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MINISTRY OF AGRICULTURE

MOGAMBO IRRIGATION PROJECT

GROUNDWATER AND SALINITY STUDY
OCTOBER – NOVEMBER 1987

SIR M MACDONALD & PARTNERS LIMITED
Consulting Engineers
JOHN BINGLE PTY. LIMITED
Agricultural Management Consultants Australia

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MOGAMBO IRRIGATION PROJECT

Groundwater and Salinity Study

October to November 1987

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SUMMARY AND CONCLUSIONS

Salts are present in the soil profile, especially in the Jbl soils (30% of the project), at levels which are high enough to cause concern.

Gypsum and $CaCO_3$ in substantial amounts are present in many of the soils. The relatively high concentrations of these salts in the soils will result in over-estimation of the soil EC if measurements are taken in 1 : 5 soil water suspensions. It is therefore recommended that EC_e (electrical conductivity of the saturation extract), which simulates field conditions better, be used.

Presently salinisation of the root zone profile is not a problem. Groundwater is often very saline (EC varies from 1 to 60 mS/cm), but presently at a depth which does not affect plant production, except in small areas near reservoirs where capillary rise from shallow saline groundwater caused fallow land to salinise.

Increasing irrigation development in the Mogambo Irrigation Project (MIP) and other areas of the Juba river valley will put increasing pressures on the groundwater system in the future. Also the extensive land clearing for dryland smallholders agriculture will result in increasing percolation to the watertable as deep rooted natural vegetation is replaced by shallow rooted agricultural crops.

Even if in future shallow saline watertables were to become a general problem in the MIP area, rice cultivation would still be possible and may even be the most appropriate land use in this saline environment. However, water use efficiency would decrease as flushing would be needed to remove salts. Also non-rice crops in and around the MIP area would suffer yield losses if no deep drainage measures were taken in these areas.

Present water management practices should be refined. A regular re-grading of the basins, using laser guided equipment will both reduce percolation losses to the watertable and increase yields.

The MIP is a large capital intensive enterprise with a potential underlying salinity problem which justifies a concentrated investigation and monitoring programme. The following recommendations are made.

- A network of shallow observation wells (about 5 m below surface) and shallow piezometers (7 m below surface) should be installed in blocks 39 and 42 and surrounding blocks. (Some of this work was carried out during the consultancy.) The wells can be installed using hand augering equipment.

- A water balance study should be implemented in the two pilot blocks 39 and 42. This study will yield information on different percolation losses under double and single rice cropping systems. In these blocks soil salinity will be measured to a depth of 120 cm before and after irrigation to monitor salt movement in this layer.

- A set of peizometers should be installed at three sites in the MIP area down to a depth of approximately 70 m below surface. These piezometers will have to be installed at 3 m and 10 m below surface and in each subsequent sand/gravel layer found at each site. Monthly monitoring of these piezometers will yield valuable information on discharge/recharge processes, and provide early warnings on upcoming salinity problems. The installation will have to be implemented by a qualified drilling contractor. It is recommmended that the Ministry of the Juba Valley be included in this investigation.

- Laboratory facilities should be upgraded to cope with the increased workload resulting from the abovementioned monitoring activities. A competent person will have to be appointed to organise and supervise laboratory and field monitoring activities.

- The National University of Somalia should be involved as a technical backstopping agency for the MIP monitoring activities and an EM.38 soil conductivity survey be implemented by NUS in an east-west cross-section through the pilot monitoring area twice a year at the start and the finish of the gu irrigation season.

- A geo-hydrological survey should be carried out in the Juba river valley to investigate regional groundwater flow systems and their ability to copen with increasing percolation losses. The Ministry of the Juba Valley is the obvious department to co-ordinate the implementation of this survey.

- Laser guided grader-scraper equipment which can be operated using the current MIP tractors, should be purchased to improve water usage efficiency and thus minimise percolation losses to the watertable.

- A reporting system between the MIP Investigation and Monitoring section and one of the consultants should be formalised, resulting in a regular (3 monthly) information exchange between the two parties.

- A follow-up mission should be made by one of the consultants after sufficient data have been collected to warrant such a mission. The annual involvement of the consultant would be in the order of 3 to 4 weeks. The monitoring program should run for a period of at least 3 years.

1. INTRODUCTION

When agricultural operations in the Mogambo Irrigation Project (MIP) area started in 1985, the management team for the agricultural development of the area expressed its concern about the high salinity levels and low hydraulic conductivity of the subsoils. They suggested that this could seriously affect the growing of rice and other crops in the area. The same concerns were expressed by Sir M. MacDonald & Partners Limited (MMP) in their Supplementary Feasibility Study Report.

Programmes were set up to investigate:

- the effects of crop rotations, particularly rice double cropping, on watertable depth and salinity
- the nature and permeability of subsoils in both the Mogambo project and the nearby Fanoole rice project
- the influence of irrigation on root zone salinity

Tentative conclusions from the studies are:

(a) A rise of the groundwater level, which was highest on double cropped sites.

(b) Salinity of the groundwater is high.

(c) A gradual decrease in permeability with depth.

(d) Decrease in topsoil salinity after irrigation.

Through Sir M. MacDonald & Partners Limited (MMP) and John Bingle Pty. Ltd. (JBPL) the Mogambo Irrigation Project requested Messrs. H.J. Nijland and A.F. Heuperman to evaluate the salinity and groundwater situation in the project area and make recommendations for future monitoring. The terms of reference of the consultancy mission are presented in Annex 1.

Mr. H.J. Nijland arrived in Mogadishu on 17th October 1987 and completed his assignment on 15th November 1987. Annex 2 shows Mr. H.J. Nijland's itinerary.

Mr. A.F. Heuperman started his assignment in Mogambo on 1st November 1987 and completed it on the 1st December 1987. His itinerary is shown in Annex 3.

2. GENERAL DESCRIPTION OF THE PROJECT

2.1 Background

The Mogambo Irrigation Project (MIP) was first formulated in a feasibility study undertaken by TAMS/FINTECS (May 1977) and then studied in further detail in a supplementary feasibility study carried out by Sir M. MacDonald & Partners Limited (MMP) (August 1979). The supplementary study identified a net irrigable area of 6 430 ha.

The funding agencies, the Kuwait Fund for Arab Economic Development (KFAED), and the Kreditanstalt fur Wiederaufbau (KfW), considered that technical and managerial problems and uncertainies involved too great a risk in implementing the whole 6 430 ha in one step. Therefore, an additional study was conducted by MMP in 1980 which considered the initial development of an area of about 2 000 ha for predominantly surface irrigation.

In March 1984 a contract was awarded to Philip Holzman-Astaldi Joint Venture for the implementation of the irrigation, drainage and flood protection works in the project area, covering some 2 500 ha (Phase 1). These engineering works were completed in 1987.

Agricultural development of the project started in 1985. The project is operated as a state farm. The general management of the state farm is assisted by a management team from John Bingle Proprietory Limited of Australia. MMP is the project's consulting engineer.

2.2 Location

The project takes its name from the village of Mogambo which is located on the bank of Juba river, approximately 70 km by road from the coastal town of Kismayo.

The project (Phase 1 + Phase 2) covers a gross area of some 8 000 ha. The boundary of the project area to the east is formed by existing banana plantations adjacent to the river. To the north is the Trans-Juba Livestock Project and the southern end of the Juba Sugar Project area. The western boundary of the Mogambo Irrigation Project is formed by a series of interconnecting old channels on the edge of a marine plain. The southern end of the project area is just 20 km from the coastline. The district centre town of Jumama is located on the eastern side of the Juba river about 10 km from the project.

Figure 2.1 shows the general location of the project in Somalia and Figure 2.2 shows the extent of the project area (Phase 1 + Phase 2).

2.3 Climate

The climate is tropical and semi-arid with a mean annual precipitation of about 430 mm which falls mainly during the gu (April-May-June) and der (September/ October to December) seasons.

The gu season rainfall is higher and more reliable than that of the der season, normally ranging between 250 and 300 mm. May and June are the two months of heaviest rainfall and are characterised by heavy storms with intensities sometimes of 75 mm/h rather than uniform precipitation.

The der season average rainfall is around 150 mm and again is characterised by heavy storms.

The haggai season which occurs between the gu and the der seasons is characterised by cooler cloudier weather and usually light showery rain.

The jilaal season (January to March) is dry with the total precipitation during the three months rarely exceeding 10 mm. Although the four seasons are usually distinct, there is a large degree of unpredictability in the start, duration, and total rainfall of each season.

Temperatures range between 22°C (mean monthly minimum) and 31°C (mean monthly maximum) with a monthly average of between 25°C and 28°C and an annual average of 26°C.

2.4 Soils

The Juba floodplain is built up of alluvial materials of variable particle size deposited by the Juba and Shabelle rivers. Since the late tertiary period, several hundred metres of Tertiary and Quaternary deposits have been laid down. The Juba river is set slightly below the surrounding floodplain which indicates a lowering of base level during the Pleistocene era.

The major soil types which were identified in the project area, Phase 1 are:

(i) Juba meander complex levee unit - Jmxl

(ii) Juba meander complex depression unit - Jmxd

(iii) Juba basin - Jb

(iv) Juba levee - Jl

(v) Channel courses - Ch

These soil mapping units are shown in the project area in Figure 2.3.

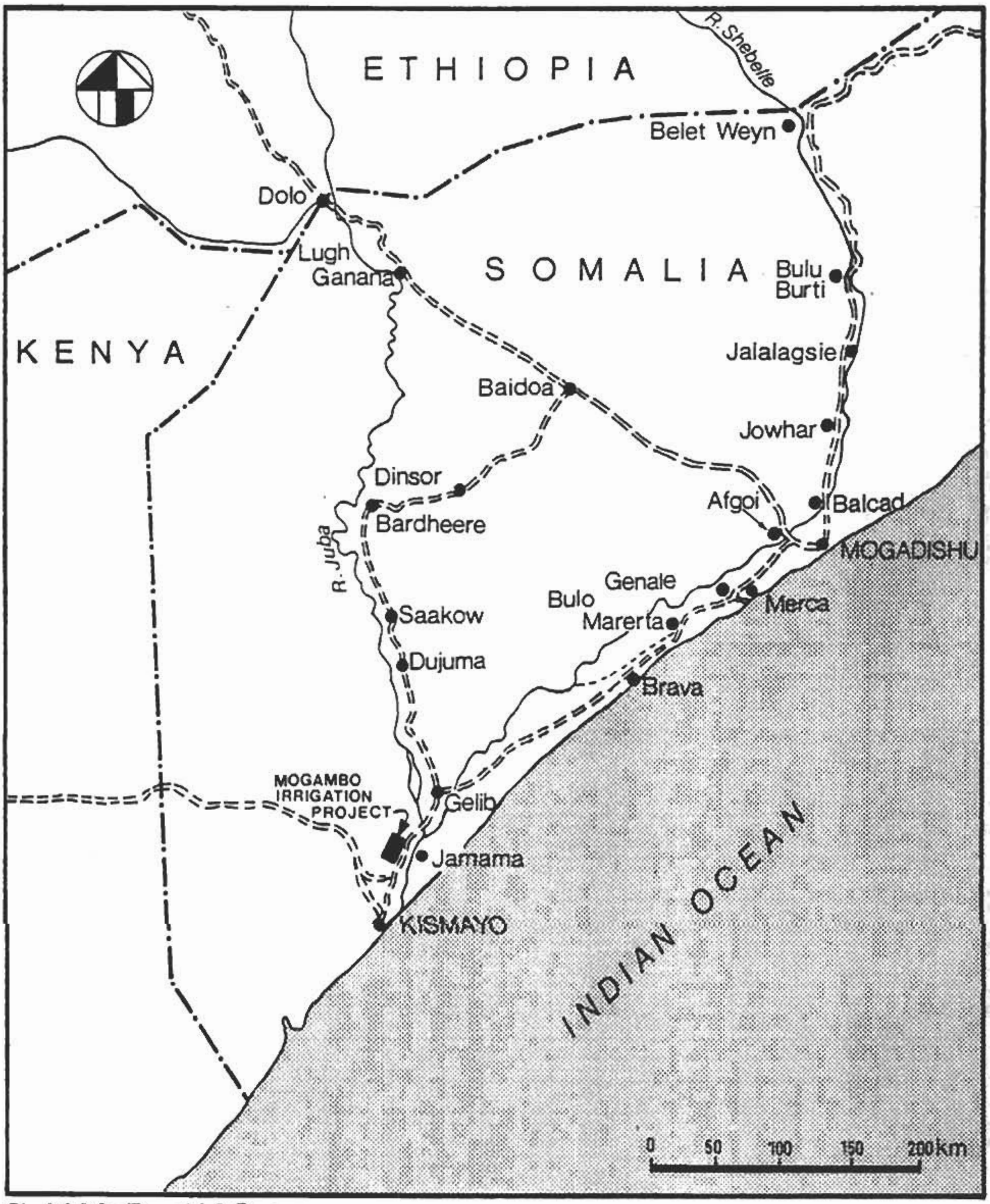
Table 2.1 summarises the net irrigable area of the units. Details of soil mapping units in each block are presented in Annex 4.

TABLE 2.1

Net Irrigable Area of Soil Units in MIP Area

Soil unit	ha	%
Jb1	634	30
Jb2-3	670	32
Jl	330	15
Jmxl	205	10
Jmxd	233	11
Ch	46	2
Total	2 118	100

Location Plan



Sir M. MacDonald & Partners

==== Road

Figure 2.2

Lower Juba River Basin with M.I.P. Location

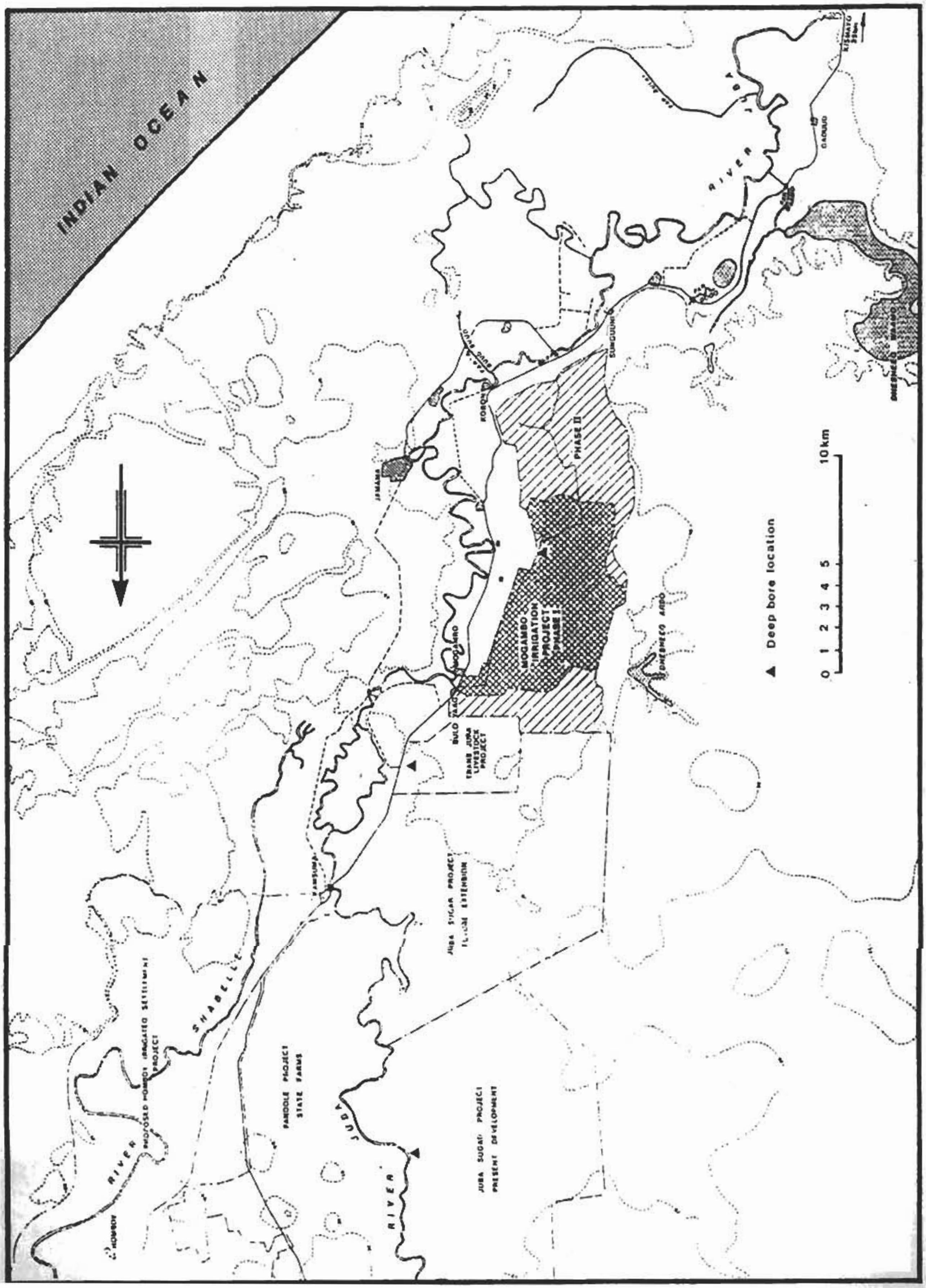
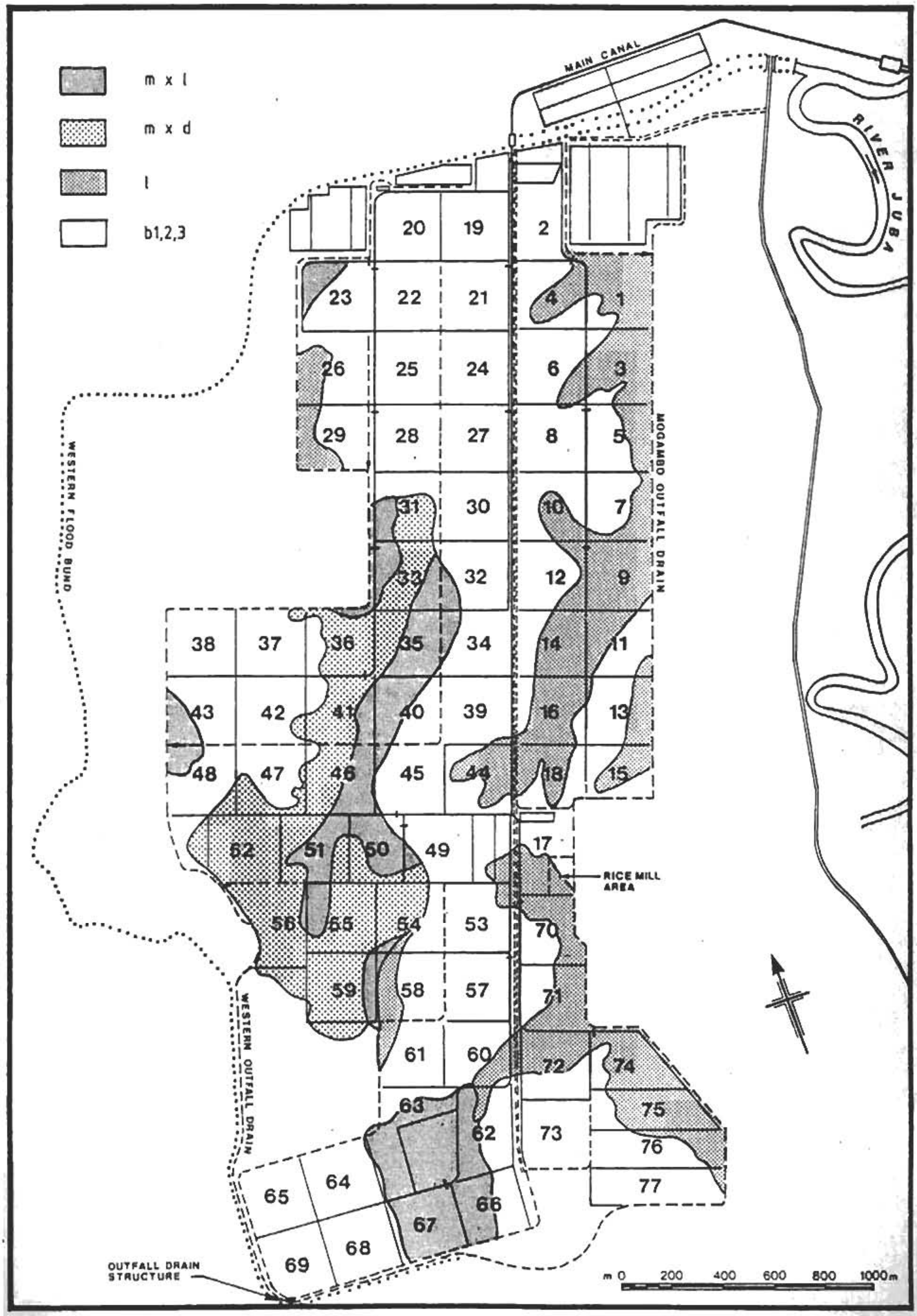


Figure 2.3

Soil Map M.I.P.



Soil unit profiles are shown in Figure 2.4.

The old channel meander complex occupies 23% of the project area. The main subdivisions are soils developed on levee formations (10%) and soils of broad flat depressions (11%).

The vertisols (Jbl, Jb2-3, Jmxd) of the Mogambo area have a distinctive morphology which influences their tillage characteristics, soil-water relationship, chemistry and fertility. The expanding lattice (montmorillonite) clays of the vertisols have the capacity to expand and contract on wetting and drying respectively. In the dry state the soils develop a shallow friable mulch with vertical cracks to a depth of at least 0.5 m. These cracks separate the structural units of soil and some of the friable surface aggregates are washed down the cracks. When the soil is re-wetted and expands, pressure develops in the lower horizons giving rise to a churning effect in the whole profile. This effect is reflected in the development of slicken sides or slip faces and wedge shapped structures in the subsoil and gilgai micro-relief. The soils have significant variations in structure ranging from course hard prismatic peds when dry, to sticky and plastic when wet, with considerable structural disintegration.

The non-vertisolic soils (Jmxl and Jl), laid down adjacent to the old channel courses, contain a high percentage of fine sands and silts, which is reflected in the widespread capping of these soils.

All the soils in the project area are highly calcareous and base saturated. Salinity levels are generally low in the topsoils but increase with depth to higher levels in the subsoil. High levels of exchangeable sodium are only encountered in the basin clay soils (Jb) which constitute 62% of the project's soils.

2.5 Irrigation and Drainage

The irrigation supply system in the project area consists of the main pump station at the Juba river, a main canal running through the project area, and storage reservoirs at the head of the distributary canals which take off from the main canal. The main canal is operated continuously.

Two irrigation methods are used in the project area:

(i) Surface irrigation (2 118 ha)

(ii) Sprinkler irrigation (163 ha)

There are six distributary canals serving 77 blocks of surface irrigation (Figure 2.5).

The method of surface irrigation used is basin irrigation. Most blocks have 14 basins of 2 ha with a slope of 1 : 2 500. Supply ditches from the distributary canals water the basins. The basins have a concrete 85 cm wide inlet and two 7.5 cm diameter pipes at the end as drainage outlets (details are shown in Figure 2.6).

The design flow of the supply ditches is 170 l/s.

TABLE 2.2

Areas Irrigated by Distributary Canals

Distributary canal	Net irrigable area (ha)
M1/C1	466
M1/C4	476
M1/C6	224
M2/C1	232
M2/C2	384
M2/C4	336
Total	2 118

The basins drain into shallow field drains. These feed into (main) collector drains which in turn feed into the Mogambo outfall drain or the Western outfall drain. The two outfall drains join at the south-western corner of the project near Block 69. The drainage water is disposed of through the western bund into lake Dhay Oboo, either by gravity flow or by pumping, depending on the water-table levels in the lake.

The surface drainage design is 1.5 l/s per hectare. Minimum slopes of the field drains are 0.05 m/km. The collector and outfall drains have minimum slopes of 0.10 m/km.

2.6 Agriculture

The project is a State-owned and operated large-scale farm. Mechanised rice growing is the main objective. Land preparation, sowing and harvesting operations are completely mechanised.

Since 1985 about 300 settlers have been introduced into the project. They occupy approximately one quarter of the area and grow irrigated crops with assistance of the MIP management.

Rotation of rice with other crops like maize, sesame, sunflower, safflower, cowpea and mungbean are being tried. The final rotation schedule has not yet been decided as more information on the potential salinity problem is needed.

The rice crop and, to a lesser extent, the alternative crops, suffer two major seasonal problems at Mogambo.

(i) Flows in the Juba river are low and unreliable during February/ March/April. Reliable river water is only available at the project pumps between May and the end of January each year.

(ii) The seasonal presence of birds (Quelea quelea). The greatest numbers usually occur between mid-August and mid-October.

