Somali Democratic Republic
Ministry of Agriculture

Mogambo Irrigation Project

Report on Phase II Development – Surface Irrigation

Sir M MacDonald & Partners Limited
Consulting Engineers
Demeter House, Station Road, Cambridge CB1 2RS England

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MOGAMBO IRRIGATION PROJECT

REPORT ON PHASE II DEVELOPMENT
SURFACE IRRIGATION

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SUMMARY

The Mogambo Irrigation Project (MIP) has suggested that a limited development of the Phase II area could be implemented with the inclusion of the basin soils not developed under Phase I together with the marginal areas of land included in the Phase II area proposed for sprinkler irrigation.

The Phase II area data have been examined and 378 ha of land previously designated as only suitable for sprinkler irrigation is considered marginally suitable for surface irrigation. An additional area of 790 ha of basin soils previously identified as suitable for surface irrigation could be developed with this marginal area to comprise a Phase IIa development of 1 168 ha of surface irrigation.

A summary of development areas in hectares is shown below:

	Surface irrigation	Sprinkler irrigation	Total
Phase I	2 052	163	2 215
Phase IIa	1 168	-	1 168
Phase IIb	-	1 862	1 862
	3 220	2 025	5 245

The original feasibility study identified a full development area of 6 400 ha. The reduction in total area to 5 245 ha is caused primarily by the extension of land owned by banana farmers into the project area.

The levee soils are more suitable for border strip or furrow irrigation whilst the heavier basin soils could be developed under basin irrigation with a small cross-slope as is currently being done in the Phase I area. The basin soils are generally suitable for paddy rice but an alternative cropping pattern which might include maize, cotton and upland rice is more suitable for the lighter levee soils.

The earthworks for land levelling of the levee soils are some 50% higher than for the basin soils at some 1 220 m^3/ha.

The total cost of the new Phase IIa development is SoSh 140.1 million at Contract M2 tender rates dated March 1983.

1. Introduction

The Supplementary Feasibility Study (MMP 1979) proposed a development of 3 300 ha by surface irrigation of predominantly heavy clay soils and 3 100 ha by overhead irrigation of areas with a more broken topography. Following discussions with State Planning Commission (SPC) and the funding agencies, it was agreed to proceed with a Phase I development of 2 052 ha of surface irrigation under double cropped rice on the heavier basin soils together with 163 ha of overhead irrigation of cotton in the der season. The double cropped rice rotation offered clear economic advantages over the alternative rice/maize rotation although it was recognised that the double cropped rice rotation would be more difficult to manage with problems of weed control, bird damage and time constraints arising from the limited period of irrigation supplies. The small area of levee soils was proposed to be developed under overhead irrigation to determine the potential of these soils with sprinkler irrigation and develop management skills that could be applied to the Phase II area.

Both the capital and running costs for sprinkler irrigation were higher than for the surface irrigation system but the more broken topography associated with the levee soils would substantially increase the cost of land levelling of these soils for surface irrigation and the large depths of cut and fill required would make these soils more difficult to manage in at least the first few years.

The Mogambo Irrigation Project (MIP) have suggested that a limited development of the Phase II area could be implemented by the inclusion of the areas of basin soils not developed under Phase I together with the marginal areas of land included in the Phase II area proposed for sprinkler irrigation but capable of economic development by surface irrigation.

This note delineates these areas and proposes surface methods of irrigation suitable for these lighter soils with a less uniform topography.

2. Land Levelling

Eight sample areas were chosen to be representative of the project area, four on each of the two major soil groups, i.e. basin and levee soils. Each sample covered an area of 300 m x 300 m with a level survey carried out on a 25 m grid. Full details of the land levelling analysis of the sample areas is given in Chapter 3 of Annex 5 of the Supplementary Feasibility Study. The four samples on the levee soils covered the conditions given in Table 1.

TABLE 1

Summary of Land Levelling Areas

Area	Soil type	Micro-relief and termitaria
1	Meander complex Levee unit	M1/M2 Few termitaria
2	Meander complex Levee unit Sand at 1.25 m	M1 Few termitaria
7	Levee Sand at 0.3 m	M2 Few termitaria
8	Meander complex Depression unit Sand at 1.0 m	M3 Termitaria

The micro-relief classifications are based on the average depths of cut and fill required for levelling as follows:

M1 - 0 to 0.25 m

M2 - 0.25 to 0.5 m

M3 - +0.5 m

The major constraints on land levelling of the levee soils are:

(a) The exposure of sand lenses which can be found at depths as shallow as 0.3 m below the surface. Exposure of these lenses would make efficient irrigation by surface methods difficult due to a large variation in infiltration rates.

(b) Large depths of fill would be subject to considerable consolidation following irrigation which would take several seasons to rectify by land planing between crops. Ideally fill depths should be limited to 0.3 m.

(c) The levee areas are frequently bisected by old river channels and fartas which would need to be removed to provide a convenient field layout pattern.

The Supplementry Feasibility Study carried out an analysis of the necessary land levelling works for each of the four levee sample areas divided into 6 or 8 plots for alternative layouts of furrows, border strips and level basins. Generally the furrow and border strip layouts gave lower quantities of earthmoving than the level basins which was more significant as the basins covered only 1.125 ha as compared with 1.5 ha for the furrows and border strip layouts. The areas were chosen so that they did not include existing old river channel and fartas and only the effect of micro-relief was being measured. If the levee area was laid out extensively to surface irrigation, it would be necessary to remove many of these old channels.

The furrow and border strip analysis allowed a range of slopes in the direction of irrigation of between 0.015% and 0.2% whilst the slope at right angles to the direction of irrigation was taken as -0.2% to 0.2% for furrows and level for border strips. The plots to be land levelled as a single unit were assumed to be 300 m long and a minimum of 50 m wide to form what is known as the 'piano-key' layout.

The earthmoving quantities for the three alternative methods of surface irrigation are given in Table 2.

