and industrial or mining development are remote possibilities.

The project as a whole, if realised, would consist of a dam in the Fish River, either a concrete buttress or rockfill structure, a canal or pipeline from the dam to the project lands and a water distribution system at the project lands."

It should be noted that the survey area has been specified so as to include lands no further away from the proposed Neckartal Dam than 50 km.

3. LOCATION

The area within which the present soil survey was carried out comprises some 850 km^2 located some 40 km to the south west of Keetmanshoop in southern South West Africa. The railway junction of Seeheim is situated within it, close to its western boundary. In terms of geographical co-ordinates the area lies between 26°45' and 27°05' south latitude, and 17°45' and 18°00' east longitude. The relevant 1:50 000 scale topographic sheets are 2617 DD (Seeheim) and 2717 BB (Chamieities).

Previous reconnaissance mapping in this area by Messrs. A.O.C. Technical Services (Pty) Ltd. had revealed the presence of possible irrigable soils, associated chiefly with the lower courses of the Schaap and Löwen rivers. In the case of the Löwen River these soils are located immediately downstream of the Naute Dam. On the basis of these early investigations Messrs. A.O.C. Technical Services identified some 1843 ha of soil which they classified as "recommended" for irrigation, while some 11703 ha were classified as "marginal". The remainder of the survey area was classified as "not recommended". According to members of the staff of the South West Africa Department of Water Affairs no detailed criteria for the identification of these classes were provided.

The present survey was restricted to the more extensive tracts of "recommended" soil identified in the course of this previous work, together with certain areas of "marginal" soil which were considered, on the basis of a preliminary field inspection by ourselves, to be worthy of consideration. In addition, some further unsurveyed areas which appeared, on the basis of preliminary airphoto study and field inspection, to warrant investigation, were included. The mapped areas are contained on the 9 sheets accompanying this report and comprise approximately 17 000 ha, although attention was, of course, focussed on the apparently deeper and more promising soils within these areas which are limited to some 8000 ha.

The area is well served by rail and road links, being traversed by the lines from Keetmanshoop to Luderitz and Seeheim to Grünau, both of which are paralleled by main roads. In addition there are good district roads linking Jurgen Siding with the Naute Dam and the latter with Gawachab Siding.

4. TOPOGRAPHY AND GEOLOGY

The valley of the Fish River and areas to the west of it are underlain by rocks of the Nama Group, which is here represented by the Fish River Subgroup. This consists of a succession of red quartzites and shales, which, in the study area, tend to occur as outcrops along the valley flanks. A few small inliers are, however, present locally elsewhere in the area. The only significant soils associated with these rocks are restricted to the alluvial deposits of the Fish River.

The greater part of the area is underlain by rocks of the Karoo Sequence, chiefly of the Dwyka Formation. These include a thin basal tillite, comprising a consolidated ground moraine, overlain by a glaciomarine boulder mudstone within which lenses of fluviatile conglomerate, quartzite and shale are locally present. Over the greater part of the area these rocks outcrop or are overlain by shallow, stony soils. A deeper cover is, however, present locally, and most of the potentially irrigable soils in the study area overlie these rocks. Beyond the limits of the river floodplains the majority of these soils are of colluvial origin, and the influence of the underlying lithology is seen clearly in the presence of scattered gravels and cobbles within most of the soil profiles, as well as the widespread occurrence of surface deflation residues of gravels, cobbles and boulders on the soil surface. In the absence of a significant vegetation cover this "desert pavement" tends to protect the soil surface from further major loss of fines through wind action; its removal during the course of land preparation works prior to irrigation would, of course, render the areas concerned very much more susceptible to wind erosion, and would necessitate the provision of windbreaks at an early stage in any agricultural development programme.

Because of the widespread effects of deflation and recurrent sheetfloods, the A-horizon of many of the soil profiles has been removed by erosion and replaced by a thin surface wash. In the vicinity of the main river channels, notably those of the Fish, Löwen and Schaap rivers, the process is, however, reversed: here the sandy bedload transported by repeated discharges is redistributed by wind on the surface of the adjacent alluvial soils as a sea of low dunes, each centred on a clump of vegetation. These dunefields have created a local microrelief of the order of 1 - 3m, and this will have to be levelled in the course of land preparation works. The areas concerned are shown in hatching on the soil maps. Levelling operations will, of course, render these areas also subject to wind erosion, and the early provision of windbreaks will again be essential.

Of note is the fact that most rocks of the Karoo Sequence in the study area are gypsiferous and saline; this characteristic is, as would be expected in such an area, reflected in the chemistry of the more susceptible soils.

The eroded remnants of a large dolerite sheet are present in the form of steep sided, bouldery hills present along both the eastern and part of the western margin of the study area. The Naute Dam is located where the Löwen River passes through one such dolerite residual in a steep, narrow gorge. These dolerite massifs are of importance for soil distributions in the area, in that they have served as sources for some of the thicker mantles of colluvial sediments in the area; significant areas of potentially irrigable soil are associated with these colluvial outwash areas.

Elevations within the study area range from 983m in the dolerite hills to the north-east of the Naute Dam to about 670m along the lower course of the Löwen River. However, potentially irrigable soils are generally limited to elevations of between about 800m and 670m, most occurring below the 760m contour. Prevailing gradients within the chief soil areas range from about 3% to approximately 0,5% (average approximately 1%).

The area may be subdivided broadly into the following units:

(i) A mobile dune field in the Schwabental area of the farm Schlangkopf, formed of sand blown from the channel of the Fish River. The highly unstable and mobile nature of these sands renders them unsuitable for cultivation.

(ii) Footslope areas separating the dolerite massifs from the principal drainage lines. These areas are occupied by a series of coalescing alluvial fans (bajadas) of varying age. Depending on the nature of individual catchments within the dolerite massifs, these fans contain varying proportions of dolerite gravels, cobbles and boulders. The more stony have been excluded from the tally of potentially irrigable soils. The older generations of fan deposits have suffered more advanced pedogenesis than the younger, and often display nodular and diffuse calcium carbonate and gypsum crystals in the associated soil profiles; they tend, also, to be saline, and are frequently deeply gullied and eroded. In consequence, the better irrigable soils are usually associated with the younger fan accumulations. Soil thicknesses tend to decrease downslope towards the toe of each fan, which forms the boundary with unit (iii) below.

It should be noted that these low-angle alluvial fans are crossed by a network of ephemeral distributary channels along which episodic floods are channelled from the higher ground. In order to control flooding and to limit possible damage to irrigation areas located on these fans, we believe that provision should be made to intercept, divert or canalize all of the major channels.

(iii) Other footslope and low interfluve areas. With few exceptions these are mantled by shallow, stony soils of low agricultural potential. Rock outcrops are common.

(iv) The lower terraces of major rivers. These occur chiefly along the Schaap and Löwen rivers and include the most extensive tracts of potentially irrigable soil in the mapping area. The soils are generally sandy, reflecting the dominant bedload of the local channels, and low surface dunes are widespread as mentioned previously. Soils belong chiefly to the Dundee Form and sandier series of the Oakleaf Form. Towards the river channels, especially that of the Löwen River, the lower part of the profile usually consists of a gravel layer, which, in a few areas, has been cemented by calcrete and gypsum. This gravel horizon will contribute significantly to the satisfactory drainage of these soils, provided that the necessary network of main drains is excavated across the terraces to dispose of any subsurface flows. Soil thicknesses in these terrace units are generally more than sufficient for the rooting requirements of most crops, profile depths in excess of 2m (and sometimes in excess of 3m) being widespread.

Attention is drawn to the presence of a braided network of ephemeral channels within this low-level terrace. This attests to the passage of repeated floods, and again indicates the need for canalization of the main channels if repeated inundation of irrigated lands along the banks of these rivers is to be avoided.

In general, the soils of the area are immature, both because of its arid climate and the intensity of local erosional processes which has resulted in frequent reworking of the parent material.

Beyond the limits of the alluvial deposits of the major rivers described in (iv) above, the soils belong, almost without exception, to various series of the Oakleaf Form. Red soils are confined almost exclusively to the alluvial fans of the footslope zone occurring in proximity to the road from Naute Dam to Gawachab Station, which parallels the left bank of the Löwen River. This colouration is attributable to the presence of a continuous dolerite ridge upslope of the soils in question; these soils themselves are generally more mature than those typical of footslope environments elsewhere in the area.

5. FIELD INVESTIGATION

For the present investigation the area mapped at a reconnaissance level by Messrs. AOC Technical Services was extended to include all of the more promising soil occurrences on 1:50 000 map sheet 2617 DD and within the area covered by the specially commissioned 1:20 000 scale photography on sheet 2717 BB. These extensions resulted in the inclusion of several soil occurrences beyond the limits of the original reconnaissance mapping. As has already been indicated, attention was confined largely to areas which, on available evidence, appeared to have a reasonably deep soil cover; intervening areas of shallow stoney soils were excluded from the pitting programme on the basis of the available mapping and examination of the aerial photographs, together with a preliminary field inspection.

The test pit positions were selected in relation to the varying complexity of soil distributions within the area; average intervals ranged from 1 pit per 4 ha (in the pilot areas) to approximately 1 pit per 50 ha in the more extensive blocks of soil. A total of 207 test pits were sunk at the positions shown on the accompanying soil maps. It should be noted that this total excludes 5 pits which could not be dug, chiefly as a result of difficulties of access. The pits that were not dug are 75, 76, 77, 125 and 126, and their positions have not been shown on the maps.

The test pits were excavated using a tractor-mounted backhoe supplied by the South West Africa Department of Water Affairs from their depot at Keetmanshoop. Wherever possible the pits were excavated to depths in excess of 2m, but a few were shallower where refusal occurred on bedrock. The pits were then profiled in accordance with standard pedological procedure, and the diagnostic soil horizons as defined in the South African

Binomial Classification (1977) were identified and described. The resulting soil profile record sheets are included in Volume 2 of this report.

The data from the test pits were augmented by extensive checking of natural exposures and surficial changes.

Representative samples were recovered from selected pits for mechanical and chemical analysis. In all, 87 such samples were taken for full analysis, comprising particle size distribution, pH, exchangeable cations of calcium, magnesium, potassium and sodium, cation exchange capacity and the electrical resistivity of the soil paste. Of these, 22 which showed signs of potential salinity were analyzed for conductivity and the sodium content of the saturated paste extract. In addition, 16 of the topsoil samples were analyzed for zinc and available phosphorus. In order to provide an assessment of the distribution of saline and potentially saline soils, additional samples were taken from at least one soil horizon in most of the test pits which contained potentially irrigable soils, but which had not been sampled for full analysis; 229 such samples were analyzed for pH and resistance of the paste. Since the nature of the salinity was adjudged to be of importance in crop selection and the planning of possible palliative measures, eight of the more saline samples taken from two groups of test pits were combined geographically into two sets of extracts whose cation and anion contents were determined. All of these analytical results are incorporated in the soil profile record sheets or in separate tables in Volume 2 of this report.

Following the fieldwork and the laboratory analyses, the airphotos were re-interpreted to subdivide and refine the initial soil units. It must be pointed out that, while the units delineated on the map are dominated by a single soil series or the association of a limited range of series, localized occurrences or other, unrecorded series may be present. Investigations to the level of detail required to identify such local variations were not possible within the budget available for this work; however, such localized variations in soil type are unlikely to have a significant bearing on the selection of irrigation units. Much more important are possible localized areas of salinity which may not have been fully revealed in the present semi-detailed mapping programme. It should be noted that the further field investigations necessary to delineate such saline areas could be undertaken by soil technicians at modest additional cost.

The field investigations for this survey were carried out by Professor T.C. Partridge, Dr. R.R. Maud and Mr. R. Stadman.

6. SOILS

Eighteen soil series belonging to six forms were identified in the survey area; these are described below in the order in which they appear in the Binomial Soil Classification for South Africa (1977) established by the Soil and Irrigation Research Institute of the Department of Agricultural Technical Services. These series are listed in the legends to the accompanying soil maps, on which are also indicated ranges of clay content and the presence or otherwise of calcium carbonate in the topsoil and subsoil horizons.

Table 6.1 provides a cross-correlation of these soils between the South African Binomial Soil Classification System (1977), the U.S. Department of Agriculture Soil Conservation Service Taxonomic Soil Classification System (1975) and the FAO-UNESCO Soil Classification System (1974).

TABLE 6.1

CORRELATION OF SOIL CLASSIFICATION

S.A.			U.S.D.A.	FAO-UNESCO
Form	Series	Code		
Hutton	Shigalo	Hu-46	Lithic Calciorthid	Calcic Yermosol
Oakleaf	Pollock	Oa-15	Typic Haplargid	Luvic Yermosol
Oakleaf	Hazelwood	Oa-25	Typic Haplargid	Calcic Yermosol
Oakleaf	Letaba	Oa-26	Typic Haplargid and Typic Natrargid	Calcic Yermosol/ Gypsic Yermosol
Oakleaf	Oakleaf	Oa-30	Typic Torripsamment	Luvic Arenosol
Oakleaf	Vaalriver	Oa-33	Typic Haplargid	Luvic Yermosol
Oakleaf	Levubu	Oa-34	Typic Haplargid	Luvic Hermosol
Oakleaf	Venda	Oa-35	Typic Haplargid	Luvic Hermosol
Oakleaf	Jozini	Oa-36	Typic Haplargid and Typic Natrargid	Luvic Hermosol
Oakleaf	Allanridge	Oa-43	Typic Haplargid and Typic Natrargid	Calcic Yermosol
Oakleaf	Okavango	Oa-44	Typic Haplargid and Typic Natrargid	Calcic/Gypsic Yermosols
Oakleaf	Calueque	Oa-45	Typic Haplargid and Typic Natrargid	Calcic/Gypsic Yermosol
Oakleaf	Limpopo	Oa-46	Typic Haplargid and Typic Natrargid	Calcic/Gypsic Yermosol

S.A.			U.S.D.A.	FAO-UNESCO
Form	Series	Code		
Fernwood	Langebaan	Fw-21	Typic Torripsamment	Eutric Regosol
Dundee	Dundee	Du-10	Typic Torrifluvent	Eutric/Calcaric Fluvisols
Glenrosa	Lomondo	Gs-25	Lithic Calciorthid	Calcic Yermosol
Mispah	Mispah	Ms-10	Lithic Camborthid	Lithosol
Mispah	Muden	Ms-20	Lithic Calciorthid	Lithosol

By far the greater proportion of the soils occurring in the area investigated classify in the Oakleaf and Dundee soil forms in the South African soil classification system. In terms of the U.S.D.A. taxonomy, these soils classify as Haplargids, and Natrargids (where sodic) in the case of the Oakleaf soils, and as a Torrifluvents in the case of the Dundee soils. In terms of the FAO-UNESCO soil classification system, the Oakleaf soils are Yermosols, while the Dundee soils are Fluvisols.

6.1 Hutton Form:

Soils of this form comprise an Orthic A horizon, overlying a Red Apedal B horizon. The single local occurrence recorded in the area occupied a middle slope locality, and, although the A horizon was red and weakly structured, was too shallow to include a B horizon.

6.1.1. Shigalo Series

This series contains 15 - 35% clay in the B horizon, which is also calcareous. In the single local occurrence recorded in this survey, no B horizon is present, and the Orthic A horizon was therefore taken as diagnostic in terms of these properties. This horizon consists of 25cm of yellowish red, hard, sandy loam (15 - 20% clay), with a weak, medium to coarse, subangular, blocky structure and occasional diffuse calcium carbonate and pebbles. Roots are numerous and the soil reaction is moderately alkaline. The transition is abrupt onto friable, weathering shale which is likely to break down to a depth of approximately 60cm under cultivation.

6.2 Oakleaf Form:

Soils of this form comprise an Orthic A horizon, overlying a Neocutanic B horizon, and are the dominant soils of this arid area, occurring on both colluvial and alluvial parent materials.

6.2.1. Pollock Series

This series contains 6 - 15% clay and coarse sand in the B horizon, which is of predominantly reddish colour and is non-calcareous. The single occurrence recorded during the survey lacks an A horizon; the Neocutanic B2 horizon consists of some 50cm of yellowish red, friable to slightly hard, sandy loam (6 - 15 clay, coarse sand), with a weak, medium, subangular, blocky structure and abundant medium and fine gravel. Roots are few and the permeability is rapid. The soil reaction is moderately alkaline.

There is a gradual transition to the underlying Stratified Alluvium, which consists of 230cm+ of fine, medium and coarse gravel in a matrix of yellowish red sandy loam. The permeability is very rapid and the soil reaction is moderately alkaline.

6.2.2 Hazelwood Series

This series contains 6 - 15% clay and coarse sand in the B horizon, which is of predominantly reddish colour and is calcareous. The single occurrence recorded during the survey comprises an Orthic A horizon which consists of 25cm of strong brown, hard, sandy loam (10 - 20% clay, medium sand), with a weak prismatic structure, occasional diffuse calcium carbonate and fine gravel. Roots are few and the permeability is rapid. The soil reaction is moderately alkaline and a slight tendency to salinity is indicated.

There is a gradual transition to the underlying Neocutanic B2 horizon which consists of 135cm+ of yellowish red, hard, sandy loam (6 - 15% clay, coarse sand), with a weak, fine, subangular, blocky structure, occasional diffuse calcium carbonate and fine gravel. Roots are absent and the permeability is rapid. The soil reaction is moderately alkaline and salinity is present.

6.2.3. Letaba Series

This series contains 15 - 35% clay in the B horizon, which is of reddish colour and is calcareous. The Orthic A horizon is occasionally absent or is replaced by (or overlain by) a thin gravelly or sandy stratified surface wash. Where present it consists of 10 - 40cm of brown (occasionally reddish or yellowish brown), friable to hard, sandy loam or, rarely, sandy clay loam (10 - 30% clay), with a weak to moderate, medium, subangular, blocky structure which frequently shows platy or prismatic tendencies, occasional nodular or diffuse calcium carbonate and fine, medium and coarse gravel. Roots are absent to numerous (generally few) and the permeability is mostly rapid. The soil reaction ranges from neutral to strongly alkaline, and salinity is sometimes present.

There is a gradual transition to the underlying Neocutanic B2 horizon, which consists of 50 - 240cm+ of yellowish red (occasionally reddish brown), friable to slightly hard, sandy loam or sandy clay loam (15 - 35% clay), with a moderate (occasionally weak), medium, subangular, blocky structure, nodular and/or diffuse calcium carbonate, and varying proportions of gravel and cobbles. Gypsum crystals are present in some profiles. Roots are absent to few, and the permeability is rapid. The soil reaction is moderately alkaline (occasionally neutral) and varying degrees of salinity are often present.

Stratified Alluvium is occasionally present at the base of the profile beneath a relatively abrupt transition. It consists of 20 - 130cm+ of fine, medium and coarse gravel, cobbles and boulders in a matrix of reddish or yellowish brown loamy sand. A calcrete/gypcrete cement is occasionally present in this matrix. The permeability is mostly very rapid and the soil reaction is moderately alkaline. Varying degrees of salinity are occasionally present.