Figure 2.4

Profile Description of Soil Units

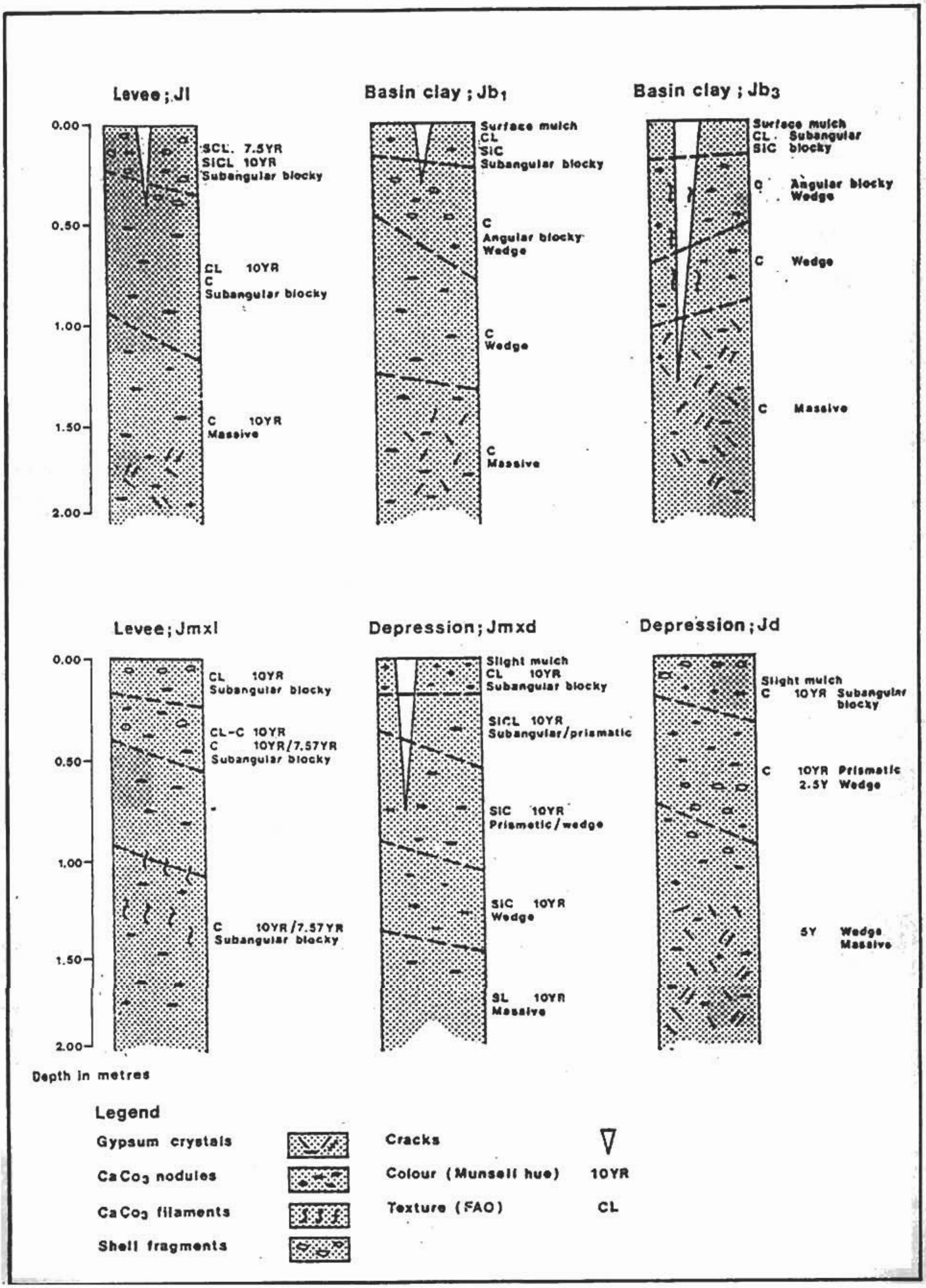
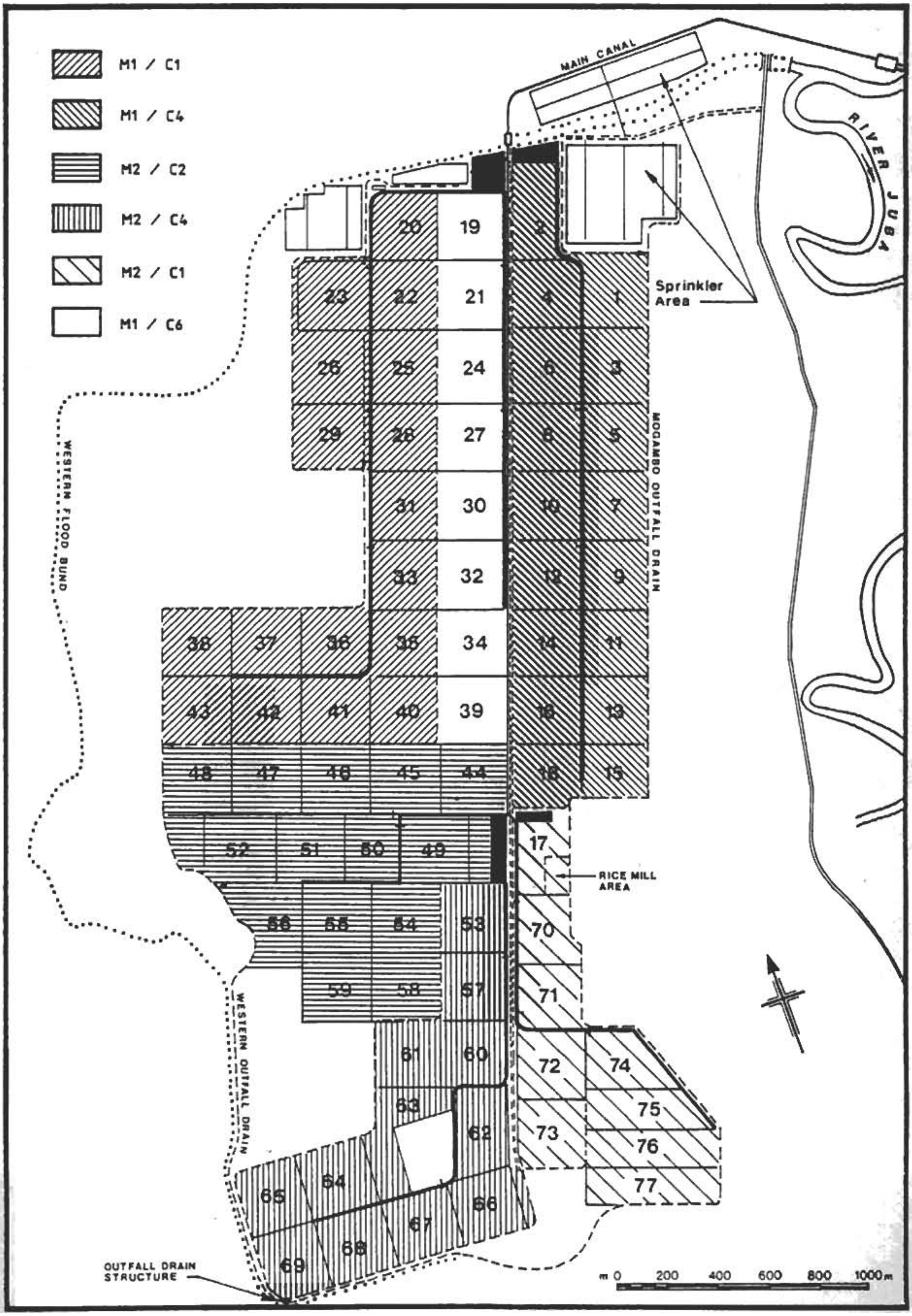
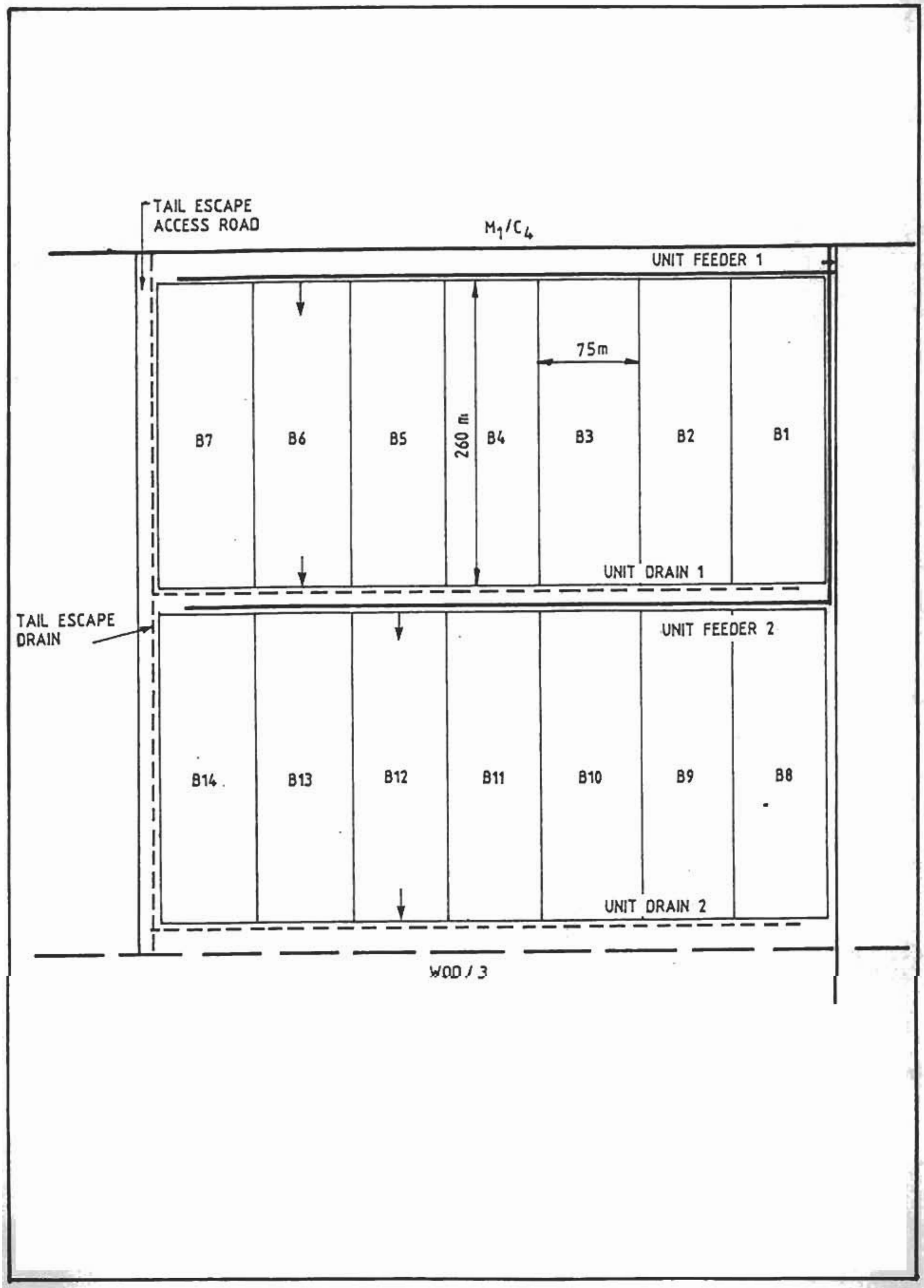


Figure. 2.5

Command Areas of the Distributary Canals




TAIL ESCAPE
ACCESS ROAD
M_1/C_4
UNIT FEEDER 1
75m
260 m
B7
B6
B5
B4
B3
B2
B1
UNIT DRAIN 1
TAIL ESCAPE
DRAIN
UNIT FEEDER 2
B14
B13
B12
B11
B10
B9
B8
UNIT DRAIN 2
WOD / 3

The gu season rice crop is considered more risky and costly than the der season plantings. Weed control in the gu season can also be extremely difficult.

The settlers have a traditional preference for maize and sesame cultivation. they will grow rice in the der season in rotation with maize, sesame and legumes.

3. REVIEW OF THE AVAILABLE DATA

3.1 Soil Characteristics

3.1.1 Salinity

The soil survey carried out in 1979 as part of the supplementary feasibility study presents soil salinity data for 144 sampling sites in the project area.

The average EC_e values (electrical conductivity measured in the saturation extract) of the different soil mapping units at depths of 0 to 25 cm, 25 to 50 cm, 50 to 100 cm and 100 to 150 cm have been summarised in Table 3.1 which also gives limited data for greater depths. The EC_e values have been plotted against depth in Figure 3.1.

TABLE 3.1

Average EC_e Values in the Soil Mapping Units in mS/cm

Number of samples	Soil type	Depth in cm 0-25	25-50	50-100	100-150
28	Jb1	1.3	1.9	4.6	6.2
15	Jb2	1.1	1.2	2.0	3.8
19	Jb3	1.0	1.3	1.3	3.2
5	Jl	1.2	0.9	3.3	3.5
41	Jmxl	1.6	1.6	3.0	4.0
36	Jmxd	1.2	1.1	1.8	3.2

Number of samples	Soil type	Depth in cm 200-250	250-300	300-350	350-400	400-450	450-500
3	Jb1	10.0	10.7	9.4	11.9	11.6	13.8
1	Jb2	8.2	8.5	8.6	8.2	8.2	8.1
-	Jb3	-	-	-	-	-	-
1	Jl	7.7	8.5	6.9	7.3	9.2	10.2
1	Jmxl	8.4	8.3	8.3	8.2	8.2	8.2
2	Jmxd	2.0	3.8	4.6	3.1	0.8	-

Source: Supplementary feasibility study 1979, MMP.

The Jb1 soils have soil salinity levels of more than 4 mS/cm starting at a depth of 50 cm and increasing to more than 6 mS/cm at depths greater than 150 cm.

The other soil types have salinity levels less than 4 mS/cm in the profiles up to a depth of 150 cm.

The few samples taken at depths between 200 and 500 cm indicate high but constant salinity levels for all but Jmxd EC_e values of more than 10 mS/cm were recorded.

Jbl soil samples taken in August 1986 in Block 2, adjoining the storage reservoirs (see Figure 3.2) were analysed. The results are given in Table 3.2.

TABLE 3.2

Soil Salinity Data for Block 2 Basin 5 and Adjacent Dry Land Area, August 1986

Distance from reservoir (m)	Depth (cm)	Non-irrigated EC_e (mS/cm)	Non-irrigated SAR	Irrigated EC_e (mS/cm)	Irrigated SAR
0	0 - 50	3.3	2.7	1.7	0.7
	50 - 100	5.1	17.6	4.7	5.6
	100 - 150	11.0	20.2	8.5	13.7
50	0 - 50	2.2	2.0	0.8	-
	50 - 100	3.9	11.5	6.2	14.8
	100 - 150	8.0	13.6	8.8	18.9
100	0 - 50	2.3	3.7	2.7	1.0
	50 - 100	9.8	16.5	5.0	4.0
	100 - 150	14.0	23.8	7.5	13.4
150	0 - 50	1.8	5.7		
	50 - 100	7.0	11.0		
	100 - 150	8.2	13.8		

Soil salinity levels in the non-irrigated area were slightly higher than those in the irrigated area and the topsoil salinity increased with proximity to the reservoir.

In the irrigated soils salts were washed from the top layers to the deeper layers by the ponded water in the rice fields. Leaching was apparently still possible as shown by the increase in soil salinity with depth.

These measurements confirm the findings of the salinity survey in 1979, which found high soil salinity levels in the Jbl soils.

It must be noted that gypsum was found throughout the profile (see Section 3.1.2). While gypsum is a harmless salt from the exchangeable cation point of view, the gypsum concentrations of 0.25% found in the Jbl subsoil (MIP supplementary feasibility study, 1979) could be partly responsible for the high EC_e values).

3.1.2 Sodicity

Table 3.3 summarises the percentage of samples with an exchangeable sodium percentage (ESP) value greater than 15%. The table refers to the same samples as mentioned in Table 3.1.

Average EC_e Values in the Soil Mapping Units

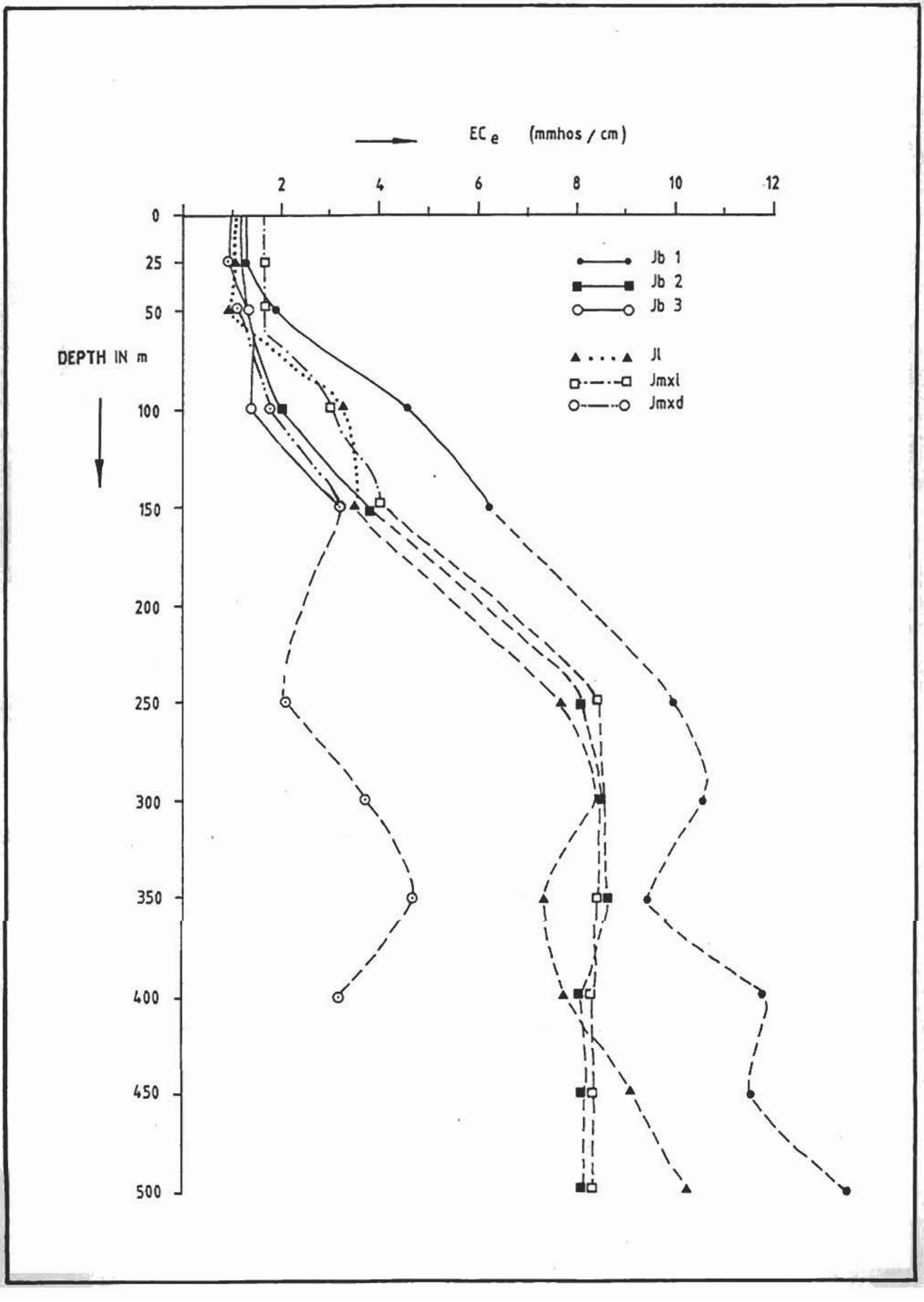


Figure 3.2

Location of 1986 Observation Wells

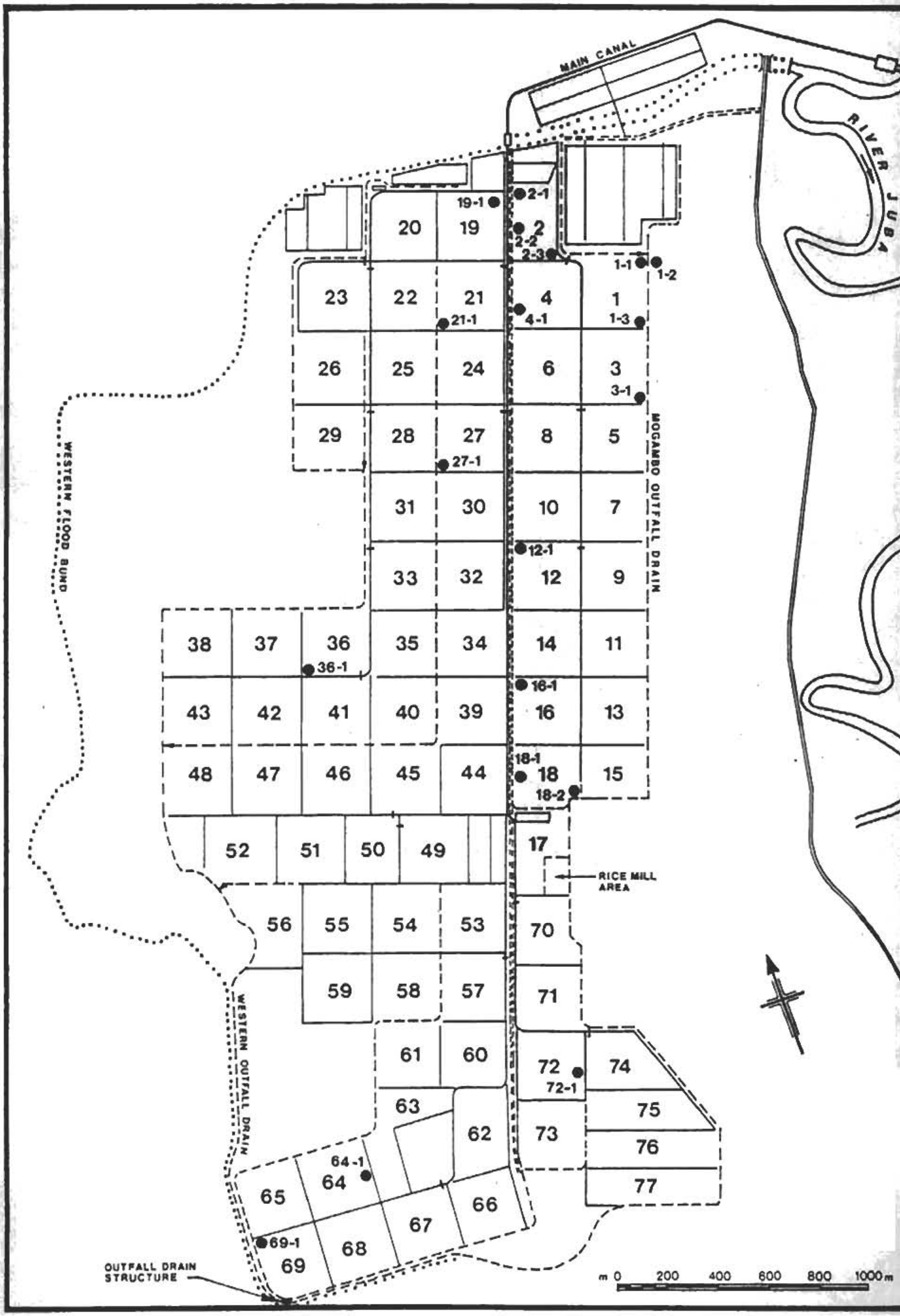


TABLE 3.3

Percentage of Soil Samples with ESP Values Greater Than 15%

Number of samples	Soil type	Depth in cm 0-25	25-50	50-100	100-150
28	Jbl	0	14	32	43
15	Jb2	0	7	7	7
19	Jb3	0	0	5	10
5	Jl	0	0	0	20
41	Jmxl	0	0	5	22
36	Jmxd	0	0	3	8

Source: Supplementary feasibility study 1979, MMP.

The table shows that the majority of the soils have no sodicity problems in the topsoil. In the Jbl soils, however, ESP values greater than 15% were found in the upper horizons. Generally this will reduce the leaching of salts as the hydraulic conductivity will be low due to dispersion of the clay. However, the presence of gypsum, especially in the subsoil, in combination with the high salinity levels in the Jbl soils will have a positive influence on the structural stability and it might be expected that the hydraulic conductivity values will be higher than the ESP values are indicating.

The Consultants found, when installing observation wells in Block 42, that both gypsum and $CaCO_3$ were present throughout the profile from about 1 m down to a depth of 7 m.

In the literature (K.J. Beek et al: ILRI), in some cases vertisols with measured ESP of 40 and above - well above the 15% that has been used to define sodic soils - have been reported to produce good yields. Sodic soils with such exceptionally high ESPs have been found to contain the zeolite mineral analcine, and part of the sodium may occur trapped within this mineral. In standard laboratory procedures, part of this 'zeolite sodium' is extracted, in addition to the 'plant available sodium' that occurs absorbed on the clay surface.

A soil sample taken in Block 42 (Jbl soil type) at a depth of 100 to 150 cm will be taken to Australia to investigate this possibility.

3.1.3 Hydraulic Conductivity

Table 3.4 summarises the data on hydraulic conductivity measured in 1979.

TABLE 3.4

Vertical and Horizontal Hydraulic Conductivity (Kv and Kh) Average Values in m/d

Soil type	Kv		Kh
	Depth in cm		
	0-25	50-150	50-200
Jbl	0.3(5)	0.05(3)	0.002-0.04(3)
Jb2/Jb3	0.9(2)	0.03(1)	0.01(1)
Jl	0.6(4)	-	0.002-0.04(3)
Jmxl	1.3(4)	-	0.04-1.5(3)
Jmxd	0.3(2)	-	0.01-0.8(2)

Numbers in parentheses indicate the number of observations. The above data show that the hydraulic conductivity decreases with depth.

Hydraulic conductivity was measured in Jbl soils in Block 7 and 19 in 1986. The results are presented in Table 3.5.

TABLE 3.5

Vertical and Horizontal Hydraulic Conductivity of Jbl Soils (Basin Clay)

Block/ basin	Crop	Depth (cm)	Kh (m/d)	Depth (cm)	Kv (m/d)
19/7	Rice	90-150	0.024		
	Gu 1986	150-210	0.024	200	0.053
		210-270	0.006	268	0.030
7/7	Rice	90-150	0.006		
	Der 1986	150-210	*		
		210-270	*		

Note: * Nominal rate of 0.0004 mm/d; equipment not accurate below 0.003 mm/d.

The above data confirms the very low hydraulic conductivity of the Jbl soil mentioned in Table 3.4.

All the above data have been obtained from tests using infiltration rings or the inversed augerhole method. The water used for the tests was surface water which is of very good quality. However, because of the considerable salt levels in the soil profile, percolating water will soon become saline while moving down the profile, thus keeping the soils flocculated and resulting in higher actual hydraulic conductivities than those measured in the field tests. The low values in Jbl in Table 3.5 could thus well be misleading.

No data are available on potential percolation losses to underlying aquifers.

3.2 Groundwater

3.2.1 Depth

During the feasibility study in 1979 it was found that for most of the area the depth to groundwater was greater than 2 m and in many areas greater than 5 m. The salinity of the groundwater varied from 0.6 to 5.7 mS/cm.

In a tubewell located in the Trans-Juba Livestock Project area the watertable was found at 7 m below soil surface; salinity of the groundwater was 2 mS/cm.

Since March 1986 depth to watertable data have been collected in the project area. Seventy observation wells were installed to a depth of approximately 4 m. Due to vandalism many of them were destroyed. The data collected so far have been summarised in Annex 5. The location of the observation wells has been indicated in Figure 3.2.

Groundwater hydrographs of some observation wells are shown in Figure 3.3. These hydrographs indicate that the watertable rose rapidly near the storage reservoirs (observation wells Nr 2-1 and 19-1) after irrigation started in the gu season of 1986. Water levels in these wells dropped to a depth of 2 to 3 m below surface after irrigation stopped. No further watertable rise was observed in the following der season 1986/87 and gu season 1987; the average water level remained between 250 and 300 cm below soil surface, except for the observation well Nr 2-1 nearest to the reservoir. The water level at that site averaged 140 cm below soil surface.

Generally, the existing data show that the water level in the greater part of the area has now risen to within 3 to 4 m of the soil surface during the irrigation seasons. The observation wells reached to a depth of 4 m, so it could not be assessed how far the water levels had dropped in some of the wells after irrigation was stopped.

However, compared with 1979 when the greatest part of the area had water levels below 5 m, the data indicate an increase in the watertable levels of the area.

Whether the natural sub-surface drainage flow can cope with increased percolation losses cannot be assessed at present. More data should be collected, especially on the existence of a possible regional aquifer at a depth of 15 to 20 m, which is suggested in the 'Master Plan' of the Juba valley. An investigation of this type is beyond the technical abilities of MIP and should be implemented through the Ministry of the Juba Valley.

3.2.2 Salinity

The electrical conductivity (EC) of groundwater samples taken from the observation wells are presented in Table 3.6.

The above data show that the EC of the groundwater is often very high, especially in the basin clay soils in Block 2 where values up to 60 mS/cm were measured. This is similar to seawater.

If the watertable will continue to rise then the growing of crops, other than rice, will be severely limited, unless adequate drainage is provided to facilitate the flushing of salts from the soils.

Rice growing will still be quite feasible but drainage run off will be more saline and surrounding non-irrigated land will become salinised.

3.2.3 Aquifier Characteristics

Not much data are available on the substrata in the region. Three bore logs are available on deep bores in and around the MIP, one in the Juba Sugar Project, one in the Trans-Juba Livestock Develpment Project and one at the rice mill in the MIP. Annex 6 presents the bore log descriptions. For location of the bores see Figure 2.2.

The vertical-section between the three boreholes, as presented in Figure 3.4 suggests the existence of a sandy gravel aquifer wedging into the clay layer. If this is correct one can expect that, as inputs to the aquifer higher up in the catchment area increase with the development of more irrigated areas, water will be forced out of the aquifer upwards to the surface, resulting in salinisation (groundwater discharge area).