TABLE 2

Average Land Levelling Quantities (m^3/ha) and Maximum Depth of Cut and Fill (m)

	Area 1	Area 2	Area 7	Area 8	Average
Furrow Irrigation					
Average land levelling quantity	584	498	485	672	560
Maximum depth of cut	0.7	0.3	0.52	0.49	0.50
Maximum depth of fill	1.2	0.75	0.57	0.60	0.78
Border Strip Irrigation					
Average land levelling quantity	608	508	490	711	580
Maximum depth of cut	0.75	0.35	0.55	0.46	0.53
Maximum depth of fill	0.39	0.79	0.55	0.73	0.59
Level Basin Irrigation					
Average land levelling quantity	640	591	484	1 131	711
Maximum depth of cut	0.62	0.37	0.52	0.79	0.58
Maximum depth of fill	1.30	0.75	0.63	0.71	0.85

A comparison with the three sample areas for level basins on the basin soils gave an average quantity of earthworks of 484 m^3/ha and average maximum depth of cut and fill of 0.46 and 0.42. Using the 2 ha sloping basins now being implemented for the Phase I area it is estimated that the land levelling requirements will rise to 650 m^3/ha. The basin soil area in Phase II contains more old channel features than the Phase I area. The necessary volume of fill material to the existing farta channels in the Phase II basin soil area has been estimated at 150 m^3/ha.

The difference in the micro-topography and land levelling quantities between the basin and levee soils is marginal. The main difference between the two soils is the higher density of old river channels and fartas associated with levee soils. In addition flooding from the old fartas has built up local levees associated with the channels making their removal a major task. It has been estimated that on average fill to the existing fartas involves a volume of 595 m^3/ha.

Termitaria are generally associated with the lighter levee soils and it was estimated that on the few sample areas the volume of termitaria constituted some 55 m^3/ha and this represents an additional land levelling quantity.

A summary of the volume of earthmoving for land levelling is given in Table 3.

TABLE 3

Land Levelling Quantities

	Land levelling quantities (m^3/ha)
Basin soils - 2 ha basins	
Levelling for micro-topography	650
Levelling for fartas	150
Total	800
Levee soils - furrow or border strip irrigation	
Levelling for micro-topography	570
Levelling for fartas	595
Levelling termitaria	55
TOTAL	1 220

From these results the following conclusions can be drawn:

(i) Surface irrigation on the basin soils requires less land levelling than on the levee soils.

(ii) Furrow and border strip irrigation of levee soils involves less earthmoving than level basin irrigation of the same soils.

(iii) It will not be possible on the levee soils to limit depths of fill to 0.30 m so that significant settlement of fill on the first irrigation is inevitable and will be particularly severe on the backfilled fartas.

3. Soil Factors

The land classification criteria are described in detail in Chapter 3 of Annex 2 - Soils of the Supplementary Feasibility Study. Classes 1, 2 and 3 were considered suitable for surface irrigated agriculture whilst Class 4S was considered suitable for irrigation by sprinklers and Class 6 was considered unsuitable.

The criteria for surface irrigation are as follows:

(i) Irrigation by surface methods was not considered suitable for soils with a coarse soil texture. In the classification the coarsest acceptable texture is a sandy loam containing at least 15% clay.

(ii) For the majority of soils, alkalinity is not a limitation.

(iii) Soil salinity is generally a rectifiable hazard.

(iv) The main limitation to surface irrigation is topography, as discussed previously. The problem of exposing more permeable soils as a result of land levelling was encountered at four bore sites and these were downgraded to Class 4S. However generally the limitation for Class 4S was topographical.

(v) Infiltration rates for the soils were generally low. The results of surface infiltration tests are given in Appendix V to Annex 2 of the Supplementary Feasibility Study. The average terminal rates of infiltration for the various soil types are shown in Table 4.

TABLE 4

Terminal Infiltration Rates (mm/h)

Soil type	Terminal infiltration rate (mm/h)
Jl	24
Jmxl	53
Jb1	13
Jb2, 3	34
Jd	6.5
Jmxd	12
BM	158
MP	15

Beach Remnant (BM) and Marine Plain (MP) soils are not included in the irrigated areas. The meander complex soils (Jmxl) are the predominant levee soils and have an average terminal infiltration rate of 53 mm/h with a range of 17 to 69 mm/h in the tests carried out. These are considered coarse soils for surface irrigation but can be irrigated efficiently by surface methods if carefully managed. The infiltration tests by double ring infiltrometer tend to overestimate the infiltration rates of deeply cracked soils such as the flood-plain basin clays. Tests conducted on wetted profiles of these soils with disturbed profiles showed that much lower intake rates applied and demonstrated the effectiveness of puddling.

4. Cropping and Crop Water Requirements

The cropping patterns proposed in the Supplementary Feasibility Study (MMP, August 1979) and the Additional Study (March 1980) are summarised below:

Surface irrigation on basin clay soils	-	Paddy rice (gu season)	75%
	-	Paddy rice (der season)	
Sprinkler irrigation on levee soils	-	Upland rice (gu season)	33%
		Maize 1 (der season)	33%
		Cotton (der season)	34%
		Maize 2 (der season)	33%

In order to maximise the surface irrigation area it is recommended that the most uniform levee soils are developed for surface irrigation. Upland rice, maize and cotton can be irrigated by surface methods and are therefore recommended for these areas. MIP has considered other cropping patterns (half yearly report - gu season 1985) but as yet no alternative cropping patterns have been implemented

The irrigation requirements at field level are based on crop water requirements calculated in the Feasibility Study and on the field efficiencies shown in Table 5.

TABLE 5

Field Efficiencies

Crop	Surface irrigation	Sprinkler irrigation
Paddy rice	0.80	-
Upland rice	0.60	0.75
Cotton	0.60	0.75
Maize	0.60	0.75

The field irrigation requirements are summarised in Table 6.

The readily available soil moisture (between 0.1 and 1 bar tension) in Jmxl and Jmxd soils is shown in Table 7.

TABLE 7

Readily Available Water Capacity

Crop	Average rooting depth (m)	AWC (mm/m of soil)		RAWC (mm)		Maximum irrigation interval at peak water requirements (days)
		Jmxl	Jmxd	Jmxl	Jmxd	
Cotton	1.0	181	228	94	59	11
Maize	1.0	181	228	94	59	11
Upland rice	0.8	181	228	75	47	11

Hence an irrigation interval of 10 days would be suitable at times of peak irrigation requirements.