6.2.4. Oakleaf Series

This series contains 0 - 6% clay and fine sand in the B horizon, which is of predominantly non-red colour and is non-calcareous. The Orthic A horizon is usually absent and is, in many areas, replaced by 15 - 20cm of gravelly or sandy stratified surface wash.

The Neocutanic B2 horizon consists of 90 - 120cm of brown, friable, sand (0 - 6 clay, fine sand), with a weak, medium, subangular, blocky structure. Roots are numerous and the permeability is very rapid. The soil reaction is strongly alkaline (occasionally moderately alkaline).

Stratified Alluvium is sometimes present beneath an abrupt transition, and consists of 90 - 150cm+ of fine, medium and coarse gravel and cobbles in a matrix of brown sand or loamy sand. The permeability is very rapid and the soil reaction is strongly alkaline. Salinity is very occasionally present in this material.

6.2.5. Vaalriver Series

This series contains 6 - 15% clay and fine sand in the B horizon, which is predominantly non-red and non-calcareous. The Orthic A horizon is often absent or is replaced by 10 - 30cm of gravelly or sandy stratified surface wash. Where present it consists of some 40cm of brown, slightly hard, sandy loam (6 - 15% clay, medium sand), with a weak, medium, subangular, blocky structure. Roots are few and the permeability is rapid. The soil reaction is moderately alkaline.

There is a gradual transition to the underlying Neocutanic B2 horizon, which consists of 50 - 110cm of brown or dark yellowish brown, friable to hard, loamy sand or sandy loam (6 - 15% clay, fine sand), with a weak to moderate, fine to medium, subangular, blocky structure and occasional fine gravel. Roots are few to numerous and the permeability is rapid to very rapid. The soil reaction is moderately to strongly alkaline.

Stratified Alluvium is frequently present as a basal horizon beneath a gradual to abrupt transition. It consists of 20 - 150cm+ of interbedded brown or dark yellowish brown sandy loam, loamy sand and gravelly sand (with fine, medium and coarse gravels and cobbles). The permeability is rapid to very rapid and the soil reaction is moderately to strongly alkaline.

6.2.6. Levubu Series

This series contains 6 - 15% clay and medium sand in the B horizon, which is predominantly non-red and non-calcareous. The Orthic A horizon is sometimes absent and is replaced by 10 - 20cm of gravelly or sandy stratified surface wash. Where present it consists of 15 - 30cm of brown, friable, sandy loam or loamy sand (6 - 15% clay, fine or medium sand), with an apedal or platy structure and fine gravel in some occurrences. Roots are numerous and the permeability is rapid to very rapid. The soil reaction is strongly alkaline.

There is a gradual to abrupt transition to the underlying Neocutanic B2 horizon, which consists of 30 - 120cm+ of brown or dark yellowish brown, friable to slightly hard, sandy loam or loamy sand (6 - 15% clay, medium sand), with a weak, fine to medium, subangular, blocky structure (sometimes tending platy) and varying amounts of medium and fine gravel. Roots are few and the permeability is rapid to very rapid. The soil reaction is moderately to strongly alkaline.

Stratified Alluvium is frequently present as a basal horizon beneath a fairly abrupt transition. It consists of 60 - 220cm+ of interbedded brown, dark yellowish brown or reddish brown loamy sand and gravelly sand (with fine, medium and coarse gravels and cobbles). Calcium carbonate is sometimes present towards the base of the horizon. The permeability is rapid to very rapid and the soil reaction is moderately to strongly alkaline. A moderate degree of salinity is sometimes present.

6.2.7. Venda Series

This series contains 6 - 15 clay and coarse sand in the B horizon, which is predominantly non-red and non-calcareous. The Orthic A horizon is usually absent and is sometimes replaced by 10 - 20cm of gravelly or sandy stratified surface wash. Where present it consists of 10 - 20cm of brown or dark yellowish brown friable, loamy sand or sandy loam (6 - 15% clay, medium or coarse sand), with a weak, fine, subangular, blocky or platy structure and abundant medium and fine gravel. Roots are numerous and the permeability is rapid.

There is a gradual to abrupt transition to the underlying Neocutanic B2 horizon, which consists of 35 - 120cm of dark yellowish brown or brown, friable to slightly hard, sandy loam (6 - 15% clay, coarse sand), with a weak, fine to medium, subangular, blocky structure and abundant fine, medium and coarse gravels. Roots are few to numerous and the permeability is rapid. The soil reaction is moderately alkaline.

Stratified Alluvium (or Colluvium) is sometimes present as a basal horizon beneath a gradual to fairly abrupt transition. It consists of 60 - 215cm+ of abundant fine, medium and coarse gravel in a matrix of yellowish brown sandy loam. Roots are numerous and the permeability is very rapid. The soil reaction is moderately alkaline and slight salinity is occasionally present.

It should be noted that, in some areas, weathering shale is present directly beneath the Neocutanic B2 horizon.

6.2.8. Jozini Series

This series contains 15 - 35% clay in the B horizon, which is predominantly non-red and non-calcareous. The Orthic A horizon is frequently absent and is sometimes replaced by 10 - 35cm of gravelly or sandy stratified surface wash. Where present it consists of 10 - 35cm of dark yellowish brown or brown, slightly hard to hard, sandy loam or sandy clay loam (10 - 35% clay, fine to coarse sand), with a weak platy or medium, subangular, blocky structure and varying amounts of fine and medium gravel. Roots are few and the permeability is moderate to rapid. The soil reaction is moderately alkaline and slight salinity is sometimes evident.

There is a gradual to abrupt transition to the underlying Neocutanic B2 horizon, which consists of 40 - 100cm of dark yellowish brown or brown, hard (sometimes slightly hard), sandy loam (15 - 35% clay), with a weak to moderate, fine to medium, subangular, blocky structure (occasionally tending prismatic) and varying amounts of fine, medium and coarse gravel. Roots are few to numerous and the permeability is generally moderate to rapid. The soil reaction is moderately alkaline, and slight to moderate salinity is frequently present although strong salinity is rare.

Stratified Alluvium is sometimes present as a basal horizon beneath a gradual to fairly abrupt transition. It consists of 60 - 150cm+ of abundant fine, medium and coarse gravels and cobbles in a matrix of yellowish brown sandy loam or loamy sand. The permeability is rapid to very rapid and the soil reaction is strongly alkaline. A slight to moderate degree of salinity is often present.

6.2.9. Allanridge Series

This series contains 6 - 15 clay and fine sand in the B horizon, which is calcareous and predominantly non-red. Up to 20cm of gravelly or sandy stratified surface wash sometimes replaces the Orthic A horizon. Where the latter is present it consists of some 30cm of brown, slightly hard, sandy loam (6 - 15% clay, fine sand), with a platy tending prismatic structure. Roots are few and the permeability is rapid. The soil reaction is moderately alkaline.

There is a gradual to abrupt transition to the underlying Neocutanic B2 horizon, which consists of 90 - 120cm of brown, slightly hard, sand loam (6 - 15 clay, fine sand), with a weak, medium, subangular, blocky structure, occasional nodular calcium carbonate and occasional fine gravel. Roots are few and the permeability is rapid. The soil reaction is moderately alkaline.

Stratified Alluvium is usually present as a basal horizon. It consists of 50 - 100cm+ of abundant fine, medium and coarse gravels, cobbles and boulders in a brown sandy matrix. The permeability is very rapid.

6.2.10. Okavango Series

This series contains 6 - 15% clay and medium sand in the B horizon, which is calcareous and predominantly non-red. Some 5 - 70cm of sandy or gravelly stratified surface wash sometimes overlies or replaces the Orthic A horizon. Where the latter is present it consists of 15 - 20cm of dark yellowish brown or brown, friable to slightly hard, sandy loam or loamy sand (6 - 15% clay, medium sand), with a weak, fine subangular blocky structure (often tending platy) and occasional medium and fine gravel. Roots are absent to numerous and the permeability is rapid. The soil reaction is moderately alkaline.

There is a gradual to abrupt transition to the underlying Neocutanic B2 horizon, which consists of 40 - 200cm of brown, dark yellowish brown or yellowish brown, slightly hard to hard, loamy sand or sandy loam (6 - 15% clay, medium sand), with a weak, medium, subangular, blocky structure, nodular and diffuse calcium carbonate, and varying amounts of fine and medium gravel. Roots are absent to numerous and the permeability is generally rapid. The soil reaction is moderately alkaline (occasionally neutral) and moderate to strong salinity is sometimes present.

Stratified Alluvium or Colluvium is sometimes present as a basal horizon beneath a gradual to fairly abrupt transition. It consists of 70 - 170cm+ of fine, medium and coarse gravel and cobbles in a brown sandy matrix, in which calcareous concretions are sometimes present. The permeability is rapid to very rapid and the soil reaction is moderately alkaline. Varying degrees of salinity are present in some profiles, but strong salinity is rare.

It should be noted that a Lithocutanic horizon or weathering shale sometimes takes the place of the Stratified Alluvium/Colluvium.

6.2.11. Calueque Series

This series contains 6 - 15% clay and coarse sand in the B horizon, which is calcareous and predominantly non-red. Some 10 - 15cm of sandy or gravelly stratified surface wash sometimes overlies or replaces the Orthic A horizon. Where the latter is present it consists of 20 - 30cm of dark yellowish brown or brown, hard (sometimes friable), sandy loam (sometimes loam) (6 - 25% clay, medium and coarse sand), with a weak to moderate, fine to medium, subangular, blocky structure, often tending platy or even prismatic where salinity is present. Occasional calcium carbonate is present, as are varying quantities of fine and medium gravel. Roots are absent to few, and the permeability is moderate to rapid. The soil reaction is neutral to moderately alkaline and salinity is occasionally present.

There is a gradual to abrupt transition to the underlying Neocutanic B2 horizon, which consists of 20 - 110cm of varying hues of brown and yellowish brown, friable to hard, sandy loam or loamy sand (6 - 15% clay, coarse sand), with a weak to moderate, fine to medium, subangular, blocky structure, nodular and diffuse calcium carbonate, and varying quantities of fine and medium gravel. Roots are absent to numerous and the permeability is rapid. The soil reaction is moderately to strongly alkaline and moderate to strong salinity is sometimes present.

Stratified Alluvium or Colluvium is sometimes present as a basal horizon beneath a gradual to fairly abrupt transition. It consists of 60 - 220cm+ of fine, medium and coarse gravels and cobbles in a matrix of brown or yellowish brown sandy loam or loamy sand containing nodular and diffuse calcium carbonate. Permeability is rapid to very rapid and the soil reaction is neutral to strongly alkaline. Slight to strong salinity is occasionally present.

It should be noted that a Lithocutanic horizon or weathering shale sometimes takes the place of the Stratified Alluvium/Colluvium.

6.2.12. Limpopo Series

This series contains 15 - 35% clay in the B horizon, which is calcareous and predominantly non-red. Some 5 - 60cm of sandy or gravelly stratified surface wash sometimes overlies or replaces the Orthic A horizon. Where the latter is present it consists of 10 - 60cm of varying hues of brown or yellowish brown (sometimes olive), friable to hard, sandy loam or loamy sand (occasionally loam or sandy clay loam) (6 - 25% clay), with a weak to moderate, medium, subangular, blocky structure, often tending platy or prismatic where salinity is present. Calcium carbonate is sometimes present, as are varying quantities of fine and medium gravel. Roots are absent to numerous and the permeability is rapid (occasionally moderate). The soil reaction is neutral to moderately alkaline and salinity is frequently present.

There is a gradual to fairly abrupt transition to the underlying Neocutanic B2 horizon, which consists of 25 - 210cm+ of varying hues of brown or yellowish brown (sometimes olive), hard (sometimes friable or slightly hard), sandy loam or sandy clay loam (15 - 35% clay), with a weak to moderate, fine to medium, subangular blocky structure (with occasional platy or prismatic tendency), nodular and diffuse calcium carbonate (sometimes in association with gypsum crystals), and varying amounts of fine, medium and coarse gravel. Roots are absent to numerous and the permeability is moderate to rapid. The soil reaction is neutral to strongly alkaline and salinity is frequently present.

Stratified Alluvium or Colluvium is often present as a basal horizon beneath a gradual to abrupt transition. It consists of 30 - 180cm+ of fine, medium and coarse gravels, cobbles and boulders in a matrix of brown or yellowish brown sandy loam (occasionally sandy clay loam), sometimes containing calcium carbonate and gypsum. Permeability is rapid, except where the material is cemented, and the soil reaction is moderately to strongly alkaline. Varying degrees of salinity are sometimes present.

It should be noted that a Lithocutanic horizon or weathering shale sometimes takes the place of the Stratified Alluvium/Colluvium.

6.3 Fernwood Form:

Soils of this form comprise an Orthic A horizon, overlying Regic Sand. The single local occurrence recorded in the area coincides with a recent, mobile dune field produced by the deflation of alluvium from the nearby channel of the Fish River.

6.3.1. Langebaan Series

This series lacks marked wetness and comprises medium sand in the neutral to alkaline range. In the single local occurrence recorded in this survey no A horizon is present owing to the mobility of the Regic Sand. The latter consists of some 120cm+ of brown, loose, medium sand (0 - 6% clay) without any clear structure. Roots are numerous and the permeability is excessive. The soil reaction is moderately alkaline

6.4 Dundee Form:

Soils in this form comprise an Orthic A horizon overlying Stratified Alluvium, and are not differentiated into series on the basis of texture. All occurrences therefore belong to the Dundee Series. This series is associated with the younger alluvial and colluvial parent materials occupying recent colluvial fans and the lower terraces of the principal rivers.

Some 15 - 80cm of sandy or gravelly stratified surface wash often overlies or replaces the Orthic A horizon. Where the latter is present it consists of 20 - 25cm of brown or dark yellowish brown, friable to slightly hard, sandy loam or loamy sand (3 - 15% clay, medium and coarse sand), with a weak, fine, subangular, blocky structure, sometimes tending platy or apedal, and abundant gravel. Roots are numerous and the permeability is rapid. The soil reaction is moderately to strongly alkaline.

There is a gradual to abrupt transition to the underlying Stratified Alluvium, which consists of 60 - 300cm+ of various hues of brown and yellowish brown, usually friable (occasionally slightly hard or hard), interbedded loamy sand, sand and gravelly sand (with fine, medium and coarse gravels, cobbles and occasional boulders), with lenses of clay loam or silty clay in a few profiles. The structure is generally bedded or platy and nodular and diffuse calcium carbonate is sometimes present. Roots are mostly numerous, and the permeability is rapid to excessive. The soil reaction is neutral to strongly alkaline and varying degrees of salinity are occasionally present.

6.5 Glenrosa Form:

Soils of this form comprise an Orthic A horizon overlying a Lithocutanic B horizon and are most commonly encountered in zones transitional between the deeper soils of the Oakleaf Form and areas of rock outcrop.

6.5.1. Lomondo Series

This series contains 6 - 15% clay and coarse sand in the A horizon and is calcareous in or immediately below the B horizon. In the one occurrence recorded here it comprises an Orthic A horizon consisting of some 15cm of brown, friable, sandy loam (6 - 15 clay, coarse sand), with a weak, medium, subangular, blocky structure, occasional diffuse calcium carbonate and abundant medium and fine gravel. Roots are numerous and the permeability is rapid.

There is a tonguing transition to the underlying Lithocutanic B horizon, which consists of some 55cm of fine medium and coarse gravel in a sandy loam matrix, incorporating shaly bedding and containing calcium carbonate nodules. This horizon grades rapidly into weathering shale.

6.6 Mispah Form:

Soils of this form comprise an Orthic A horizon overlying rock or pedocrete, and are associated with zones of shallow bedrock, chiefly in the interfluve areas.

6.6.1. Mispah Series

This series includes a thin, non-calcareous A horizon overlying rock. The texture and other properties of this horizon, which is less than 30cm thick, vary considerably from sandy loam to clay loam with a significant gravel content; they will not be summarized further here as soils of the Mispah form are of no agricultural interest in the context of the present project proposals.

6.6.2. Muden Series

This series differs from the Mispah series in the presence of calcium carbonate in the Orthic A horizon. In all other respects the comments recorded for the Mispah series are applicable.

6.7 Irrigability Classification of Soils:

In view of the fact that the Irrigable Value system of soil classification of the Soils and Irrigation Research Institute was developed for, and is applicable only to, soils on which a surface form of irrigation is to be practised, the system developed by R.R. Maud and T.C. Partridge in 1985 for application to both surface and overhead irrigation has been used for this area, where the sandy nature of most soils will preclude irrigation by surface methods. The Maud and Partridge classification is reproduced in the legend accompanying the soil maps. It provides for five separate classes, each defined in terms of four critical limiting factors, viz. slope, soil depth, soil texture and soil structure.

Failure to meet the class requirements in relation to any one of these factors results in a shift to a lower class. In classes 2 and 3 potential salinity is an additional limiting factor; class 4 soils are presently non-irrigable owing to existing salinity or to the presence of a seasonal or permanent water table within the normal rooting depth of crops, but the rating of the soil may be improved if remedial measures, such as chemical treatment and leaching following the provision of infield drainage, are implemented; class 5 soils are unsuitable for irrigation because of the presence of more permanent limitations such as severe salinity, advanced soil erosion, active water courses, excessive stoniness and very poor soil structure. In assigning a class value to a particular soil within this system, one or more symbols are added as subscripts to all numerical values greater than 1, in order to indicate the precise nature of the limiting factor(s) in each case.

This system, which has already been applied with considerable benefit to extensive areas of soil that have been, or will be, developed within the Taung Irrigation Scheme, has some clear advantages over that currently in use. Since there is no direct correlation between the new system and the Irrigable Value Classification, no attempt has been made to apply both systems in the present case.

In applying the Maud and Partridge classification to the Neckartal project area no account has been taken of the frequent presence of a gravelly surface deflation residue over large areas. This will have to be cleared using a stone rake during the course of land preparation. The same applies to areas of moderate to severe microrelief, in the form of low dunes, which are associated with many of the sandier soils of the area, and which have been indicated by hatching on the soil maps. This microrelief will have to be eliminated by land planing during land preparation.

Attention is drawn to the semi-detailed nature of the soil survey in areas outside of those selected for the pilot projects below the Naute Dam. Because of the spacing of test pits and samples for salinity analysis, it is likely that the extent of the various categories of soil salinity and potential salinity have not always been delineated with a high level of accuracy. As has been indicated earlier, further work should be undertaken in this regard prior to finalization of the layout of the scheme.

Mention must also be made of the rather unusual state of affairs prevailing in this area, in terms of which some sandy soils with a 3_T rating, notably those of the Dundee, Oakleaf, Vaalriver and Levubu series, are often to be preferred for irrigation over heavier, more favourably textured soils such as those of the Limpopo and Letaba series, in view of the frequent susceptibility of the latter to salinity problems.