TABLE 3.6

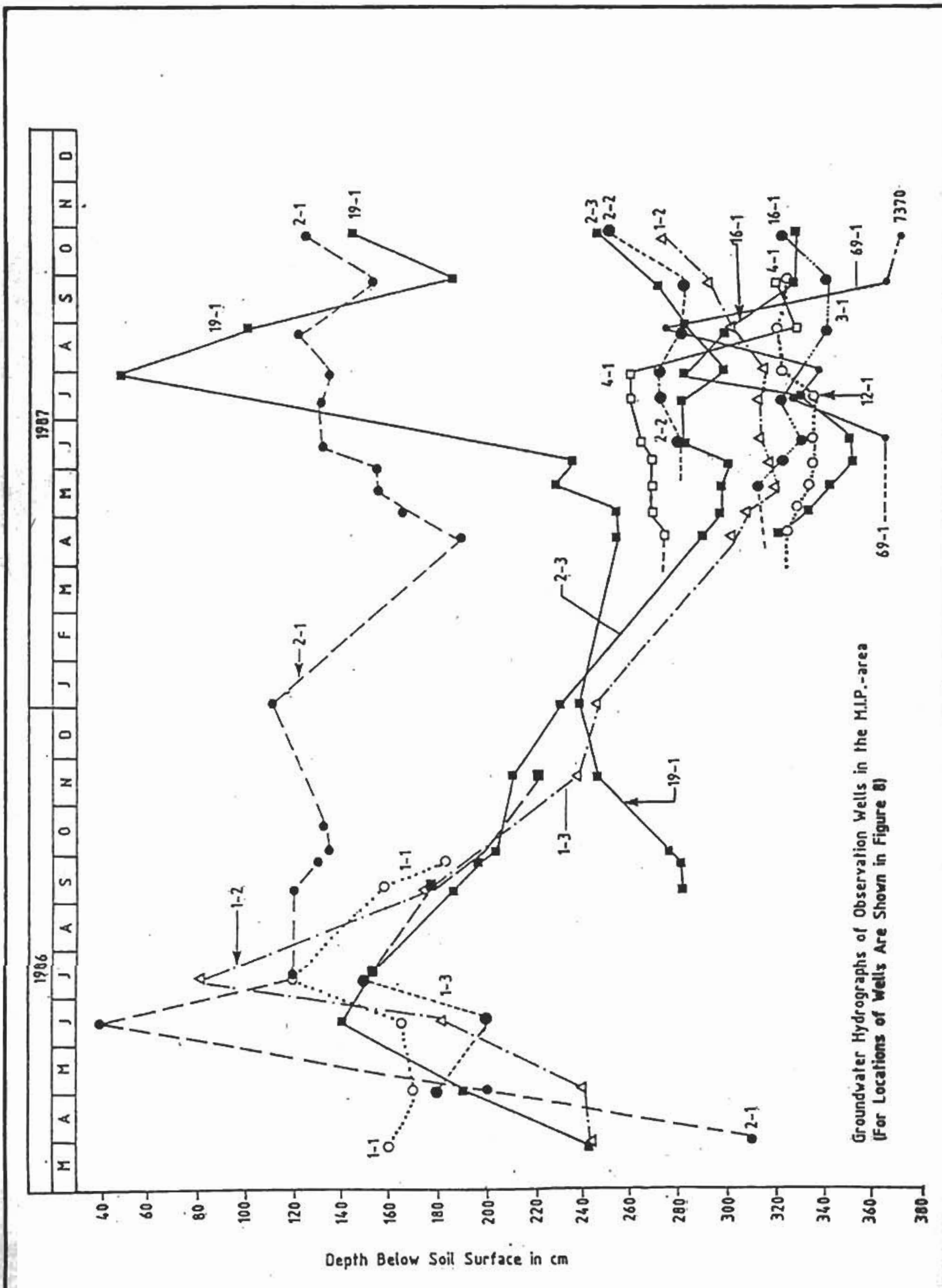
EC Values in mmhos/cm of Groundwater Samples

Number of observation well	Soil type	Date (1986 to 1987) 27/3	8/7	24/11	8/1	17/5	30/5	13/6	11/7	26/7	25/8	23/9	25/10
1-1	Jl	*	*	*	*	*	*	*	*	*	*	*	*
1-2	Jl	30	2.5	*	38	24.6	24.6	30.1	36.0	31.0	7.4	10.6	*
1-3	Jl	*	5	*	*	*	*	*	*	*	*	*	*
2-1	Jb1	61	9.7	*	60	54	72	56	54	66	33	66	64
2-2	Jb1	*	*	*	*	*	*	53	32	46	3.4	3.0	2.0
2-3	Jb1	40	5.6	*	40	50	53	38	48	47	6.2	4.8	6.2
3-1	Jl	*	*	*	*	6.3	2.4	2.6	1.3	2.1	1.3	1.0	0.6
4-1	Jb3	*	*	*	*	2.7	13.5	4.5	9.0	2.2	2.0	4.3	*
12-1	Jb3	*	*	*	*	33	33	32	33	33.5	3.0	9.2	*
16-1	Jb3	*	*	*	*	8.4	9.5	8.4	8.0	1.5	2.7	4.7	7.1
18-1	Jl	*	*	*	*	*	*	*	*	*	2.5	*	*
18-2	Jb1	*	*	*	*	*	*	*	*	*	4.4	*	*
19-1	Jb1	*	1.8	3.0	*	3.7	5.5	*	2.2	1.8	2.2	2.6	2.7
21-1	Jb3	*	*	*	10	*	*	*	*	*	*	*	*
27-1	Jb3	*	*	40	*	1.5	*	*	*	*	*	6.0	*
36-1	Jb1	*	*	*	*	*	*	*	26	29.1	10.7	15.0	*
64-1	Jb2	*	*	*	*	*	*	*	*	1.8	1.5	6.0	5.5
69-1	Jb2	*	*	*	*	*	*	1.3	1.2	2.0	0.6	1.0	*
72-1	Jb1-2	*	*	*	*	*	*	*	*	*	12.8	*	*

Note: * No data available (no water in the observation well or well destroyed)

Figure 3.3

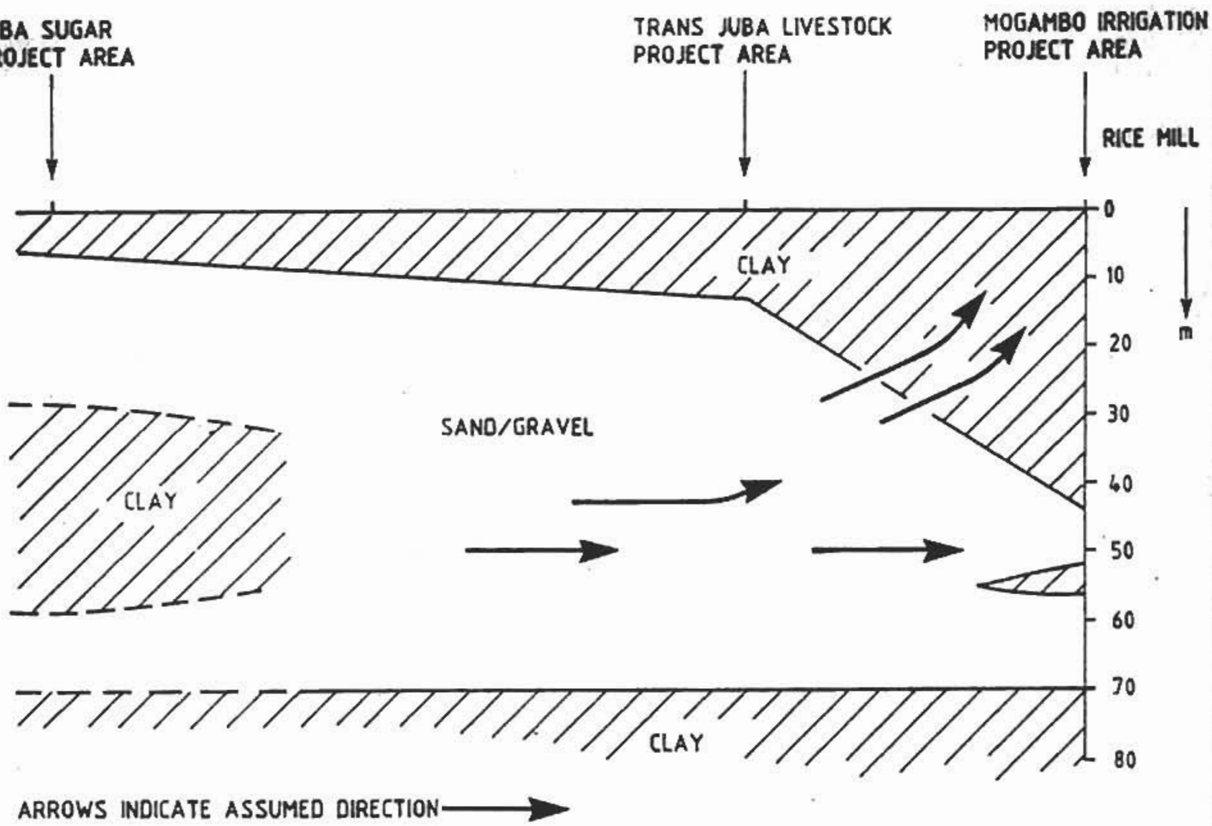
Groundwater Hydrographs



Groundwater Hydrographs of Observation Wells in the M.I.P.-area
(For Locations of Wells Are Shown in Figure 8)

Figure 3.4

Schematic Diagram Showing Sub-Strata and Groundwater Flows Upstream From M.I.P.



It is interesting to note that during excavation of the rice mill foundations no watertable was found up to 6 m below surface. Also apparently the drilling contractor did not find any water up to about 20 m below surface (personal communication). The standing watertable level after bore completion however was found at 3.8 m below surface, indicating an upward gradient in the profile. This supports the above mentioned discharge theory.

It is possible that the occurrence of the series of lakes downstream of the project area is due to such a groundwater discharge process. However, no data on the salinity in these lake systems are available to support or contradict this theory.

Annex 7 presents the mean monthly EC-values for the Juba river at the Juba Sugar Project, 30 km upstream of MIP and mean monthly river flows as measured at Mogambo (1951 to 1976). It is clear that river salinity levels increase when river flows decrease. This supports the theory that the lower reaches of the Juba river at low flow regimes, act as an interceptor for groundwater discharge.

A 1983 MMP report (Bardheere Reservoir Comparison with Alternative Solutions, MMP February 1983) devoted one chapter to Groundwater Studies. The study was based on existing information available in the UK. The study area covered the MIP (see Figure 3.5) but concentrated on the upper reaches of the Juba river catchment.

For the Tertiary formations in the lower Juba valley the report states that 'they constitute, in total, a highly transmissive aquifer'. This information is based on the Trans-Juba Livestock Development Project bore log description (Annex 6). Recharge of the Tertiary aquifers in the lower Juba basin is assumed to be from direct rainfall (and irrigation) infiltration and from seepage from the Juba river (in times of high flows). The latter source is considered to be of minor importance.

It has to be noted that it is impossible to make conclusive statements on groundwater movements based on only three observation points. Requirements for further investigations are discussed in Section 5.2.

3.3 Water Management Practices

3.3.1 Present Situation

The project originally envisaged that paddy (i.e. transplanted) rice would be grown in flat 1 ha basins. This concept was later changed to drill sown rice with rotational crops. This meant that some slope in the basins was necessary for adequately fast drainage as drilled rice will not establish under water-logged conditions and seedlings, prior to the early tillering stage, can be damaged and often killed by standing water for periods as short as 30 hours. The water temperature probably remains too high under the prevailing climatic conditions.

The basin size was increased to about 2 ha (averaging 266 x 75 mm) with a slope of 1 : 2 500, which means a drop of about 10 cm from the inlet side to the outlet side.

The altered design amounts to a border check system but does not act as such because of within basin un-eveness and the excessive width of the basins. In an effective border check system water moves evenly on a front down the basin. Inflow is stopped when there is sufficient water in the basin to complete the irrigation; very little water would have to be drained off and wasted.

Currently after sowing the basins are saturated by a short flush irrigation to germinate the rice. After seedlings emerge the basin is flushed again. Usually two flushes are needed after the initital one before permanent water is applied from four to seven weeks after initial watering. If the soil is liable to 'caking' or 'crusting' (i.e. the soil surface forms a seal which is difficult for the rice shoot to penetrate) up to four flushings may be necessary.

The flusing process consumes a lot of water as the basins are too wide and too uneven to operate effectively as a border check system. As a result the entire basin is usually filled (more often overfilled) before the inflow is stopped. This causes excessive percolation losses to the watertable rises.

Improved water management practices could lead to a considerable reduction in percolation losses and would therefore reduce the rise of the watertable (see Section 3.3.4).

Since the start of the irrigation in 1985 the amount of irrigation water applied to each block was measured at the inlet of the feeder ditch to the block. Details per block are given in Annex 8. These data have been used to calculate individual block percolation losses (see Table 3.7, Section 3.3.3).

3.3.2 Drainage

Assuming a watering time of 12 hours at an inflow rate of 170 l/s an average water supply of 370 mm can be calculated for a 2 ha basin. At the end of the 12 hours supply period, draining should commence. Assuming an average surface storage of 50 mm of which more than 50% drains off, this means that about 30 mm of water is lost at the first flushing.

In reality this may be considerably greater as more than often, basins are overfilled. The subsequent flushes take less water as the soil is already partly wet but the amount drained off remains similar. With an average of three waterings the amount of wasted water is probably around 100 mm, not counting overfilling losses. For the water balance calculations in Section 3.3.3 the amount of surface drainage water per block was estimated at 150 mm, taking into account the overfilling of the basins. The MIP agronomist thinks that under the current method of irrigation this figure underestimates the actual drainage losses.

The drainage facilities from the basin are inadequate. The surface water has to be drained off through two 7.5 cm diameter pipes. This is a legacy of the original design (with transplanted paddy rice) in which surface drainage was less critical. The two pipes cannot drain a basin under the current irrigation regime in the six hours stipulated by the needs of the project's crops. In practice banks are often cut to facilitate drainage and much time is wasted in filling the resultant holes after they are eroded by drainage. Also this practice silts up drainage ditches.

Drainage culverts at the end of each field consist of a single 20 cm pipe which is not of sufficient capacity to quickly drain the water from a number of basins simultaneously.

3.3.3 Water Balance

The 'overall' water inflow and outflow in irrigated rice basins can be described by the following equation:

$$Irr + R = ET + Dsr + Perc + dWs + dWsl$$

Figure 3.5

Location Map M.M.P. Groundwater Study

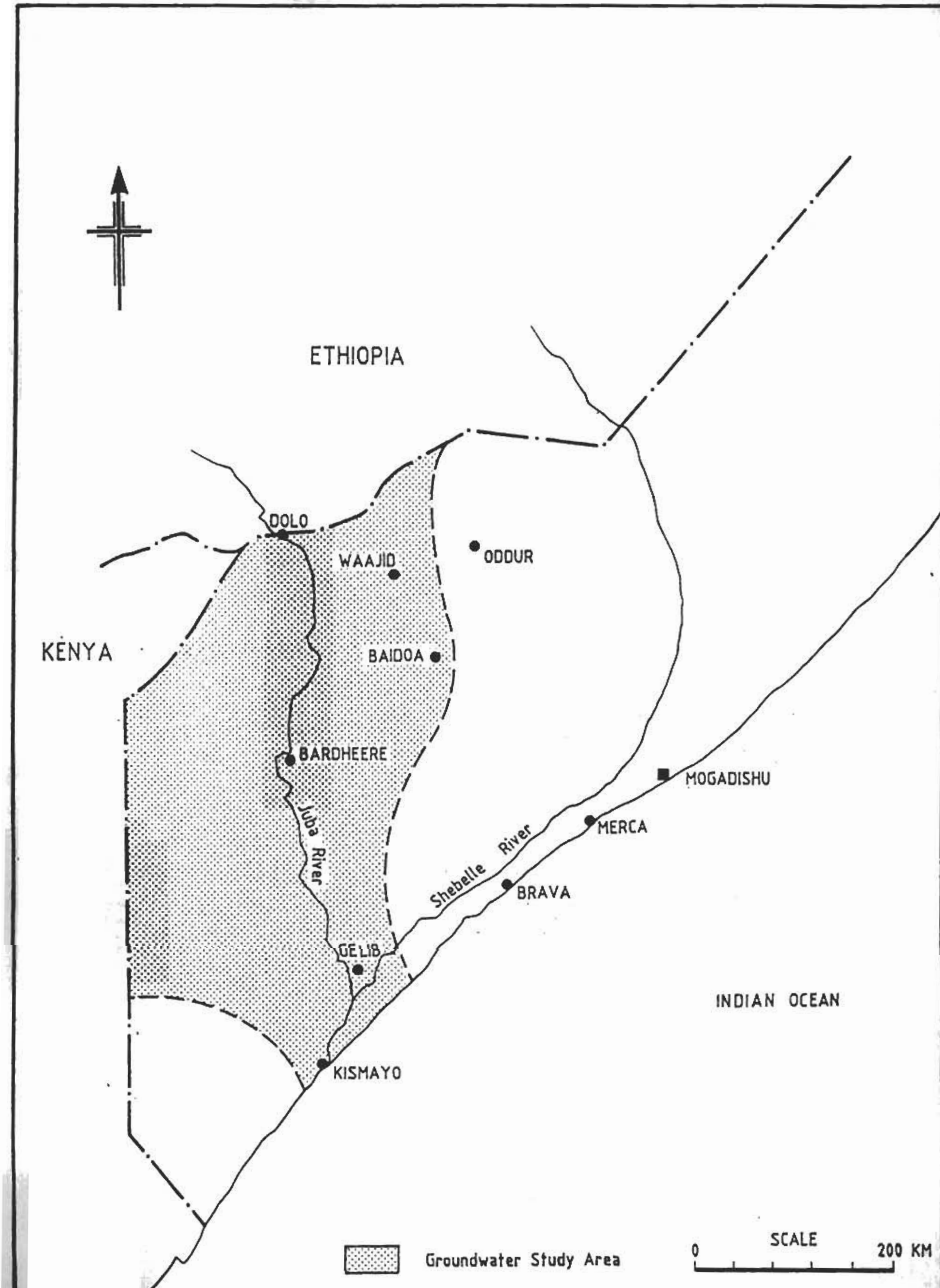


TABLE 3.7

Calculated Percolation Losses in Rice Growing Blocks (mm)

Block Nr		Soil Type	Der 1985/86	Gu 1986	Der 1986/87	Gu 1987
1	84%	Jl	-	1 163	-	-
2	92%	Jbl	113	-	-	-
3	75%	Jl	-	1 042	-	-
4	32%	Jbl/42% Jb2-3	891	-	-	-
5	75%	Jb2-3	832	-	-	-
6	40%	Jbl/50% Jb2-3	-	303	-	-
7	65%	Jbl/30% Jl	363	-	885	-
9	85%	Jl	352	-	322	-
11	50%	Jbl/50% Jl	-	-	868	-
12	72%	Jb2-3	-43	-	-	-
13	65%	Jbl/35% Jl	-	-	1171	-
14	65%	Jl	-	-	697	-
15	70%	Jbl	-	-	529	-
16	85%	Jl	-	-	1 048	-
17	35%	Jbl/30% Jb2-3/35% Jl	-	-	644	-
18	55%	Jl/30% Jbl	-	-	744	-
19	100%	Jbl	-	68	-	-
20	100%	Jbl	-	261	-	-
21	70%	Jbl/30% Jb2-3	-	358	-	-
22	75%	Jbl/25% Jb2-3	-	307	-	-
23	80%	Jbl	-	617	-	-
24	80%	Jb2-3	-	312	-	-
25	90%	Jb2-3	-	273	-	-
26	70%	Jbl	-	863	-	-
27	80%	Jb2-3	-	215	-	-
28	78%	Jb2-3	-	290	-	-
29	35%	Jb2-3/35% Jl/30% Jbl	-	379	-	-
30	70%	Jb2-3	-	286	-	-
31	40%	Jb2-3/35% Jmxd	-	648	-	-
32	70%	Jbl	-	358	-	-
33	60%	Jmxl/40% Jmxd	-	847	-	-
34	55%	Jbl/31% Jb2-3	-	686	-	-
37	98%	Jbl	-	-	1 013	-
38	97%	Jbl	-	-	544	-
43	70%	Jbl	-	-	884	-
61	70%	Jbl	-	-	-	3 854
63	50%	Jmxd	-	-	-	2 665
64	97%	Jb2-3	-	-	-	1 447
65	100%	Jb2-3	-	-	-	1 331
66	45%	Jmxl	-	-	-	2 594
67	55%	Jmxl	-	-	-	4 073
68	90%	Jb2-3	-	-	-	800
71	60%	Jb2-3	-	-	385	-
72	30%	Jbl/30% Jb2-3/30% Jl	-	-	858	-
73	50%	Jbl/50% Jb2-3	-	-	868	-
75	70%	Jl	-	-	703	-
Average	(mm/season)		418	488	763	2 395
	(mm/d)		3.2	3.8	5.9	18.4

where	Irr	=	irrigation water inflow
	R	=	rainfall
	ET	=	evapotranspiration
	Dsr	=	surface drainage outflow
	Perc	=	percolation losses
	dWs	=	change in storage of the soil water
	dWsl	=	change in storage of the surface water

Each term of the water balance represents a volume of water per unit of time and is expressed in units of discharge per area (mm) per considered time period.

The water inflow and outflow in rice basins is illustrated in Figure 3.6. At the beginning and the end of the rice growing season as the time period, the term dWsl can thus be eliminated.

The change in storage of soil water (dWs) has been estimated at 150 mm. At the beginning of the rice growing season the soil is considered dried out.

The evapotranspiration (ET) is calculated for the gu and der seasons for 105 days and 130 days rice varieties as follows:

Gu season	:	513 mm	(105 days)
		597 mm	(130 days)
Der season	:	585 mm	(105 days)
		751 mm	(130 days)

In the gu season of 1987 the 105 days rice varieties were grown commercially for the first time.

Rainfall (R) is recorded at the Mogambo Meteorological Station near the MMP office. The data are presented in Annex 8.

We assume that only 50 mm of rain water at a time can be stored extra in a flooded rice basin; the rest will be drained off through the surface drainage system. The resulting actual contribution of rainfall to the rice basins inflow is as follows:

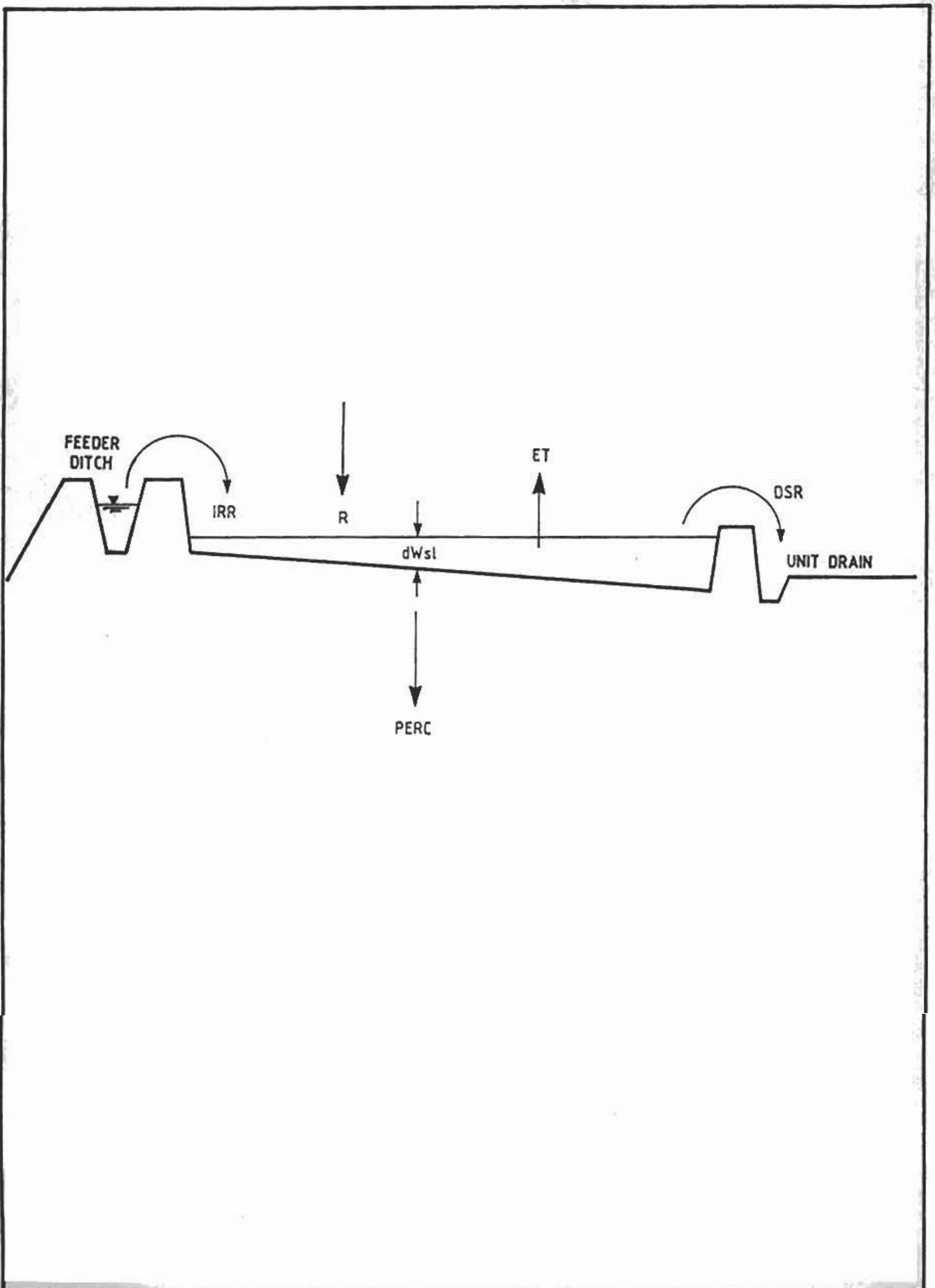
Der 1985/1986	:	55 mm
Gu 1986	:	191 mm
Der 1986/1987	:	49 mm
Gu 1987	:	192 mm

Using the above input data, percolation losses were calculated for each rice growing block for the past four seasons. The results are presented in Table 3.7.

Percolation losses were considerable in Blocks 61, 63, 66 and 67 during the gu season of 1987. The soils in these blocks are Juba meander complex soils. Percolation losses of more than 20 mm/d mean that these soils are not suitable for rice cultivation both because of the cost of water and the fact that this amount of water percolating to the watertable will cause it to rise quickly. During the first three seasons percolation losses varied on average from 3.2 to 5.9 mm/d with levee soils generally having somewhat higher percolation losses than the basin clay soils.

The higher than assumed actual drainage losses as mentioned by the MIP Agronomist (see Section 3.3.2) mean that the actual percolation losses will be lower than the values presented in Table 3.7.

Figure 3.6
Water Balance Components in a Rice Basin



More detailed water balance investigations are needed (see Section 5.2.3). However, the order of magnitude of the values in Table 3.7 indicates the high potential for watertable accessions and subsequently rising watertables in the MIP. These problems could be minimised by improving water management practices and avoiding the cultivation of rice on the meander complex soils.

3.3.4 Experiments to Improve Water Use Efficiency

The available data on percolation losses in the preceding section show the need for better irrigation practices. Currently some experiments are proposed and/or carried out by the project management team to improve the water use efficiency in the basins. These include the following:

(a) 'Toe-furrows' or 'burrow pits' are used to facilitate drainage, especially in problem basins with low or high areas adjacent to the bunds as shown in Figure 3.7. These furrows can be constructed in two passes with a delver.

(b) Larger outlet pipes or structures are proposed to facilitate drainage and reduce channel siltation problems caused by basin erosion.

(c) By constructing small cross bunds in basins as shown in Figure 3.5 better water control and less wastage could be achieved. The system is currently being tested in Block 48 and will be further examined in Block 42. If successfully adopted, a substantial saving of water can be achieved during the establishment stage.

(d) A border check (or border ditch) system as shown in Figure 3.9 is simple and would minimise water wastage. It is presently being tried in Block 42.

Uniformly graded basins will improve the existing system and also make application of a straight contour or border check system easier. This can be achieved by the use of a laser operated grader.

Under the current system attention to the following matters would improve efficiency immediately:

(a) Basins should not be overfilled and drainage should be carried out quickly after the first flush irrigations. If a relatively small area in a basin cannot be watered except by prolonging irrigation for hours or more, it should be left unwatered.

(b) At times it would be better to irrigate two or more basins simultaneously. This would put less pressure on channel structures and banks and result in less scouring which is caused by very fast concentrated water flows.

Drainage would have to be good, however to avoid waterlogging for prolonged periods during the first flush irrigations.

3.4 Cropping Pattens

Cultivation in the project area started in the gu season of 1985. Table 3.8 shows the areas cultivated with different crops for each season until der 1987/1988.