5. Surface Irrigation Systems

Surface irrigation can be carried out on the levee soils by the following methods:

TABLE 6

Field Irrigation Requirements

	J	F	M	A	M	J	J	A	S	O	N	D
Evapotranspiration, ETo (mm)	179	170	195	157	145	129	132	147	157	160	147	161
Effective rainfall, Re (mm)	0	0	0	17	22	36	32	8	0	0	0	0
					Field requirement (mm)							
Surface irrigation:												
Paddy rice (gu)	-	-	-	230	444	320	244	21	-	-	-	-
Paddy rice (der)	34	-	-	-	-	-	-	21	251	467	390	245
Upland rice	-	-	-	-	185	155	188	214	20	-	-	-
Maize 1 (following rice)	120	-	-	-	-	-	-	-	-	230	171	276
Cotton	50	-	-	-	-	-	70	169	129	230	265	249
Maize 2	45	-	-	-	-	-	-	-	213	173	245	237
Sprinkler irrigation:												
Upland rice	-	-	-	-	148	124	151	171	16	-	-	-
Maize 1 (following rice)	96	-	-	-	-	-	-	-	-	184	137	221
Cotton	40	-	-	-	-	-	56	135	103	184	212	199
Maize 2	36	-	-	-	-	-	-	-	171	139	196	189

(i) level basin;

(ii) border strips (for non-row crops);

(iii) furrow irrigation (for row crops).

Level basins have the advantage that they are easier to manage than the inclined border strips and furrows although settlement of fill areas after land levelling has caused problems for surface drainage in Mogambo. For the meander complex soils with average infiltration rates of 53 mm/h, the application of irrigation supplies should be at a sufficient rate to allow a high field efficiency. This can normally be achieved if the application rate is at least four times the infiltration rate. Hence for a 100 mm irrigation application, this must be applied in about 30 minutes. Even for the large watercourse discharge of 170 l/s used for the rice crop, the area that could be fed in 30 minutes is only 0.3 ha. Hence this system would require relatively small basins and be inappropriate for mechanised farming.

Typical border strips designs for coarse soils are shown in Table 8.

TABLE 8

Typical Border Strip Designs for Coarse Soils

Slope (%)	Depth applied (mm)	Strip width (m)	Strip length (m)	Flow (l/s)
	50	10	150	160
0.2	100	10	250	140
	150	10	400	120
	50	10	100	70
1.0	100	10	150	60
	150	10	250	60
	50	10	60	35
2.0	100	10	100	30
	150	10	200	30

Source: USDA.

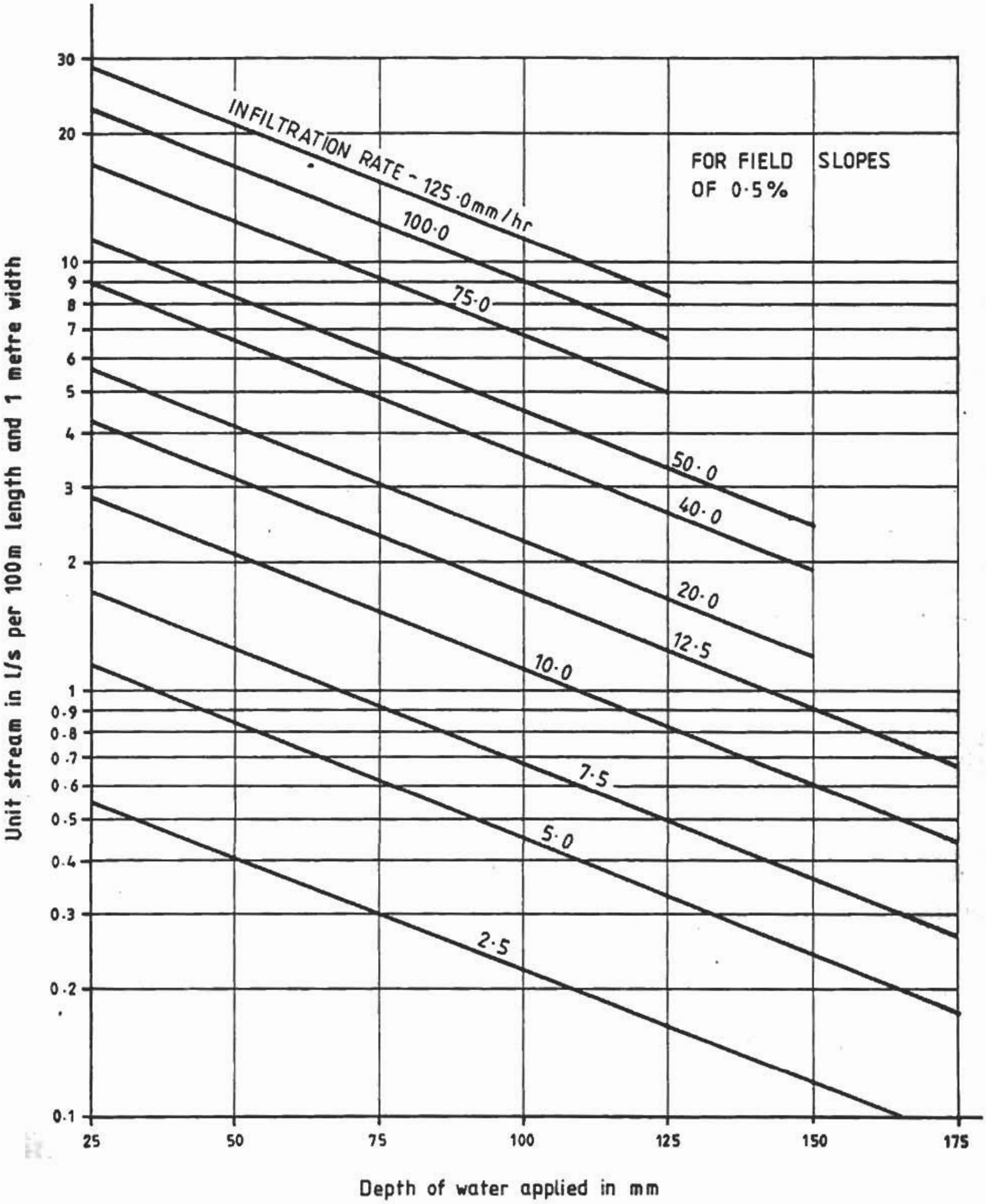
These recommendations can be tested using the US SCS curves. Figure 1 shows a plot of depth of water applied against unit stream size for various soil infiltration rates. The graph is for a 0.5% slope; for a 0.2% slope the unit stream size given for a 0.5% slope needs to be multiplied by 1.23.