Of the total area of some 8000 ha included in the survey, some 6600 ha have been assigned to irrigability classes 1 - 3; some 1029 ha (15,5%) consists predominantly of class 1 soils, some 1459 ha (22%) of class 2 soils, and some 4127 ha (62,5%) of class 3 soils.

7. PHYSICAL AND CHEMICAL PROPERTIES OF SOILS

7.1 Physical Properties:

7.1.1. Bulk Density of Soils

No specific sampling programme for the determination of bulk density was carried out in the course of the present project, as typical values for the soil series which are commonly represented in the area are reasonably well known. These are given in Table 7.1.1. below:

TABLE 7.1.1.

Soil Series	Average Bulk Density (kg/m^3)	
	Topsoil	Subsoil
Letaba Jozini Limpopo	1575	1550 - 1700*
Oakleaf Vaalriver Levubu Okavango Culueque Dundee	1625	1600 - 1750*

* Upper values assume significant gravel component

The likely range of bulk densities of all soils is 1500 - 1750. The subsoils of those profiles containing significant proportions of gravel are likely to have bulk densities towards the upper end of this range. In general, it may be stated that these soils are not too compact in their natural state. This is confirmed by the prevailing consistencies recorded in the test pits.

7.1.2. Infiltration Rates of Soils

Sustained infiltration rates were measured in the field on a number of representative soil series in the area, using a double ring infiltrometer. All of the tests were carried out for periods ranging from 1½ to 2 hours; in all cases a more-or-less constant rate of infiltration had been achieved within this time, as is to be expected in the sandy soils of this area. Longer tests were not practicable in view of the difficulty of transporting sufficient quantities of water to remote and widely spaced testing sites.

The results of the tests are presented in graphical form in the accompanying figures and are summarized in Table 7.1.2 below:

TABLE 7.1.2.

Test Pit	Soil Series	Sustained Infiltration Rate (mm/hr)
A4	Limpopo	415
A7	Jozini	200
A20	Vaalriver	400
A28	Dundee	905
A45	Dundee	550
80	Venda	230
B2	Limpopo	255
B13	Letaba	120
B16	Okavango	390
118	Vaalriver	420

Although the results obtained in these tests are somewhat higher than those which would be achieved in practice during the course of surface or sprinkler irrigation, owing to the hydraulic head present during the ring infiltrometer test, this is sometimes compensated for by the improvement of topsoil structure due to ploughing and cultivation, which normally precede the commencement of irrigation.

On the basis of these results and of the physical properties of the series concerned in relation to other soils in the area, the following ranges of values are offered for design purposes:

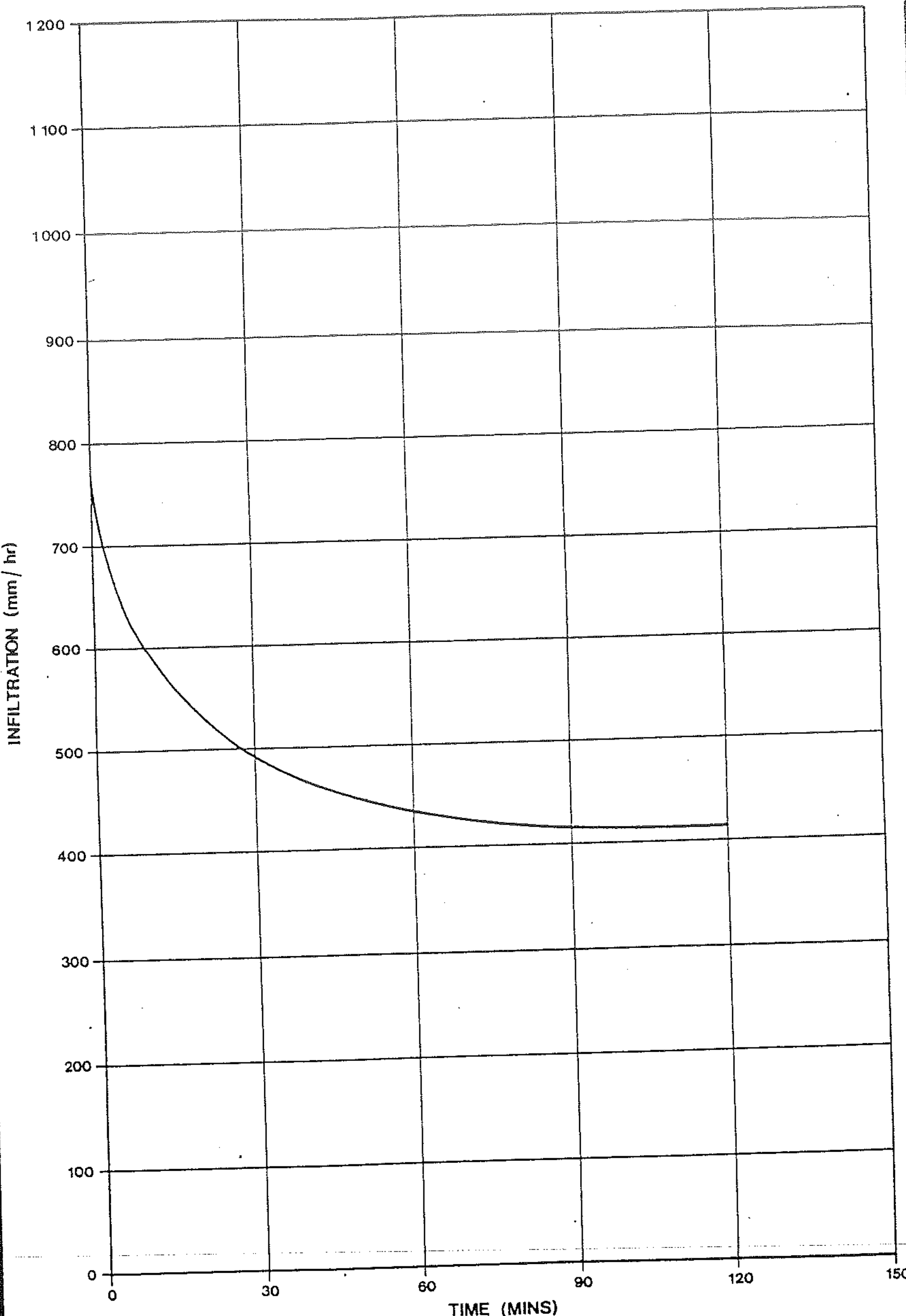
Series	Infiltration Rate (mm/hr)
Dundee	500 - 1000
Oakleaf	400 - 800
Vaalriver) Okavango) Levubu) Allanridge)	300 - 500
Venda) Calueque) Pollock) Jozini) Limpopo)	150 - 400
Hazelwood) Letaba)	100 - 200

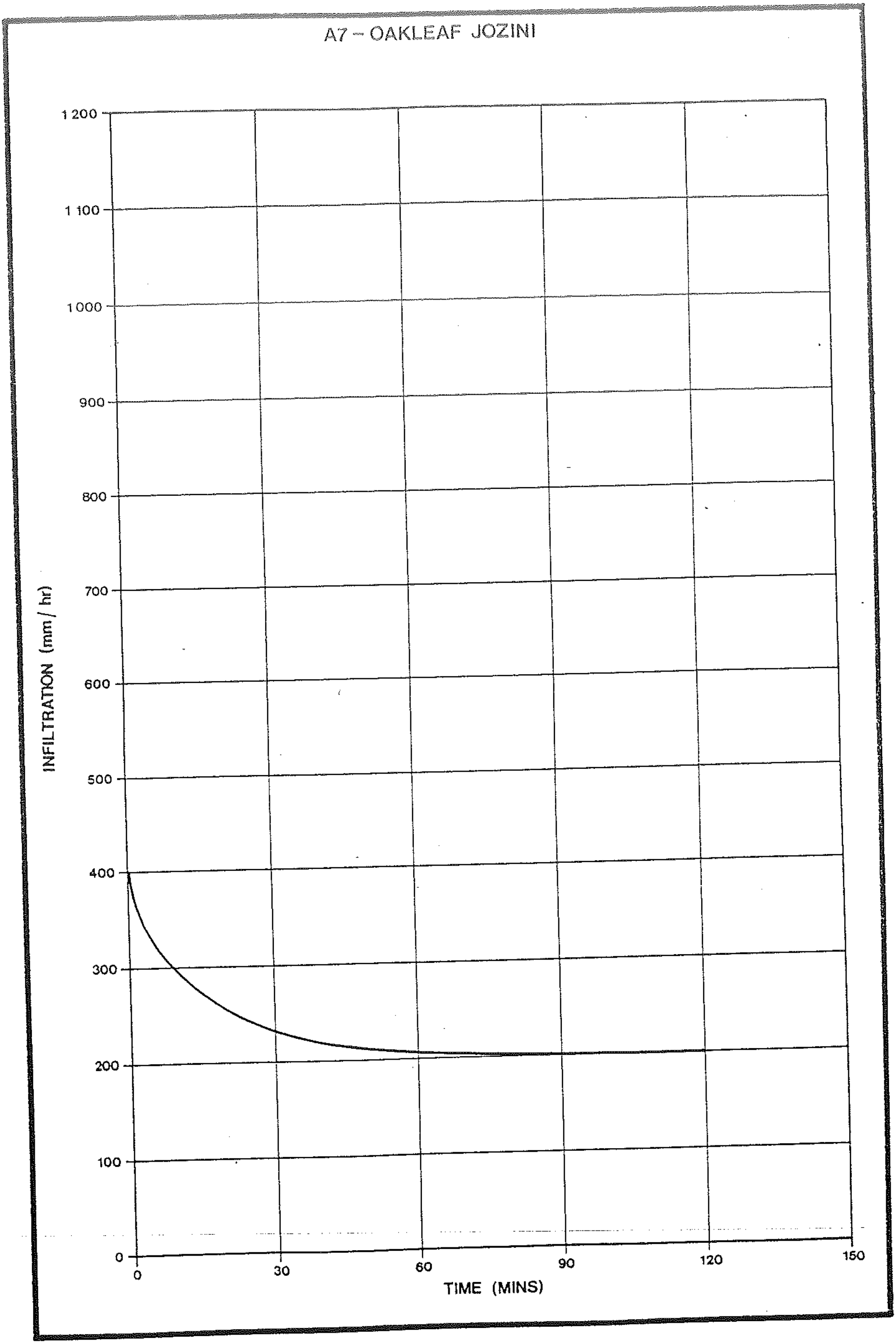
It should be noted that impermeable horizons and impeded drainage conditions in the subsoil are rare throughout the deeper soils of the project area. Impedance of drainage at shallow depth is to be expected only where bedrock or Lithocutanic structure are present, i.e. in the shallower occurrences of the various series, or in those rare cases where the gravel layer, present in the subsoil of most profiles, is cemented by calcrete or gypcrete.

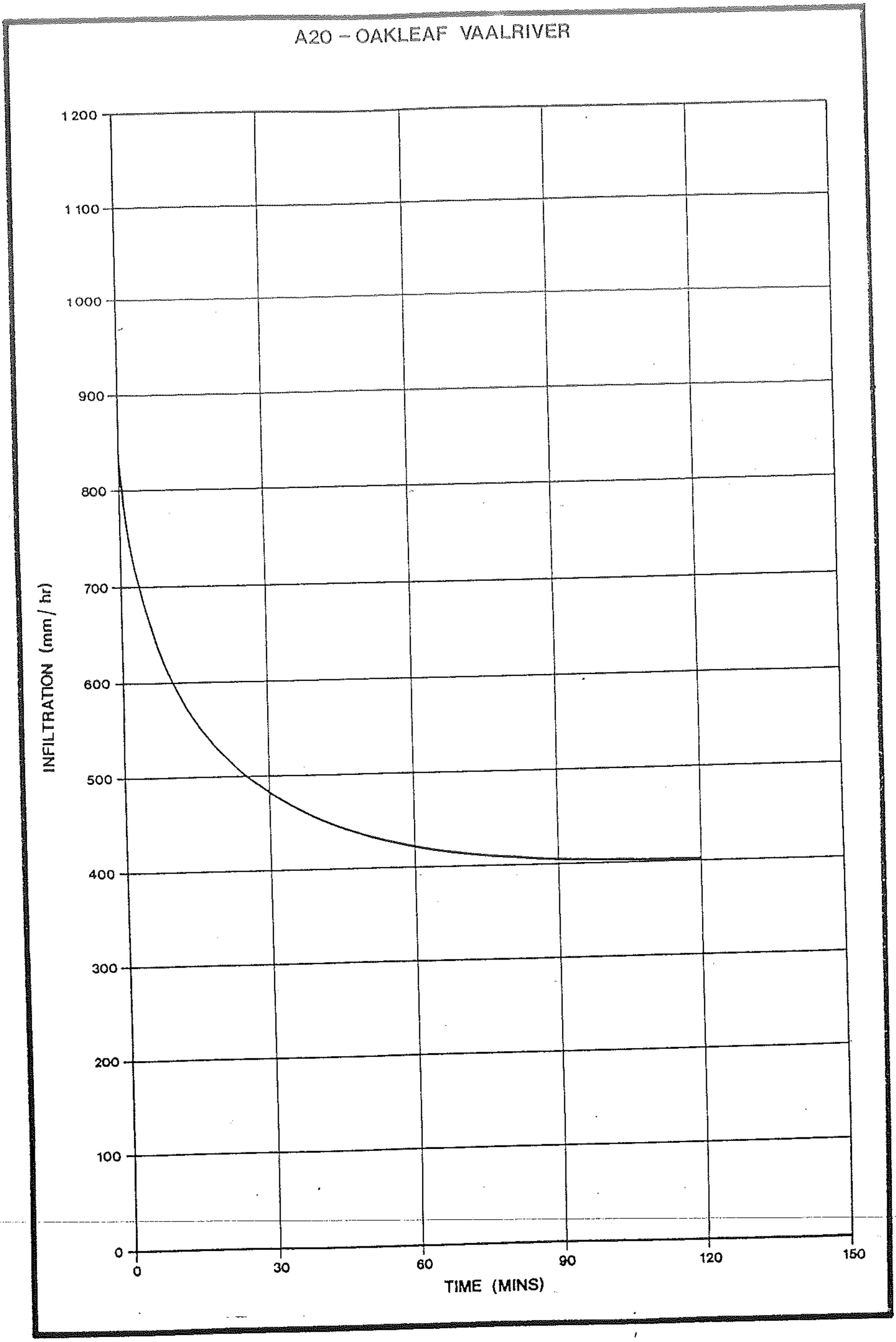
7.1.3. Available Moisture of Soils

The estimated available moisture holding capacities of the irrigable soils occurring in the area investigated are given in Table 7.1.3. below. These values have been derived from information available for similar