TABLE 3.8

Cropping Patterns MIP Area 1985 to 1988

Crop	Area in hectares					
	Gu 1985	Der 1985/86	Gu 1986	Der 1986/87	Gu 1987	Der 1987/88
Rice	153	171	511	482	212	800
Maize	122(S)	276+122(S)	532(R)	16	662	-
Mungbean	-	15	-	6	42	-
Cowpea	-	-	-	-	70	-
Sesame	-	-	18(R)	476	-	-
Sunflower	-	-	-	2	56	18
Safflower	-	-	-	44	-	-
Sorghum	-	-	-	22	-	-
Cowpea/sesame	-	-	10(R)	-	-	-
Maize/sesame	-	-	158(R)	-	-	-

Note: (S) = sprinkler irrigation
(R) = rainfed crops

Details of the crops grown per block and the cropping patterns for each season are presented in Annex 9. Crop yields were as follows:

Rice

Gu 1985	:	3	- 4.5 t/ha
Der 1985/86	:	2.6	- 5.6 t/ha
Gu 1986	:	Average	- 2.8 t/ha (Quelea attack)
Der 1986/87	:	1.6	- 3.5 t/ha (MIP)
		0.7	- 4.3 t/ha (settlers)
Gu 1987	:	Average	- 2.4 t/ha (estimated)

Sunflower

Gu 1987 : 0.57 t/ha
Der 1986/87 : 0.74 t/ha

Safflower

Der 1986/87 : 0.41 t/ha

Sorghum

Der 1986/87 : 0.28 t/ha

Mungbean

Der 1986/87 : 0.57 t/ha

Figure 3.7

Layout of a "Toe Furrow" in a Typical Basin

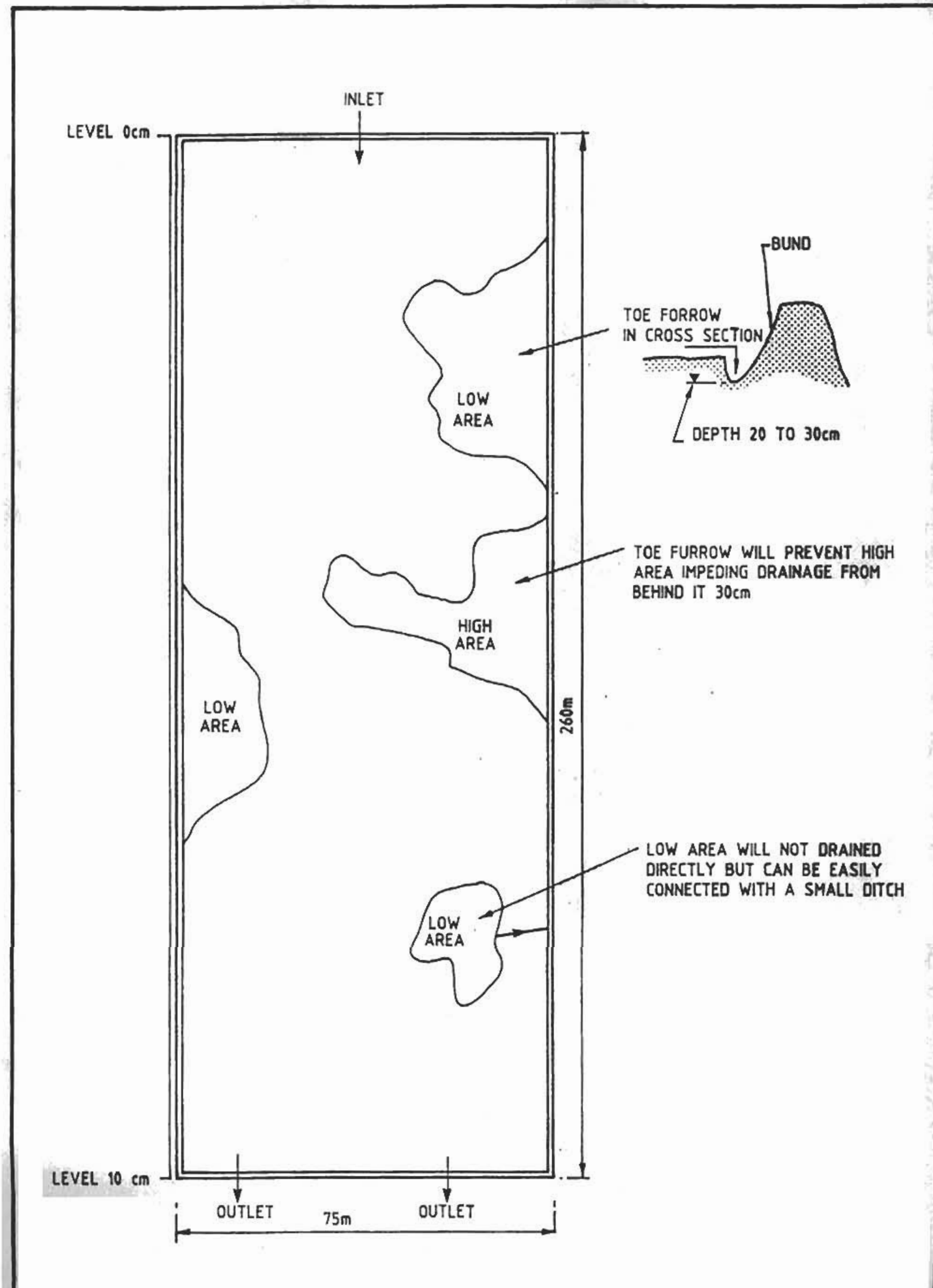


Figure 3.8
Straight Contour System Within a Basin

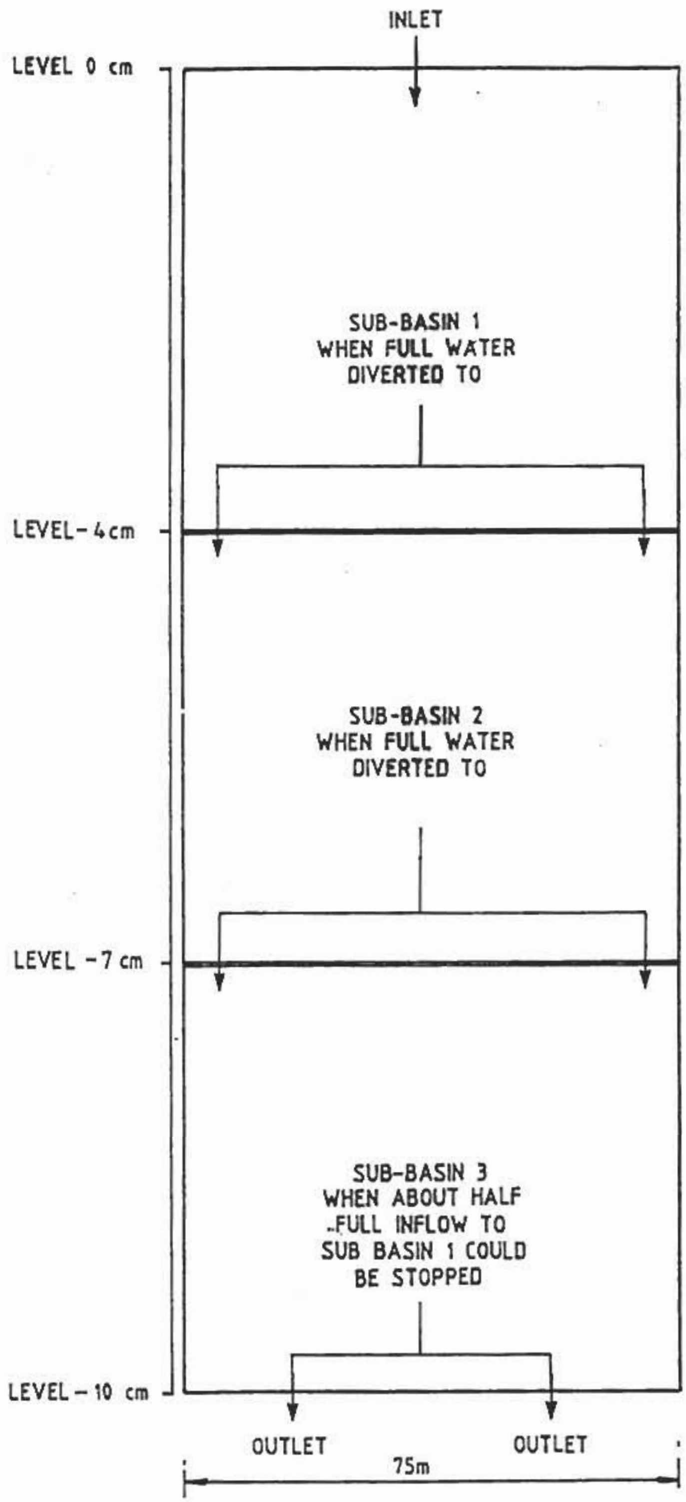
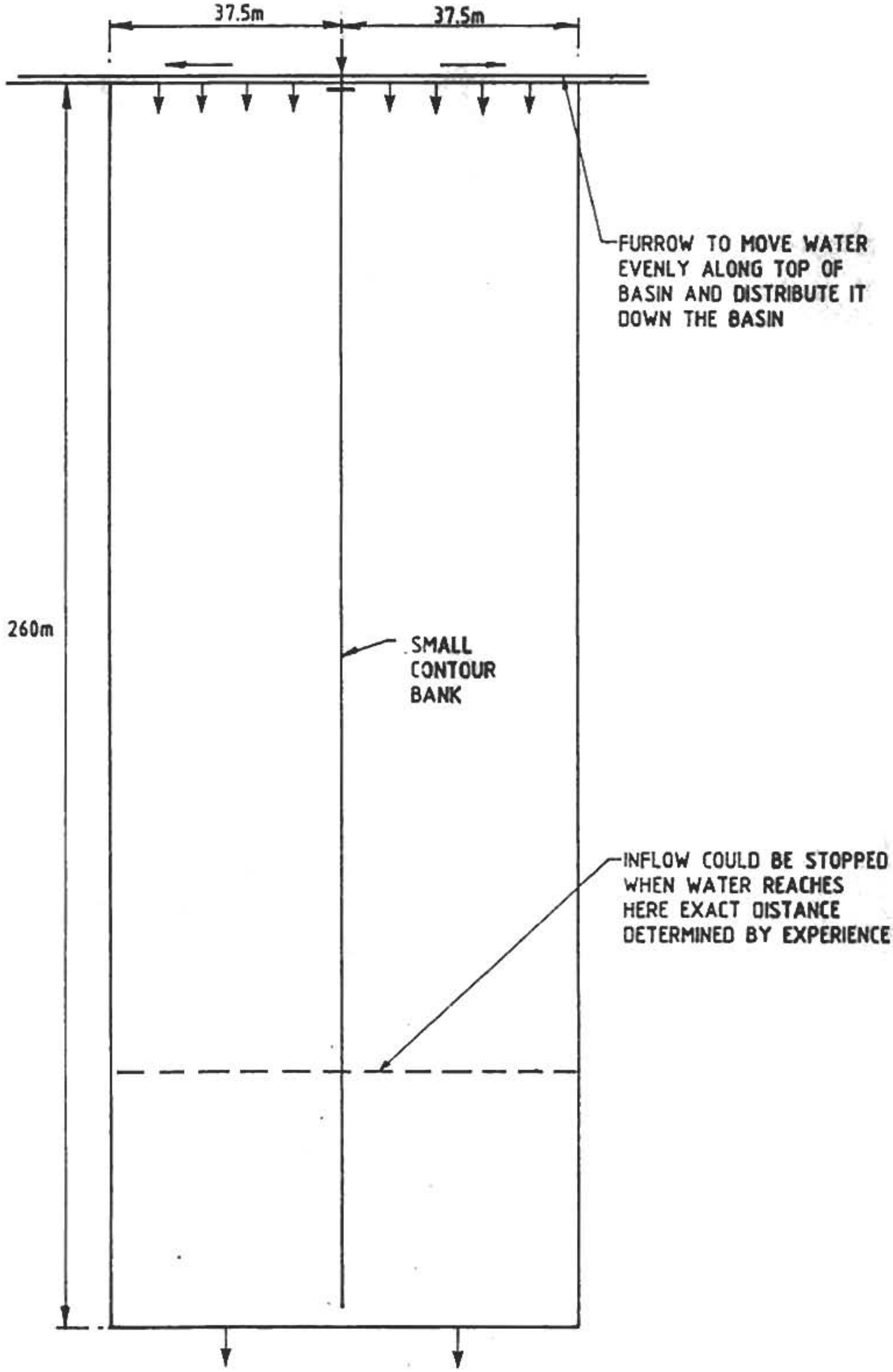


Figure 3.9
Border Check System Within a Basin



4. DATA COLLECTION DURING THE OCTOBER-NOVEMBER 1987 CONSULTANCY STUDY

4.1 Mogambo Irrigation Project Area

4.1.1 Observation Wells and Piezometers

A number of watertable observation wella and two piezometers were installed in block 42 and surrounding blocks as part of the proposed future monitoring programme in the project area (see Section 5). Table 4.1 presents the particulars of the wells. Locations of the wells are shown in Figure 4.1.

TABLE 4.1

Observation Well Characteristics

Well Nr	Depth from TP (cm)	Screen from TP (cm)
41 - 1S	270	*
41 - 1D	697	695 - 660
42 - 1S	495	490 - 240
42 - 1D	655	655 - 620
42 - 2S	590	585 - 235
42 - 3S	465	460 - 260
42 - 4S	515	510 - 260
42 - 5S	597	590 - 350
43 - 1S	553	550 - 350
37 - 1S	540	540 - 250
47 - 1S	540	540 - 250

Note: * Well depth at installation 5 m but well filled with sand. Either bail out or replace.

S = shallow

D = deep

Top pipe (TP) = natural surface (NS) + 50 cm

The wells and piezometers consist of PVC pipes which are slotted (screen) over a certain length up from the bottom of the pipe by means of a hacksaw.

The wells and piezometers are installed with a hand auger. Installation methods are discussed in Annex 10.

4.1.2 Watertable Levels and Salinities

Watertables were measured in the observation wells and piezometers on 19 November 1987 as indicated in Table 4.2.

Figure 4.2 shows the watertable and salinity west-east cross-section through Block 42. Watertable levels are closely related to soil type, site 41-1 in Jmxd showing the shallowest level. Watertable salinities were extremely high under Jbl soils and low under the Jmxd soil type (see Table 4.2).

TABLE 4.2

Watertable and EC Measurements in Pilot Block Test Wells

Well Nr	17/11 wt	19/11 wt	22/11/1987 wt	22/11/1987 EC	Field situation
41 - 1 D		240	215	3 300	Both sides permanently flooded
S		+24	+25	950	
42 - 1 D		325	327	43 500	After two flush irrigations
S		340	340	39 000	both sides
42 - 2 S	400	395	395	46 500	Same as 42 - 1
42 - 3 S			259	58 000	Same as 42 - 1
42 - 4 S		277	275	36 000	Same as 42 - 1
42 - 5 S	330	318	323	56 500	Basin one side permanently flooded
43 - 1 S	503 d		230	5 000	After two irrigations both sides

Note: wt = watertable in cm below surface, EC in micromhos/cm

Generally, the more permeable soil types are better leached and have less saline but shallower watertables than the heavier soil types (Jbl) which show (at the beginning of the rice growing season) deeper but highly saline watertables.

In site 41 - 1 (Jmxd/Jmxl) both adjoining basins were permanently flooded and a perched watertable was established. However, the deeper piezometer was rising at a rate of about 10 cm per day indicating that the whole profile could be saturated in about 20 days from 22 November 1987.

Figure 4.1

Location of Testwells Installed during Consultancy Study

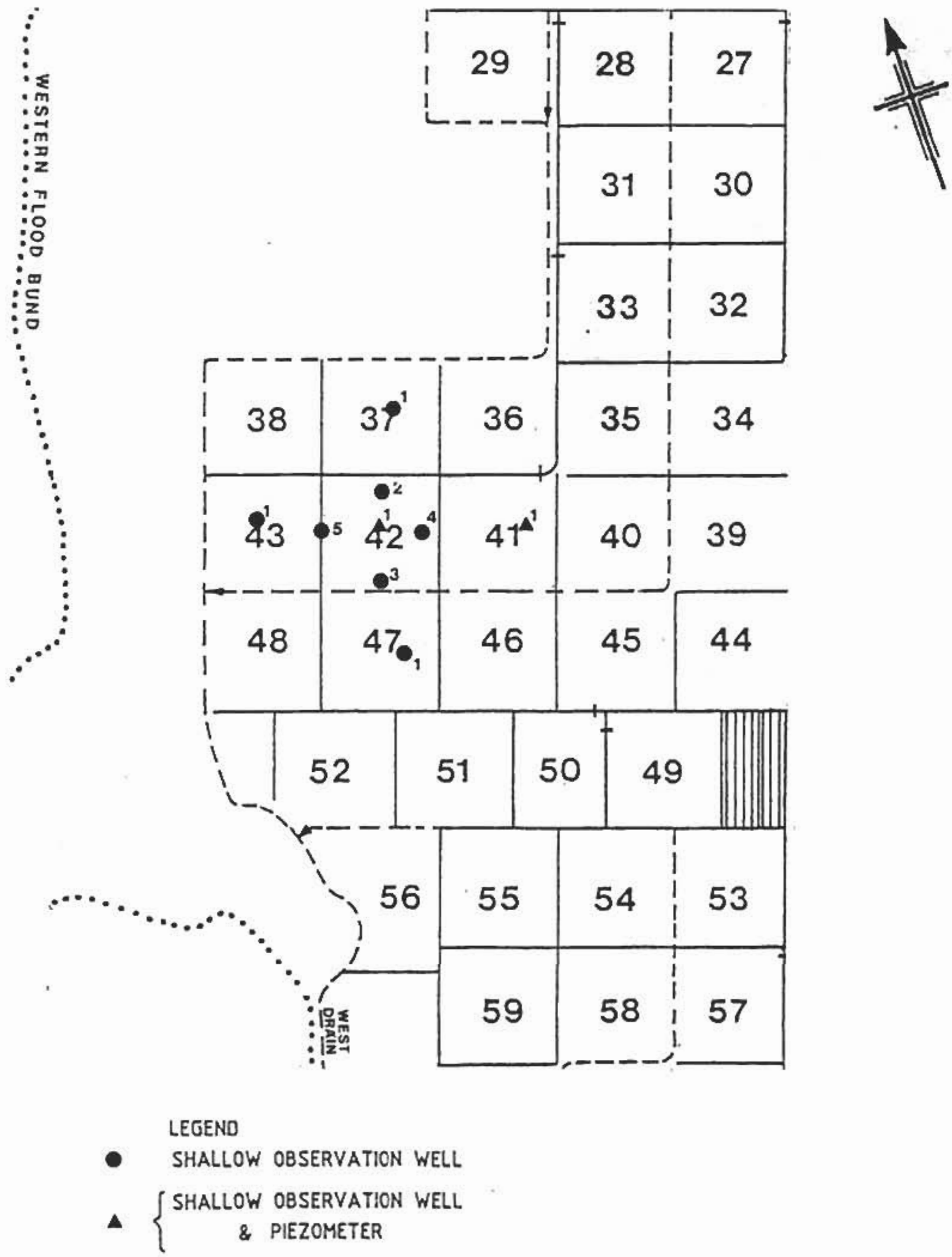
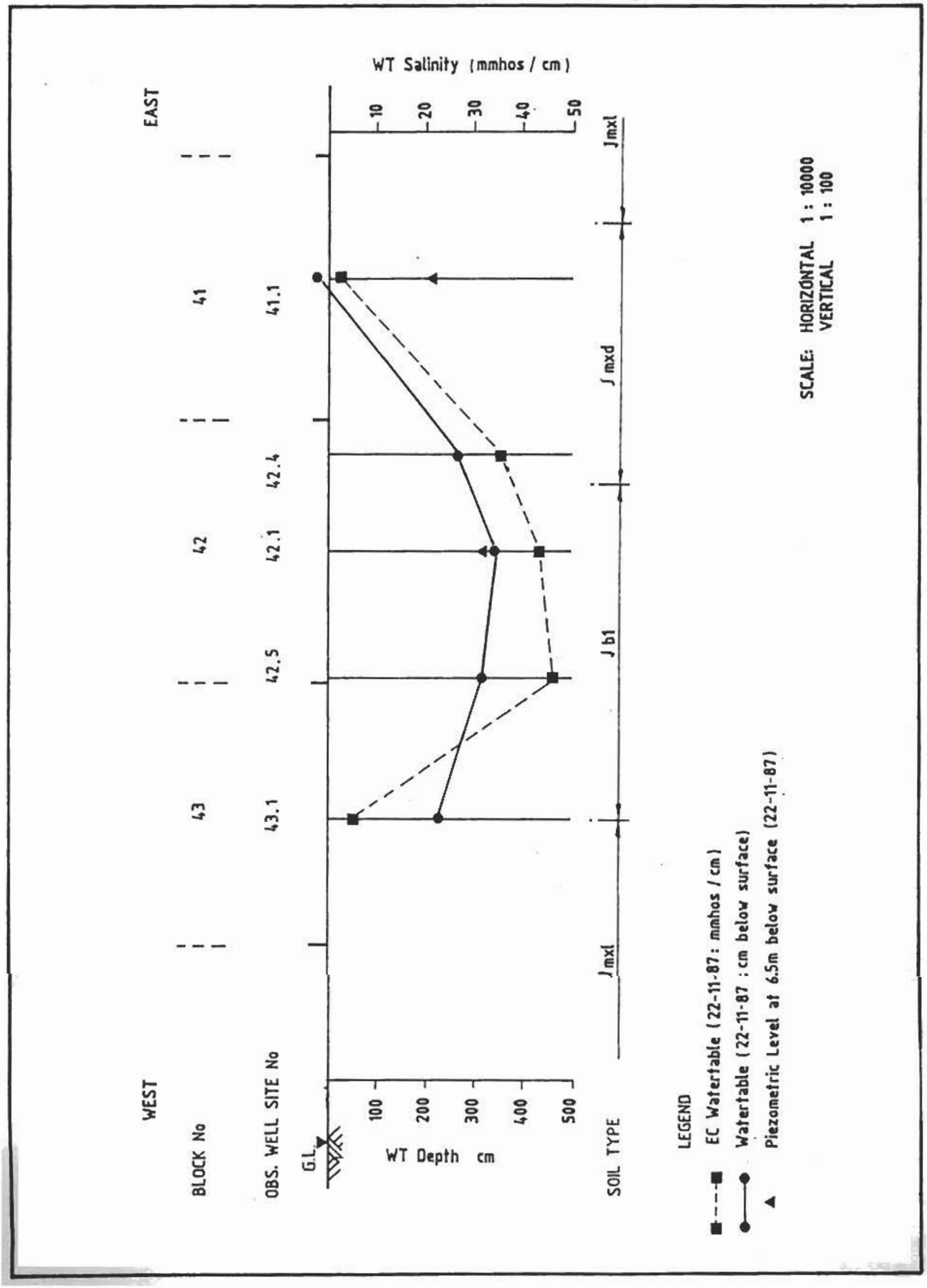


Figure 4.2

Watertable Level and Salinity Cross-Section Through Block 43, 42 and 41



4.1.3 Soil Salinities

Soil samples were taken at 50 cm depth intervals during test well installation in Blocks 41, 42 and 43. The samples were analysed for electrical conductivity in the 1 : 5 soil/water extract ($EC_{1:5}$). Results are presented in Table 4.3. High salinities were found at depths below 1.5 m in most profiles. Conversion of the $EC_{1:5}$ to EC_e values is difficult as the presence of salts of low solubility will make the relationship non-linear. However, correlation of $EC_{1:5}$ and EC_e data from the Juba Sugar Project (Supplement to Appendix VIII, Soils of the Bridging Area and North Kamsuma, 1976) showed EC_e 4 x $EC_{1:5}$ in the lower ranges up to $EC_{1:5}$ = 4 mS/cm. This would suggest EC_e values in the subsoil in the MIP of around 20 mS/cm which is far too high for any plants to survive. At most sites these salinities were found at the relatively shallow depth of 100 to 150 cm below surface.

TABLE 4.3

$EC_{1:5}$ of Soil Samples in Blocks 41, 42 and 43

Depth	41-1	42-1	42-2	42-3	42-4	42-5	43-1	Jbl Ave.	Jmxd Ave.
0 - 50	0.76	0.46	0.60	0.44	1.12	0.82	0.93	0.58	0.93
50 - 100	0.88	0.61	1.23	1.38	1.80	4.50	0.76	1.9	1.3
100 - 150	5.30	3.20	4.60	1.16	5.50	4.75	4.30	3.5	5.4
150 - 200	5.70	4.20	4.20	4.90	5.20	4.50	4.60	4.5	5.5
200 - 250	5.70	4.20	5.50	5.75	5.50	4.10	0.86*	4.9	5.6
250 - 300	6.05	4.80		5.90	6.50	3.90		4.9	6.3
300 - 350	6.00	5.40		3.60	6.20	5.60	1.71	4.9	6.1
350 - 400	5.00	5.50		4.00	5.10	6.60	1.46	5.4	5.1
400 - 450	2.60	5.20		4.25	4.50	4.50	3.10	4.7	4.5
450 - 500	2.80	6.70		7.00	3.50	3.50	2.50	5.7	3.5
500 - 550	5.50	6.50		7.00	3.00	3.60	2.25	5.7	4.3
550 - 600	6.00	3.60							
600 - 650	5.10	4.35							
650 - 700		4.40							
700 - 750		4.50							
Soil type	Jmxd	Jbl	Jbl	Jbl	Jmxd	Jbl	Jmxl	Jbl	Jmxd
Land use	rice	rice	rice	rice	rice	rice	rice		

Note: * unreliable results.

4.2 Fanoole Rice Farm Area

The Fanoole rice farm area is situated about 25 km north of the MIP area on the left bank of the Juba river. Presently about 1 600 ha is cropped for lowland rice. The farm is managed and operated by a team of Chinese technicians. Rice cultivation started in 1980.

Discussion with the Chinese soil scientist at the Fanoole rice farm revealed that they had found EC_e values of more than 20 mS/cm at a depth of 200 cm. The watertable in the Fanoole rice farm was at a level of 9 to 15 m below soil surface. According to the soil scientist no rise in watertable had been observed after 8 years of rice cultivation with one crop of rice per field a year. However, no groundwater hydrographs were available to support his statements. He stressed the need for adequate surface drainage facilities to flush the salts from the surface layer. He was of the opinion that not much water was percolating through the clay layer, which has a very tight structure at depth of 100 to 150 cm. This was considered an impeding layer.

This subsoil also contains gypsum.

The Fanoole rice farm subsoils are all sandy clays according to the USBR soil survey from April 1986.

4.3 Juba Sugar Project Area

The Juba Sugar Project (JSP) is located approximately 30 km north of the MIP on the western bank of the Juba river. The project covers an area of 8 000 ha cultivated to sugar cane which is irrigated by overhead sprinklers. Irrigation started in 1978. At project initiation concern was expressed about the potential salinity hazard caused by rising watertables (Planning and Design Study for the Juba Sugar Project, Vol. 5, Appendix VIII, Soils Data, 1976).

Disregarding potential percolation losses caused by irrigation, dramatic changes in land use, both within and outside the project, can be expected to result in watertable rise. The establishment of the project resulted in increased population densities and consequently land clearing of large areas for agricultural smallholders farms. The replacement of the original deep rooted vegetation by the shallow rooted agricultural crops will permit water to percolate below the root zone to the watertable during the wet season. No local data are available to confirm this process.

As irrigation intensities are very low up to present (about 50% of optimum irrigation requirements) percolation losses so far have been limited. However, soils in parts of the sugar cane area show very high infiltration rates (up to 2.5 m/d) and intensification of the irrgation practices could result in sharp rises in watertables in these areas.

To monitor this process, a series of 40 test wells to a depth of 3 m below surface was installed, starting in 1985. Data on groundwater quality and waterable levels in 28 wells are presented in Annex 11.

In general, watertable salinities range between 1 and 2 mS/cm (much lower than found during the MIP Block 42 study), with the exception of three wells which show higher salinity levels.

The average waterable levels are lowest during the dry months of January to March and remain fairly constant during the rest of the year.

The JSP management is well aware of the potential salinity hazard underlying its project area and spends considerable efforts on monitoring the situation. Collaboration between MIP and JSP in this field should seriously be considered.

5. RECOMMENDATIONS

5.1 General

Not enough data are available to predict potential watertable rises and salinisation processes under different irrigation regimes. In the following section a monitoring programme is proposed. It is stressed that the proposal only covers the minimum requirements needed for a useful monitoring programme, taking into account the shortage of trained personnel and transport in MIP. The programme will collect data on watertable levels and salinities and soil salinities in a representative part of the MIP. Different soil types will be covered with major emphasis on the Jbl soils which are most important from the point of view of rice production.

Additional information to be collected on deeper substrata is also discussed.

5.2 Pilot Block Monitoring

Two blocks are selected with predominantly Jbl soil type: Block 42 is proposed to be double cropped with rice while Block 39 will have one rice crop per year. Where feasible the nine blocks surrounding these two pilot blocks will have to be managed in the same way as the pilot block. The data to be collected are discussed below.

5.2.1 Watertable Observations

Watertables are measured in shallow observation wells. Their installation and operation is discussed in Annex 10. Figure 5.1 shows the proposed monitoring area. Shallow observation wells will be installed in the centre of each block and an additional four wells will be installed in the two pilot blocks. This results in a total of 21 observation sites which should be measurable in one or two days (depending on the season) by one person equipped with a motorbike.

In the centre of the pilot blocks, piezometers of 7.5 m depth below natural surface (NS) or 8 m from top pipe (TP) are proposed to be installed. On other sites where very shallow watertables are found which could be expected to be perched, additional piezometers should be installed. During the consultancy study this was done at Site 41.1 where a shallow watertable was found within 0.5 m from the surface.