Hence for a soil with an infiltration rate of 50 mm/h, a field slope of 0.2%, a depth of water applied of 100 mm and a border strip 240 m long and 8 m wide, the unit stream size is given as:

$$4.5 \times 2.4 \times 8 \times 1.23 \text{ l/s} = 106.3 \text{ l/s}$$

Figure 1

Curves For Estimating Unit Streams For Border Strip Irrigation



This compares very well with line 2 of Table 5 as:

$$\frac{140 \times 8}{10} = 112 \text{ l/s}$$

For these border strip dimensions, 100 mm could be applied to 27 ha in just over 5 days with a unit stream size of 110 l/s. Hence the peak requirement of 276 mm in December for maize is equivalent to a 12 hour discharge of 55 l/s for 27 ha and a watercourse with a discharge of 110 l/s could operate on an alternate basis to give long basins suitable for mechanised farming.

The allowable erosion-free discharge for an 8 m wide border strip with a 0.2% slope is given by Criddle as 140 l/s.

Typical furrow designs suitable for row crops such as maize and cotton are given in Table 9.

TABLE 9

Maximum Recommended Furrow Lengths (m)

Furrow slope (%)	Depth applied (mm) 50	75	100	125
0.05	60	90	150	190
0.1	90	120	190	220
0.2	120	190	250	300
0.3	150	220	280	400
0.5	120	190	250	300
1.0	90	150	220	250

Source: FAO Surface Irrigation

For a furrow slope of 0.2%, a furrow length of 240 m and a furrow spacing of 0.9 m, 100 mm could be applied to 27 ha in 5 days with a furrow discharge of 2.5 l/s.

The maximum non-erosive furrow discharge for a slope of 0.2% is estimated at 3 l/s. (FAO - Surface Irrigation)

Hence a standard field length of 240 m could be used for both furrow and border strip irrigation with a watercourse discharge of 110 l/s operating alternately at times of peak irrigation requirements.

The final designs for border strip or furrows should be confirmed by field trials before being employed generally on the project.

6. Surface Irrigation Field Unit

The standard field unit is shown in Figure 2. Unit shapes and sizes should be kept standard as far as possible but some irregular units will be required to fit plot boundaries. The field unit has a net area of approximately 27 ha. The unit size has been kept at 570 m square, the same as the rice units to allow as much standardisation as possible. Each unit is served by its own offtake from a distributary canal, discharging into a unit feeder channel. The unit feeder will be a level top canal, with command varying between 0.20 and 1.00 m. The unit feeder design discharge will be 110 l/s and the channel will have a minimum freeboard of 0.20 m.

Water will be conveyed to the plots from the unit channel via a turnout and a head ditch running along the top of the field. Water will be turned out of the head ditch into the furrows or border strips by breaching the bank of the head ditch as required. At the tail of each border or group or furrows will be a unit drain the capacity of which is based on a unit discharge of 1.5 l/s per hectare gross.

The orientation of the furrows or border strips within the field unit will be chosen by the direction of the existing major ground slope. Given the broken nature of the topography of the levee soils, it may be necessary to incorporate several directions of flow for different parts of the field unit, to minimise the land levelling quantities and depths of fill.

7. Development Areas

7.1 Introduction

Provisional layouts for Phase II development have been prepared to determine the areas of surface and sprinkler irrigation. The layouts have been prepared to make the best use of the remaining basin clay soils and the most uniform levee soils for surface irrigation. Areas of particularly uneven topography should remain as sprinkler irrigation areas. Figure 3 shows the provisional layout of the Phase II development and Table 10 summarises the area.