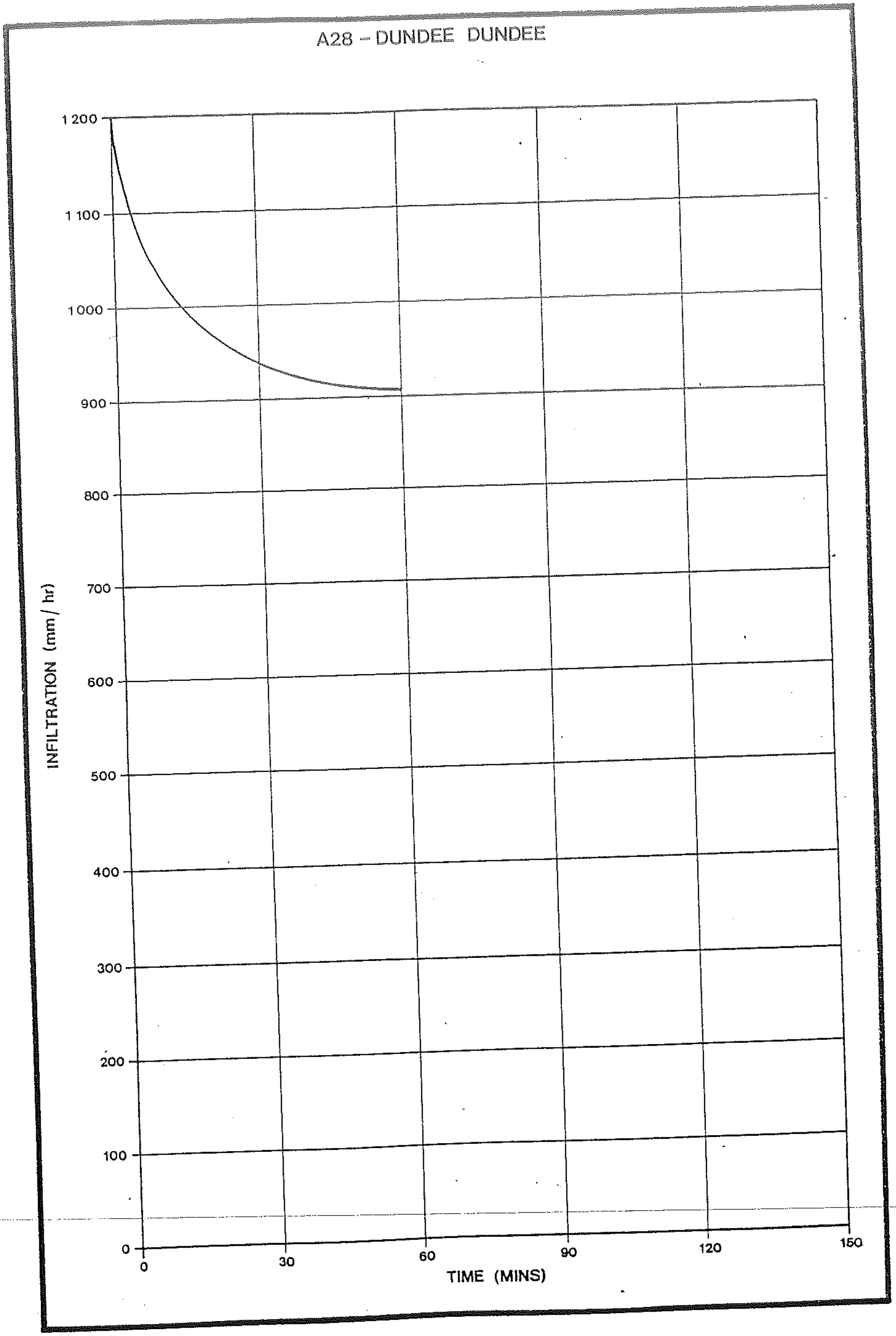
A4 – OAKLEAF LIMPOPO

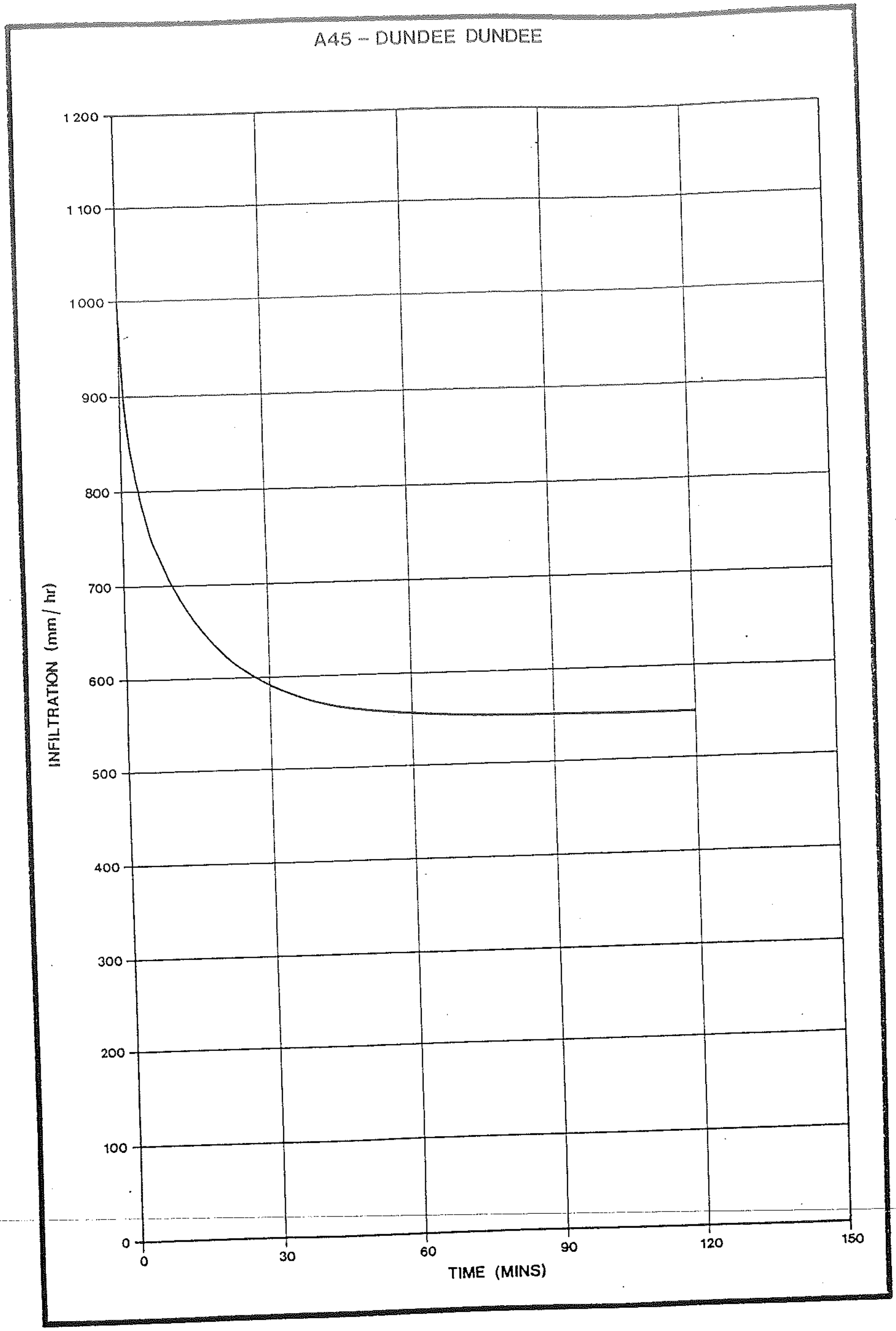


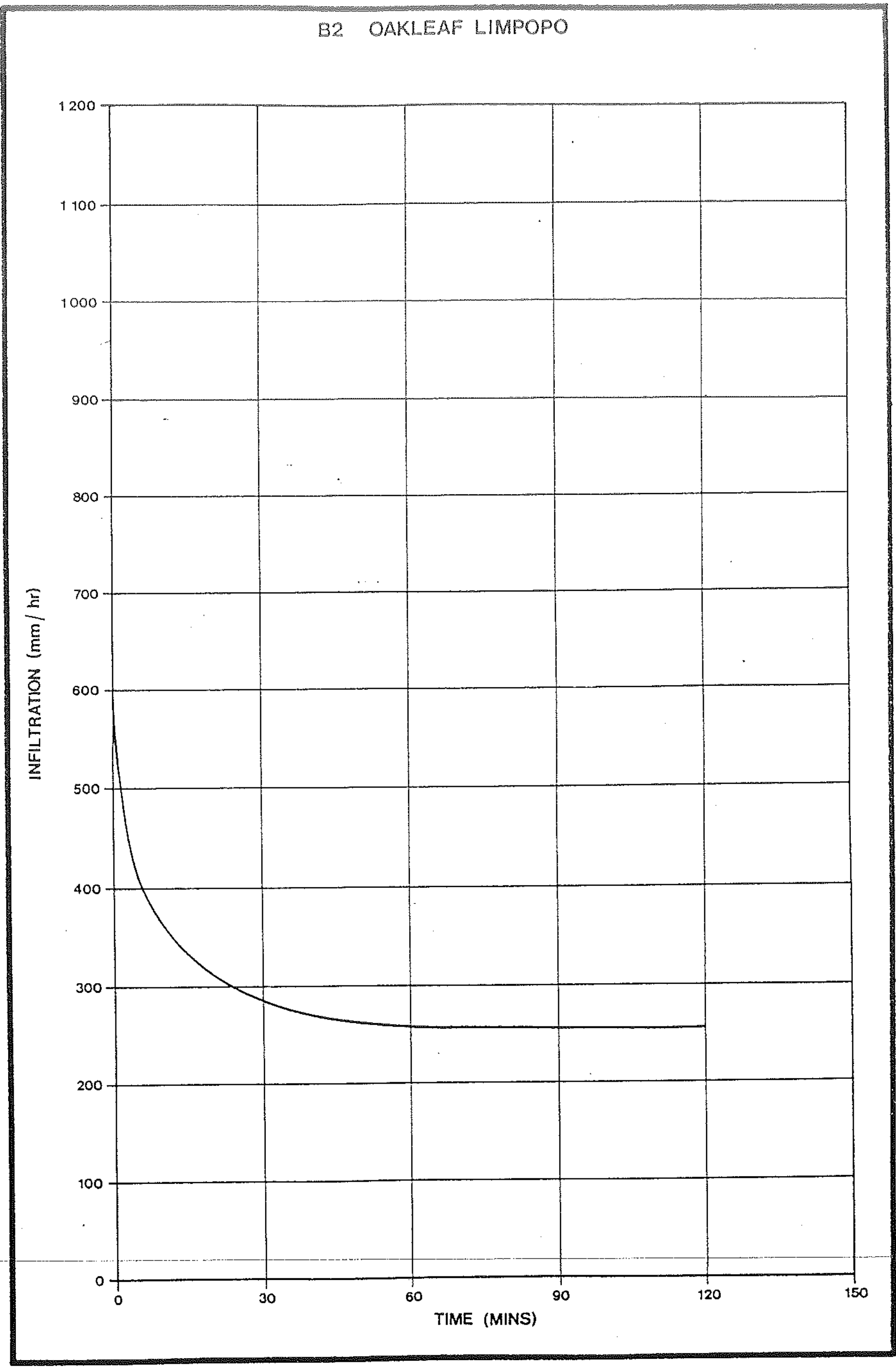

A7 - OAKLEAF JOZINI
INFILTRATION (mm/ hr)
1 200
1 100
1000
900
800
700
600
500
400
300
200
100
0
0
30
60
90
120
150
TIME (MINS)



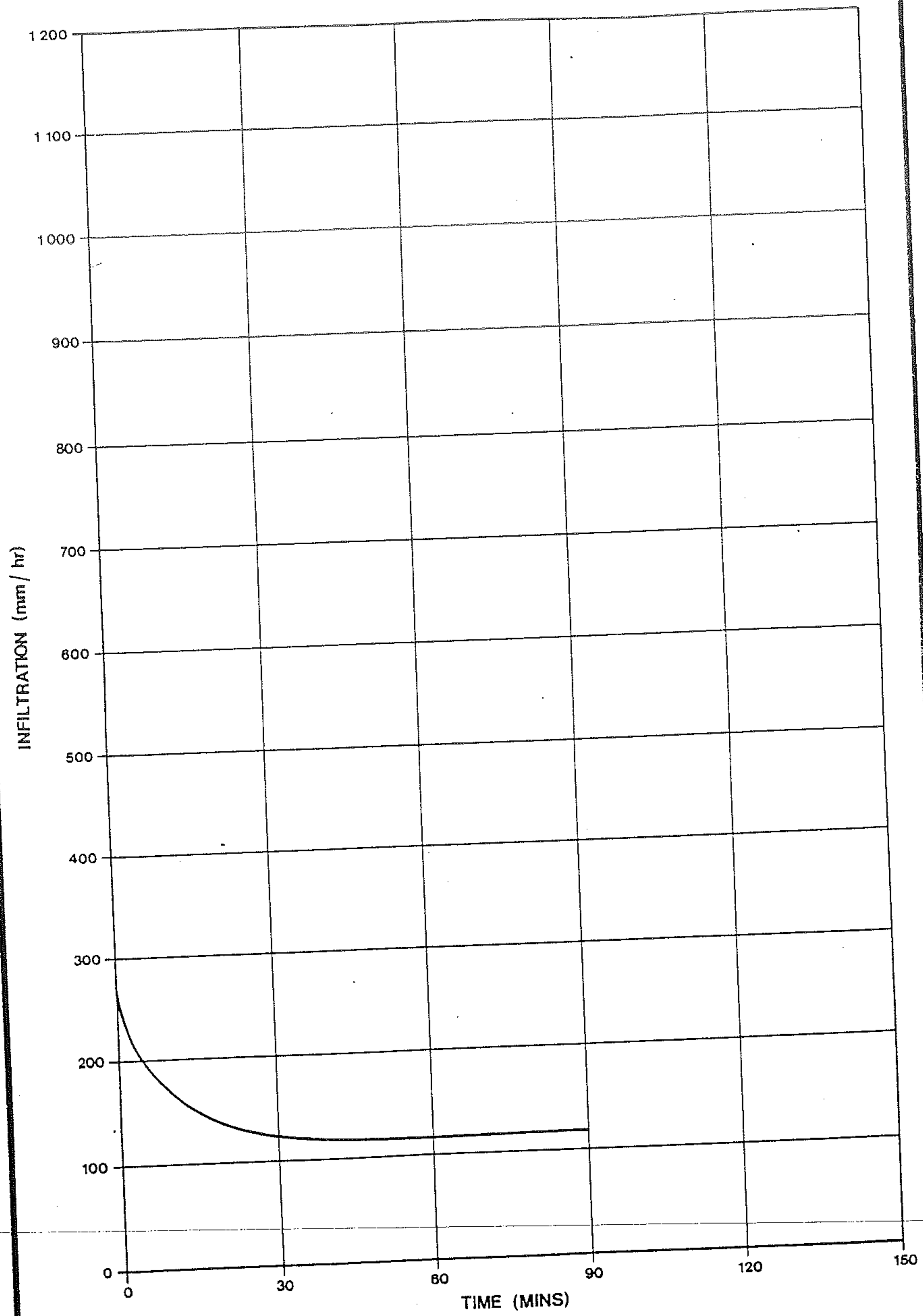
A20 - OAKLEAF VAALRIVER
1 200
1 100
1 000
900
800
700
600
500
400
300
200
100
0
INFILTRATION (mm/hr)
0
30
60
90
120
150
TIME (MINS)

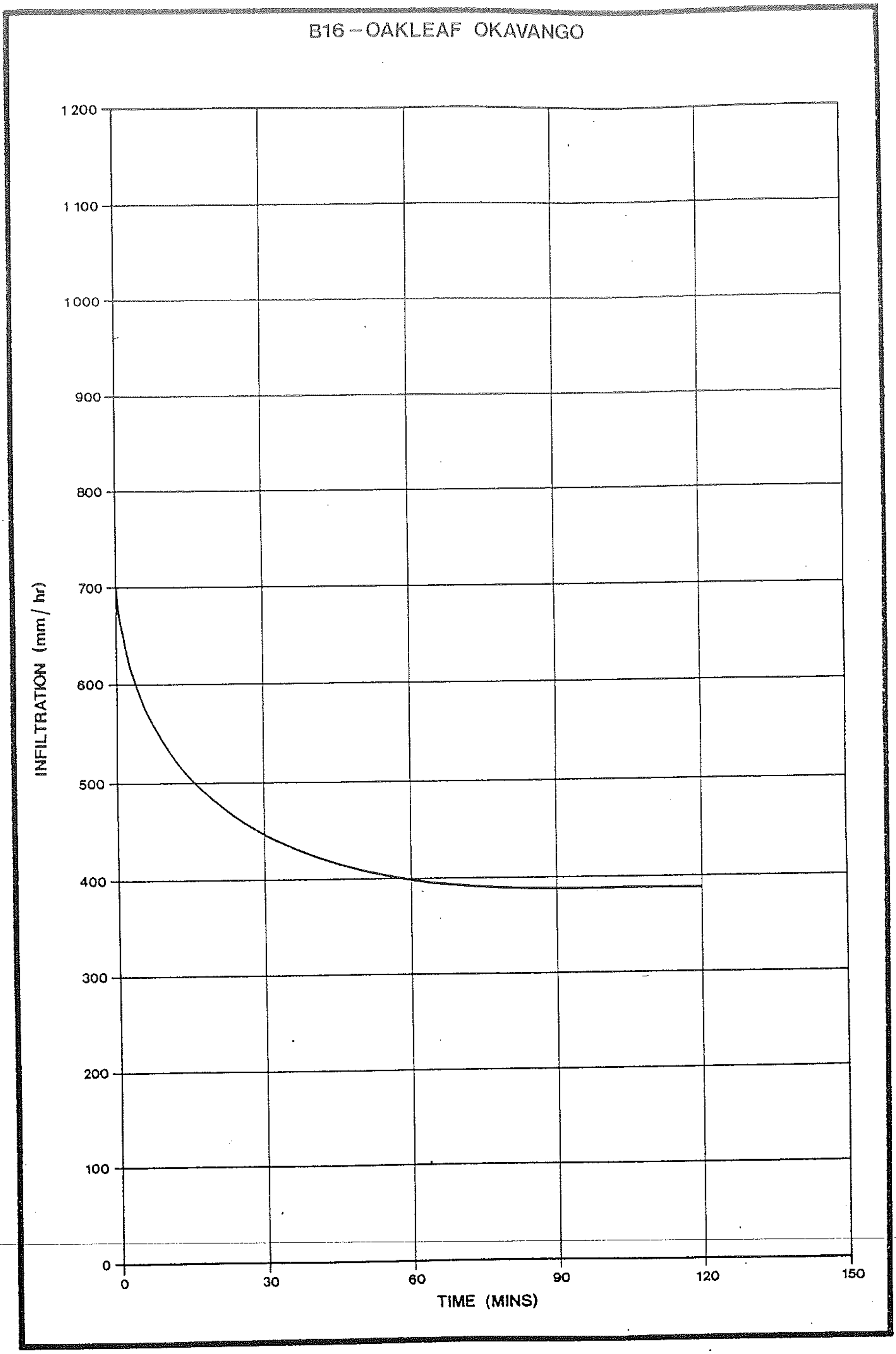

A28 - DUNDEE DUNDEE
INFILTRATION (mm/hr)
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
30
60
90
120
150
TIME (MINS)


A45 – DUNDEE DUNDEE
INFILTRATION (mm/ hr)
1 200
1 100
1000
900
800
700
600
500
400
300
200
100
0
0
30
60
90
120
150
TIME (MINS)

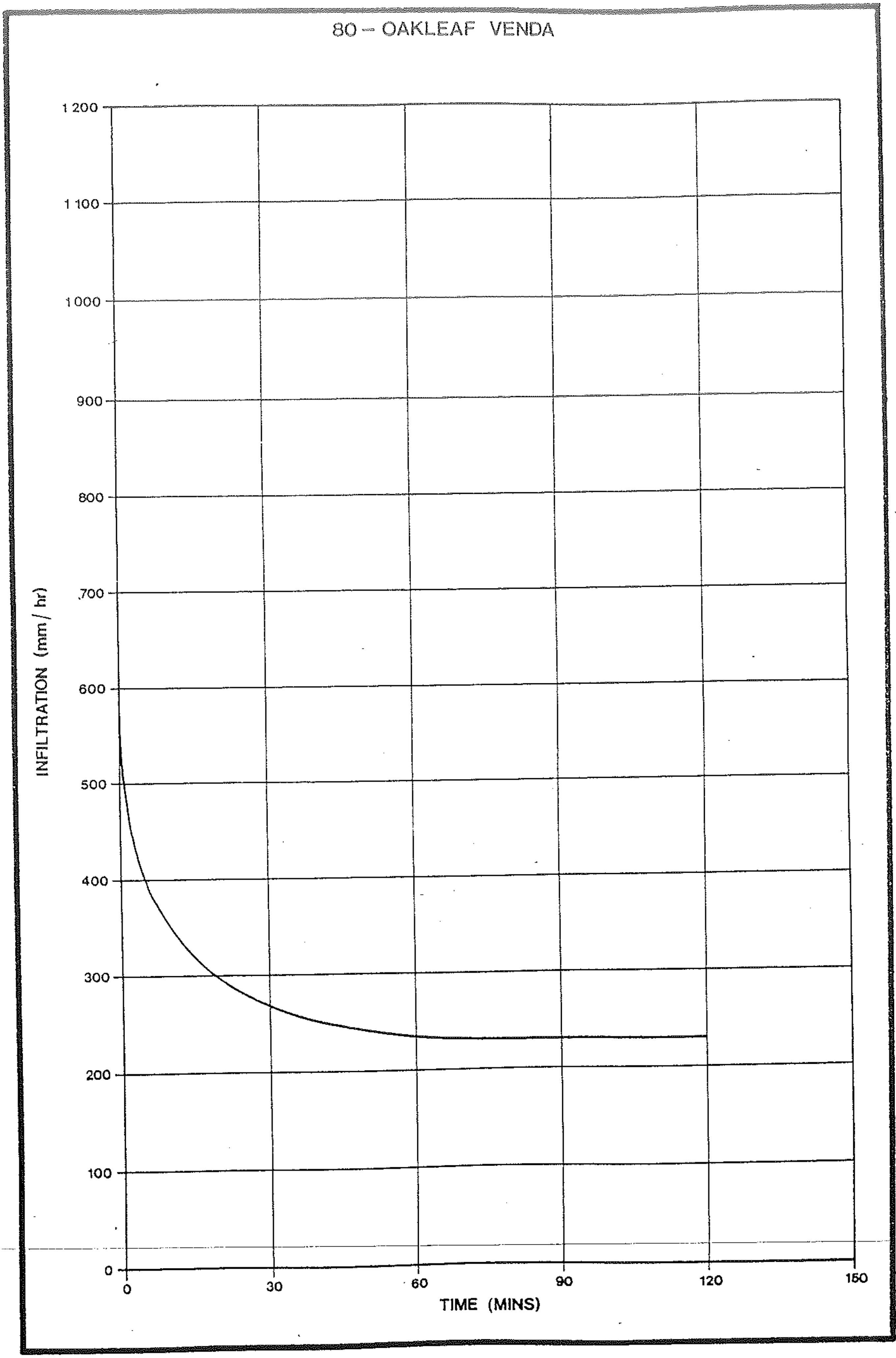

B2 OAKLEAF LIMPOPO
INFILTRATION (mm/hr)
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
30
60
90
120
150
TIME (MINS)