All wells should be measured initially three times per week to gain an insight in their response to rainfall and irrigation events. After an intensive monitoring period of at least one month covering such events, monitoring can be reduced to weekly intervals. This has to continue for a period of one year, after which the monitoring frequency might be further reduced, depending on the experience obtained during the first year.

All watertable and piezometric data should be processed immediately after collection by plotting them on cross-sectional diagrams as shown in Figure 4.2 and by producing hydrographs of individual wells as shown in Figure 3.3.

Watertable salinity samples should be taken simultaneously with watertable observations. Results should be plotted at the individual hydrograph diagrams. A small digital portable EC meter should be purchased for this purpose at a cost of approximately US$ 300.

5.2.2 Soil Salinity Observations

To monitor soil salinity in the top 1.2 m of the profile, soil samples should be taken at the beginning and the end of each crop rotation as follows:

- four basins in each pilot block are selected (Nr 2, 6, 9 and 13)
- composite samples are taken at 10 sites half way down the basin at 0 to 15 cm and 15 to 30 cm depth as indicated in Figure 5.2. At two of these sites samples are taken at 30 to 60, 60 to 90 and 90 to 120 cm. This results in a total of eight samples per basin (two composite 0 to 15 and 15 to 30 cm, two 30 to 60, two 60 to 90 and two 90 to 120 cm) or 32 samples per pilot block for each sampling.

All samples should be analysed for EC_e. Although this method is more elaborate than $EC_{1:5}$, it is considered better to approach the field situation as the presence of gypsum and $CaCO_3$ will result in too high EC1 : 5 readings.

Laboratory equipment for EC_e measurements will have to be purchased. Specifications and prices will be supplied through John Bingle Pty Ltd. in Australia. A short training course for the laboratory supervisor (one or two days) will have to be arranged through the Somalia National University in Mogadishu.

Besides this routine monitoring, local investigations will be required in problem areas such as near the storage reservoirs where rice crops seem to be affected by salinity. Monitoring these sites at monthly time intervals in the same way as indicated above will supply information on salt accumulation processes in the soil profile.

5.2.3 Water Balance Study

To quantify percolation losses to the watertable under double and single rice cropping systems, a water balance study is proposed to be implemented in the two pilot blocks 42 and 39. The following parameters will have to be measured or estimated:

- water inflow at each block inlet (Irr)
- rainfall (at MIP office site) (R)
- evapotranspiration (ET; based on A-pan at MIP office site and crop factor for different crop stages)
- runoff from each individual basin, estimated from the depth of water at the lower end of the basin at end of each irrigation (Dsr).

Based on these parametrs percolation losses Perc can be assessed as follows:

$$Irr + R = ET + Dsr + Perc$$

The change in soil and surface water storage can be neglected if the w balance is calculated for one year periods.

Figure 5.1

M.I.P. Monitoring Area

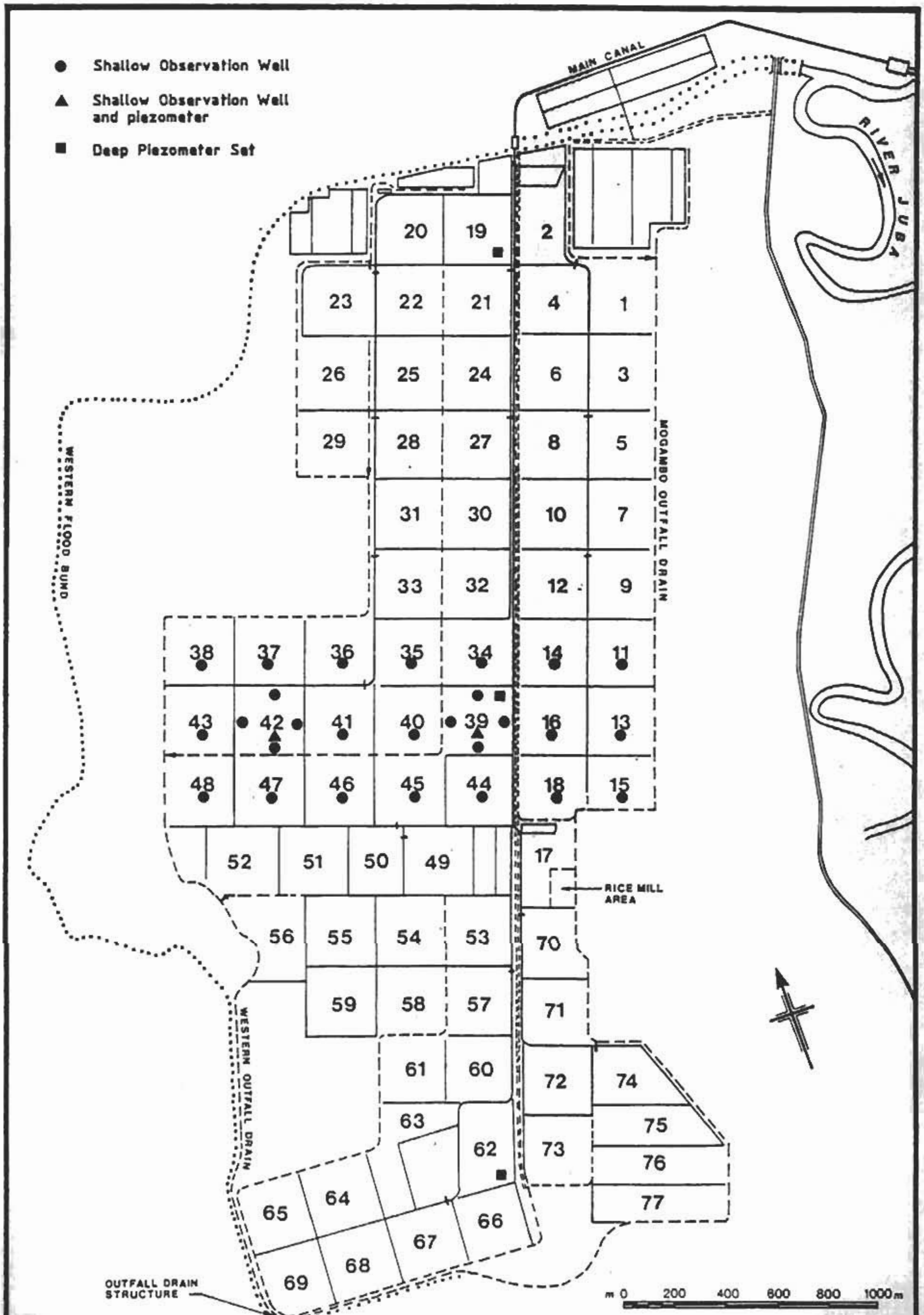
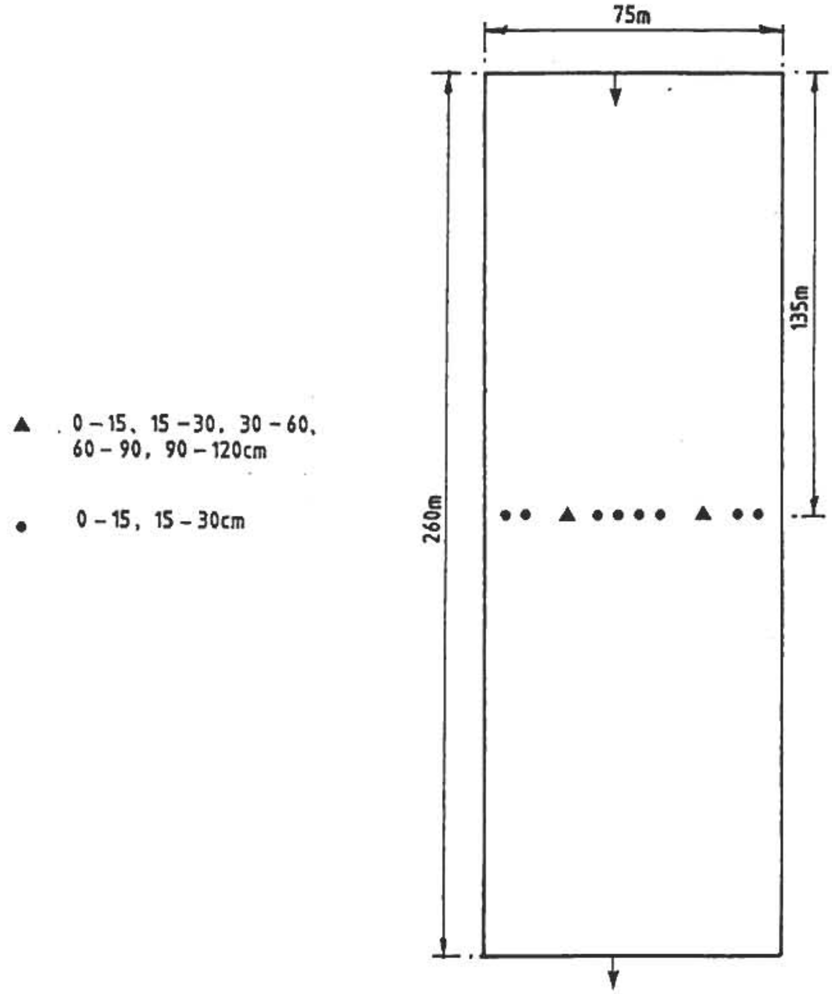


Figure 5.2

Soil Sampling Locations



5.3 Deep Piezometer Installation

Information on deeper groundwater flows is of vital importance to understand and predict trends in watertable changes. It is therefore recommended that piezometer sets are installed at three sites in the project area at the approximate locations shown in Figure 5.1. Piezometers will have to be installed at 3 m and 10 m depths and at the bottom of each sand aquifer found down to a depth of approximately 70 m. Detailed bore log descriptions should be obtained during drilling in order to estimate transmissivity values of the different aquifers. The piezometer sets could be installed either in one large diameter borehole or separate smaller boreholes at say 2 m horizontal spacing. The selected option depends on the available machinery, the price quoted by the contractor and the skills of the contractor (i.e. his ability to drill exactly vertical holes).

This type of work is expensive as it requires the use of a qualified drilling contractor. However, deep aquifer pressure levels are a very important component of the geo-hydrological problems underlying the MIP and for that matter the lower Juba river basin and results from this type of investigation will be most valuable in the future.

The installation of the piezometers should be done in close collaboration with the Ministry of the Juba Valley which has the overall responsibility for water management in the Juba river basin.

5.4 Organisation of Monitoring Activities

5.4.1 Staffing Requirements

The monitoring activities proposed in Section 5.2 require the formation of a Monitoring and Investigations Section with the full-time input of a Technical Officer, preferably with experience in monitoring work. This officer could initially work in close collaboration with the expatriate Agronomist and Irrigation Engineer. He/she will require the assistance of two labourers, one of which should be trained to do routine laboratory measurements.

5.4.2 Transport

To be able to regularly take field measurements, the Monitoring Unit should have the full-time use of a motorbike and have part-time access to a vehicle for soil sampling and well installation purposes.

5.4.3 Equipment and Facilities

The Monitoring Unit should have a laboratory at its disposal to do soil and water analyses. Initially the laboratory should be able to perform the following analyses:

- EC in saturation extract
- EC 1 : 5 extract

For this the following equipment is needed:

- laboratory glassware
- laboratory scale
- suction apparatus for saturation extract
- soil crusher

For fieldwork the following equipment is needed:

- 80 mm soil auger, 8 m long, for test well installation
- 50 mm soil augers, 1.2 m long, for soil sampling
- water level measurement equipment
- simple digital read out EC meter

Detailed specifications on above equipment will be supplied through John Bingle Pty Ltd. in Sydney, Australia.

5.4.4 Training

A short 1 or 2 day training course should be organised at the Somalia National University to familiarise the Monitoring Unit staff with the use of the laboratory equipment. Alternatively assistance could be sought from the Juba Sugar Project Agronomy Laboratory.

5.5 Collaboration with the National University of Somalia and the Juba Sugar Project

Both NUS and JSP are prepared to assist MIP in the implementation of its Monitoring and Investigation Programme. It is strongly recommended that arrangements are made to formalise this collaboration so that the Monitoring and Investigations Officer to be appointed will have the advantage of local technical advice and assistance.

The NUS has an EM-38 soil conductivity meter which can measure in situ soil conductivity in the field. It is recommended that this instrument be used twice a year in a transverse through the two pilot blocks 42 and 39 and in the basins which are being soil sampled (see Section 5.2.2). The latter sites could be used for calibration of the instrument for the local soil types.

Until the time that laboratory facilities at MIP are upgraded, either the JSP Soil Laboratory or the Ministry of Agriculture Soils Laboratory in Mogadishu should be requested to do EC_e analyses.

5.6 Improved Lay Out

In order to minimise water usage and maximise production, basins must be uniform in grade. This is especially important in a potentially saline environment. Uniform grades can only be achieved by the use of a laser guided scraper-grader. The purchase of such equipment is strongly recommended.

6. FOLLOW-UP MISSIONS

It is recommended that liaison between MIP and one of the consultants is formalised such that regular reports on the progress in the monitoring activities, including collected field data, are sent to the Consultant. After at least one full year data have been collected and processed, a short 2 week evaluation mission would be warranted.

The total annual involvement of the Consultant would be in the order of 3 to 4 man-weeks of which 2 weeks will be spent at the MIP. The total monitoring programme should run for a period of at least 3 years to generate enough data to assess the salinity/watertable situation in the MIP.

ACKNOWLEDGEMENTS

The Consultants wish to express their sincere thanks for the assistance and co-operation they received from both Somali and expatriate staff during their stay at MIP.

Special thanks are conveyed to the MIP management staff, especially Messrs Jim Sumbak and Robin Walley, to Mr. Ahmed Abdullahi Ali for his invaluable field assistance, to the Chinese experts of the Fanoole Rice Farm for their exchange of information and to Messrs Keith Ward, Selle Farah Elmi and Mohamed Abdi Namus from the Juba Sugar Project for their assistance in the collecting of important field data.

REFERENCES

1.	Sir M. MacDonald & Partners Ltd.	1979	Mogambo Irrigation Project - Supplementary Feasibility Study.
	Sir M. MacDonald & Partners Ltd.	1980	Mogambo Irrigation Project - Additional Study for an Alternative Development.
	J.E.C. Holthouse, A.H. Hassan and R.H. Chisholm	1987 to 1990	Mogambo Irrigation Project - Farm Plan.
	R.H. Chisholm	1985 to	Mogambo Irrigation Project - Research Summary.
2.	ILRI		Publication Nr 27. K.J. Beek et.al, Problem Soils, Their Reclamation and Management.
3.	FAO		Soils Bulletin Nr 42: Soil Survey Investigations for Irrigation.
4.	Sir M. MacDonald & Partners Ltd.	1983	Bardheere Reservoir Comparison with Alternative Solutions, Chapter 5, Groundwater Studies.
5.	Booker McConnell Ltd.	1976	Planning and Design Study for the Juba Sugar Project, Volume 5, Appendix VIII, Soils Data.

ANNEX 1

TERMS OF REFERENCE

ANNEX 1

TERMS OF REFERENCE

1. The consultants should work together and produce a joint report. A draft of their findings must be produced before their departure from the project for comment by the client.

2. Conduct a review of all previous data on the chemical and physical nature of the soils of the project area and review past monitoring work. Any available information on the subject matter will be provided by the Plant Production Specialist and the Irrigation Engineer.

3. Conduct investigations to determine the physical structure of the soil profile to a depth appropriate to the investigations (perhaps to 5 m).

4. Provide recommendations on an appropriate monitoring system involving a piezometer and tubewell network. Specify equipment necessary for this monitoring system including interpretation.

5. Provide a summary report of the problem which should include advice as to the appropriate future management of the soils. Also comment on suggestions in Attachment 1.

6. Provide information on equipment to be used for the installation of network equipment for routine monitoring of the project. Equipment as listed below may be necessary:

   (a) Tractor linkage or pick-up mounted hydraulic boring and/or coring machine.

   (b) Capable of augering holes of up to 100 mm diameter to suitable depths. Augers of 25, 50, 75 and 100 mm diameter to be supplied, plus spares of each size.

   (c) Hydraulic pump to be either tractor PTO or engine-driven (diesel).

   (d) Spare parts in addition to spare augers to be supplied for the engine, hydraulic pump, hydraulic ram/s, gear box/es. Total value of 10% of machine costs of which 75% to be supplied as fast-wearing parts.

7. Where possible the consultants should collaborate with the National University of Somalia in the devising of an elaborated monitoring system. The continuing role of the University in the interpretation of indications from the monitoring systems should be specified.

8. Recommendations for a short term follow up consultancy to comment on progress with the mónitoring system at an appropriate time (perhaps 2 to 24 months after the initial consultancy) should be made.

9. The consultants should spend a maximum of one calendar month in Somalia.

Attachment 1

It has been proposed, in order to obtain further information, that the farm programme should include the following trials:

(a) At least one 28 ha block at an acceptable distance from night storage reservoirs to be continuously cropped (double-cropped) with rice and resulting perched water levels and changes in conductivity to be monitored.

(b) At least a second 28 ha block to be cropped with rice every der season and an alternating crop every gu season and monitored similarly to the double-cropped block.

(c) MIP to irrigate the surface of those already salt-affected areas adjacent to the night storage reservoirs and to plant these areas with rice.

ANNEX 2

ITINERARY H.J. NIJLAND

ANNEX 2

ITINERARY - H.J. NIJLAND

16 October	Amsterdam to Frankfurt by LH 1697, Frankfurt to Mogadishu by HH 503.
17 October	Mogadishu; MMP office, meeting with Mr. W. Pemberton.
18 October	Mogadishu; MMP office, studying project documents.
19 October	Mogadishu to Mogambo by car.
20 October	Mogambo; meeting with Messrs Mike Chauhan, resident engineer, Robin Walley, irrigation engineer of MMP. Brief visit to the project area and introduction to Deputy General Manager of MIP, Mr. Mohammed Ali Faher.
21 to 23 October	Studying project documents at Holzman camp; offices are closed due to Public Holidays.
24 October	Mogambo; meeting with Mr. J. Sumbak, agronomist of JBPL at MIP. Field visit.
25 October	Mogambo; field visit to check and measure watertable level and salinity in observation wells, accompanied by Mr. Ahmed.
26 to 31 October	Mogambo; MMP office, reviewing available data on groundwater table, soil salinity, irrigation, etc.
1 and 2 November	Mogambo; MMP office, reviewing data, report writing, arrival of Mr. Alfred Heuperman.
3 November	Mogambo; field visit with Messrs Alfred Heuperman and Jim Sumbak.
4 November	Mogambo; MMP office, report writing.
5 November	Mogambo; installation of observation wells in block 42.
6 November	Kismayo.
7 November	Mogambo; installation of observation wells in block 42, interrupted by heavy rains. Visit to Fanoole Rice Farm, discussions with Chinese experts.
8 to 10 November	Mogambo; MMP office, report writing.
11 November	Mogambo; MMP office, report writing. Visit the Juba Sugar Project area to collect data on groundwater levels and soil salinity. Discussions with Mr. Keith Ward, Agricultural Manager of JSP.
12 November	Mogambo; MMP office, report writing.
13 November	Mogambo to Mogadishu by car, accompanied by Mr. Jim Sumbak.

14 November	Mogadishu; meeting with representatives of the National University of Somalia to discuss their participation in the monitoring activities in the MIP area. Meeting with General Manager of MIP, Mr. Abdi Hassan Shirwac.
15 November	Departure to the Netherlands.

ANNEX 3

ITINERARY A.F. HEUPERMAN

ANNEX 3

ITINERARY - A.F. HEUPERMAN

27 October	Leave Australia.
28 to 31 October	Stopover Nairobi to arrange Somali visa.
1 November	Arrived Mogadishu.
2 November	Travel to Mogambo by car.
3 November	Meet MIP management staff and MMP consultant. Discussion of work schedule. Field visit.
4 November	Travel to Kismayo to buy pipes for test-well installation. Prepare fieldwork.
5 November	Test-well installation in field.
6 November	Day off.
7 November	Test-well installation. Visit Fanoole Rice Farm.
8 to 9 November	Test-well installation. Study available reports.
10 November	Report writing and revising.
11 November	Visit Juba Sugar Project. Discussions with Agronomist and Irrigation Engineer on salinity situation.
12 November	Finalise final draft with MMP consultant. Discuss additional work to be done.
13 November	MMP consultant leaves for Holland. Day off.
14 to 18 November	Continue field programme on test-well installation and report preparation.
19 November	Discuss MIP salinity situation with Juba Sugar Project Irrigation Engineer. Joint field visit.
20 November	Day off.
21 November	Construction of test-well maintenance equipment in MIP workshop. Report preparation.
22 to 26 November	Completion of test-well installation programme. Report ready for discussion by MIP staff.
27 November	Day off.
28 Novembver	Meeting with MIP management staff to discuss report.
29 November	Travel to Mogadishu by car with Mr. Sumbak.

30 November to 1 December	Mogadishu. Visit GM MIP to submit draft report and Somali National University to discuss future participation in MIP monitoring programme*.
2 December	Departure to Australia via Nairobi.

Note: * Visit Vice-Minister of Agriculture Dr. Moor to discuss follow-up activities.

ANNEX 4

DISTRIBUTION OF SOIL MAPPING UNITS IN THE MIP

ANNEX 4

DISTRIBUTION OF SOIL MAPING UNITS IN THE MIP

Distributary canal		Block Nr	Area (ha)	Soils in %					
				Jbl	Jb2/3	Jl	Jmxl	Jmxd	Other
M1/C1		1	28	8	8	84	-	-	-
		2	18	92	-	7	-	-	1
		3	28	5	20	75	-	-	-
		4	28	32	42	25	-	-	1
		5	28	-	75	25	-	-	-
		6	28	40	50	10	-	-	-
		7	28	-	65	30	-	-	5
		8	28	20	78	-	-	-	2
		9	28	-	-	85	-	15	
		10	28	5	70	20	-	-	5
		11	28	50	-	50	-	-	-
		12	28	5	72	20	-	-	3
		13	28	65	-	35	-	-	-
		14	28	2	33	65	-	-	-
		15	28	70	-	30	-	-	-
		16	28	7	8	85	-	-	-
		18	28	30	15	55	-	-	-
Sub-total	(ha)		466	118	147	192			9
	(%)			25	32	41			2
M1/C4		20	28	100	-	-	-	-	-
		22	28	75	25	-	-	-	-
		23	28	80	-	1	19	-	-
		25	28	10	90	-	-	-	-
		26	28	70	10	20	-	-	-
		28	28	20	78	-	-	-	2
		29	28	30	35	35	-	-	-
		31	28	10	40	-	12	35	3
		33	28	-	-	-	60	40	-
		35	28	3	-	-	68	28	1
		36	28	25	-	-	3	71	1
		37	28	98	-	-	-	2	-
		38	28	97	-	-	3	-	-
		40	28	30	30	-	40	-	-
		41	28	10	-	-	20	70	-
		42	28	88	-	-	-	12	-
		43	28	70	-	-	28	-	2
Sub-total	(ha)		476	228	86	14	71	72	5
	(%)			48	18	3	15	15	1

Distributary canal		Block Nr	Area (ha)	Soils in % Jbl	Jb2/3	Jl	Jmxl	Jmxd	Other
M1/C6		19	28	100	-	-	-	-	-
		21	28	30	70	-	-	-	-
		24	28	15	80	-	-	-	5
		27	28	12	80	-	-	-	8
		30	28	10	70	-	10	-	10
		32	28	70	20	-	-	-	10
		34	28	55	31	-	12	-	2
		39	28	30	65	5	-	-	-
Sub-total	(ha)		224	90	116	2	7		9
	(%)			40	52	1	3		4
M2/C1		17	20	35	30	35	-	-	-
		70	24	-	50	50	-	-	-
		71	28	-	60	40	-	-	-
		72	28	30	30	40	-	-	-
		73	28	50	50	-	-	-	-
		74	28	10	10	80	-	-	-
		75	26	15	15	70	-	-	-
		76	30	40	40	20	-	-	-
		77	20	35	35	-	25	-	5
Sub-total	(ha)		232	56	81	86	7		2
	(%)			24	35	37	3		1
M2/C2		44	28	-	50	50	-	-	-
		45	28	35	60	-	5	-	-
		46	28	5	-	-	60	35	-
		47	28	60	-	-	-	40	-
		48	28	60	-	-	23	15	2
		49	28	45	42	-	2	10	1
		50	28	12	1	-	30	57	1
		51	28	-	-	-	75	25	-
		52	28	-	-	-	5	95	-
		54	28	35	-	5	10	45	5
		55	28	-	-	-	20	80	-
		56	20	-	-	-	5	95	-
		58	28	65	-	30	3	-	2
		59	28	-	-	1	17	80	2
Sub-total	(ha)		304	88	42	23	69	158	4
	(%)			23	11	6	18	41	1

Distributary canal		Block Nr	Area (ha)	Soils in % Jbl	Jb2/3	Jl	Jmxl	Jmxd	Other
M2/C4		53	28	15	82	3	-	-	-
		57	28	17	83	-	-	-	-
		60	28	25	60	15	-	-	-
		61	28	70	7	15	5	-	3
		62	28	20	25	15	25	-	15
		63	28	30	12	-	50	-	8
		64	28	-	97	-	3	-	-
		65	28	-	100	-	-	-	-
		66	28	20	20	-	45	15	-
		67	28	-	30	-	55	-	15
		68	28	-	90	-	-	-	10
		69	28	-	97	-	-	-	3
Sub-total	(ha)		336	54	198	13	51	3	17
	(%)			16	59	4	15	1	15
TOTAL	(ha)		2 218	634	670	330	205	233	46
	(%)			30	32	15	10	11	2

ANNEX 5

WATERTABLE LEVELS IN THE MIP AREAS

ANNEX 5

WATERTABLE LEVELS IN THE MIP AREA

Number of observation well	Soil type	Date 27/3	5/5	13/6	8/7	6/9	11/9	16/9	21/9	26/9	1/10	6/10	11/10	16/10	21/10
1-1	J1	160	170	165	120	159	177	184	*	*	*	*	*	*	*
1-2	J1	240	240	180	80	174	180	185	*	*	*	*	*	*	*
1-3	J1	-	180	200	150	175	183	189	195	196	202	206	210	215	215
2-1	Jb1	310	200	40	120	120	123	126	129	129	135	133	133	132	125
2-2	Jb1	*	*	*	*	*	*	*	*	*	*	*	*	*	*
2-3	Jb1	240	190	140	150	186	189	192	195	196	201	204	207	211	213
3-1	J1	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4-1	Jb3	*	*	*	*	*	*	*	*	*	*	*	*	*	*
12-1	Jb3	*	*	*	*	*	*	*	*	*	*	*	*	*	*
16-1	Jb3	*	*	*	*	*	*	*	*	*	*	*	*	*	*
18-1	J1	*	*	*	*	*	*	*	*	*	*	*	*	*	*
18-2	Jb1	*	*	*	*	*	*	*	*	*	*	*	*	*	*
19-1	Jb1	*	d	5	5	282	281	280	279	276	276	274	270	271	269
21-1	Jb3	d	d	*	240	177	185	191	198	201	208	209	214	218	*
27-1	Jb3	d	d	270	*	263	263	263	*	*	*	*	*	*	*
36-1	Jb1	*	*	*	*	*	*	*	*	*	*	*	*	*	*
64-1	Jb2	*	*	*	*	*	*	*	*	*	*	*	*	*	*
69-1	Jb2	*	*	*	*	*	*	*	*	*	*	*	*	*	*
72-1	Jb1-2	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Notes:
- * no data available (observation well not yet installed or destroyed)
- d dry. All measurements in cm below the surface
- ** site flooded
- 25/8 most sites were inundated by 193 mm of rain from 8 to 11 August with rainwater entering the observation wells

Number of observation well	Soil type	31/10	24/11	8/1	19/4	2/5	17/5	Date 30/5	13/6	11/7	26/7	25/8	23/9	25/10
1-1	J1	*	*	*	*	*	*	*	*	*	*	*	*	*
1-2	J1	*	236	242	303	308	318	316	312	311	313	300	290	273
1-3	J1	216	220	*	*	*	*	*	*	*	*	*	*	*
2-1	Jb1	*	*	111	189	167	156	157	131	132	135	123	155	124
2-2	Jb1	*	*	*	d	d	d	d	280	271	272	282	280	248
2-3	Jb1	*	209	229	289	295	294	298	282	280	299	280	268	247
3-1	J1	*	*	*	d	d	313	322	329	313	328	338	340	323
4-1	Jb3	*	*	*	274	270	270	269	265	260	259	327	319	*
12-1	Jb3	*	*	*	324	328	332	334	334	334	321	320	324	*
16-1	Jb3	*	*	*	321	333	342	350	349	327	281	297	326	326
18-1	J1	*	*	*	d	d	d	d	d	d	d	347	d	d
18-2	Jb1	*	*	*	d	d	d	d	d	d	d	344	d	d
19-1	Jb1	*	245	237	254	254	227	234	*	290	57**	101	186	143
21-1	Jb3	*	240	236	*	*	*	*	*	*	*	*	*	*
27-1	Jb3	*	220	d	d	d	289	*	*	*	*	d	439	d
36-1	Jb1	*	*	*	*	*	*	*	*	320	406	412	404	*
64-1	Jb2	*	*	*	*	*	*	*	*	*	258	188	240	281
69-1	Jb2	*	*	*	*	*	*	*	365	326	337	275	366	d
72-1	Jb1-2	*	*	*	353	d	d	d	d	d	d	348	d	d