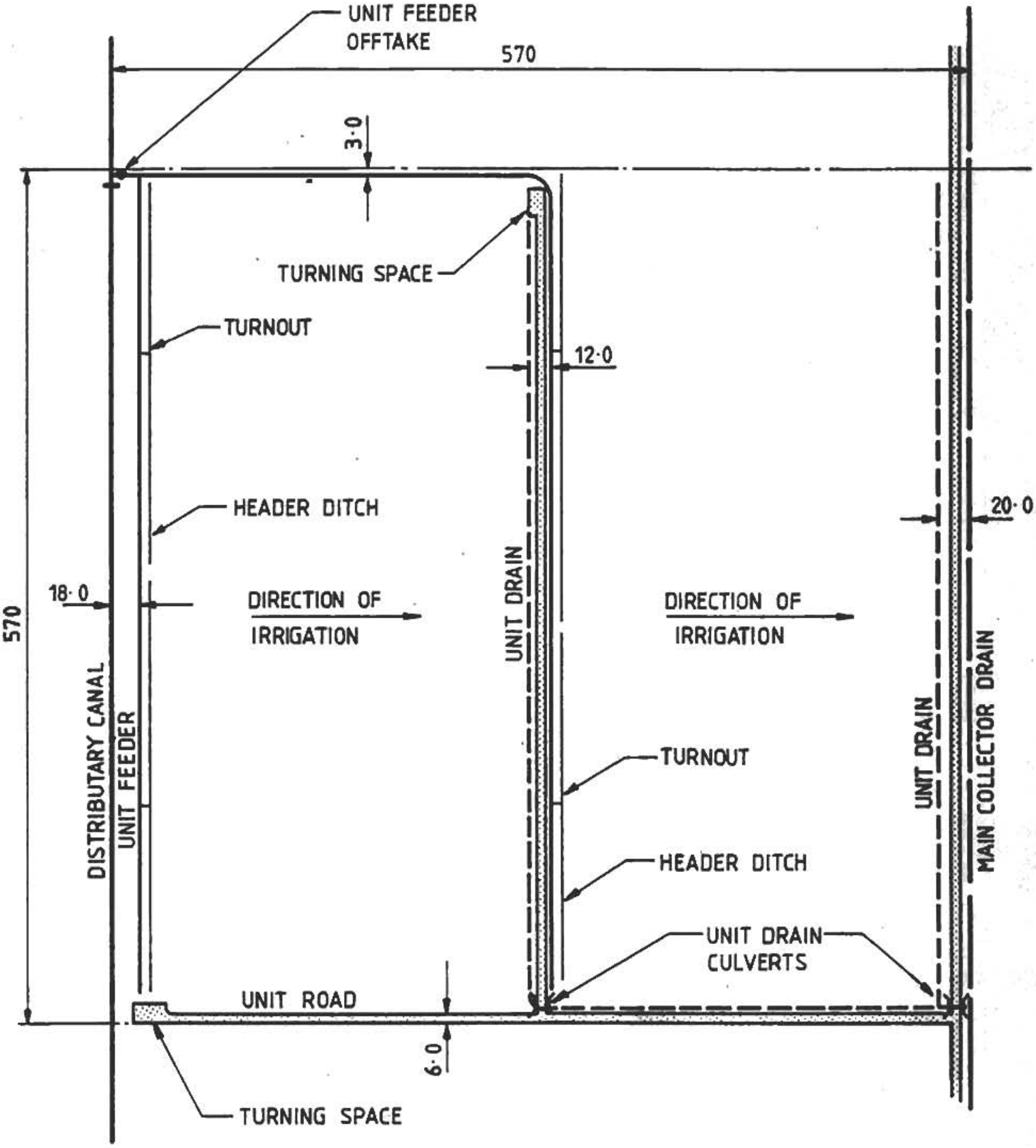
TABLE 10

Development Areas (ha)

	Surface irrigation		Sprinkler	Total
	Basin soils	Levee soils	irrigation	
Existing Phase I				
Sub-total	2 052	0	163	2 215
Phase II				
North of flood relief channel	376	0	493	869
West of Phase I area	0	0	789	789
South of Phase I area	414	378	580	1 372
Sub-total	790	378	1 862	3 030
TOTAL	2 842	378	2 025	5 245

Figure. 2

Typical Surface Irrigation Field Unit for Levee Soils



Approximate scale 1 : 400

Dimensions in metres

The original feasibility study identified a full development area of 6 400 ha compared with the 5 245 ha identified in this report. The reduction in area is caused primarily by the extension of land owned by the banana farmers into the south-east part of the project area. A second, smaller area of land in the north-east has been reserved for low cost housing for the project.

7.2 Main Canal Capacity

The main canal and its associated structures constructed under Phase I have a design capacity of 6.5 m^3/s. To check that this is sufficient for the potential full Phase II area of 5 245 ha the irrigation water requirements must be calculated as described below.

Recommended cropping pattern:

(a) Surface irrigation on basin clay soils:

Paddy rice (gu)	75% of 2 842 ha	=	2 132 ha
Paddy rice (der)	75% of 2 842 ha	=	2 132 ha

(b) Surface irrigation on levee soils:

Upland rice (gu)	33% of 378 ha	=	125 ha
Maize 1 (der)	33% of 378 ha	=	125 ha
Cotton (der)	34% of 378 ha	=	128 ha
Maize 2 (der)	33% of 378 ha	=	125 ha

(c) Sprinkler irrigation on levee soils:

Upland rice (gu)	33% of 2 025 ha	=	668 ha
Maize 1 (der)	33% of 2 025 ha	=	668 ha
Cotton (der)	34% of 2 025 ha	=	689 ha
Maize (der)	33% of 2 025 ha	=	668 ha

The irrigation water requirements and required main canal flows are given in Table 11.

The main canal flows are derived by obtaining for each crop in each month, the *field* requirement (mm) which is the net requirement divided by the *field* efficiency. The field requirements, are then applied to the total area of each crop and the results added together for each month. The main canal flow is thence obtained by applying a coefficient to allow for conveyance losses in the distributary canals, main canal and storage reservoirs. The results of these calculations given in Table 11 show that the peak main canal flow is 5.76 m^3/s. This is less than the 'as constructed' capacity of the head of the main canal and is therefore acceptable.

It can be seen from Table 11 that there is spare canal capacity in the gu season and if short season rice varieties become available, the cropping intensity of paddy rice in the gu season could be increased to 100%. There is also an opportunity for a small increase in cropping intensity in the der season to bring the main canal flow in October up to the design capacity at the head of 6.5 m^3/s.