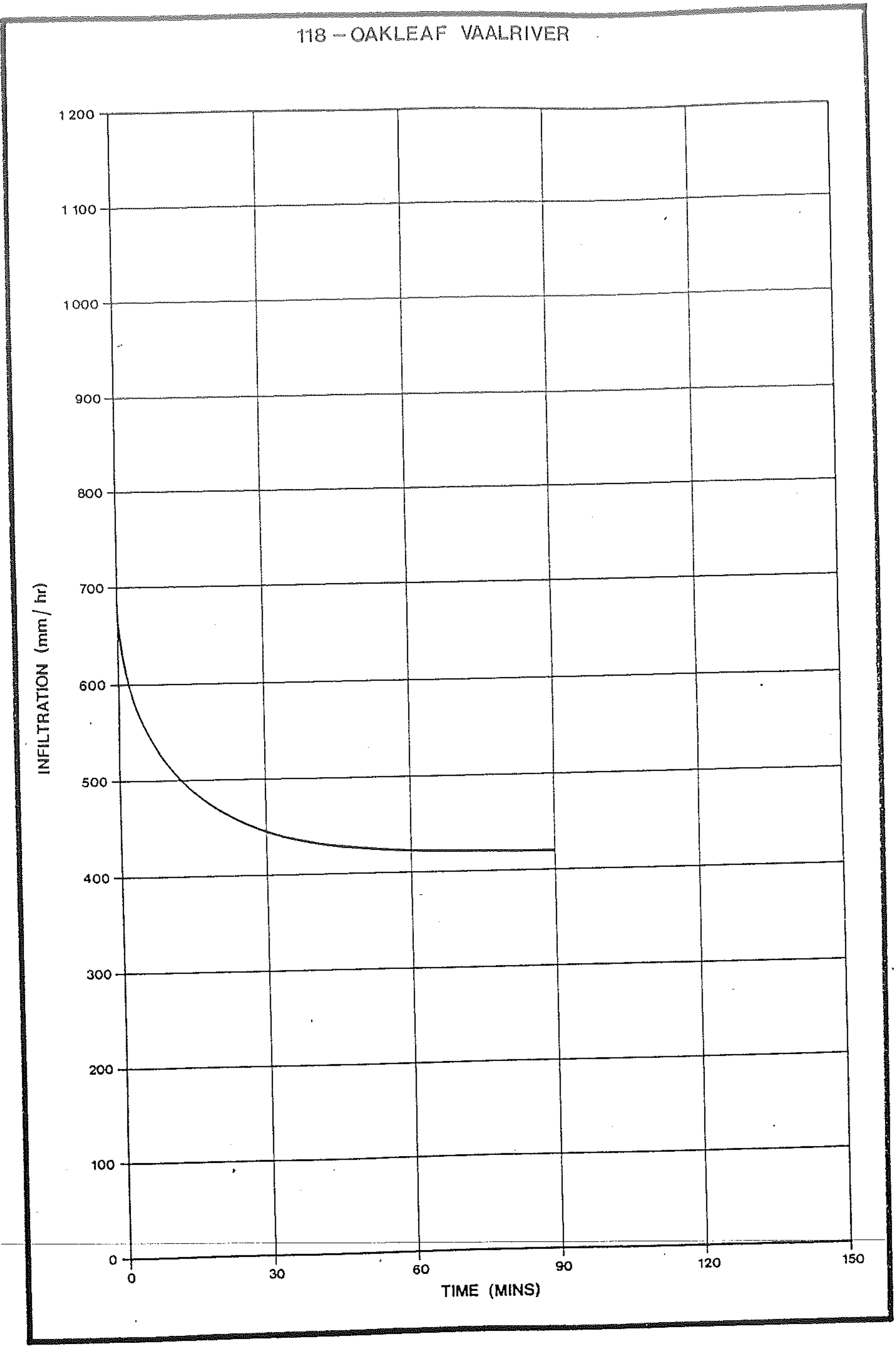
B13 – OAKLEAF LETABA





B16 – OAKLEAF OKAVANGO
INFILTRATION (mm / hr)
1 200
1 100
1 000
900
800
700
600
500
400
300
200
100
0
0
30
60
90
120
150
TIME (MINS)


80 — OAKLEAF VENDA
INFILTRATION (mm/hr)
1 200
1 100
1 000
900
800
700
600
500
400
300
200
100
0
0
30
60
90
120
150
TIME (MINS)



118 – OAKLEAF VAALRIVER
INFILTRATION (mm/hr)
1 200
1 100
1000
900
800
700
600
500
400
300
200
100
0
0
30
60
90
120
150
TIME (MINS)

soils elsewhere, as it was not practical to sample and test actual soils in the area as part of the present investigation.

TABLE 7.1.3.

Estimated Available Moisture (mm/m)	Soil Form and Series
65	Oakleaf - Oakleaf Fernwood - Langebaan
70	Oakleaf - Pollock - Hazelwood - Venda - Calueque
	Dundee - Dundee
	Glenrosa - Lomondo
75	Oakleaf - Levubu - Okavango
80	Oakleaf - Vaalriver - Allanridge
100	Oakleaf - Letaba - Jozini - Limpopo
	Hutton - Shigalo

As may be seen from the table, on account of their general sandiness, the available moisture content of the soils of the area is low. Most of the available moisture, however, will be in the 'freely available' form.

From the values given in the table, the depths of the soil profiles involved, and the rooting depth of the specific crop grown on any of the soils, the value of total available moisture (TAM) can be arrived at. This value, together with that of the prevailing peak and daily evapotranspiration in the region, can be used for the design of the maximum capacity of any irrigation system that may be installed in the area investigated, and for the determination of irrigation frequency requirements at various times during the year or crop cycle.

7.1.4. Erodibility of Soils

On account of the general sandiness of the majority of the soils in the area, and the lack of vegetation cover due to the prevailing arid climatic conditions, the soils of the area are very susceptible to erosion both by wind and water. For climatic reasons erosion by wind-action is much more of a problem than erosion by water. Soil movement by the prevailing strong southerly winds in the region is particularly marked, giving rise in places to a pronounced micro-relief.

Whereas normal soil conservation measures should be adequate to deal with water erosion, in view of the relatively subdued topography in spite of the soils being somewhat dispersive due to their sodium content, very particular attention will have to be given to measures to minimise wind erosion in any development of the area. In this regard the orientation of the long axes of rectangular fields at right angles to the prevailing southerly wind direction could be contemplated, and the provision of suitable windbreaks, also at right angles to the wind direction, at very frequent intervals throughout the developed area will have to be ensured. It is probable that the best fast-growing trees to form suitable windbreaks in terms of the conditions prevailing in the area are a species of Casuarina, the pepper tree (Schinus molle), and mesquite (Prosopis juliflora).

7.1.5. Susceptibility of Soils to Surface Compaction and Crusting

In view of their general sandiness, the majority of the soils in the area will not be significantly susceptible to compaction as a result of their usage for irrigated crop production. Such soils similarly will not be very susceptible either to surface crust formation, except, perhaps where fine sand is the dominant constituent of the sand fraction.

The few heavier soils in the area with a clay content in excess of about 15 per cent might, however, be more susceptible to compaction and surface crusting, but this could be dealt with by means of suitable ploughing or scarifying, as is normally implemented elsewhere also as a weed control measure, without undue difficulty.

7.2 Chemical Properties:

7.2.1. Present Nutrient Status of Soils

7.2.1.1. Nitrogen

A characteristic of many of the soils in the area is the absence, due to its removal by wind erosion, of the topsoil horizon. Additionally, the organic matter content of the topsoils, where present, as is normal in such arid areas, is low to very low. As the natural nitrogen status of a soil is related to its organic matter content, the low to very low organic matter status of the topsoils and exposed subsoil horizons in the area will result in a very low nitrogen content in these soils.

Thus for optimal crop production under irrigation adequate application of nitrogen fertilizers will be essential both at time of planting, and subsequently as a top dressing in respect of some crops. On the sandier soils in the area, split topdressings may be required to ensure adequate plant uptake and to reduce leaching loss.

For major crops likely to be grown in the area such as cotton, maize, sorghum, wheat and citrus, nitrogen fertilizer requirements are likely to be of the order of 150 to 200 kgN/ha, this reducing to about 50 kgN/ha in the case of lucerne, and to 20 kgN/ha in the case of groundnuts.

On account of the general alkaline nature of the soils in the area, surface application of urea as a nitrogen fertilizer should be avoided as volatilisation losses will otherwise occur.

7.2.1.2. Phosphorus

The results of the determination of 'available' phsophorus carried out on some sixteen representa tive topsoils in the area investigated show the level of phosphorus to vary in the range 0 - 37 mg/kg, averaging 16 mg/kg, which is moderate. Thus varying quantities of phosphorus fertilizer will be required for crops grown on soils in the area, actual quantities being dependent both on specific crop requirements and on the phsophorus content of the soil at any locality.

For the likely major crops such as cotton, sorghum, wheat, maize, citrus and lucerne, phosphorus applications of 50 kgP/ha, or somewhat more, are likely to be required. In the case of groundnuts, applications of about 30 kgP/ha are likely to be required.

7.2.1.3. Potassium

'Available' potassium content of the topsoils in the area investigated varies in the range 60 to 350 kgK/ha, averaging about 175 kgK/ha which is moderate for such sandy soils. Potassium levels in the subsoil are somewhat lower.

Potassium content of the soils is thus also rather variable through the area and adequate potassium fertilization for specific crops will be required in terms of soil potassium levels at any locality.

For the likely major crops in the area such as cotton, sorghum, wheat, maize, citrus and lucerne, potassium applications at the rate of up to about 100 kgK/ha are likely to be required in general, with groundnuts requiring only about 40 kgK/ha.

7.2.1.4. Calcium and Magnesium

Calcium content of the soils in the area investigated, which are generally calcareous, is variable in the range 2500 to 45000 kgCa/ha, but in general is high to very high, averaging about 9000 kgCa/ha. This high calcium content is present in both non-saline and saline soils in the area. The calcium content of subsoils is usually considerably higher than that of topsoils.

Thus application of any calcium fertilizer to the soils in the area investigated is unlikely to be required in the foreseeable future.

The generally high calcium contents of the soils could adversely affect the uptake of phosphorus in some crops, and this factor will have to be assessed during any pilot scheme in the area.

Magnesium content of the soils of the area is also variable, ranging from about 80 kgMg/ha to 1300 kgMg/ha, and averaging about 150 kgMg/ha, which is moderate to high.

Calcium : magnesium ratios are generally of the order of 10 or more, which is very high. This could give rise to an adverse situation regarding magnesium availability to some crops, which will have to be further assessed during any pilot scheme in the area.

7.2.1.5. Minor Elements

The generally high calcium content and pH of the soils of the area are likely to have an important effect on crop micronutrient availability. Important in this regard are the elements boron, iron, manganese and zinc.

The results of the analysis of sixteen topsoil samples from representative soils in the area indicate that 'available' zinc varies in the range 1,2 to 5,2 mg/kg, with an average of 3,0 mg/kg. This level of zinc should be adequate for most crops. Crops likely to be cultivated that are sensitive to zinc deficiency are maize, citrus and cotton.

It will thus be very important in the initial pilot development of the area to monitor the situation regarding minor element nutrition of the various crops grown, so that in any larger scale development, any problems in this regard can be obviated by suitable fertilization.

There would be every merit in the initial stages of development of the pilot scheme in the area, to carry out suitable fertilizer trials involving both major and minor nutrient elements for the range of crops likely to be grown, so that the overall situation in respect of crop fertilization can be adequately assessed.

7.2.2 Soil Reaction, Alkalinity and Salinity

The pH values of the soils in the area are generally alkaline. The pH values of topsoils are in the approximate range 7,5 to 9,2, averaging about 8,2, while pH values in the subsoils range from about 7,5 to 8,8 averaging about 8,0. At these levels most soils are moderately alkaline. There is some indication that the saline soils in the area have somewhat lower pH values than their non-saline analogues. This is very probably due to the buffering effect on the pH of the saline soils due to their salt content.

The exchangeable sodium percentage (ESP), which is the measure of soil alkalinity or sodicity, varies from about 0,1 to 19,1 in the case of non-saline topsoils in the area, averaging about 3,9, the comparable values for saline soils being from about 9,9 to 82,9, averaging about 48,9. In the case of subsoils in non-saline horizons it varies from about 0,1 to 77,3, averaging about 9,8; in saline subsoil horizons it varies from about 0,6 to 77,3, averaging about 31,5. The lower limit for alkali or sodic soils is an ESP of 15. From the values given above it is apparent that non-saline topsoils in the area are not alkali or sodic in general; this is also the case with non-saline subsoils, although the ESP values of the latter are substantially higher than for the topsoils. Saline topsoils and subsoils in the area are generally alkali or sodic, the subsoils being somewhat less so than the topsoils.

Salinity in the soils in the area is fairly widespread, although erratic in its distribution. In general, it tends to be more strongly developed in the more clayey soils of the area, particularly in the Oakleaf-Limpopo soils, than in the more sandy soils, in which, on account of their permeability, leaching of salts can take place. Even in some sandy soils, however, salinity may be present locally.

Salinity values in the non-saline soils of the area vary in the approximate range (measured in terms of electrical resistance of the soil paste at 16°C) 200 to 2800 ohms, averaging about 1075 ohms in the case of the topsoils; the comparable values for saline topsoils are from about 16 to 180 ohms, averaging about 84 ohms (600 mS/m). In the case of non-saline subsoil horizons, electrical resistance varies from about 260 to 1800 ohms, averaging about 670 ohms, the comparable values for saline subsoil horizons being 30 to 160 ohms and averaging 75 ohms (650 mS/m).

These results indicate that even in non-saline soil profiles in the area, there is a general tendency, as is normal in such an environment, for the subsoil horizons to be somewhat more saline than the topsoil horizons, even though the resistance is well above the salinity threshold limit.

Salinity threshold limits for the soils occurring in the area are:-

Soil Class	Electrical Resistance of Saturated Paste at 16°C	Conductivity of Saturated Extract
Non-saline	> 180 ohms	< 200 mS/m
Slightly saline (NA(P)1)	180 - 125 ohms	200 - 400 mS/m
Moderately saline (NA(P)2)	125 - 80 ohms	400 - 600 mS/m
Saline (NA1)	80 - 50 ohms	600 - 1600 mS/m
Highly saline (NA2)	<50 ohms	>1600 mS/m

Where soils in the area are gypsic, as is the case in some areas, the threshold values, up to the lower unit of the saline soil class, can be raised by 200 mS/m. Saturated extract analyses on representative soil samples in the area, show that sodium is the dominant cation present therein by some 5 to 10 times.

Figure 7.2.2(1) shows the relationship between resistance and conductivity of the saturated paste, while Figure 7.2.2(2) shows the relationship between conductivity and soluble sodium content.

On account of the tendency of the subsoils in the area to be more saline than the topsoils, it is essential that adequate subsoil drainage be provided as part of any irrigation development in the area to prevent the development of any salinity in topsoil horizons by the upward migration of subsoil salts in the long term. This applies particularly to soils of the Limpopo, Jozini, Letaba and Calueque series.

On account of the presence of salinity, and to a lesser extent related alkalinity or sodicity, in some of the soils of the area, it will be necessary, as far as is practicable, to locate crops with the appropriate salinity and alkalinity tolerances in relation to the varying salinity of the slightly and moderately saline soils of the area, if these are incorporated into the irrigation scheme.

It should be noted that sodic and gypsic salinity can be distinguished only by means of costly and time consuming laboratory analyses. In the case of the more strongly saline soils this distinction would be of academic interest only.

7.3 Biological Properties

In view of the generally sandy nature of the soils and their very low organic matter content, it is possible that nematode (eelworm) problems could affect some sensitive crops that may be grown thereon. This is particularly likely in the case of the very sandy soils. With the build-up of organic matter in the soils

FIGURE: 7.2.2 (1)