ANNEX 6

BORE LOG DESCRIPTIONS OF DEEP BORES

Figure A6-2

Trans - Juba Livestock Development Project Deep Bore

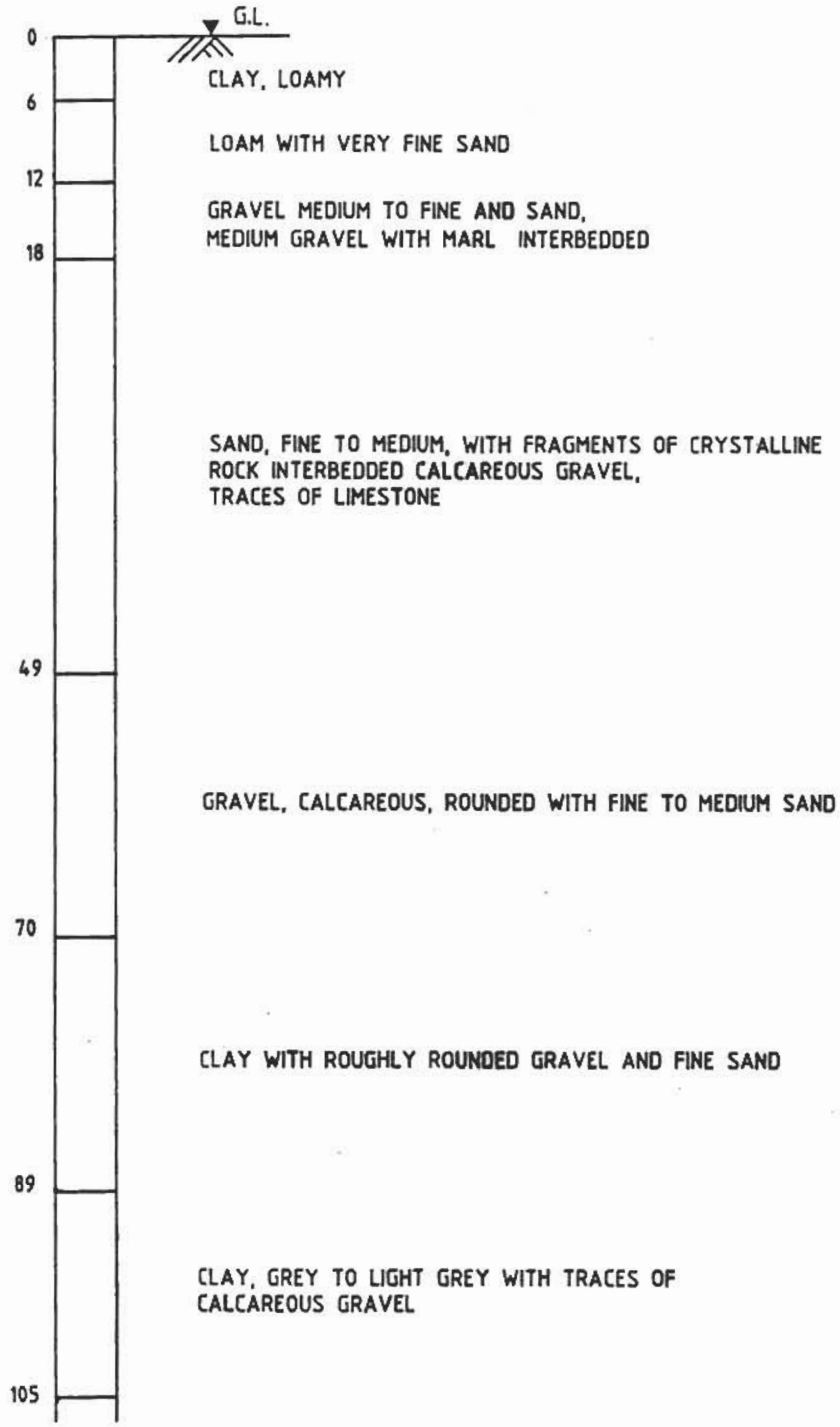
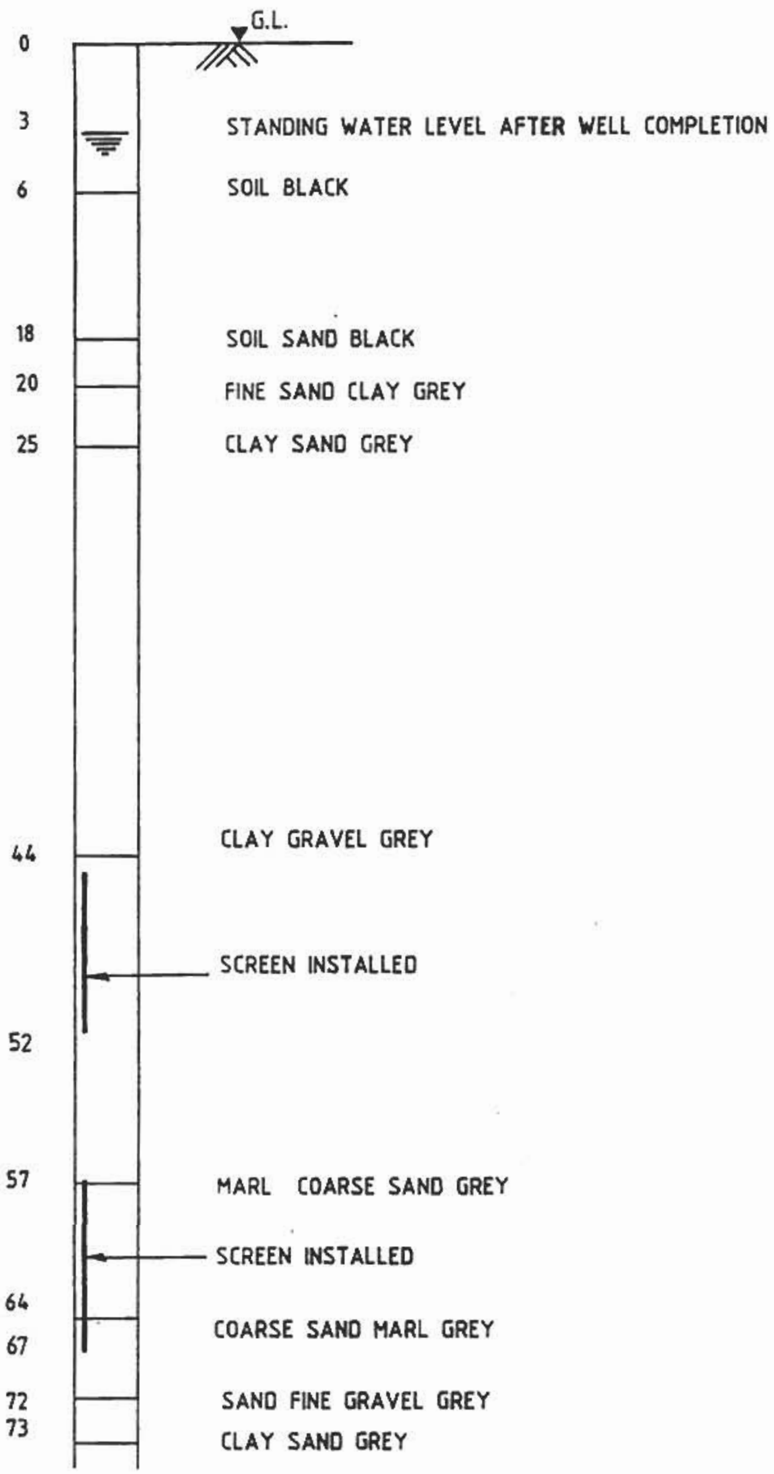


Figure A6-3

M. I. P. Rice Mill Deep Bore



ANNEX 7

MONTHLY MEAN EC VALUES AND MEAN MONTHLY FLOWS IN THE JUBA RIVER

ANNEX 7

MONTHLY MEAN EC VALUES AND MEAN MONTHLY FLOWS IN THE JUBA RIVER

Month	1977	1978	1979	1980	1981	1982 (mS/cm)	1983	1984	1985	1986	Mean monthly EC	Mean monthly flows 1951-76 (Ml x 1 000)
January	-	0.6	0.4	0.6	0.7	0.7	0.3	0.3	0.5	0.5	0.5	162
February	-	0.8	0.4	1.0	1.0	0.9	0.5	0.5	0.9	0.9	0.8	57
March	-	0.7	0.4	1.3	1.2	1.3	0.5	0.8	1.5	1.2	1.0	69
April	-	0.6	0.8	1.6	0.9	0.9	0.8	1.2	1.3	1.2	1.0	190
May	-	0.4	0.4	1.3	0.6	0.5	0.5	1.0	0.5	0.4	0.6	577
June	0.3	0.3	0.2	0.5	0.6	0.3	0.2	0.5	0.2	0.3	0.3	438
July	0.1	0.2	0.2	0.2	0.6	0.2	0.2	0.3	0.1	0.2	0.2	451
August	0.1	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	671
September	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	719
October	0.3	0.3	0.3	0.2	0.2	0.2	0.4	0.2	0.2	0.2	0.2	843
November	0.7	0.4	0.3	0.3	0.3	0.4	0.2	0.3	0.3	0.3	0.3	832
December	0.5	0.3	0.4	0.4	0.4	0.3	0.2	0.3	0.3	0.4	0.3	473

Notes: EC measured at Juba Sugar Project
Flow measurements taken at Mogambo (1951 to 1976)

ANNEX 8

SOIL, LAND AND WATER USE DATA FOR INDIVIDUAL BLOCKS IN THE MIP (1985 to 1988)

ANNEX 8

SOIL, LAND AND WATER USE DATA FOR INDIVIDUAL BLOCKS IN THE MIP (1985-1988)

Abbreviation	Crop
R	Rice
Mu	Mungbean
Cp/ses	Cowpea/sesame
Ma/ses	Maize/sesame
Ses	Sesame
R/Sa/Su	Rice/safflower/sunflower
R+Saf	Rice and safflower
Sorg	Sorghum
Mu+Cp	Mungbean and cowpea
Mu+Su	Mungbean and sunflower
Cp+Su	Cowpea and sunflower
Cwpea	Cowpea

ANNEX 8

SOIL, LAND AND WATER USE DATA FOR INDIVIDUAL BLOCKS IN THE MIP

Distributary M1/C1 Der 1985/86

Block			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18
Crop			Maize	Rice	Maize	Rice	Rice	Maize	Rice	Maize	Rice	R+Mu	Maize	Rice	Maize	Maize	Maize	Maize	Maize
Area:	Sown		27	18	27	27	27	27	28	27	28	30	28	28	28	28	28	28	28
	Harvested		n/a	4	n/a	4	27	n/a	28	n/a	28	15	n/a	12	n/a	n/a	n/a	n/a	n/a
Soils %	Jh1		8	92	5	32	-	40	-	20	-	5	50	5	65	2	70	7	30
	Jh2&3		8	-	20	42	75	50	65	78	-	70	-	72	-	33	-	8	15
	J1		84	7	75	25	25	10	30	-	85	20	50	20	35	65	30	85	55
	Jmxl		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Jmxd		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Other		-	1	-	1	-	-	5	2	15	5	-	3	-	-	-	-	-
Month	Week	Rain (mm)	(B) mm per 10 day irrigation																
1985 Oct	1-10	18	0	131	0	0	15	0	204	0	41	0	0	0	0	0	0	0	0
	11-20	3	0	43	0	280	205	0	34	0	213	0	0	183	0	0	0	0	0
	21-31	0	0	84	0	0	131	0	146	0	141	138	9	57	0	0	0	9	0
Nov	1-10	0	0	196	0	114	85	0	108	0	126	96	190	9	19	0	0	0	0
	11-20	12	49	37	0	171	140	103	12	0	14	38	120	189	123	25	0	0	0
	21-30	15	94	0	116	28	9	104	93	101	0	0	22	22	0	174	0	164	28
Dec	1-10	5	146	0	105	0	15	123	104	146	98	78	75	0	0	69	0	96	99
	11-20	2	53	134	0	157	154	11	114	24	127	85	0	97	0	0	0	21	9
	21-31	0	0	92	32	190	232	0	165	0	78	77	89	26	95	75	0	62	0
1986 Jan	1-10	0	0	83	0	123	164	0	26	0	149	36	101	92	65	38	0	67	23
	11-20	0	0	148	0	193	193	14	203	0	124	37	44	50	0	72	0	88	39
	20-31	0	0	58	0	308	168	34	94	0	151	32	104	91	128	104	0	120	26
Feb	1-10	0	0	73	0	142	141	0	58	0	63	7	0	56	3	0	0	18	25
	11-20	0	0	15	0	123	122	0	0	0	23	29	0	39	0	0	0	0	0
	21-28	0	0	16	0	57	53	0	0	0	0	15	0	41	0	0	0	0	7
Der	Totals	55	341	1 109	253	1 887	1 828	389	1 359	271	1 348	668	754	953	432	556	0	634	254

SOIL, LAND AND WATER USE DATA FOR INDIVIDUAL BLOCKS IN THE MIP

Distributary M1/C1 Der 1986/87

Block			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18
Crop			-	-	-	-	-	-	Rice	-	Rice	-	Rice	-	Rice	Rice	Rice	Rice	Rice
Area:	Sown		0	0	0	0	0	0	28	0	14	0	28	0	28	28	28	28	28
	Harvested		0	0	0	0	0	0	28	0	14	0	20	0	28	8	16	8	12
Soils %	Jb1		8	92	5	32	-	40	-	20	-	5	50	5	65	2	70	7	30
	Jb2&3		8	-	20	42	75	50	65	78	-	70	-	72	-	33	-	8	15
	J1		84	7	75	25	25	10	30	-	85	20	50	20	35	65	30	85	55
	Jmxl		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Jmxd		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Other		-	1	-	1	-	-	5	2	15	5	-	3	-	-	-	-	-
Month	Week	Rain (mm)	(B) mm per week irrigation																
1986																			
Oct	17-23	0	0	0	0	0	0	0	143	0	303	0	113	0	305	2	218	1	94
	24-30	11	0	0	0	0	0	0	181	0	43	0	229	0	16	308	60	278	144
	31-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	164	0	283	225
Nov	7-13	4	0	0	0	0	0	0	101	0	193	0	17	0	21	126	140	104	6
	14-20	0	0	0	0	0	0	0	46	0	0	0	114	0	188	60	80	0	0
	21-27	22	0	0	0	0	0	0	49	0	71	0	95	0	33	65	0	20	46
	28-4	12	0	0	0	0	0	0	117	0	271	0	0	0	0	18	0	16	171
Dec	5-11	0	0	0	0	0	0	0	100	0	327	0	0	0	40	142	120	128	98
	12-18	0	0	0	0	0	0	0	0	0	344	0	119	0	157	100	65	138	0
	19-25	0	0	0	0	0	0	0	0	0	29	0	88	0	87	76	91	104	61
	26-1	0	0	0	0	0	0	0	119	0	116	0	82	0	160	69	61	66	126
1987																			
Jan	2-8	0	0	0	0	0	0	0	164	0	211	0	134	0	182	130	12	173	105
	9-15	0	0	0	0	0	0	0	112	0	56	0	136	0	151	36	139	121	83
	16-22	0	0	0	0	0	0	0	162	0	109	0	160	0	164	83	71	161	162
	23-29	0	0	0	0	0	0	0	140	0	149	0	118	0	146	39	132	134	137
	30-5	0	0	0	0	0	0	0	141	0	155	0	121	0	160	79	104	128	40
Feb	6-12	0	0	0	0	0	0	0	128	0	124	0	99	0	133	84	88	89	91
	13-19	0	0	0	0	0	0	0	98	0	51	0	150	0	125	28	61	25	95
	20-26	0	0	0	0	0	0	0	86	0	96	0	96	0	107	91	91	82	84
	27-5	0	0	0	0	0	0	0	86	0	96	0	96	0	107	91	91	82	84
Der	Total	49	0	0	0	0	0	0	1 887	0	2 647	0	1 870	0	2 173	1 699	1 531	2 050	1 776

SOIL, LAND AND WATER USE DATA FOR INDIVIDUAL BLOCKS IN THE MIP

Distributary M1/C4 Der 1986/87

Block			20	22	23	25	26	28	29	31	33	35	36	37	38	40	41	42	43
Crop										?	?	?	Rice	R ice	Rice	Sesame	Sesame	Rice	Rice
Area:	Sown		0	0	0	0	0	0	0	1	1	10	28	28	24	28	28	28	28
	Harvested		0	0	0	0	0	0	0	n/a	n/a	n/a	0	12	8	n/a	n/a	0	12
Soils %	Jb1		100	75	80	10	70	10	30	10	-	3	25	98	97	30	10	88	70
	Jb2&3		-	25	-	90	10	78	35	40	-	-	-	-	-	30	-	-	-
	J1		-	-	1	-	20	-	35	-	-	-	-	-	-	-	-	-	-
	Jmxl		-	-	19	-	-	-	-	12	60	68	3	-	3	40	20	-	28
	Jmxd		-	-	-	-	-	-	-	35	40	28	71	2	-	-	70	12	-
	Other		-	-	-	-	-	2	-	3	-	1	1	-	-	-	-	-	2
Month	Week	Rain (mm)	(B) mm per week irrigation																
1986																			
Oct	19-25	0	0	0	0	0	0	0	0	0	0	0	317	324	310	0	5	22	36
	26-1	11	0	0	0	0	0	0	0	440	440	0	66	8	67	0	0	323	359
Nov	2-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0	73	0
	9-15	4	0	0	0	0	0	0	0	0	0	0	92	99	47	123	152	0	0
	16-22	2	0	0	0	0	0	0	0	0	0	0	66	193	195	129	202	0	0
	23-29	20	0	0	0	0	0	0	0	0	0	0	0	76	89	71	104	0	63
	30-6	12	0	0	0	0	0	0	0	0	0	284	0	0	0	123	173	0	131
Dec	7-13	0	0	0	0	0	0	0	0	0	0	635	0	0	0	105	28	180	21
	14-20	0	0	0	0	0	0	0	0	0	0	1 080	0	0	0	0	0	51	0
	21-27	0	0	0	0	0	0	0	0	0	0	194	0	42	0	0	0	0	0
	28-3	0	0	0	0	0	0	0	0	0	0	0	0	176	80	0	0	0	130
1987																			
Jan	4-10	0	0	0	0	0	0	0	0	0	0	0	0	16	144	0	0	0	138
	11-17	0	0	0	0	0	0	0	0	0	0	0	0	118	34	0	0	0	133
	18-24	0	0	0	0	0	0	0	0	0	0	124	10	137	92	0	0	0	112
	25-31	0	0	0	0	0	0	0	0	0	0	0	0	201	232	0	0	0	165
Feb	1-7	0	0	0	0	0	0	0	0	0	0	0	133	164	43	0	0	0	165
	8-14	0	0	0	0	0	0	0	0	0	0	0	0	159	122	3	0	0	156
	15-21	0	0	0	0	0	0	0	0	0	0	0	0	89	104	0	0	0	96
	22-28	0	0	0	0	0	0	0	0	0	0	0	0	85	103	0	0	0	60
Mar	1-7	0	0	0	0	0	0	0	0	0	0	0	0	64	81	0	0	0	66
	8-14	0	0	0	0	0	0	0	0	0	0	0	0	65	63	0	0	0	58
Der	Totals	49	0	0	0	0	0	0	0	440	440	2 517	684	2 015	1 804	596	663	650	1 886

SOIL, LAND AND WATER USE DATA FOR INDIVIDUAL BLOCKS IN THE MIP

Distributary M1/C6 Der 1986/87

Block			19	21	24	27	30	32	34	39
Crop			?	-	-	-	-	-	-	Ses
Area:	Sown		10	0	0	0	0	0	0	28
	Harvested		n/a	0	0	0	0	0	0	n/a
Soils %	Jb1		100	30	15	12	10	70	55	30
	Jb2&3		-	70	80	80	70	20	31	65
	J1		-	-	-	-	-	-	-	5
	Jmxl		-	-	-	-	10	-	12	-
	Jmxd		-	-	-	-	-	-	-	-
	Other		-	-	5	8	10	10	2	-
Month	Week	Rain (mm)	(B) mm per week irrigation							
1986										
Oct	28-3	0	91	0	0	0	0	0	0	0
Nov	4-10	4	4	0	0	0	0	0	0	83
	11-17	0	0	0	0	0	0	0	0	92
	18-24	2	0	0	0	0	0	0	0	115
	25-1	23	22	0	0	0	0	0	0	64
Dec	2-8	9	52	0	0	0	0	0	0	195
	9-15	0	0	0	0	0	0	0	0	100
	16-22	0	52	0	0	0	0	0	0	0
	23-29	0	50	0	0	0	0	0	0	0
	30-5	0	37	0	0	0	0	0	0	0
1987										
Jan	6-12	0	54	0	0	0	0	0	0	0
	13-19	0	203	0	0	0	0	0	0	0
	20-26	0	207	0	0	0	0	0	0	0
	27-2	0	0	0	0	0	0	0	0	0
Feb	3-9	0	158	0	0	0	0	0	0	0
	10-16	0	97	0	0	0	0	0	0	0
	17-22	0	184	0	0	0	0	0	0	0
Der	Totals	38	1 255	0	0	0	0	0	0	649

SOIL, LAND AND WATER USE DATA FOR INDIVIDUAL BLOCKS IN THE MIP

Distributary M2/C1 Der 1986/87

Block			17	70	71	72	73	74	75	76	77
Crop			Rice	R/sa/su	Rice	Rice	R+Saf	Rice	Rice	R/sa/mu	Sorg
Area:	Sown		18	28	28	28	28	28	28	30	22
	Harvested		14	28	24	28	28	0	18	30	4
Soils %	Jb1		35	-	-	30	50	10	15	40	35
	Jb2&3		30	50	60	30	50	10	15	40	35
	J1		35	50	40	40	-	80	70	20	-
	Jmxl		-	-	-	-	-	-	-	-	25
	Jmxd		-	-	-	-	-	-	-	-	-
	Other		-	-	-	-	-	-	-	-	5
Month	Week	Rain (mm)	(B) mm per week irrigation								
1986 Oct	21-27	11	279	102	166	200	73	277	263	0	0
	28-3	0	99	2	0	122	312	47	0	299	77
Nov	4-10	4	55	0	51	0	37	51	0	0	104
	11-17	0	0	113	23	57	26	66	124	0	0
	18-24	2	94	22	56	90	124	0	0	32	0
	25-1	23	0	18	60	0	0	0	31	0	0
Dec	2-8	9	167	0	43	0	0	0	101	0	0
	9-15	0	37	14	0	66	0	0	19	0	18
	16-22	0	129	10	86	131	96	0	47	79	127
	23-29	0	0	35	106	94	88	0	33	26	0
1987	30-5	0	33	51	171	150	131	0	132	59	90
Jan	6-12	0	43	71	106	98	127	100	132	38	83
	13-19	0	238	91	34	0	155	9	103	30	0
	20-26	0	257	73	30	266	126	0	164	79	0
	27-2	0	107	33	201	210	55	0	174	40	0
Feb	3-9	0	58	26	103	120	137	0	18	17	0
	10-16	0	108	49	64	40	146	0	150	15	0
	17-23	0	76	11	97	175	61	0	64	0	0
	24-2	0	33	0	0	40	50	0	29	0	0
Mar	3-9	0	0	0	0	0	90	0	0	0	0
	10-16	0	14	0	0	0	35	0	0	0	0
Der	Totals	49	1 828	721	1 397	1 860	1 870	550	1 583	716	498

SOIL, LAND AND WATER USE DATA FOR INDIVIDUAL BLOCKS IN THE MIP

Distributary M2/C2 Der 1986/87

Block			44	45	46	47	48	49	50	51	52	54	55	56	58	59
Crop			Ses	Ses	Ses	Ses	Ses	Ses	Ses	Ses	Ses	Ses	-	-	-	-
Area:	Sown		28	28	28	28	28	28	28	28	28	28	0	0	0	0
	Harvested		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0	0	0
Soils %	Jb1		-	35	5	60	60	45	12	-	-	35	-	-	65	-
	Jb2&3		50	60	-	-	-	42	1	-	-	-	-	-	-	-
	J1		50	-	-	-	-	-	-	-	-	5	-	-	30	1
	Jmxl		-	5	60	-	23	2	30	75	5	10	20	5	3	17
	Jmxd		-	-	35	40	15	10	57	25	95	45	80	95	-	80
	Other		-	-	-	-	2	1	-	-	-	5	-	-	2	2
Month	Week	Rain (mm)	(B) mm per week irrigation													
1986																
Nov	4-10	4	165	117	109	0	0	0	0	0	0	0	0	0	0	0
	11-17	0	199	156	128	133	35	80	0	0	0	0	0	0	0	0
	18-24	2	85	201	190	166	4	241	0	0	0	0	0	0	0	0
	25-1	23	0	26	99	97	41	117	91	0	0	4	0	0	0	0
Dec	2-8	9	0	0	146	162	150	67	156	137	34	27	0	0	0	0
	9-15	0	0	0	26	29	342	0	91	308	190	9	0	0	0	0
	16-22	0	0	0	0	0	25	0	0	347	288	308	0	0	0	0
	23-29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	30-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987																
Jan	6-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	13-19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27-2	0	0	69	0	0	33	61	0	0	44	0	0	0	0	0
Der	Totals	38	448	570	697	587	629	565	339	791	556	347	0	0	0	0

SOIL, LAND AND WATER USE DATA FOR INDIVIDUAL BLOCKS IN THE MIP

Distributary M2/C4 Der 1986/87

Block			53	57	60	61	62	63	64	65	66	67	68	69
Crop			Ses	Ses	Ses		Maize							
Area:	Sown		28	28	28	0	16	0	0	0	0	0	0	0
	Harvested		n/a	n/a	n/a	0	16	0	0	0	0	0	0	0
Soils %	Jb1		15	17	25	70	20	30			20			
	Jb2&3		82	83	60	7	25	12	97	100	20	30	90	97
	Jbl		3	-	15	15	-	-	-	-	-	-	-	-
	Jmxl		-	-	-	5	25	50	3	-	45	55	-	-
	Jmxd		-	-	-	-	-	-	-	-	15	-	-	-
	Other		-	-	-	3	15	8	-	-	-	15	10	3
Month	Week	Rain (mm)	(B) mm per week irrigation											
1986														
Nov	4-10	4	0	0	0	0	105	0	0	0	0	0	0	0
	11-17	0	0	0	0	0	42	0	0	0	0	0	0	0
	18-24	2	0	0	0	0	0	0	0	0	0	0	0	0
	25-1	23	17	0	0	0	0	0	0	0	0	0	0	0
Dec	2-8	9	180	0	0	0	0	0	0	0	0	0	0	0
	9-15	0	42	255	60	0	28	0	0	0	0	0	0	0
	16-22	0	302	154	327	0	102	0	0	0	0	0	0	0
	23-29	0	0	0	0	0	94	0	0	0	0	0	0	0
	30-5	0	0	0	0	0	96	0	0	0	0	0	0	0
Jan	6-12	0	0	0	0	0	71	0	0	0	0	0	0	0
1987	13-19	0	0	0	0	0	87	0	0	0	0	0	0	0
	20-26	0	0	0	0	0	186	0	0	0	0	0	0	0
DER	Totals	38	541	409	388	0	811	0	0	0	0	0	0	0