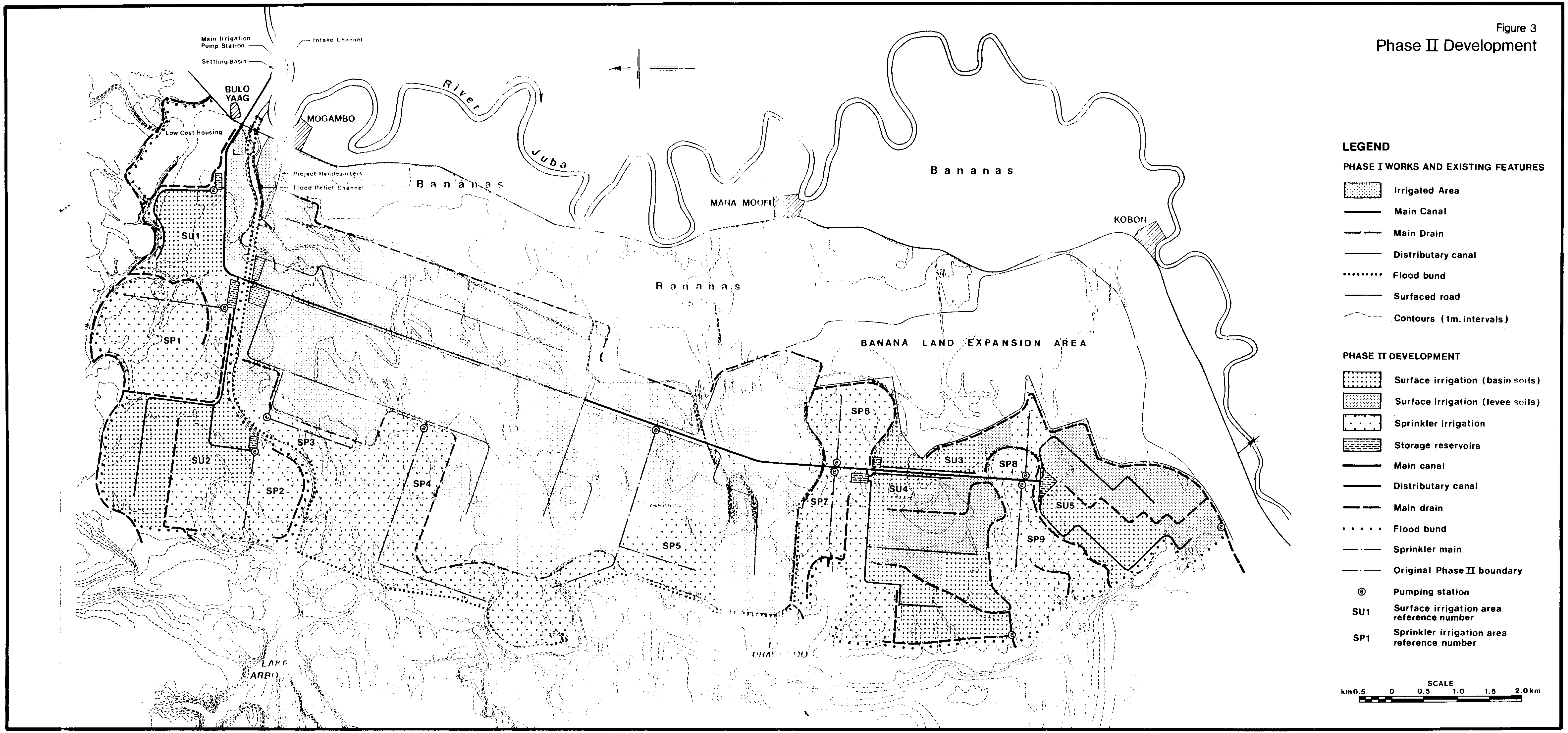


Figure 3
Phase II Development

TABLE 11

Irrigation Water Requirements and Main Canal Flow for Full Phase II Development

Month		J	F	M	A	M	J	J	A	S	O	N	D
Field requirement (mm)													
Surface irrigation:													
Paddy rice	2 132 ha	-	-	-	230	444	320	244	21	-	-	-	-
Paddy rice	2 132 ha	34	-	-	-	-	-	-	21	251	467	390	245
Upland rice	125 ha	-	-	-	-	185	155	188	214	20	-	-	-
Maize 1	125 ha	120	-	-	-	-	-	-	-	-	230	171	276
Cotton	128 ha	50	-	-	-	-	-	70	169	129	230	265	249
Maize 2	125 ha	45	-	-	-	-	-	-	-	213	173	245	237
Sprinkler irrigation:													
Upland rice	668 ha	-	-	-	-	148	124	151	171	16	-	-	-
Maize 1	668 ha	96	-	-	-	-	-	-	-	-	184	137	221
Cotton	669 ha	40	-	-	-	-	-	56	135	103	184	212	199
Maize 2	668 ha	36	-	-	-	-	-	-	-	171	139	196	189
Main canal flow (m^3/s)		0.85	-	-	2.06	4.34	3.29	2.81	1.40	3.26	5.76	5.39	4.18

Note: Main canal flow (m^3/s) $= \sum \frac{\text{field requirement (mm)} \times \text{area (ha)} \times 10}{\text{number of days in month} \times 24 \times 3\,600 \times 0.92}$

Where 0.92 = coefficient to allow for distribution losses (from MMP, Additional Study, 1980)

Three pumps are presently installed at the main irrigation pumping station; two at 2.2 m^3/s and one at 1.1 m^3/s. This is sufficient for the Phase I design flow of 3.7 m^3/s plus a standby. If the potential surface irrigation area only is developed under Phase II then the total net irrigated area would be 3 383 ha and the peak main canal flow approximately 4.5 m^3/s. One additional 1.1 m^3/s pump unit could be installed to meet these requirements. If the full potential

Phase II area is developed, requiring a peak main canal flow of 5.76 m^3/s, then two additional 1.1 m^3/s pump units would be needed. For the full main canal capacity of 6.5 m^3/s, one additional 2.2 m^3/s and two 1.1 m^3/s pump units would be required.

7.3 Discussion on Phase II Areas

The potential Phase II development areas are shown on Figure 3 and individual areas are discussed below.

Area SU1 — Potential surface irrigation on basin clay soil having a net area of approximately 114 ha. The ground levels in this area are too high to be irrigated directly from the main canal and so an additional small pumping station would be required. The area of SU1 could be increased if the area reserved for low cost housing could be reduced.

Area SP1 — Potential sprinkler irrigation on uneven levee soils having a net area of approximately 302 ha. Several natural drainage channels (fartas) occur in this area which, combined with the uneven topography, make it impractical for surface irrigation.

Area SU2 — Potential surface irrigation on basin clay soil having a net area of approximately 262 ha. This area is in command and can be irrigated via a new storage reservoir fed from the main canal just north of the flood relief channel.

Area SP2 — Potential sprinkler irrigation on uneven levee soils, part of which would be out of command for direct gravity irrigation, having a net area of approximately 191 ha. Could be irrigated from a sprinkler pump station and small storage reservoir located at the tail of a new distributary canal required for SU2.

To develop any or all four of these areas north of the flood relief channel would require the construction of the northern and north-western flood bunds as well as the completion of the bund along the flood relief channel. The density of the natural vegetation within the four areas, particularly SU2 and SP2, is greater than that within the Phase I area.

Areas SP3 and SP4 — Potential sprinkler irrigation generally on very uneven levee soils having a total net area of approximately 645 ha. Several fartas occur in these areas which, combined with the uneven topography and remoteness from the existing Phase I canals, make them impractical for surface irrigation. Two pumping stations would be required at the locations noted below:

SP3 - from existing distributary canal M1/C4.2

SP4 - from existing distributary canal M1/C4

These two areas are located within areas of dense natural vegetation.

Area SP5 An area of relatively even levee soils covering 144 ha. However it is remote from the main canal and the two nearest distributary canals M2/C2.1 and M2/C4 do not have sufficient head to feed this area by gravity. This area has therefore been retained for sprinkler irrigation.

Areas SP6 and SP7 Potential sprinkler irrigation generally on very uneven levee soils or on areas which would be out of command for direct gravity irrigation. Net areas for SP6 and SP7 are approximately 123 ha and 212 ha, respectively. Could be irrigated from sprinkler pump stations positioned along the main canal.