NECKARTAL SOILS: RELATIONSHIP BETWEEN RESISTANCE AND CONDUCTIVITY OF SATURATED PASTE

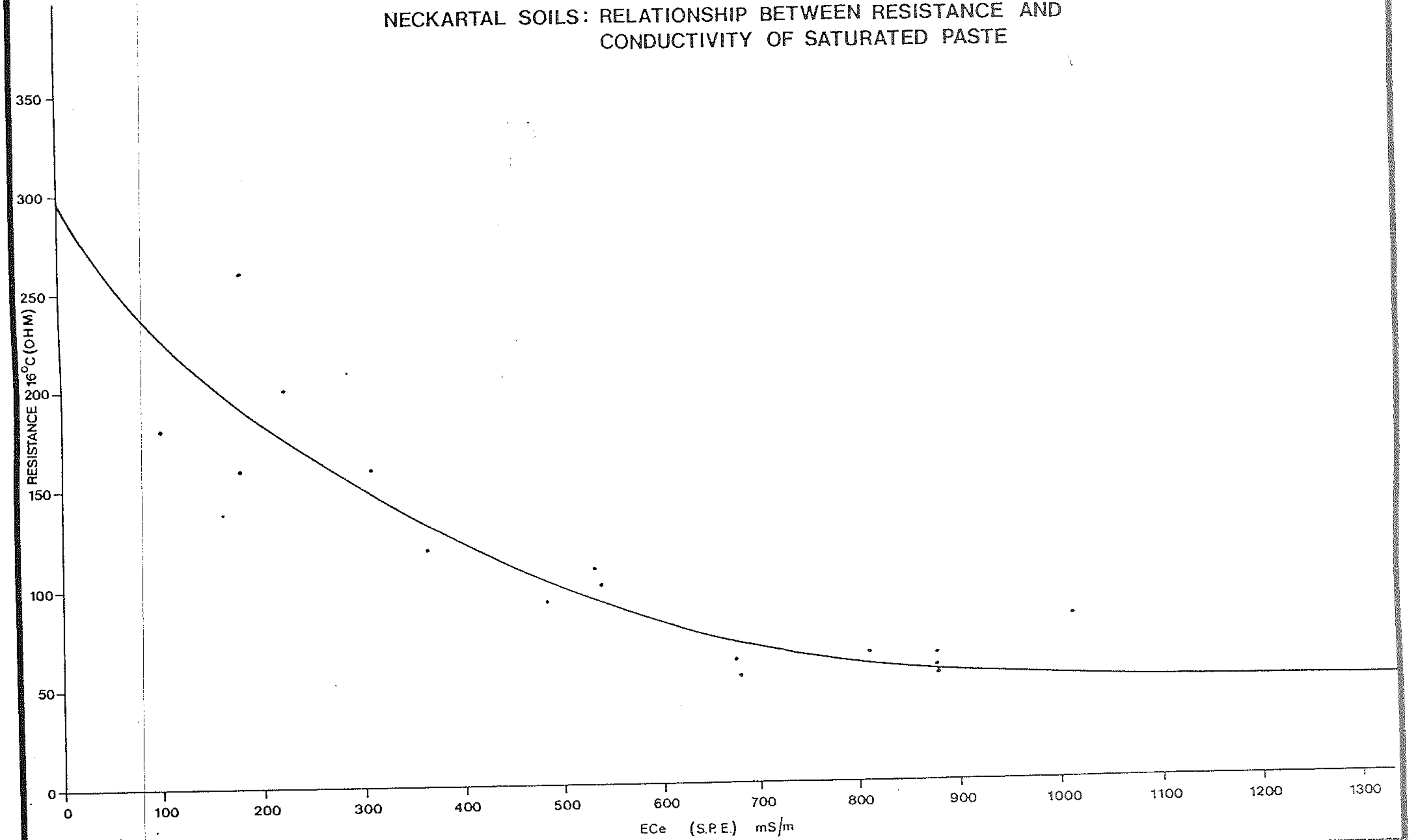
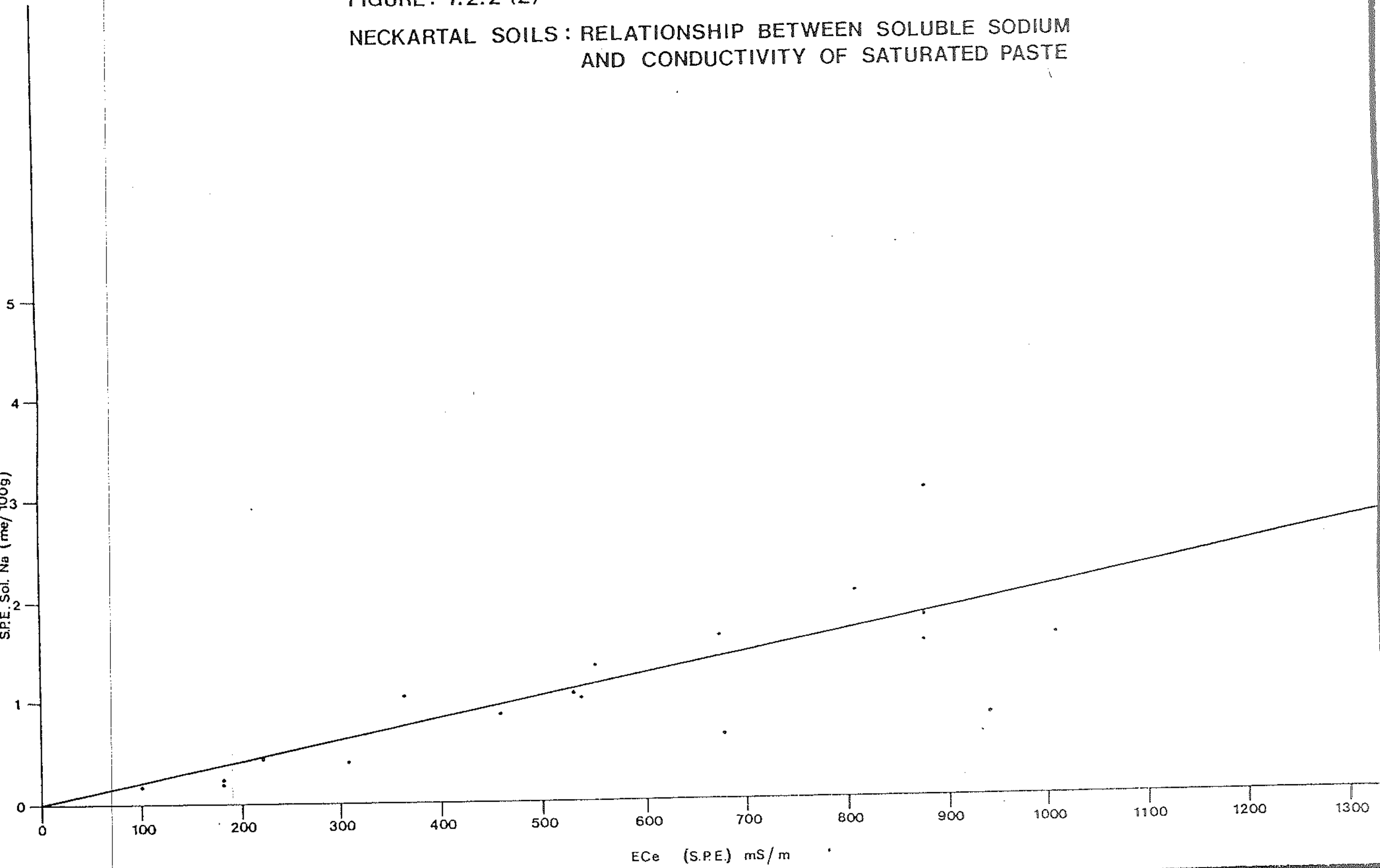


FIGURE: 7.2.2 (2)

NECKARTAL SOILS: RELATIONSHIP BETWEEN SOLUBLE SODIUM AND CONDUCTIVITY OF SATURATED PASTE



with time, as will happen during cultivation, any such problem would tend to be much reduced, if not entirely eliminated. Some attention to this matter will be necessary at the time of any initial pilot development in the area.

8. IRRIGATION WATER QUALITY

Two recent chemical analyses of water from the Naute Dam on the Löwen River, which will be used to irrigate at least the pilot schemes in the area of possible development, are given in Table 8 below.

TABLE 8

NAUTE DAM - CHEMICAL ANALYSIS OF WATER

	Sampling date 19-2-87	Sampling date 25-2-87
pH	7,9	8,2
Total Dissolved Solids mg/l	548	518
Na^{+} mg/l	125	144
Ca^{++} mg/l	100	88
Mg^{++} mg/l	42	42
K^{+} mg/l	9	9
Cl^{-} mg/l	112	109
SO_4^{--} mg/l	133	137
Sodium Adsorbtion Ratio	2,6	3,2

In terms of these analyses, the water that will be used for irrigation classifies as a C3 - S1 water in U.S.DA. classification. C3 water is defined as high salinity water which cannot be used for irrigation on soils with restricted drainage. Even with adequate drainage, special management for salinity control is required, and plants with good salt tolerance should be selected. S1 water is defined as being usable for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium.

It should be noted, however, that the water composition in respect of salinity falls just within the C3 threshold, and it is thus very likely that after one of the infrequent fillings of the Naute Dam by the Löwen River the water will revert to a C2 water for a period of time. C2 water is a medium salinity water defined as being usable if a moderate amount of leaching occurs. Plants with moderate salt tolerances can be grown in most cases without special practices for salinity control.

When water from the Fish River is used for irrigation in the area, as would happen if the proposed Neckartal Dam is built, it is likely to have much the same chemical composition as that in the Naute Dam at present.

8.1 Drainage Requirements

The soils of the area investigated are for the most part sandy and free draining and will thus not be unduly subject to salt build-up from the irrigation water applied to them. In many places at the base of the soil profile, especially in the alluvial Dundee-Dundee soils along the Löwen River, a gravel horizon is present which will materially assist subsoil drainage.

In all soils other than those which are non-saline, and free draining, it will be necessary to provide adequate subsoil drainage in fields to ensure adequate continuous leaching through the profile and thus the prevention of any salt build-up in the soil profile. Even in areas of non-saline soils the provision of a limited amount of subsoil drainage would be advisable for the same reason. Soils in which there is a particular need for such drainage include the Limpopo, Jozini, Letaba and Calueque series.

In that the soils in the area will permit only of the use of overhead forms of irrigation, with its inherent good control of irrigation water application, the situation regarding possible soil salinity build-up in the long term is much better than would be the case if surface irrigation was possible.

On the initial pilot areas, and in any further major development of the area as a whole, it will be essential to instal a spatially well distributed system of observation well tubes to a suitable depth in the subsoil (2,5 to 3,5m) to monitor groundwater and soil salinity conditions on a continuous basis, so that suitable preventative or remedial measures can be timeously implemented if required.

The provision of adequate subsoil drainage will be an essential portion of any irrigation development in the area so that soil salinity conditions can be controlled.

9. POSSIBLE CROPS SUITABLE FOR CULTIVATION IN THE AREA INVESTIGATED

In terms of the Ehlers* climatic classification of crop suitability, the area investigated is a summer temperature region 88 and a winter temperature region 35. In relation to these categories the following crops are likely to be suitable for economic cultivation in the area under irrigated conditions. These crops are indicated in the Ehlers classification as being optimal or suboptimal under arid or semi-arid climates. The suitability of these crops for cultivation in the area investigated has also been assessed in the light of information available from other authorities, as well as from experience in similar arid environments elsewhere.

(a) Fibre crops

Cotton

(b) Food crops

Sorghum

Maize

Wheat

Rice

Millet (Bullrush)

(c) Oil and protein crops

Groundnuts

Safflower

Sesame

Olives

(d) Fruit

Oranges (Valencia)

Grapes

Watermelon

Dates

(e) Fodder crops

Lucerne

Weeping lovegrass (Eragrostis curvula)

Guinea grass (Panicum maximum)

Rhodes grass (Chloris gayana)

Blue Buffalo grass (Cenchrus ciliaris)

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* J.H. Ehlers, Ekologiese Beplanning van Gewasse. Departement Landboutegniese Dienste, Transvaalstreek, Pretoria.

The more important of these crops are considered individually below.

9.1 Cotton (Gossypium hirsutum)

Cotton prefers an intermediate to heavy textured soil. Thus in the area investigated it should be grown as far as is possible on the heaviest textured soils available, viz. the Oakleaf-Letaba, -Jozini, and -Limpopo soils.

Optimum soil pH for cotton is 7 to 8. Cotton is also salinity tolerant. At an electrical conductivity of the saturated soil extract of 1000 mS/m, the reduction in crop yield is only 10 per cent, a 50 per cent crop reduction in crop yield occurring at a conductivity of 1600 mS/m.

Cotton is, however, sensitive to strong winds, and adequate protection in this regard will have to be ensured in view of the winds prevalent in its growing season during the late summer months.

Adequate pest control will have to be provided, and the cultivation of cotton in the area will have to be included in a rotation with other suitable crops such as sorghum.

Under good conditions of management in terms of the irrigated conditions prevailing in the area a yield about 3 tonnes seed cotton per hectare, or possibly somewhat higher, should be achievable.

9.2 Sorghum (Sorghum bicolor)

Sorghum is tolerant of a wide range of soil textures ranging from heavy clays to light sandy soils. Thus in the area investigated it could be grown on the Oakleaf-Letaba, -Jozini, -Limpopo, -Vaalriver, -Allanridge, -Levubu, -Okavango, and -Calueque soils, as well as on the Dundee-Dundee soils.

Optimum soil pH for sorghum growth is 6 to 8. Sorghum is moderately tolerant of salinity, a 10 per cent reduction in yield being associated with a saturated soil extract conductivity value of 600 mS/m, and a 50 per cent reduction in yield occurring at a value of 1200 mS/m.

Sorghum is drought-resistant and is very well suited for cultivation in a rotation with cotton.

With good conditions of management, a yield of some 3 to 4 tonnes per hectare is likely to be realized in the area investigated.

9.3 Maize (Zea mays)

Maize prefers a well drained and aerated soil of intermediate texture for its optimal cultivation. It is, however, moderately sensitive to salinity, a 10 per cent reduction in yield occurring with a saturated soil electrical conductivity of 500 mS/m, and a 50 per cent reduction occurring at a conductivity of 700 mS/m. Thus, in the area investigated, maize should be grown preferably on non-saline Oakleaf-Letaba, -Jozini, and -Limpopo soils.

Maize is adversely affected by strong winds as will be prevalent in its growing season during late summer.

Under good conditions of management with irrigation, yields of the order of 4 to 5 tonnes per hectare are likely to be achieved in the area investigated.

9.4 Wheat (Triticum aestinum)

Wheat prefers an intermediate textured soil. Thus, in the area investigated, it should preferably be cultivated on Oakleaf-Letaba, -Jozini and -Limpopo soils.

Wheat prefers a soil pH of about 6 to 7. It is moderately sensitive to salinity, a 10 per cent yield reduction being associated with a saturated soil extract conductivity value of 700 mS/m, and a 50 per cent yield occurring at a conductivity of 1400 mS/m. At seedling stage, however, the salinity should not exceed 400 to 500 mS/m. Thus wheat should be grown preferably on non-saline or, at worst, slightly saline soils.

Wheat is drought tolerant, ear initiation being the most critical period for water supply. High temperatures (38 - 40^{o}C) may retard heading and may cause the crop to ripen prematurely after flowering.

Under good conditions of irrigated management a yield of about 4 tonnes per hectare is likely to be achievable in the area.

9.5 Rice (Oryza sativa)

Non-paddy irrigated rice requires intermediate textured soils in general, although somewhat sandier soils can be utilized for its production.

A soil pH of 5,5 to 6 is preferred for rice cultivation. Rice is moderately sensitive to salinity, a 10 per cent yield reduction being associated with a saturated soil extract conductivity value of 500 mS/m, and a 50 per cent yield reduction occurring at a conductivity of 800 mS/m. Thus rice should preferably be grown on non-saline or slightly saline Oakleaf-Jozini, -Venda, -Levubu and -Vaalriver soils in the area investigated.

With good conditions of management under irrigated conditions in the area, a yield of 2,5 to 3,5 tonnes per hectare of unhusked grain should be achievable.

9.6 Millet (Bullrush) (Pennisetum typhoides)

Bullrush millet tolerates very poor soils, including coarse sands. Optimum soil pH for its cultivation is, however, 5 to 6. It is moderately salt tolerant. Millet could probably thus be grown on Oakleaf-Oakleaf, -Vaalriver, -Levubu, -Pollock, -Venda, and -Jozini soils in the area.

Millet is drought tolerant. It can be grown in a rotation following groundnuts.

Yield of millet under irrigated conditions in the area is likely to be about 3 tonnes per hectare.

9.7 Groundnuts (Arachis hypogaea)

Soils suitable for groundnuts are light sandy to intermediate textured, even coarse sandy soils being tolerated.

Optimum soil pH is in the range 5,5 to 7 for growth, groundnuts being moderately sensitive to salinity with a 10 per cent yield reduction likely to occur at a saturated soil extract conductivity of 300 mS/m, a 50 per cent yield decline being associated with a conductivity value of 800 mS/m.

Thus groundnuts can be cultivated on virtually all the soils in the area under irrigated conditions, providing the soils are no worse than slightly saline.

Groundnuts are a legume crop and can therefore conveniently be used in a rotation with cotton and cereal crops such as sorghum, maize, rice, wheat and millet. Rhiyolium innoculation of the seed may be necessary to stimulate adequate leguminous nitrogen fixation.

Yields of groundnuts in the area investigated under irrigated conditions and good management are likely to be in the range 1,5 - 2,0 tonnes per hectare of unshelled nuts.

9.8 Safflower (Carthamus tinctorius)

Safflower can be satisfactorily cultivated on soils of intermediate and sandy texture. Soils have, however, to be reasonably deep because of the taprooting characteristics of the plant.

Soil pH for satisfactory plant growth should be in the range 6 to 8. Safflower is moderately tolerant of soil salinity, a 10 per cent yield reduction being associated with a saturated soil extract conductivity of 800 mS/m, and a 50 per cent yield reduction with a conductivity of 1200 mS/m. Thus safflower can be grown on almost all soils in the area.

The crop is frost tolerant. For early growth, cool temperatures (15 - 20°C) are required, but in later growth the crop can withstand much greater temperatures, provided they do not exceed 43°C.

Safflower needs to be grown in a suitable rotation under irrigated conditions to prevent pest and nematode development.

Yields of safflower under good management irrigated conditions in the area investigated are likely to be of the order of 1,5 to 2,0 tonnes per hectare of seeds with a 40 per cent oil yield.

9.9 Sesame (Sesamum indicum)

Sesame is best grown on intermediate and sandy soil. For its satisfactory growth, a pH value of the soil in the range 5,5 to 7,0 is desirable. Sesame has a low salinity tolerance, however, a 10 per cent crop yield decline being associated with a saturated soil extract conductivity of about 200 mS/m, and a 50 per cent yield decline being associated with a conductivity of about 600 mS/m. Thus sesame in this area should only be grown on non-saline Oakleaf-Vaalriver, -Levubu, -Venda, -Jozini, -Letaba, -Allanridge, -Okavango, -Calueque, -Limpopo and Dundee-Dundee soils.

On account of its taprooting characteristics sesame needs a deep soil (>1m) for its satisfactory growth. The crop needs to be grown in a suitable rotation to prevent root disease development. Overall, the ecological requirements of sesame are similar to those of cotton. Sesame is sensitive to day length and both long- and short-day forms occur. Sesame cultivars are either shattering or non-shattering.

Sesame seeds have an oil content of 45 to 55 per cent. Likely yield under well managed irrigation conditions is likely to be about 1 tonne per hectare for shattering cultivars, the yield of non-shattering cultivars being about 25 per cent less.

9.10 Olives (Olea europaea)

Olive trees generally prefer a deep sandy soil. Soil pH should preferably be about 7 for optimum olive tree growth. Olives are moderately tolerant of soil salinity, a 10 per cent yield reduction occurring at a saturated soil extract conductivity of 400 mS/m. They can thus be grown on non-saline, slightly and moderately saline soils in the area.

A relatively low winter temperature ($<10^{\circ}C$) is required for flower bud initiation.

Olive yields tend to be somewhat variable from year to year, but with good management under irrigated conditions could yield 40 kg per tree; with a tree density of about 400 per hectare possible under irrigation, a yield of about 1,6 tonnes olives per hectare, with an oil content of about 18 per cent, is possible. Olives can, of course, also be used as a fruit.

9.11 Oranges (Valencias)

In terms of the climatic conditions prevailing in the area investigated only valencia oranges, and possibly grapefruit, are suitable for cultivation.

Citrus requires a deep intermediate to sandy textured soil for optimal growth. On sandy soils organic manuring is essential. Thus citrus can be grown on the non-saline and slightly saline soils of the Oakleaf and Dundee forms in the area.

Soil pH for satisfactory citrus growth should be in the range 5 to 8. Citrus is, however, sensitive to soil salinity, a 10 to 20 per cent yield decline of oranges occurring with a saturated soil extract conductivity of 250 mS/m. Citrus is also sensitive to soil alkalinity.

With good management under irrigation, (drip irrigation is possibly the most suitable form in terms of prevailing conditions) a yield of oranges of about 30 tonnes per hectare, with a tree density of about 450 trees per hectare, is likely.

9.12 Grapes (Vitis vinifera)

Grapes require light-textured sandy soils for their optimal growth. Soil pH should be in the range 6 to 7. Grapes are moderately sensitive to soil salinity, a 10 per cent yield decline occurring with a saturated soil extract conductivity of 250 mS/m, and a 50 per cent yield decline at 700 mS/m. Thus in the area investigated, grape cultivation should be limited to non-saline and slightly saline soils.