SOIL, LAND AND WATER USE DATA FOR INDIVIDUAL BLOCKS IN THE MIP

Distributary M1/C1 Gu 1986

Block			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18
Crop			Rice	-	Rice	-	?	Rice	Cp/ses	Ma/ses	Ma/ses	Maize	Ma/ses	Maize	Ses	?	-	Ses	Ma/ses
Area:	Sown		27	0	27	0	10	9	10	10	6	11	16	10	6	10	0	8	18
	Harvested		n/a	0	n/a	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	n/a	n/a
Soils %	Jb1		8	92	5	32	-	40	-	20	-	5	50	5	65	2	70	7	30
	Jb2&3		8	-	20	42	75	50	65	78	-	70	-	72	-	33	-	8	15
	J1		84	7	75	25	25	10	30	-	85	20	50	20	35	65	30	85	55
	Jmxl		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Jmxd		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Other		-	1	-	1	-	-	5	2	15	5	-	3	-	-	-	-	-
Month	Week	Rain (mm)	(B) mm per week irrigation																
1986																			
Apr	26-2	7	0	0	0	0	0	127	0	93	0	0	0	0	0	0	0	0	0
May	3-9	0	156	0	276	0	0	796	0	0	0	0	0	0	0	0	0	0	0
	10-16	14	196	0	289	0	0	719	0	0	0	0	0	0	85	0	0	0	0
	17-23	11	188	0	95	0	316	119	74	428	125	0	0	0	463	205	0	0	66
	24-30	184	22	0	0	0	52	0	17	40	35	0	0	0	77	37	0	0	7
	31-6	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun	7-13	11	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	14-20	20	166	0	43	0	0	119	0	0	0	0	0	0	0	0	0	0	0
	21-27	27	153	0	77	0	0	108	0	0	0	0	0	0	0	0	0	0	0
	28-4	6	108	0	78	0	0	59	0	0	0	0	0	0	0	0	0	0	0
Jul	5-11	7	216	0	296	0	0	251	0	0	0	0	0	0	0	0	0	0	0
	12-18	0	179	0	195	0	0	76	0	0	0	0	0	0	0	0	0	0	0
	19-25	7	181	0	0	0	0	312	0	0	0	0	0	0	0	0	0	0	0
	26-1	4	52	0	102	0	0	97	0	0	0	0	0	0	0	0	0	0	0
Aug	2-8	0	121	0	190	0	0	148	0	0	0	0	0	0	0	0	0	0	0
	9-15	0	57	0	64	0	0	112	0	0	0	0	0	0	0	0	0	0	0
	16-22	0	5	0	55	0	0	98	0	0	0	0	0	0	0	0	0	0	0
	23-29	4	70	0	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	30-5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gu	Totals	325	1 938	0	1 813	0	368	3 139	91	561	160	0	0	0	625	242	0	0	72

SOIL, LAND AND WATER USE DATA FOR INDIVIDUAL BLOCKS IN THE MIP

Distributary M1/C4 Gu 1986

Block			20	22	23	25	26	28	29	31	33	35	36	37	38	40	41	42	43
Crop			Rice	Rice	Rice	Rice	Rice	Rice	Rice	Rice	Rice	Ma/ses				Maize			
Area:	Sown		28	28	28	28	28	28	28	28	28	14	0	0	0	28	0	0	0
	Harvested		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0	0	n/a	0	0	0
Soils %	Jb1		100	75	80	10	70	10	30	10	-	3	25	98	97	30	10	88	70
	Jb2&3		-	25	-	90	10	78	35	40	-	-	-	-	-	30	-	-	-
	J1		-	-	1	-	20	-	35	-	-	-	-	-	-	-	-	-	-
	Jmxl		-	-	19	-	-	-	-	12	60	68	3	-	3	40	20	-	28
	Jmxd		-	-	-	-	-	-	-	35	40	28	71	2	-	-	70	12	-
	Other		-	-	-	-	-	2	-	3	-	1	1	-	-	-	-	-	2
Month	Week	Rain (mm)	(B) mm per week irrigation																
1986																			
Apr	19-25	27	99	120	0	135	0	91	0	102	0	0	0	0	0	0	0	0	0
	26-2	7	0	0	0	0	0	0	101	0	0	0	0	0	0	0	0	0	0
May	3-9	0	286	284	263	211	283	218	135	292	329	0	0	0	0	0	0	0	0
	10-16	14	0	0	57	0	0	0	0	108	13	0	0	0	0	0	0	0	0
	17-23	11	0	0	34	0	67	0	40	0	91	0	0	0	0	0	0	0	0
	24-30	184	0	0	15	0	14	0	12	0	20	0	0	0	0	0	0	0	0
	31-6	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun	7-13	11	66	83	61	0	82	0	0	0	0	0	0	0	0	0	0	0	0
	14-20	20	158	170	121	107	161	108	74	105	102	0	0	0	0	0	0	0	0
	21-27	27	0	16	111	131	124	131	87	161	161	0	0	0	0	0	0	0	0
	28-4	6	0	0	99	27	99	0	79	71	122	0	0	0	0	0	0	0	0
Jul	5-11	7	144	50	124	160	121	175	96	128	177	0	0	0	0	0	0	0	0
	12-18	0	81	171	142	27	121	27	112	105	149	0	0	0	0	0	0	0	0
	19-25	7	0	27	87	113	39	117	36	115	21	0	0	0	0	0	0	0	0
	26-1	4	133	0	109	68	49	100	41	86	151	0	0	0	0	0	0	0	0
Aug	2-8	0	0	92	59	0	106	29	90	0	168	0	0	0	0	0	0	0	0
	9-15	0	0	0	24	0	84	0	7	82	48	0	0	0	0	0	0	0	0
	16-22	0	0	0	16	0	35	0	34	0	0	0	0	0	0	0	0	0	0
	23-29	4	0	0	0	0	92	0	78	0	0	0	0	0	0	0	0	0	0
	30-5	2	0	0	0	0	92	0	63	0	0	0	0	0	0	0	0	0	0
Gu	Totals	352	967	1 013	1 323	979	1 569	996	1 085	1 354	1 553	0	0	0	0	0	0	0	0

SOIL, LAND AND WATER USE DATA FOR INDIVIDUAL BLOCKS IN THE MIP

Distributary M1/C6 Gu 1986

Block			19	21	24	27	30	32	34	39
Crop			Rice	Rice	Rice	Rice	Rice	Rice	Rice	Ma/ses
Area:	Sown		28	28	28	28	28	28	28	14
	Harvested		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Soils	Jb1		100	30	15	12	10	70	55	30
	Jb2&3			70	80	80	70	20	31	65
	Jbl									5
	Jmxl						10		12	
	Jmxd									
	Other				5	8	10	10	2	
Month	Week	Rain (mm)	(B) mm per week irrigation							
1986										
Apr	19-25	27	135	146	128	98	43	0	0	0
	26-2	7	0	0	0	0	0	0	0	0
May	3-9	0	136	352	306	272	236	236	20	0
	10-16	14	0	0	0	21	91	133	142	0
	17-23	11	31	0	0	0	0	14	127	0
	24-30	184	0	0	0	0	0	0	0	0
	31-6	21	0	0	0	0	0	0	0	0
Jun	7-13	11	78	0	0	0	0	0	0	0
	14-20	20	77	98	86	49	65	9	0	0
	21-27	27	0	130	124	96	74	65	66	0
	28-4	6	33	91	86	70	58	60	41	0
Jul	5-11	7	101	16	81	67	126	99	125	0
	12-18	0	94	16	15	89	119	83	140	0
	19-25	7	0	159	164	134	0	107	113	0
	26-1	4	70	30	28	26	79	104	100	0
Aug	2-8	0	19	0	0	0	67	95	115	0
	9-15	0	0	26	0	0	36	59	55	0
	16-22	0	0	0	0	0	0	0	79	0
	23-29	4	0	0	0	0	0	0	126	0
	30-5	2	0	0	0	0	0	0	98	0
Sep	6-12	0	0	0	0	0	0	0	44	0
Gu	Totals	352	774	1 064	1 018	921	992	1 064	1 392	0

SOIL, LAND AND WATER USE DATA FOR INDIVIDUAL BLOCKS IN THE MIP

Distributary M1/C1 Gu 1987

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18
Block			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18
Crop			Maize	Maize	Maize	Maize	Maize	Maize	Maize	Maize	Maize	Maize	?	Maize	?	?	?	?	?
Area:	Sown		28	18	28	28	28	28	28	28	28	28	10	28	0	10	10	10	10
	Harvested		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	n/a	n/a	n/a	n/a
Soils %	Jb1		8	92	5	32	-	40	-	20	-	5	50	5	65	2	70	7	30
	Jb2&3		8	-	20	42	75	50	65	78	-	70	-	72	-	33	-	8	15
	J1		84	7	75	25	25	10	30	-	85	20	50	20	35	65	30	85	55
	Jmxl		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Jmxd		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Other		-	1	-	1	-	-	5	2	15	5	-	3	-	-	-	-	-
Month	Week	Rain (mm)	(B) mm per week irrigation																
1987																			
Jun	3-9	3	227	244	168	296	173	282	0	294	0	181	0	68	0	0	0	0	0
	10-16	34	100	218	114	8	174	10	0	8	0	47	0	95	0	0	0	0	0
	17-23	6	0	0	0	0	0	25	0	0	169	0	197	0	0	69	83	32	280
	24-30	0	0	0	0	0	0	0	0	0	96	0	169	0	0	278	0	122	27
Jul	1-7	14	0	0	0	0	0	0	60	0	0	0	53	9	0	105	0	246	0
	8-14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	195	0	78	0
	15-21	0	86	0	0	0	31	86	0	76	0	107	0	0	0	0	0	202	0
	22-28	3	68	44	86	58	49	0	0	85	26	11	0	60	0	0	0	0	47
	29-4	2	0	42	0	0	41	0	0	17	34	0	0	0	0	0	0	0	3
Gu	Totals	62	481	548	368	361	468	403	60	480	325	346	419	233	0	647	83	680	357

SOIL, LAND AND WATER USE DATA FOR INDIVIDUAL BLOCKS IN THE MIP

Distributary M1/C4 Gu 1987

Block			20	22	23	25	26	28	29	31	33	35	36	37	38	40	41	42	43
Crop			Maize	Maize	Maize	Maize	Maize	Maize	Maize	Maize	?								
Area:	Sown		28	28	28	28	28	28	28	28	10	0	0	0	0	0	0	0	0
	Harvested		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0	0	0	0	0	0	0	0
Soils %	Jb1		100	75	80	10	70	10	30	10	-	3	25	98	97	30	10	88	70
	Jb2&3		-	25	-	90	10	78	35	40	-	-	-	-	-	30	-	-	-
	J1		-	-	1	-	20	-	35	-	-	-	-	-	-	-	-	-	-
	Jmxl		-	-	19	-	-	-	-	12	60	68	3	-	3	40	20	-	28
	Jmxd		-	-	-	-	-	-	-	35	40	28	71	2	-	-	70	12	-
	Other		-	-	-	-	-	2	-	3	-	1	1	-	-	-	-	-	2
Month	Week	Rain (mm)	(B) mm per week irrigation																
1987																			
May	6-12	27	1	23	0	1	0	1	0	16	3	0	0	0	0	0	0	0	0
	13-19	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27-2	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
																0	0	0	0
																0	0	0	0
Jun	3-9	11	163	154	156	24	0	17	0	5	10	0	0	0	0	0	0	0	0
	10-16	184	113	170	200	2	196	4	176	0	0	0	0	0	0	0	0	0	0
	17-23	21	25	0	102	259	96	196	474	0	0	0	0	0	0	0	0	0	0
	24-30	11	0	0	0	0	0	2	281	0	0	0	0	0	0	0	0	0	0
																0	0	0	0
																0	0	0	0
Jul	1-7	20	0	0	0	0	0	0	44	0	0	0	0	0	0	0	0	0	0
	8-14	27	0	0	0	0	0	44	0	0	0	0	0	0	0	0	0	0	0
	15-21	6	82	0	223	0	167	13	62	0	0	0	0	0	0				
	22-28	7	58	100	9	63	107	28	112	0	0	0	0	0	0	0	0	0	0
	29-4	0	0	0	0	0	0	0	200	0	0	0	0	0	0				
Aug	5-11	7	11	0	0	0	0	0	0	0	0	0	0	0	0				
		342	452	446	690	349	565	305	1 349	21	13	0	0	0	0				

SOIL, LAND AND WATER USE DATA FOR INDIVIDUAL BLOCKS IN THE MIP

Distributary M1/C6 Gu 1987

Block			19	21	24	27	30	32	34	39
Crop			Maize	Maize	Maize	Maize	Maize	-	-	-
Area:	Sown		28	28	28	28	28	0	0	0
	Harvested		n/a	n/a	n/a	n/a	n/a	0	0	0
Soils %	Jb1		100	30	15	12	10	70	55	30
	Jb2&3		-	70	80	80	70	20	31	65
	J1		-	-	-	-	-	-	-	5
	Jmxl		-	-	-	-	10	-	12	-
	Jmxd		-	-	-	-	-	-	-	-
	Other		-	-	5	8	10	10	2	-
Month	Week	Rain (mm)	(B) mm per week irrigation							
1987										
Jun	3-9	3	113	7	140	6	5	0	0	0
	10-16	34	145	230	290	170	168	0	0	0
	17-23	6	0	31	60	131	384	0	0	0
	24-30	0	0	0	0	0	242	0	0	0
Jul	1-7	14	0	0	0	0	105	0	0	0
	8-14	0	0	0	0	0	0	0	0	0
	15-21	0	44	0	0	205	57	0	0	0
	22-28	3	82	62	130	15	177	0	0	0
	29-4	2	0	0	0	13	33	0	0	0
Aug	5-11	192	0	5	0	0	6	0	0	0
Gu	Totals	254	384	334	619	539	1 177	0	0	0

SOIL, LAND AND WATER USE DATA FOR INDIVIDUAL BLOCKS IN THE MIP

Distributary M2/C2 Gu 1987

Block			44	45	46	47	48	49	50	51	52	54	55	56	58	59
Crop			-	-	-	-	-	-	-	-	-	-	Mu+CP	MU+SU	MU+SU	CP+SU
Area:	Sown		0	0	0	0	0	0	0	0	0	0	28	28	28	28
	Harvested		0	0	0	0	0	0	0	0	0	0	14	28	28	14
Soils %	Jb1		-	35	5	60	60	45	12	-	-	35	-	-	65	-
	Jb2&3		50	60	-	-	-	42	1	-	-	-	-	-	-	-
	J1		50	-	-	-	-	-	-	-	-	5	-	-	30	1
	Jmxl		-	5	60	-	23	2	30	75	5	10	20	5	3	17
	Jmxd		-	-	35	40	15	10	57	25	95	45	80	95	-	80
	Other		-	-	-	-	2	1	-	-	-	5	-	-	2	2
Month	Week	Rain (mm)	(B) mm per week irrigation													
1987																
May	13-19	4	0	0	0	0	0	0	0	0	0	0	122	49	33	50
	20-26	11	0	0	0	0	0	0	0	0	0	0	112	101	82	20
	27-2	5	0	0	0	0	0	0	0	0	0	0	11	0	0	1
Jun	3-9	3	0	0	0	0	0	0	0	0	0	0	0	26	20	0
	10-16	34	0	0	0	0	0	0	0	0	0	0	0	17	138	0
	17-23	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	24-30	0	0	0	0	0	0	0	0	0	0	0	91	0	73	0
Jul	1-7	14	0	0	0	0	0	0	0	0	0	0	134	0	141	265
	8-14	0	0	0	0	0	0	0	0	0	0	0	90	0	25	120
	15-21	0	0	0	0	0	0	0	0	0	0	0	7	0	54	19
	22-28	3	0	0	0	0	0	0	0	0	0	0	0	102	109	0
	29-4	2	0	0	0	0	0	0	0	0	0	0	10	196	83	0
Aug	5-11	192	0	0	0	0	0	0	0	0	0	0	13	14	13	0
Gu	Totals	274	0	0	0	0	0	0	0	0	0	0	590	505	772	475

SOIL, LAND AND WATER USE DATA FOR INDIVIDUAL BLOCKS IN THE MIP

Distributary M2/C4 Gu 1987

Block			53	57	60	61	62	63	64	65	66	67	68	69
Crop			CP+SU	Cwpea	-	Rice	-	Rice	Rice	Rice	Rice	Rice	Rice	-
Area:	Sown		28	28	0	18	0	28	28	28	28	16	28	0
	Harvested		14	0	0	26	0	28	28	26	28	16	26	0
Soils %	Jb1		15	17	25	70	20	30	-	-	20	-	-	-
	Jb2&3		82	83	60	7	25	12	97	100	20	30	90	97
	J1		3	-	15	15	15	-	-	-	-	-	-	-
	Jmxl		-	-	-	5	25	50	3	-	45	55	-	-
	Jmxd		-	-	-	-	-	-	-	-	15	-	-	-
	Other		-	-	-	3	15	8	-	-	-	15	10	3
Month	Week	Rain (mm)	(B) mm per week irrigation											
1987														
Apr	16-22	4	0	0	0	11	0	62	0	0	118	219	35	0
	23-29	0	0	0	0	10	0	140	65	165	49	254	58	0
	30-6	21	0	0	0	14	0	164	253	183	87	69	152	0
May	7-13	10	0	0	0	298	0	160	131	80	114	36	133	0
	14-20	4	0	0	0	253	0	29	67	70	63	158	10	0
	21-27	11	98	96	0	0	0	152	0	0	139	321	0	0
	28-3	5	54	0	0	152	0	205	1	0	221	234	87	0
Jun	4-10	8	153	0	0	30	0	190	69	182	246	366	307	0
	11-17	29	40	0	0	154	0	198	321	220	327	551	118	0
	18-24	6	0	0	0	305	0	316	200	113	329	581	0	0
	25-1	0	0	5	0	195	0	196	99	114	168	295	34	0
Jul	2-8	14	63	44	0	291	0	285	147	159	256	373	83	0
	9-15	0	4	32	0	529	0	410	292	211	337	359	194	0
	16-22	0	0	0	0	404	0	405	218	158	321	371	131	0
	23-29	5	64	0	0	298	0	322	179	245	335	323	140	0
	30-5	0	46	0	0	212	0	113	90	111	171	269	24	0
Aug	6-12	192	14	0	0	34	0	23	21	26	18	0	0	0
	13-19	9	0	0	0	23	0	0	0	0	0	0	0	0
	20-26	3	0	0	0	174	0	0	0	0	0	0	0	0
	27-2	13	0	0	0	181	0	0	0	0	0	0	0	0
Sep	3-9	15	0	0	0	361	0	0	0	0	0	0	0	0
	10-16	2	0	0	0	322	0	0	0	0	0	0	0	0
	17-23	0	0	0	0	306	0	0	0	0	0	0	0	0
Gu	Totals	351	534	177	0	4 559	0	3 370	2 152	2 036	3 300	4 778	1 505	0

ANNEX 9

CROPPING PATTERN PER BLOCK IN THE MIP AREA
(1985 to 1988)

ANNEX 9

CROPPING PATTERN PER BLOCK IN MIP AREA (1985 to 1988)

Block Nr	Area (ha)	Gu 1985	Der[1] 1985/86	Gu 1986	Der 1986/87	Gu 1987	Der 1987/88
1	28	R(27)	M(27)	R(27)	-	M	R
2	18	R	R	-	-	M	R
3	28	R(27)	M(27)	R(27)	-	M	-
4	28	R(27)	R(27)	-	-	M	R
5	28	-	R(27)	-	-	M	-
6	28	R(27)	M(27)	R(9)	-	M	-
7	28	-	R	C/S(10)*	R	M	-
8	28	R(27)	M(27)	M/S(10)*	-	M	-
9	28	-	R	M/S(9)*	R(14)	M	-
10	28	-	R/MB(30)	M(14)*	-	M	-
11	28	-	M	M/S(16)*	R	-	-
12	28	-	R	M(10)*	-	M	-
13	28	-	M	S(6)*	R	-	-
14	28	-	M	-	R	-	-
15	28	-	M	-	R	-	-
16	28	-	M	S(8)	R	-	-
18	28	-	M	M/S(18)*	R	-	-
20	28	-	-	R	-	M	-
22	28	-	-	R	-	M	-
23	28	-	-	R	-	M	-
25	28	-	-	R	-	M	-
26	28	-	-	R	-	M	-
28	28	-	-	R	-	M	-
29	28	-	-	R	-	M	-
31	28	-	-	R	-	M	-
33	28	-	-	R	-	-	-
35	28	-	-	M/S(14)*	-	-	R
36	28	-	-	-	R	-	-
37	28	-	-	-	R	-	-
38	28	-	-	-	R(24)	-	R(27)
40	28	-	-	M*	S	-	R
41	28	-	-	-	S	-	R
42	28	-	-	M	S	-	R
43	28	-	-	-	R	-	R
19	28	-	-	R	-	M	R
21	28	-	-	R	-	M	R
24	28	-	-	R	-	M	R(24)
27	28	-	-	R	-	M	-
30	28	-	-	R	-	M	-
32	28	-	-	R	-	-	-
34	28	-	-	R	-	-	R
39	28	-	-	M/S(14)*	S	-	R
17	20	-	-	-	R(18)	-	R(18)
70	24	-	-	-	R(8)-Su(2) Sa(18)	-	Su
71	28	-	-	-	R	-	R
72	28	-	-	-	R	-	R
73	28	-	-	-	R(20)-Sa(8)	-	
74	28	-	-	-	R	-	R

Block Nr	Area (ha)	Gu 1985	Der[1] 1985/86	Gu 1986	Der 1986/87	Gu 1987	Der 1987/88
75	26	-	-	-	R	-	R
76	30	-	-	-	Sa(18)-MB(6) R(6)	-	R
77	20	-	-	-	Sa(22)	-	R(18)
44	28	-	-	M*	S	-	R
45	28	-	-	M*	S	-	R
46	28	-	-	M/S*	S	-	R
47	28	-	-	M*	S	-	R
48	28	-	-	M(12)*	S	-	R(20)
49	28	-	-	M/S(16)*	S	-	R
50	28	-	-	M(22)*	S	-	R
51	28	-	-	M*	S	-	-
52	28	-	-	M(26)*	S	-	-
54	28	-	-	M(12)*	S	-	-
55	28	-	-	M/S(16)*	-	C(14)-MB(14)	-
56	20	-	-	S(4)*	-	Su(14) MB(14)	-
58	28	-	-	M*	-	Su(14) MB(14)	-
59	28	-	-	M(16)*	-	Su(14) C(14)	-
53	28	-	-	M/S(20)*	S	C(14) Su(14)	R
57	28	-	-	M*	S	C(28)	-
60	28	-	-	M*	S	-	-
61	28	-	-	M(24)*	-	R	-
62	28	-	-	M(16)*	M(16)	-	-
63	28	-	-	M(18)*	-	R	-
64	28	-	-	M(22)*	-	R	-
65	28	-	-	M(24)*	-	R	-
66	28	-	-	M*	-	R	-
67	28	-	-	M(8)*	-	R(16)	-
68	28	-	-	M*	-	R	-
69	28	-	-	M*	-	R	-

Notes: (1) 301 ha of maize failed due to lack of der season rains and the subsequent need to 'water up'; some areas were replanted with sesame.

* Rainfed crop, temporary tenant agreement.

R	Rice	M/S	Maize/sesame intercropped	S	Sesame
M	Maize	C/S	Cowpea/sesame intercropped	Sa	Safflower
MB	Mungbean	C	Cowpea	Su	Sunflower
		So	Sorghum		

Figure A9-1

Cropping Pattern Der 1985-1986

Annex 9 (continuation)

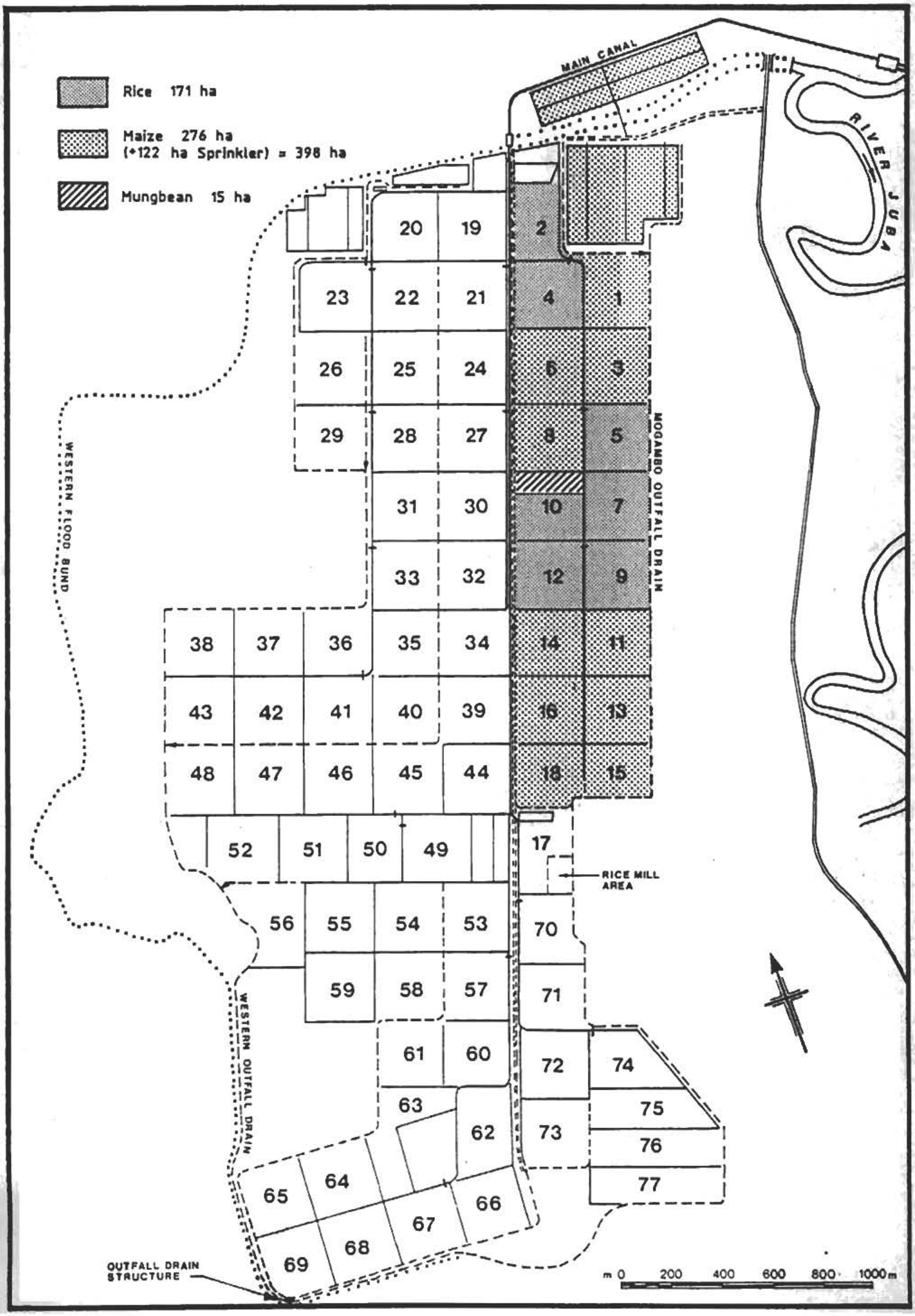


Figure A9-2

Cropping Pattern Der 1986-1987

Annex 9 (continuation)