Area SU3 Potential surface irrigation on basin clay soils (approximately 50 ha) and levee soils (approximately 13 ha). Could be irrigated via a new distributary canal and storage reservoir fed from the main canal. Further surface irrigation prevented because of an expansion in the banana land.

Area SU4 Potential surface irrigation on basin clay soils (approximately 243 ha) and reasonably uniform levee soils (approximately 162 ha). Could be irrigated via new distributary canals and a storage reservoir fed from the main canal.

Areas SP8 and SP9 Potential sprinkler irrigation on uneven levee soils with several fartas having a new area of approximately 245 ha. Could be irrigated from sprinkler pump stations positioned along the main canal.

Area SU5 Potential surface irrigation on basin clay soils (approximately 121 ha) and reasonably even levee soils (approximately 203 ha). Could be irrigated via new distributary canals and a storage reservoir at the tail of the main canal.

The develop any or all of the areas to the south of the Phase I area would necessitate the extension of the main canal and the western flood bund. The ground levels in part of the area south of Phase I are such that adequate surface drainage cannot be provided without pumping drainage water from a lower level main collector to the outfall drain.

Two drainage pump stations are considered necessary; one to pump drainage water from the drain draining SU4 and SP9 and one to pump from the drain draining SU5.

8. Costs for Phase II Development - Surface Irrigation

8.1 Introduction

This section describes the build-up of costs for the Phase IIa development of the surface irrigation areas. The surface irrigation development areas are split into two separate regions, namely:

(i) North of flood relief channel: 376 ha net of surface irrigation on basin clay soils.

(ii) South of Phase I area: 414 ha net of surface irrigation on basin clay soils and 378 ha net on levee soils.

8.2 Unit Costs

8.2.1 Rates

The basic rates used for this cost estimate are those from Contract M2, dated March 1983. The estimate for Phase II can then be compared to the M2 tender sum. Some details quoted in Contract M2 are listed below:

(i) The proportion of foreign currency in Contract M2 varied for each Bill of Quantities and was an average of 78%. It is expected that a similar proportion will be applicable for Phase II.

(ii) The Contract M2 tender rates, dated March 1983, were based on an exchange rate of US$ 1 = SoSh 15.108.

8.2.2 Bush Clearance

The majority of the natural vegetation within the Phase II area can be classified as dense bush having more than 50 trees per hectare.

Contract M2 rate = SoSh 10 668/ha

This has been applied to the gross irrigated area.

8.2.3 Land Levelling, Planing and Survey

The costs of land levelling for the two methods of surface irrigation on the two different soil types are based on the quantities given in Table 3.

Contract M2 rate for 500 m^3/ha = SoSh 12 657/ha

Contract M2 rate for additional volumes = SoSh 15/m^3

Thus the March 1983 rates for land levelling on the two types of soil are:

For basin clay soils - SoSh 17 157/ha

For levee soils - SoSh 23 457/ha

The rates for level survey and land planing at March 1983 prices are:

Level survey	=	SoSh 757/ha
Land planing	=	SoSh 1 009/ha

8.2.4 Flood Bunds

The average volume of fill required for the flood protection bunds is 16 228 m^3/km. Based on the M2 Contract rate of SoSh 29/m^3 this gives a rate of SoSh 470 612/km.

8.2.5 Earthworks

The overall earthworks cost for canals, drains, reservoirs and infield channels but excluding flood bunds is derived from the M2 Contract rates for Bill Parts Nr 3A and 3B and the cost of surface irrigation works for the 1 168 ha surface irrigation area as follows:

Cost of Earthworks for network	Cost of Earthworks for infield channels
SoSh 17 887 000	SoSh 6 280 000

Thus total earthworks cost for 1 168 ha of surface irrigation = SoSh 24 167 000.

March 1983 rate = SoSh 20 691/ha

8.2.6 Structures

The overall cost of canal and drain structures, excluding irrigation and drainage pump stations, is derived from the M2 Contract rates for Bill Parts Nr 4A, 4B, 5A and 5B and the cost of the structures for the 1 168 ha surface irrigated area are as follows:

Cost of structures for network		Cost of structures for infield system
SoSh 11 608 000		SoSh 6 565 000
Total for 1 168 ha	=	SoSh 18 173 000
Thus the March 1983 rate	=	SoSh 15 559/ha

8.2.7 Additional Pump at Main Irrigation Pump Station

To develop the Phase IIa surface irrigation area an additional 1.1 m^3/s pump unit is required at the main irrigation pump station. The cost of the pump, diesel engine, fuel storage tank, spare parts and supervision has been estimated from the rates given in Nominated Sub-Contract M2.1 as SoSh 2 100 000. The cost of handling and installing this plant is estimated from Bill Part Nr 10 in Contract M2 as SoSh 630 000.

The total cost of the additional pumping unit at March 1983 prices is thus approximately SoSh 2 740 000.

8.2.8 New Irrigation Pump Station for Surface Irrigation Area SU1

The irrigation pumping station supplying 114 ha of basin clay soils in area SU1 north of the flood relief channel should have a design capacity of 0.16 m^3/s. By comparing the costs and capacities of the main irrigation pump station and the drainage pump station given in Bill Parts Nr 6 and 7 of Contract M2 the cost of the civil works for a 0.16 m^3/s pump station is estimated as SoSh 194 000. A similar comparison for the costs of pumping plant gives an estimated cost of SoSh 485 000 at March 1983 prices.

The total cost of a 0.16 m^3/s pump station at March 1986 prices is therefore SoSh 679 000.

8.2.9 Drainage Pump Stations

Two drainage pump stations are needed to drain the parts of the Phase IIa area in the south as detailed below:

(i) To drain SU4 and SP9 needs a pump design capacity of 0.65 m^3/s.

(ii) To drain SU5 needs a pump design capacity of 0.50 m^3/s.

The costs of these two pump stations have been estimated in a similar manner to that described in Section 8.2.8 and are given in the following table.

TABLE 12

Cost Estimates for Drainage Pump Stations

Pump station design capacity (m^3/s)	Costs at March 1983 prices (SoSh)		
	Civil works	Pumping plant	Total
0.65	763 000	1 942 000	2 705 000
0.50	585 000	1 530 000	2 115 000
			4 820 000

8.2.10 Water Control Equipment

The cost of water control equipment is derived from the rates given in the Nominated Sub-Contract M2.2 and Bill Part Nr 10 in the main Contract M2.