With good management under irrigation (drip irrigation probably being the most satisfactory form of irrigation in terms of the prevailing conditions) a grape yield of 5 to 10 tonnes per hectare is possible with a vine density of 2000 vines per hectare.

9.13 Watermelons (Citrullus vulgaris)

Watermelons grow best on soils with an intermediate texture. Soil pH for optimum growth of watermelons is 5,8 to 7,2. They are moderately sensitive to soil salinity. Thus, in the area investigated, they should be grown on non-saline and slightly saline soils only. Suitable soils are Oakleaf-Letaba, -Jozini and -Limpopo.

With good management under irrigated conditions, the yield of watermelons in the area should be about 30 tonnes per hectare.

9.14 Dates (Phoenix dactylifera)

Date palms prefer deep intermediate to light sandy-textured soils. For their optimal growth, soil pH should be in the range 6,5 to 8,0. Date palms have a relatively high tolerance to salinity. A 10 per cent yield reduction occurs with a saturated extract conductivity of 700 mS/m, a 50 per cent yield reduction occurring at a conductivity of 1800 mS/m. They can thus be grown on any of the soils of the area that are less than moderately saline.

Dates prefer the water table to be located within a depth of 3m below the ground level.

Dates start producing after 4 to 8 years, and reach full production after 15 to 20 years, after which yields diminish gradually, their useful life terminating at about 40 to 50 years. Dates can be intercropped with other crops such as sorghum, lucerne etc; they are usually planted along field boundaries, roads, etc.

Annual yield of dates should be in the range 6 to 8 tonnes per hectare with good management under irrigated conditions.

9.15 Lucerne (Medicago sativa)

Lucerne grows best on deep intermediate-textured soils. Optimal soil pH for its growth is 6,5 to 7,5. It is moderately sensitive to soil salinity, a 10 per cent yield reduction occurring at a saturated soil extract conductivity of 350 mS/m, and a 50 per cent reduction at a conductivity of 900 mS/m. Thus in the area investigated lucerne should be grown on non-saline or slightly saline Oakleaf-Letaba, -Jozini, and -Limpopo soils preferably, although -Venda and -Calueque soils could also be used.

As a legume lucerne can be grown beneficially in a rotation involving cotton, maize and wheat.

Under irrigated conditions with good management, yields should be of the order of 80 tonnes per hectare per year fresh material with a 20 per cent dry matter content.

9.16 Pasture Grasses

Several pasture grasses could be grown under irrigated conditions in the area investigated in terms of the prevailing climatic conditions. These include Weeping lovegrass (Eragrostis curvula), Guinea grass (Panicum maximum), Rhodes grass (Chloris gayana) and Blue Buffalo grass (Canchrus ciliaris). A good pasture also is a mixture of lucerne and Rhodes grass.

Pastures are best grown on intermediate-textured soils. Soil pH values for their optimal growth are variable but are in the general range 5,5 to 7,0. Grasses are variable in their tolerance of soil salinity. For example, the 10 per cent yield reduction saturated extract conductivity for Lovegrass (Eragrostis) is 300 mS/m, the 50 per cent yield reduction conductivity being 800 mS/m; the comparable values for Bermuda grass (Cynodon dactylon) are 850 mS/m and 1500 mS/m respectively. Thus, in general, pasture grasses should be grown on intermediate-textured soils that are either non-saline or slightly saline.

Yields of grasses are very variable. Under good management conditions with irrigation, yields of the order of 100 tonnes/hectare/annum of dry matter should be achievable.

9.17 Miscellaneous (Vegetables)

Although the generally prevailing climatic conditions are not specifically suited to their production on a field scale in the area investigated, there is little doubt that with a judicious selection of suitable cultivars and planting times, crops of some vegetables on a limited scale will be obtainable under irrigated conditions in the area investigated.

Thus it should be possible to grow cabbages in the autumn, while the growing of tomatoes, beans, carrots, etc, should be possible in the early spring.

In respect of vegetable crops, intermediate-textured soils are the most favourable, soil pH requirements for cabbage being 6,0 to 7,5 and for tomatoes 5,0 to 7,0. Most vegetables are soil salinity sensitive with 10 per cent yield reductions occurring when saturated soil extract conductivities are about 300 mS/m.

The investigation of the economics of the production of any of the crops recommended above and their marketing, are beyond the scope of this investigation. Such investigations must, however, be undertaken prior to any decisions being taken to commence large-scale development in the area investigated.

It is considered essential that one or more initial pilot study areas be established on a representative basis within the area. These should run for a period of several years at least prior to any final decision regarding major development of the area.

In such pilot study areas the following factors would have to be investigated and evaluated:-

- Crop cultivar types on various soils
- Times of planting and harvest
- Fertilizer trials in respect of both major and minor plant nutrients on the prevailing relatively high pH soils
- Irrigation scheduling in conjunction with monitoring of soil salinity development
- Crop Rotations
- Crop Yields with related economic and marketing evaluations

Prior to any further major development in the area it will be necessary to undertake detailed investigation and mapping of prevailing salinity conditions, such as has already been undertaken in the two possible pilot study areas, as soil salinity will be the major factor determining what crops can be grown economically in which portions of the area.

In summary, it is considered that it will be possible to grow the following crops satisfactorily under irrigation in the area investigated:

Cotton, Sorghum, Maize, Wheat, (Rice), Millet, Groundnuts, Safflower, Sesame, Olives, Oranges, Grapes, Watermelons, Dates, Lucerne and Pasture Grasses. Limited amounts of vegetables such as cabbage, tomatoes, beans and carrots could also be considered.

Of these, the most important that could be considered for major field-scale production are:-

Cotton, Sorghum, Maize, Groundnuts, Oranges and Lucerne.

These crops (other than oranges) can form a very satisfactory and necessary crop-rotation.

10. IRRIGATION

10.1 Reference

This section was prepared by Messrs. Eksteen, van der Walt & Nissen, Consulting Civil, Structural and Agricultural Engineers of 30 Schoeman Street, Pietersburg (Tel. 01521 - 6577).

10.2 General

In determination of the irrigation requirements of proposed crops, climatological data have been derived from "Agroclimatological Data for the Fish and Tributary River Valleys to the south-west of Keetmanshoop : F.M. Gamble (Ph.D)". Furthermore the publication "Estimated Irrigation Requirements of Crops in South Africa", ISBN 0 621 08269 4 was used for adopting crop root depths, soil moisture depletion limits and crop factors.

10.3 Crop/Soil Relationships

From the estimated available soil moisture values of the recommended soil forms/series for the applicable crops, general values for available soil moisture have been adopted as set out in Table 10.3.1. With acceptance of the crop root depth and permissible depletion fractions of the available soil moisture as dictated by EIRCSA, the cyclic crop water requirement has been calculated as further set out in Table 10.3.1. for each crop type listed.

Owing to the high evaporation characteristic of the area, it should be accepted that low irrigation applications (<25mm) would prove ineffective. Hence, cyclic crop water requirements of values less than 25mm should be regarded as academic only.

TABLE 10.3.1 : PERMISSIBLE SOIL MOISTURE DEPLETION FOR A VARIETY OF CROPS

CROP	RECOMMENDED SOIL FORM/SERIES	ESTIMATED AVAILABLE SOIL MOISTURE mm/m	ADOPTED AVAILABLE SOIL MOISTURE mm/m	CROP ROOT DEPTH mm	PERMISSIBLE DEPLETION OF AVAILABLE SOIL MOISTURE %	CROP WATER REQUIREMENT mm/cycle
COTTON	Oakleaf - Letaba - Jozini - Limpopo	100 100 100	100	1000 1000	50 70	50 70
SORGHUM	Oakleaf - Letaba, Jozini, Limpopo - Vaalriver, Allanridge - Levubu, Okavango - Calueque	100 80 75 70	70	700	50	25
MAIZE	Oakleaf - Letaba - Jozini - Limpopo	100 100 100	100	600 900	80 50	48 45
RICE	Oakleaf - Jozini, Vaalriver - Levubu - Venda	80 75 70	75	300 600 900	60 50 50	14 23 34
GROUNDNUTS	All soils non saline to slightly saline	65-100	75	50 600 900	90 40 50	34 18 34
LUCERNE	Oakleaf - Letaba, Jozini, Limpopo - Venda, Calueque	100 70	80	1000	50	40
CULTIVATED PASTURES	All medium textured soils, non saline to slightly saline	65-100	80	400	60	19
CITRUS	Oakleaf	65-100	75	600	50	23
GRAPES	Light-textured soils, non saline to slightly saline	65-80	75	750	50	28
TOMATOES	Medium textured soils	65-80	75	400 500 600	25 40 50	8 15 23
BEANS	Medium textured soils	65-80	75	450 600	90 50	31 23
CABBAGE	Medium-textured soils	65-80	75	400 500 600	25 40 50	8 15 23

10.4 Crop Water Requirements

Crop water requirements have been calculated as set out in Table 10.4.1. The following legend to abbreviated terms applies:

Ra	:	Annual rainfall (mm/month)
Eo	:	Class A-pan evaporation (mm/month)
Dsm	:	Permissible soil moisture depletion (mm)
k	:	Crop factor (weighed average for month)
Et	:	Evapotranspiration (mm/day, mm/month)
S	:	Irrigation cycle (days)

The monthly Class A-pan evaporation values recorded for Keetmanshoop over a period of some 4 years have been adopted. It is accepted that actual figures for the target area would prove slightly higher.

The annual rainfall in relation to the Class A-pan evaporation values proves fairly insignificant for the purpose of determining crop water demands. Furthermore, the variability in annual rainfall (ca. 54% deviation from mean annual rainfall) illustrates a high degree of unreliability. Hence, for the purpose of calculating crop water demands, the contribution of natural rainfall has been ignored.

Crop factors (k) have been calculated as the weighted average for each appropriate month during the growing season. From them, the monthly and seasonal crop water demands have been derived. It should, however, be noted that crop factors for certain crops (e.g. cotton, maize, rice, beans and cabbage) vary considerably within critical weeks of the growing season. Hence, peak crop factors have been derived within each calendar month and the peak daily crop water requirement and critical cycle determined.

TABLE 10.4.1 : CROP WATER REQUIREMENTS

CROP	IRRIGATION PARAMETER	MONTH J	F	M	A	M	J	J	A	S	O	N	0	TOTAL	SEASONAL CROP WATE DEMAND(mm
	Ra mm/M	23	33	38	15	4	1	1	1	3	5	10	12	146	
	Eo mm/M	465	373	328	251	185	170	206	246	323	396	465	495	3903	
COTTON	Dsm mm	70	70	70							50	50	50		1468
	k	0,81	0,60	0,45							0,30	0,46	0,78		
	Et mm/M	377	224	148							119	214	386		
	Et mm/d	12,2	8,0	4,8							3,8	7,1	12,5		
	S days	5,8	8,8	14,7							13	7	4		
	peak : k	0,87	0,73	0,46							0,3	0,64	0,87		
	: Et mm/d	13,1	9,7	4,9							3,8	9,9	13,9		
	: S days	5,4	7,2	14,4							13	5	3,6		
MAIZE	Dsm mm	45	45								48	48	45		1782
	k	0,93	0,5								0,5	0,9	1,1		
	Et mm/M	433	187								198	419	545		
	Et mm/d	14,0	6,7								6,4	14,0	17,6		
	S days	3,2	6,8								7,5	3,4	2,6		
	peak: k	1,1	0,5								0,7	1,0	1,1		
	: Et mm/d	16,5	6,7								8,9	15,5	17,6		
	: S days	2,7	6,8								5,4	3,1	2,6		
RICE	Dsm mm	23	23	34							14	23	23		2314
	k	1,1	1,05	1,0							0,6	0,75	1,0		
	Et mm/M	512	392	328							238	349	495		
	Et mm/d		14,0	10,6							7,7	11,6	16,0		
	S days		1,6	3,2							1,8	2	1,4		
	peak : k	1,1	1,1	1,0							0,5	0,9	1,1		
	: Et mm/d	16,5	14,7	10,6							7,7	14,0	17,6		
	: S days	2	1,6	3,2							1,8	1,6	1,3		
GROUNDNUTS	Dsm mm	18	34	34								34	18		1117
	k	0,6	0,5	0,5								0,3	0,7		
	Et mm/M	279	187	164								140	347		
	Et mm/d	9,0	6,7	5,3								4,7	11,2		
	S days	2	5,1	6,4								7,3	1,6		
LUCERNE	Dsm mm	40	40	40	40	40	40	40	40	40	40	40	40		2769
	k	0,8	0,8	0,8	0,7	0,6	0,5	0,5	0,5	0,6	0,7	0,8	0,8		
	Et mm/M	372	298	262	176	111	85	103	123	194	277	372	396		
	Et mm/d	12,0	10,7	8,5	5,9	3,6	2,8	3,3	4,0	6,5	8,9	12,4	12,8		
	S days	3,3	3,8	4,7	6,8	11,2	14,1	12,0	10,1	6,2	4,5	3,2	3,1		
CULTIVATED PASTURES	Dsm mm	19	19	19	19	19	19	19	19	19	19	19	19		2769
	k	0,8	0,8	0,8	0,7	0,6	0,5	0,5	0,5	0,6	0,7	0,8	0,8		
	Et mm/M	372	298	262	176	111	85	103	123	194	277	372	396		
	Et mm/d	12,0	10,7	8,5	5,9	3,6	2,8	3,3	4,0	6,5	8,9	12,4	12,8		
	S days	1,6	1,8	2,2	3,2	5,3	6,7	5,7	4,8	2,9	2,1	1,5	1,5		

TABLE 10.4.1(CONTD) : CROP WATER REQUIREMENTS

CROP	IRRIGATION PARAMETER	MONTH J	F	M	A	M	J	J	A	S	O	N	D	TOTAL	SEASONAL CROP WATER DEMAND(mm
	Ra mm/M	23	33	38	15	4	1	1	1	3	5	10	12	146	
	Eo mm/M	465	373	328	251	185	170	206	246	323	396	465	495	3903	
CITRUS	Dsm mm	23	23	23	23	23	23	23	23	23	23	23	23		3492
	k	0,88	0,99	1,1	0,98	1,0	0,9	0,75	0,84	0,72	0,87	0,92	0,81		
	Et mm/M	409	369	361	246	185	153	155	207	233	345	428	401		
	Et mm/d	13,2	13,2	11,6	8,2	6,0	5,1	5,0	6,7	7,8	11,1	14,3	12,9		
	S days	1,7	1,7	2	2,8	3,9	4,5	4,6	3,5	3,0	2,1	1,6	1,8		
GRAPES	Dsm mm	28	28	28	28	28	28	28	28	28	28	28	28		1353
	k	0,5	0,55	0,5	0,21	0,21	0,21	0,21	0,21	0,23	0,27	0,31	0,41		
	Et mm/M	233	205	164	53	39	36	43	52	74	107	144	203		
	Et mm/d	7,5	7,3	5,3	1,8	1,3	1,2	1,4	1,7	2,5	3,4	4,8	6,5		
	S days	3,7	3,8	5,3	15,9	22,3	23,5	20,1	16,8	11,3	8,1	5,8	4,3		
TOMATOES	Dsm mm	23	23								15	15	23		1239
	k	0,7	0,7								0,3	0,4	0,7		
	Et mm/M	326	261								119	186	347		
	Et mm/d	10,5	9,3								3,8	6,2	11,2		
	S days	2,2	2,5								3,9	2,4	2,1		
BEANS	Dsm mm										31	23	23		779
	k										0,35	0,63	0,7		
	Et mm/M										139	293	347		
	Et mm/d										4,5	9,8	11,2		
	S days										6,9	2,4	2,1		
	peak: k										0,4	0,7	0,7		
	: Et mm/d										5,1	10,9	11,2		
	: S days										6,1	2,1	2,1		
CABBAGE	Dsm mm			31	31	23	23								558
	k			0,45	0,64	0,7	0,7								
	Et mm/M			148	161	130	119								
	Et mm/d			4,8	5,4	4,2	4,0								
	S days			6,5	5,8	5,5	5,8								
	peak: k			0,6	0,7	0,7	0,7								
	: Et mm/d			6,3	5,9	4,2	4,0								
	: S days			4,9	5,3	5,5	5,8								

From Table 10.4.1, the following critical information should be noted:

- High peak evapotranspiration (range 6,3 to 17,6 mm/day)
- Short critical cycles (range 1,3 to 4,9 days)

It is thus evident that, irrespective of the type of proposed crop chosen, consistent irrigation would be required 7 days per calendar week to meet the calculated crop water demands. This would necessitate a high degree of skill and excellent management in respect of scheduling and operation. This is irrespective of the type of irrigation system employed.

10.5 Crop Irrigation Requirements

Table 10.5.1. illustrates the probable crop irrigation requirements with reference to a variety of irrigation systems. Close scrutiny of the required system capacities reveals a distinct variance for the different systems, owing to the widely varying irrigation efficiencies. In general, application efficiencies will be comparatively low, owing to the arid environment with high temperatures and strong winds.

TABLE 10.5.1 : CROP IRRIGATION REQUIREMENTS

Note : Irrigation ti
23h/day; 7 days /week

CROP	FOLIAGE COVER	IRRIGATION SYSTEM: TYPE	IRRIGATION SYSTEM: EFFICIENCY	ANNUAL IRRIGATION DEMAND: SEASONAL CROP WATER DEMAND	ANNUAL IRRIGATION DEMAND: SYSTEM IRRIGATION DEMAND	SYSTEM CAPACITY: PEAK CROP Et	SYSTEM CAPACITY: SYSTEM IRRIGATION DEMAND	SYSTEM CAPACITY: IRRIGATION APPLICATION PER CYCLE	SYSTEM CAPACITY: CRITICAL CYCLE	SYSTEM CAPACITY: SYSTEM CAPACITY
	%		%	mm	mm/a	mm/day	mm/day	mm	days	l/s.ha
COTTON	100	Travelling Gun	50	1468	2936	13,9	27,8	100	3,6	3,36
	100	Centre Pivot	70		2097		19,9	71		2,4
	100	Drip	90		1631		15,4	56		1,86
MAIZE	100	Travelling Gun	50	1782	3564	17,6	35,2	90	2,6	4,25
	100	Centre Pivot	70		2546		25,1	64		3,03
	100	Drip	90		1980		19,6	50		2,37
RICE	100	Flood	50	2314	4628	17,6	35,2	46	1,3	4,25
	100	Centre Pivot	70		3306		25,1	33		3,03
GROUNDNUTS	100	Travelling Gun	50	1117	2234	11,2	22,4	36	1,6	2,71
	100	Centre Pivot	70		1596		16	26		1,93
LUCERNE	100	Lateral Roll	65	2769	4260	12,8	19,7	62	3,1	2,38
	100	Centre Pivot	70		3956		18,3	57		2,21
CULTIVATED PASTURES	100	Lateral Roll	65	2769	4260	12,8	19,7	29	1,5	2,38
		Centre Pivot	70		3956		18,3	27		2,21
CITRUS	70	Dragline Sprinkler	65	3492	3761	14,3	15,4	25	1,6	1,86
		Microspray	85		2876		11,8	19		1,43
		Drip	90		2716		11,1	18		1,34
GRAPES	100	Drip	90	1353	1503	7,5	8,3	31	3,7	1,01
TOMATOES	125	Drip	90	1239	1721	11,2	15,6	32	2,1	1,88
BEANS	100	Travelling Gun	50	779	1558	11,2	22,4	46	2,1	2,71
		Centre Pivot	70		1113		16	33		1,93
CABBAGE	70	Travelling Gun	50	558	781	6,3	8,8	43	4,9	1,06
		Centre Pivot	70		558		6,3	31		0,76

10.6 Irrigation Systems

10.6.1 Portable Pipe Sprinkler Systems

Because of the high evapotranspiration rates and short irrigation cycles, most systems would require to be operated around the clock at peak demand stages of crop growth. This would necessitate a considerable labour input.