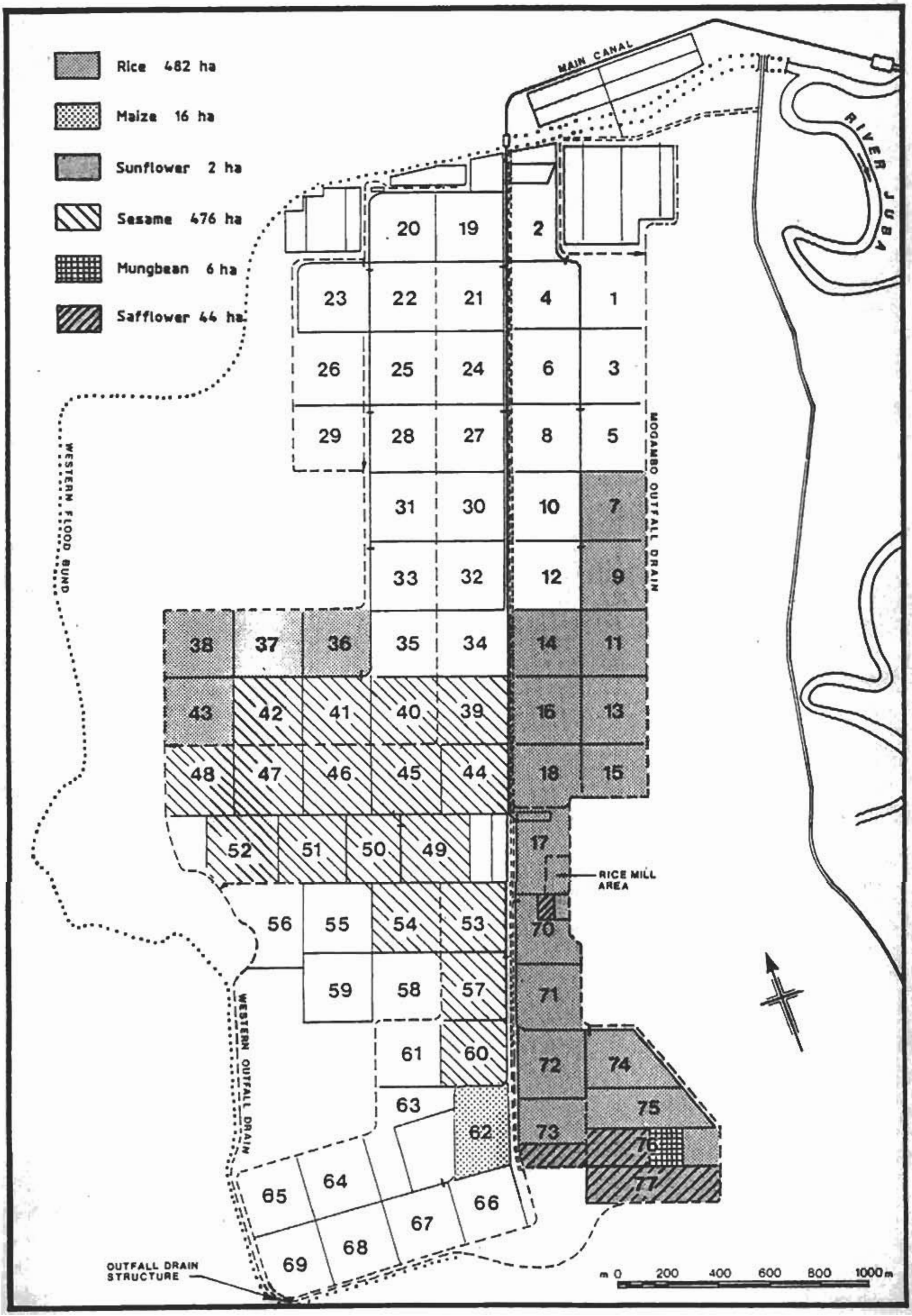


Figure A9-3

Cropping Pattern Der 1987-1988

Annex 9 (continuation)

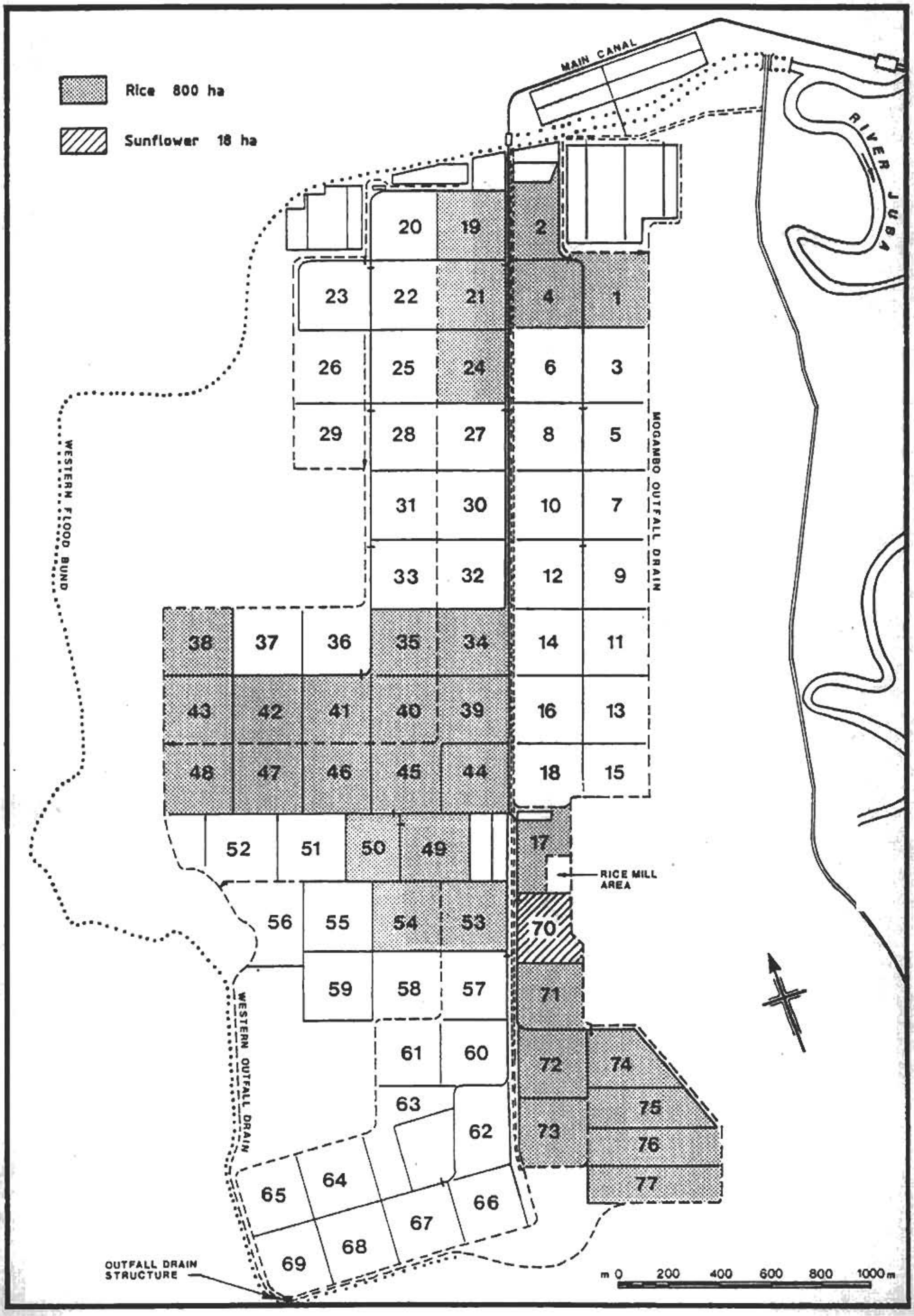


Figure A9-4

Cropping Pattern Gu 1985

Annex 9 (continuation)

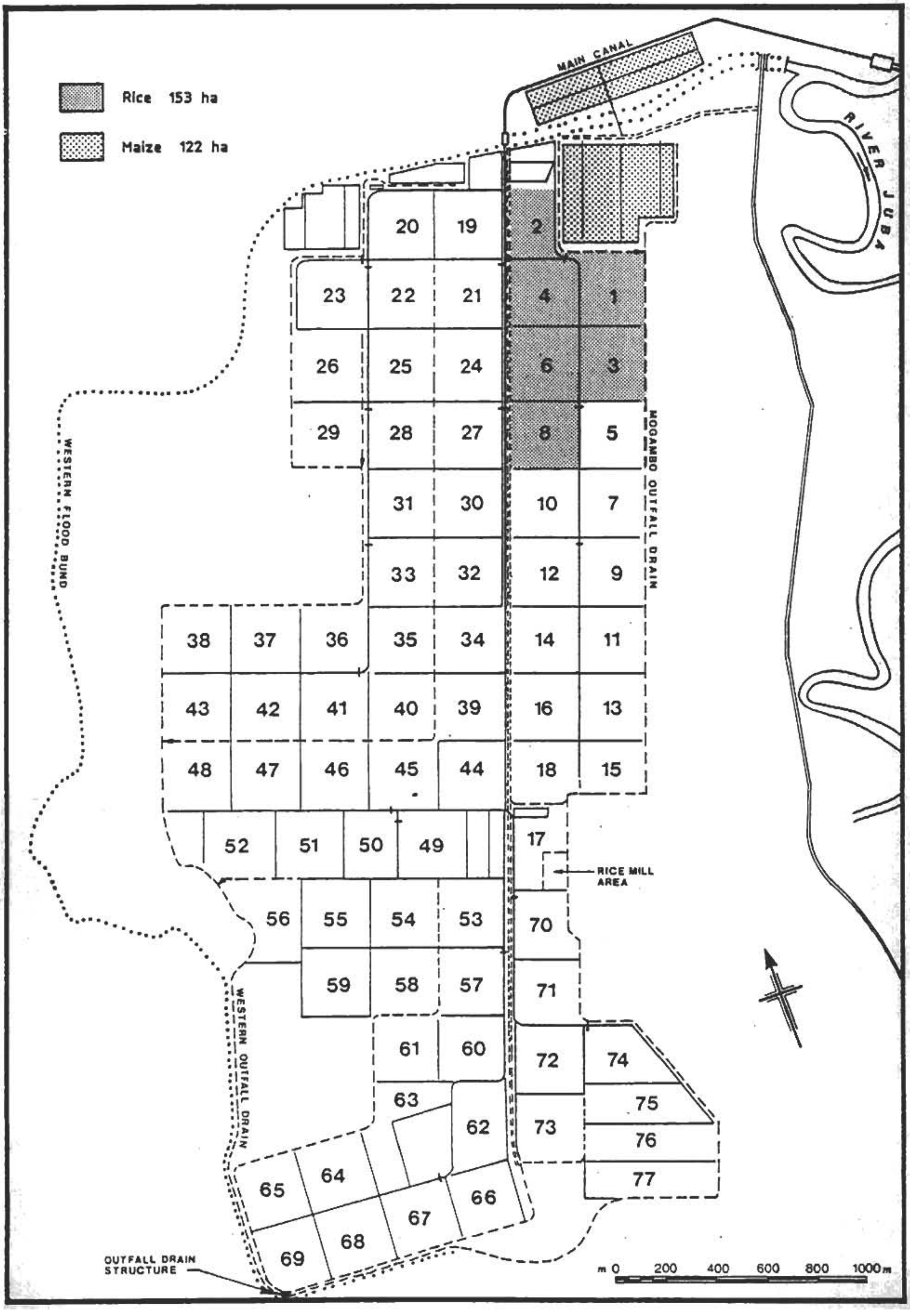
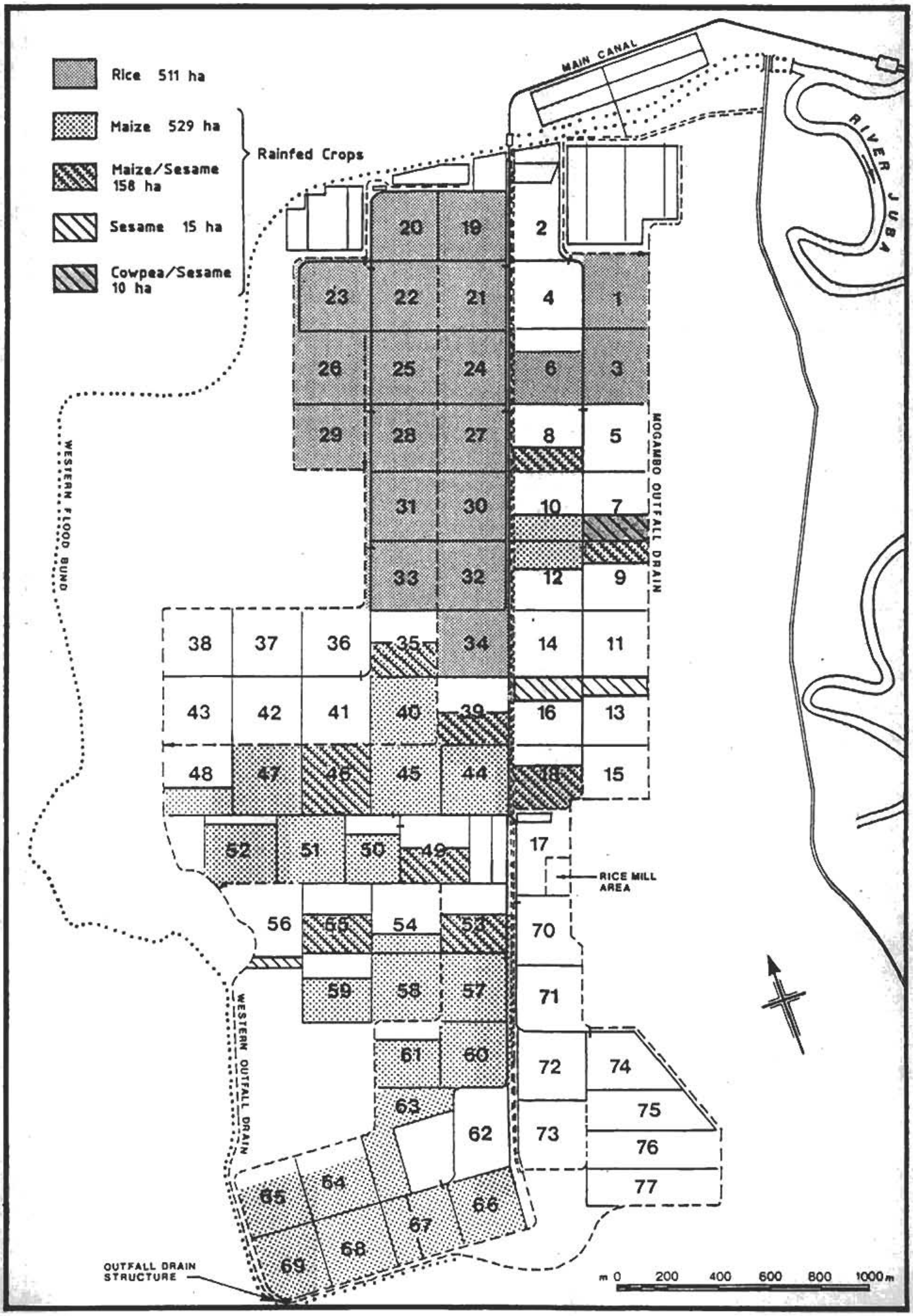


Figure A9-5

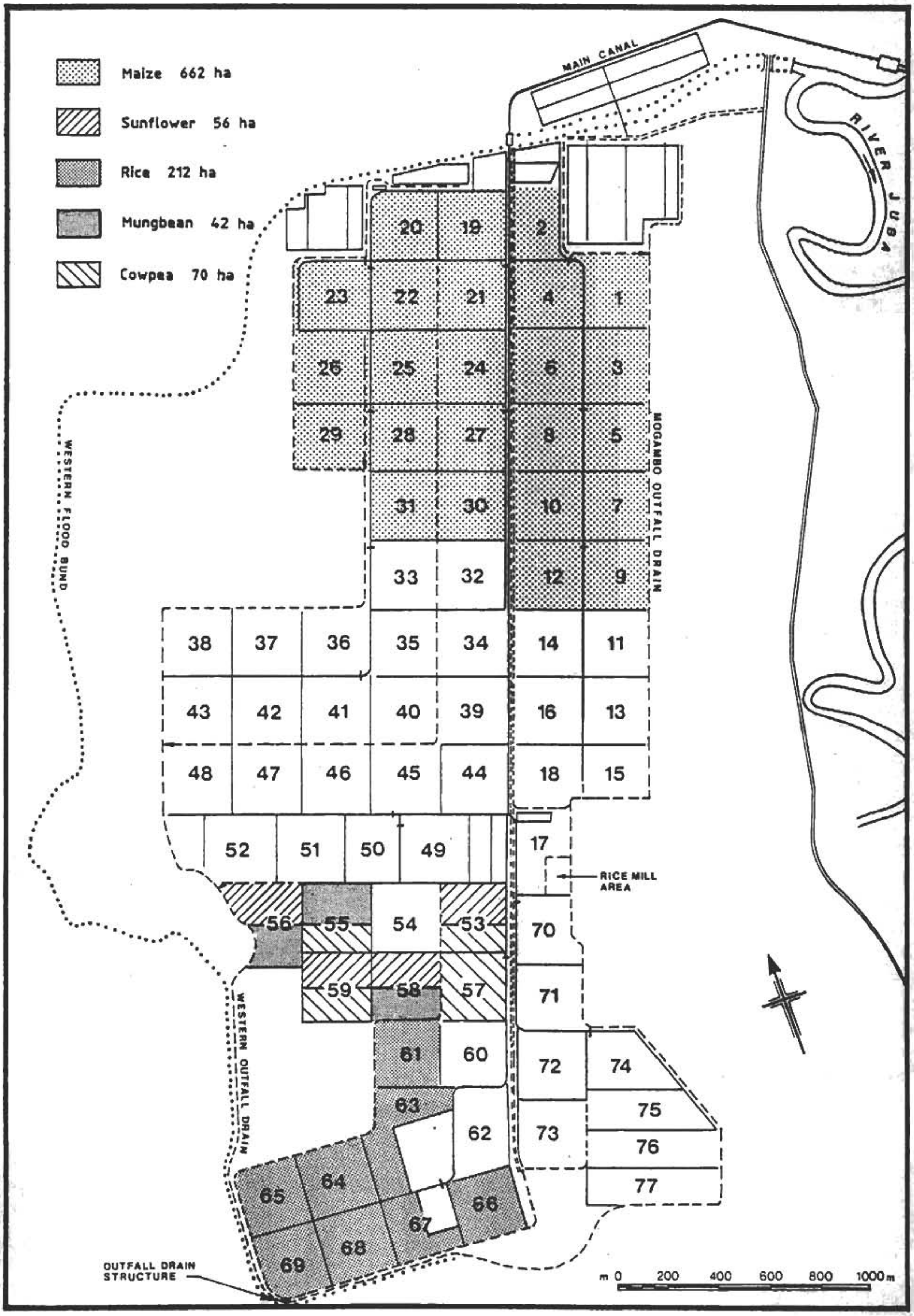
Cropping Pattern Gu 1986

Annex 9 (continuation)



Cropping Pattern Gu 1987

Annex 9 (continuation)



ANNEX 10

OBSERVATION WELL AND PIEZOMETER INSTALLATION

ANNEX 10

OBSERVATION WELL AND PIEZOMETER INSTALLATION

In a homogeneous soil there will be an equilibrium level where the pressure of groundwater equals that of the soil air. This level is called the watertable level. Groundwater flow is caused by differences in potential (= level) of the groundwater between two points. It is essential to have an insight into groundwater levels fluctuations and groundwater flows for a sound judgement in problems related to salinisation.

Shallow Observation Wells

Shallow observation wells (SOWs) serve to measure watertable levels. Holes are drilled using an 80 mm hand soil auger. The depth of the hole depends on the maximum expected depth of the watertable. For practical purposes, in the MIP the hole should be about 5 m deep. Sometimes during augering the hole is found to collapse. This can be prevented by keeping the hole filled with muddy water. PVC pipe with a 40 mm diameter is slotted with a hacksaw over a length of about 3 m. The bottom of the pipe is folded over and glued with tape or/and PVC glue. Two pipes are joined together using a sleeve and PVC glue and tape. After dropping two handfuls of coarse sand or fine gravel at the bottom of the hole, the pipe is inserted and more sand or gravel is added to envelop the screened length of the pipe. About 4 litres of sand per metre of slotted pipe is required. The remaining hole is filled with bentonite pellets or alternatively hand made clay pellets, made of vertisolic clay (Jb3). It is important that this clay plug is well compacted and watertight to prevent surface water entering the SOW. To prevent vandalism the top of the pipe is protected by a steel cap anchored in concrete.

The SOW should be installed on field bunds to prevent machinery damage and flooding problems. To facilitate comparison between the sites, the top of all pipes (TP) should be cut off at 50 cm above natural surface (NS). At the end of this annex a cross-sectional diagram of an SOW is presented.

Piezometers

Less permeable layers in a soil profile cause the groundwater in the profile to have different potentials at different depths. This difference in potential is measured in piezometers. They resemble SOWs except that the pipe is slotted only where the groundwater potential is to be measured.

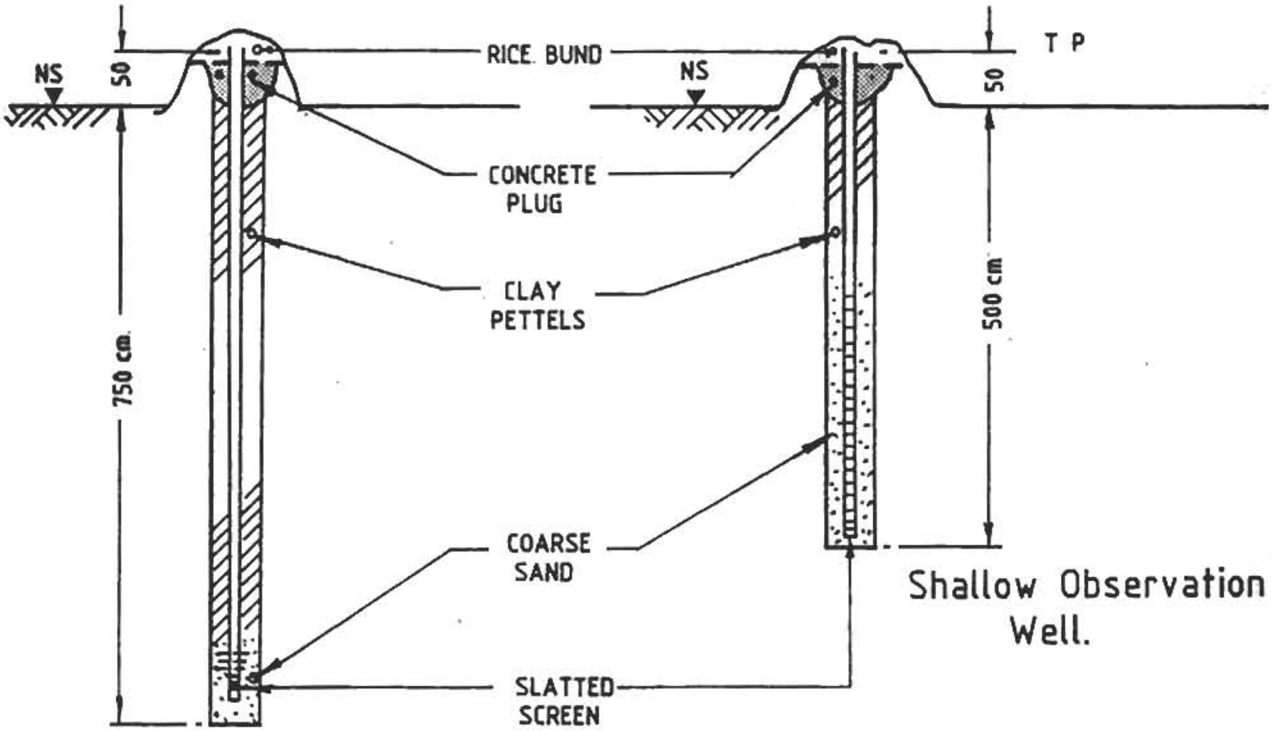
The maximum depth at which a hand auger can be used is 8 m. This means that piezometers can be installed down to a depth of 7.5 m from NS. The slotted length at the bottom should be about 30 cm which means that about 1.5 litre of sand should be added as envelope material. The utmost care should be taken to ensure that the rest of the hole is well plugged with clay tablets.

Levelling of the TP

To be able to draw watertable contour maps, all SOW and piezometer TP levels must be measured with reference to mean sea level.

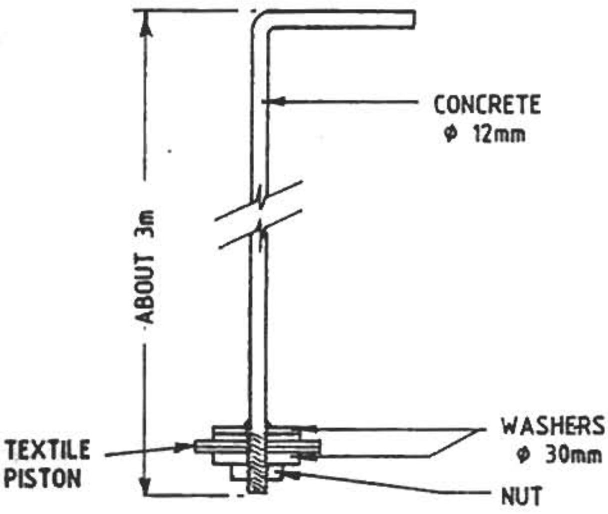
Well Maintenance

During installation, the slots in the observation wells can easily be blocked by clay. The wells should therefore be developed by using a simple plunger which is moved vigorously up and down the water filled pipe. Accumulated fine material in a pipe should be removed by a bailer provided with a bottom valve. Diagrams of these implements are presented below.

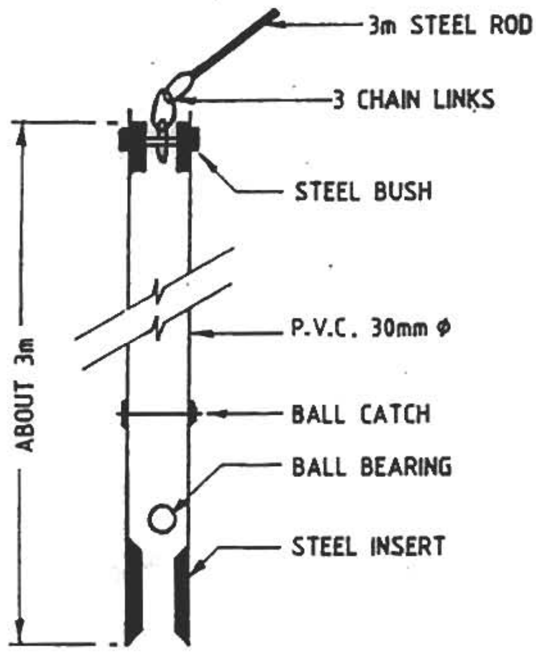


Shallow Observation Well.

Piezometer



Plunger



Sand Bailer

ANNEX 11

WATERTABLE LEVELS AND SALINITY IN THE JUBA SUGAR PROJECT

ANNEX 11

WATERTABLE LEVELS AND SALINITY IN THE JUBA SUGAR PROJECT

Well Nr		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	EC mS/cm Dec 1986
KN	1	230	240	30	40	-	-	-	150	0	149	140	146	1.0
	6	dry	dry	230	250	207	220	220	200	50	130	39	80	2.1
	9	220	dry	250	270	250	260	250	dry	280	170	dry	dry	-
	14	200	150	220	200	138	60	120	180	0	54	80	155	0.6
	16	-	-	270	dry	240	280	dry	250	192	211	dry	dry	-
	18	dry	50	-	-	-	-	-	105	118	205	162	191	1.3
	19	dry	280	dry	dry	170	100	dry	210	80	180	290	dry	1.9
	25	240	180	260	dry	130	150	265	235	235	225	89	156	3.5/8.2*
	26	250	dry	140	230	135	160	225	dry	250	144	170	203	1.4
	31	dry	-	dry	50	82	80	dry	125	234	230	dry	270	-
	32	230	dry	150	240	40	70	185	192	156	214	125	147	2.0
	36	0	dry	100	40	0	0	0	55	55	44	71	90	1.9
SBL	1	-	100	200	190	100	40	100	138	182	190	183	193	5.5/4.2*
	3	dry	dry	-	-	-	-	-	105	112	205	162	191	-
LS	04	dry	235	250	280	210	210	220	74	0	55	80	91	0.4
	06	dry	dry	20	10	-	-	-	-	-	-	-	-	-
	08	290	245	220	145	230	220	dry	180	127	155	164	137	1.4
	11	dry	225	dry	dry	140	150	210	225	222	275	117	120	0.9
	16	dry	275	280	--	235	-	190	97	66	190	179	238	1.1
	18	260	178	250	230	150	146	50	67	0	0	262	38	0.7
	19	220	dry	240	245	235	238	230	190	20	55	12	63	0.3
	21	dry	240	dry	dry	260	270	180	200	138	170	173	169	1.9
	22	dry	-	270	265	270	265	dry	230	280	295	dry	dry	-
	25	dry	-	dry	dry	280	260	dry	243	160	196	192	217	20.5/22.1*
	30	220	dry	230	230	0	0	0	57	0	91	240	277	0.6
	32	dry	150	80	50	-	-	-	285	188	180	-	dry	-
	33	dry	dry	dry	dry	275	280	dry	dry	290	dry	-	-	-
	35	290	200	210	104	210	90	0	85	106	100	-	-	-
Average		263	240	219	191	173	161	198	177	130	163	172	187	

Notes: * Resampled

For calculation of average values, dry wells were taken as 300 cm below surface.

Source: Juba Sugar Project Irrigation and Drainage Section (personal communication).