M2.2 - Supply of gates and provision of supervision = SoSh 4 891 964

M2 Bill Part Nr 10 - Installation and handling of gates = SoSh 1 838 041

This gives a total cost of SoSh 6 730 005 at March 1983 prices for all water control equipment for the Phase I surface irrigation area of 2 052 ha.

Thus rate at March 1983 prices = SoSh 3 280/ha

8.2.11 Miscellaneous Items

A sum for engineering design and supervision has been included together with an allowance for physical contingencies of 20% of the engineering works.

8.3 Cost of Surface Irrigation Development North of Flood Relief Channel

The salient features of the area north of the flood relief channel are as follows:

Net area of surface irrigation on basin soils	=	376 ha
Gross area = 1.2 x 376	=	453 ha
Length of northern flood bund	=	11.5 km
Length of north bund along flood relief channel	=	4.6 km
Additonal pump unit at main irrigation pump station	=	1.1 m^3/s
New irrigation pump station	=	0.16 m^3/s

The estimated cost of development of the surface irrigation area north of the flood relief channel is given in Table 13. Costs of housing, water supply, surfaced roads and other infrastructure works are not included.

8.4 Cost of Surface Irrigation Development South of Phase I Area

The salient features of the area south of the existing Phase I scheme are as follows:

Net area of surface irrigation on basin soils	=	414 ha
Net area of surface irrigation on levee soils	=	378 ha
Gross area = 1.2 x 792	=	951 ha
Length of western flood bund	=	10.0 km
Addition pump unit at main irrigation pump station	=	1.1 m^3/s
New drainage pump stations	=	0.65 m^3/s and 0.50 m^3/s

The estimated cost of this development excluding housing, water supply, surfaced roads and other infrastructure works is given in Table 14.

TABLE 13

Cost Estimate for Surface Irrigation Development North of Flood Relief Channel

Item	Unit	Quantity	Rate (SoSh)	Amount (SoSh)
Bush clearing	ha	453	10 668	4 832 604
Level survey	ha	376	757	284 632
Land planing	ha	376	1 009	379 384
Land levelling	ha	376	17 157	6 451 032
Flood bunds	km	16.1	470 612	7 576 853
Earthworks	ha	376	20 691	7 779 816
Structures	ha	376	15 559	5 850 184
Additional 1.1 m^3/s pump at main pump station (Part cost for 376 ha)	Nr	0.32	2 740 000	876 800
New 0.16 m^3/s irrigation pump station	Nr	1	679 000	679 000
Water control equipment	ha	376	3 280	1 233 280
Sub-total				35 943 585
Engineering design and supervision (10%)	Sum	-	-	3 594 358
Contingencies at 20%	-	-	-	7 907 589
TOTAL				47 445 532

Note : Costs are given at Contract M2 tender rates, March 1983.

TABLE 14

Cost Estimate for Surface Irrigation Development South of Existing Phase I Scheme

Item	Unit	Quantity	Rate (SoSh)	Amount (SoSh)
Bush clearing	ha	951	10 668	10 145 268
Level survey	ha	792	757	599 544
Land planing	ha	792	1 009	799 128
Land levelling - basin soils	ha	414	17 157	7 102 998
Land levelling - levee soils	ha	378	23 457	8 866 746
Flood bunds	km	10	470 612	4 706 120
Earthworks	ha	792	20 691	16 387 272
Structures	ha	792	15 559	12 322 728
Additional 1.1 m^3/s pump at main pump station (Part cost for 792 ha)	Nr	0.68	2 740 000	1 863 200
New 0.65 m^3/s drainage pump station	Nr	1	2 705 000	2 705 000
New 0.50 m^3/s drainage pump station	Nr	1	2 115 000	2 115 000
Water control equipment	ha	792	3 280	2 597 760
Sub-total				70 210 764
Engineering design and supervision (10%)	Sum	-	-	7 021 076
Contingencies at 20%	-	-	-	15 446 368
TOTAL				92 678 208

Note: Costs are given at Contract M2 rates, March 1983.

9. Implementation

The cost estimates for the potential Phase IIa surface irrigation development areas are summarised in Table 15.

TABLE 15

Cost Summary for Surface Irrigation Development

Location	Net area (ha)	Total cost (SoSh million)	Cost per hectare (SoSh/ha)
North of flood relief channel	376	47.4	126 064
South of Phase I area	792	92.7	117 045
TOTAL	1 168	140.1	119 949

Notes: (1) Costs are given at Contract M2 rates, March 1983.

(2) Costs of housing, water supply, surfaced roads and other infrastructure works not included.

The estimated costs of the two surface irrigation blocks are of a similar order in terms of cost per hectare, it is recommended that they are developed together as a single 1 168 ha phase. The remaining 1 862 ha of sprinkler irrigation could be developed at a later date as a separate Phase IIb area.

APPENDIX 1

COMPARISON OF COSTS FOR SURFACE AND SPRINKLER IRRIGATION

A cost comparison is made between the surface irrigation of Phase IIa and the sprinkler irrigation of Phase IIb.

The Surface Irrigation Costs are given in Table 15. The annual costs have been discounted at 10% over the 25 year life of the project. The sprinkler irrigation costs have been based on Contract M2 rates including the nominated sub-contracts.

Surface Irrigation

Item	Cost per hectare SoSh
Capital cost of system	119 949
Discounted maintenance of system	15 300
Fuel costs for irrigation pump station	970
Total	136 219

Sprinkler Irrigation

Bush clearance	10 668
Pump stations and buried mains	73 500
Portable equipment	27 000
Discounted replacement of pumps and engines	4 850
Discounted replacement of field equipment	5 050
Discounted maintenance of pumps and engines	340
Discounted maintenance of pump station civil works and buried mains	6 250
Fuel costs	9 750
Land planing	1 261
Total	138 669

Within the accuracy of these figures it can be seen that the surface irrigation of Phase IIa is of the same order of cost as the sprinkler irrigation alternative. However, the sprinkler irrigation would be more expensive in financial terms because of the pumping costs.