A comparative scheme, but in a less arid climate where irrigation sets are handmoved 3 times per day during daylight hours with a 4 day cycle, dictates a labour requirement of 1 man/32ha. During peak irrigation conditions it is even necessary to move the sets at night, requiring shifts with a nett labour requirement of 1 labourer/18 ha and in addition, artificial lighting equipment.

Furthermore, the arid conditions would necessitate close sprinkler spacings, in the order of 12m x 12m, with a comparatively high infield layout cost. Irrigation efficiencies are expected to be in the order of 60 - 65%.

10.6.2 Lateral Roll

This system has the advantage of semi-mechanised operation, requiring one labourer per 120ha. Capital cost for within-field equipment (subsurface pipework included) is currently of the order of R1700/ha. Energy requirements (assuming water available at atmospheric pressure at field edge) for the crops listed, accepting an overall pump efficiency of 65%, would be 2012 kW.h per hectare per 1000mm irrigation depth applied.

10.6.3 Centre Pivots

Owing to the short irrigation cycles, fixed units are recommended. Units of 10, 16, 20 and 30ha are popular sizes in the current market. Although larger units are available, infiltration limitations and cycle times for one revolution with the required application cycle will not be met.

The following table summarizes capital costs and energy requirements for medium-low pressure (210 kPa operational) systems:

TABLE 10.6.1 : COST OF CENTRE PIVOT SYSTEMS

Centre Pivot Coverage (ha)	Capital cost of within-field equipment			Energy requirements per hectare per 1000mm irrigation depth applied* (kW.h)
	Machine (R/ha)	Subsurface eq. (R/ha)	Total (R/ha)	
10ha (fixed)	3 545	1 958	5 503	1 600
15ha (fixed)	2 842	1 689	4 531	1 470
20ha (fixed)	2 665	2 405	5 070	1 655
30ha (fixed)	2 151	1 961	4 112	1 510

* Assume a) Irrigation water available at atmospheric pressure at field edge
b) Overall pump efficiency 65%

10.6.4 Drip Systems

For irrigation of cash crops, dripperlines with integral drippers and pressure compensating function would be recommended. Capital costs for within-field equipment (filtration systems included but excluding automation facilities) is currently of the order of R5 300 per hectare. Energy requirements (assuming water available at atmospheric pressure at field edge) for the cash crop listed, would be 840 kW.h per hectare per 1000mm irrigation depth applied.

10.6.5 Travelling Gun Irrigation Systems

Another type of mechanised overhead irrigation system that could possibly be considered is a travelling gun system. This system has the advantage that rectangular blocks of land are possible and has a relative low capital cost of ±R4000/ha (including infield subsurface piping), and being mechanised, short cycle irrigation frequency requirements could be met. The cost is of the same order as that of the 30 ha fixed centre pivot installation. The system has, however, many other disadvantages such as low irrigation efficiencies, high energy and management requirements, compared with those of a centre pivot installation. Where the geometry of a particular piece of ground is, however, unsuitable for centre pivots, the travelling gun system could be considered in lieu of lateral roll or drip systems.

10.7 Overall Irrigation Requirement

In general, the overall irrigation requirement of a proposed scheme can only be determined once a cropping programme has been established. However, in absence thereof, a hypothetical farming model, with an areal extent of 1000 ha may be considered, using the following model parameters:

- Most important field crops are cotton, maize, groundnuts, cabbage, lucerne and citrus.
- Areal utilisation:

Summer	:	500 ha cotton
		100 ha maize
		200 ha groundnuts
Winter	:	50 ha cabbage
Perennial	:	100 ha citrus
		100 ha lucerne
		1050 ha

- Land use efficiency : 105%

Adopting the seasonal crop water demands (Table 10.4.1) and irrigation efficiencies for centre pivots in respect of summer and winter crops, drip systems for citrus, and lateral roll systems for lucerne, the mean annual irrigation demand for a 1000 ha model totals 24,28 Mm^3/a. This corresponds with a mean annual applied irrigation depth of 2428 mm.

10.8 Irrigation Layout

10.8.1 General

The soil maps have been studied and the possible utilisation of irrigability classes 1, 2 and 3 soils have been included in a preliminary conceptual layout of the Neckartal irrigation scheme. The layout includes that of a 200 ha pilot scheme. The following irrigation layout parameters were used in order to ascertain the possible extent of such a conceptual reconnaissance layout.

(a) An economic farm unit was accepted to be 30 ha and the general layout was built around multiples thereof.

(b) A centre pivot circle of 30 ha fits geometrically well with the general occurrences of suitable irrigable soils and was accepted as the standard plot layout base. In order, however, to permit maximum utilization of available soils the following smaller circle combinations were also included:

3 x 10 ha, 2 x 15 ha and 20 + 10 ha.

(c) Long or narrow blocks of land unsuitable for the above centre pivot layout have been included where possible as 30 ha rectangular blocks for travelling gun type irrigation.

(d) No allowance has been made in the layout for lateral roll or drip systems (excepting the pilot layout as described), but these could readily be included on smaller outfall blocks of land.

10.8.2 <u>General Extent of Possible Irrigation Layout</u>

The extent of each of the identified irrigation blocks is shown in the tabulation below.

BLOCK NAME & NO.	NO. OF 30ha PLOTS AND AREA (ha) FOR EACH TYPE OF LAYOUT GEOMETRY					TOTAL NO. PLOTS	AREAS (ha) FOR EACH IRRIGABILITY CLASS AND PERCENTAGE UTILIZATION OF AVAILABLE LAND			
	1x30ha	3x10ha	2x15ha	10+20ha	TRAV.GUN 30ha		Class 1	Class 2	Class 3	TOTAL
GAWACHAB (7)	14 420	8 240	2 60	4 120	3 90	31	300 (83%)	200 (57%)	430 (63%)	930 (67%)
NAUTE (4,5 & 6) (Excluding pilot areas)	10 300	9 270	2 60	2 60	5 150	28	90 (53%)	290 (65%)	460 (58%)	840 (60%)
VISHOEK/ DAGBREEK (3)	2 60			3 90	2 60	7		90	120	210
SCHAAPPLAATS (1,2,3 & 4)	19 570	3 90	6 180	4 120	4 120	36	290 (36%)	280 (78%)	510 (45%)	1080 (59%)
SCHLANGKOPF (1 & 2)	16 480		1 30		1 30	18	65 (75%)	95 (70%)	380 (33%)	540 (45%)
						120 ===	745 === (80%)	955 === (69%)	1900 ==== (50%)	3600 ==== (59%)
PILOT SCHEME										200
TOTAL AREA OF SCHEME										3800 ========

10.8.3 Main Conveyance

The above extents have been based on the possible command by the following main conveyance system:

(a) A main canal beginning at reduced level 760m at Schlangkopf (receiving water from the Neckartal dam) crossing the Schaap river at Schaapplaats and terminating some 5km to the north of the Naute dam, in all 22km long. (The estimated cost range of this canal reach is R22M.)

(b) This canal would traverse the Schlangkopf block and water could be directly abstracted.

(c) The Schaapplaats and Vishoek blocks would be provided with water via a 22km long main supply pipeline (1500 - 500 dia.) located along the Schaap river proposed canalisation. The cost of this conveyor is estimated at R15M.

(d) The southern blocks (Naute and Gawachab) would also be served with a pipeline between the termination point of the main canal (described in (a)) and Gawachab. The proposed route would follow the Löwen river and water could be abstracted directly therefrom. A 1500mm pipeline reducing to a nominal size at the end, in total 20km long, would cost approximately R14M.

The locality of the Naute dam is such that spillages from a main canal could be accommodated therein obviating the necessity of having a balancing dam at the end of the canal. This balancing function of the Naute dam is therefore very important and is an inherent cost saving feature.

10.8.4 General Description of Individual Blocks

(a) Gawachab and Naute blocks

Good utilization of available soils is possible. The topography is, however, such that it would be a pre-requisite that the Löwen river should be canalised.

(b) Schaapplaats and Vishoek blocks

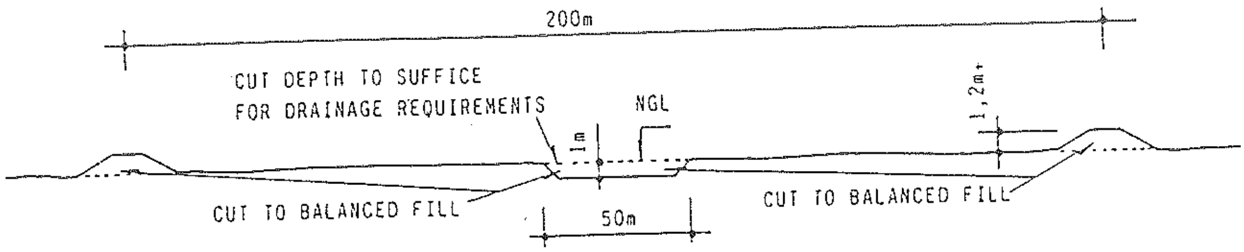
The Schaap river traverses this area and canalisation thereof would be required. Good utilization of available irrigable soils is possible. We have, however, excluded the irrigable soils (144 ha) above the 760m contour.

(c) Schlangkopf block

We have excluded all soils (Class 3 irrigability) lying above the 780m contour.

10.8.5 Stormwater Measures and Canalisation

Various measures would be required to cope with stormwater and drainage problems in the study area. In the first instance it is necessary (as stated elsewhere) to canalise the Löwen and Schaap rivers where they traverse the proposed irrigation development. A possible low cost measure as depicted below could suffice.



PROPOSED CANALIZATION PROFILE

The canal cut in the centre of the proposed main canalisation could be used as an underground drainage collector. The estimated costs of these canalisation systems are:

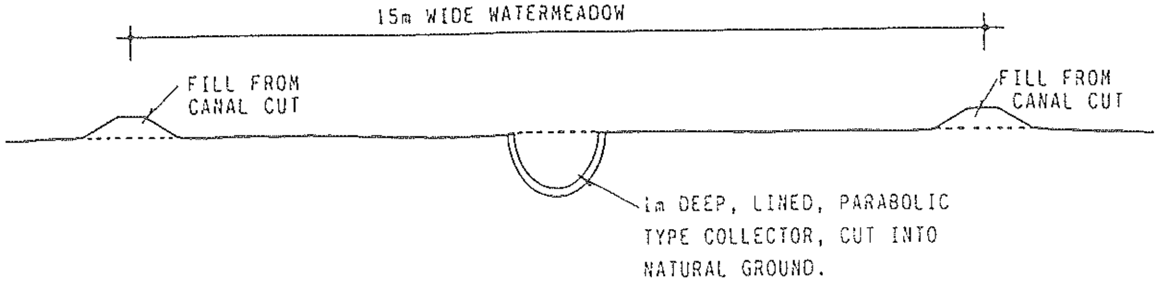
Löwen	18 km	R1,6M	
Schaap	19 km	R1,5M	R3,1M

The proposed infield stormwater measures are:

(a) Standard trapezoidal shaped cut to fill type training banks 1m deep, discharging into formed watermeadows, natural depressions and formed drainage canals.

(b) Watermeadows to be provided with irrigation water for the establishment of vegetation.

(c) In areas with subsoil drainage a prerequisite (NA symbol on land irrigability classification), it is proposed to have a drainage collector/ watermeadow type combination structure, with diagrammatic details depicted below.



DRAINAGE COLLECTOR / WATER MEADOW TYPE

COMBINATION STRUCTURE

The following tabulation gives the extent and costs of infield stormwater measures. The tabulation also shows the area that should be drained.

	Stormwater measures		Management measures for soils with potential salinity	
	Water meadows (km)	Training banks (km)	Drainage collector (km)	Area to be drained (ha)
. Gawachab (7)	6	15	3,8	160
. Naute (5 & 6)	14	24	3,8	40
. Vishoek & Dagbreek (3)	3	6	-	-
. Schaapplaats (1,2,3 & 4)	4	20	1,8	20
. Schlangkopf (1 & 2)	8	9	4,1	325
	35	74	13,5	545
Unit cost	R4 500	R600	R50 000	R5 000
Cost estimate	R0,16M	R0,04M	R0,68M	R2,73M

10.8.6 The Naute Pilot Irrigation Layout

This proposed irrigation layout is situated just below the Naute dam and forms part of the Naute layout shown on sheets 5 and 6 of the 1:20 000 soils map and described elsewhere. The proposed pilot scheme comprises of blocks A and B on the right and left banks respectively of the Löwen river.

The following irrigable areas occur on the demarcated areas:

	Area A	Area B	Total
Class 1	10	37	47
Class 2	18	22	40
Class 3	180	0	180
	208	59	267 ha

External stormwater runoff measures for these pilot areas should form part of the future Naute layout. The following are envisaged:

Area A : Watermeadows on the western and north-eastern sides and a training bank all along the road, discharging into the western watermeadow. In addition one broad base bank would be required within the block traversing the entire area.

Area B : At the southern end of this area a drainage collector/watermeadow would be required in order to drain the potentially saline soils occurring in that area. A training bank running all along the pilot area (above the road) would discharge in the latter drain. These measures could suffice.

The following irrigation layout systems would fit these areas:

Area A:	30 ha centre pivot circles	:	3 no
	10 ha centre pivot circles	:	1 no
	Micro irrigation experimental plots in 1 ha elements	:	60 no
	TOTAL AREA		160 ha
Area B:	40 ha rectangular block for a travelling gun and/or lateral roll systems	:	40 ha
			200 ha

10.8.7 Energy Requirements

The total energy requirement in order to pump the water from the main conveyance systems within the proposed scheme to the various sprinkler systems would be of the order of 10 000 kW. A maximum of approximately 15 pumpstations throughout the scheme should suffice.

10.8.8 Cost Estimate of Possible Irrigation Development

An endeavour has been made to determine the possible extent of the development cost of an irrigation scheme based on a very generalised layout as described above. In the cost estimate below, the following items were excluded:

(a) Infrastructural development

- Main water conveyor from the dam to the upper end of the scheme (Schlangkopf) including supplying water to reduced level 760m as accepted in the conceptual layout.
- Main access roads
- Main electricity supply for an area of 34 km long from Schlangköpf to Gawachab and 16 km wide between Schaapplaats and Vishoek.
- Impounding works (Naute and Neckartal dams)

(b) Agricultural development

- Farming supporting infrastructure such as houses and farm buildings.
- Agricultural costs in respect of land and seed bed preparation and other farming and crop inputs.

The cost of water conveyance works within the scheme layout as described, amounts to R97,6M. This cost can be considered as infrastructural and cannot be judged against the irrigation development. The irrigation layout costs of R44,3M or R11 600/ha are comparable to other irrigation schemes of the same order in arid areas in Southern Africa.

The equivalent cost of developing the pilot areas would be the following:

(a)	External supply, initially from Naute dam including pumpstations	: R1,2M
(b)	Irrigation layout	: R2,3M

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NECKARTAL IRRIGATION PROJECT : COST ESTIMATE OF IRRIGATION LAYOUT

Item	Description	Quant.	Unit	Rate	Amount
1.	MAIN INFRASTRUCTURAL COSTS				
1.1	Main conveyance system				
	(a) Main canal from beginning of study area (at Schlangkopf) to Naute area	22	km	R1000 per m	R22,0M
	(b) Main supply pipeline from Naute area to Gawaschab	20	km	R 700 per m	R14,0M
	(c) Main distribution pipeline from main canal at Schaapplaats to Vishoek area	22	km	R 680 per m	R15,0M
1.2	Canalization of main drainage systems				
	(a) Löwen river		sum		R 1,6M
	(b) Schaap river		sum		R 1,5M
1.3	Pumpstations				
	(a) Inlet sumps for pumpstations adjacent to open conveyor	10	no	R20000	R 0,2M
	(b) Buildings	15	no	R60000	R 0,9M
	(c) Mechanical equipment (20% standby)	12000	kW	R 350	R 4,2M
	(d) Pipework	11000	l/s	R 500	R 5,5M
	(e) Electrical installations (20% standby)	12000	kW	R 600	R 7,2M
1.4	Contingencies including minor works	10	%	R 72M	R 7,2M
1.5	Preliminary and general costs and establishment	15	%	R 79M	R 7,9M
	SUBTOTAL CONSTRUCTION COSTS				R87,2M
1.6	Engineering, supervision and administration	12	%	R 87M	R10,4M
	PROJECT COST MAIN INFRASTRUCTURE				R97,6M

Item	Description	Quant.	Unit	Rate	Amount
2.	IRRIGATION LAYOUT COSTS				
2.1	Land preparation				
	(a) Clearing of soil surface of small boulders and gravel by raking	4000	ha	R 600	R 2,40M
	(b) Planing and land levelling where adverse micro relief occurs in the form of small dunes	1200	ha	R1300	R 1,56M
2.2	Storm runoff and land improvement measures				
	(a) Forming of water meadows	35	km	R4500	R 0,16M
	(b) Training banks	74	km	R 600	R 0,04M
	(c) Drainage collector	13,5	km	R50000	R 0,68M
	(d) Inland drainage measures (provisional)	545	ha	R5000	R 2,73M
	(e) Wind breaks, planting and establishment	4000	ha	R 500	R 2,00M
	(f) Establish vegetation cover on watermeadows	100	ha	R2/m^2	R 2,00M
	(g) Fencing in of irrigation blocks (macro)	170	km	R6/m	R 1,02M
2.3	Infield irrigation development				
	(a) Irrigation equipment and infield supply main and electrical distribution	3800	ha	R4600	R17,48M
	(b) Extraover cost for additional secondary supply main and electrical distribution for isolated localities	800	ha	R1600	R 1,28M
2.4	Contingencies including minor works	10	%	R 31M	R 3,10M
2.5	Preliminary and general costs and establishment	15	%	R 34M	R 5,10M
	SUBTOTAL CONSTRUCTION COSTS				R39,55M
2.6	Engineering, supervision and administration	12	%	R 39M	R 4,75M
	PROJECT COST OF IRRIGATION LAYOUT				R44,3M
	TOTAL PROJECT COST				R141,9M