800567

NAME OF THE PROJECT

ALL INDIA CO-ORDINATED RESEARCH PROJECT ON AGRICULTURAL DRAINAGE UNDER ACTUAL FARMING CONDITIONS ON WATERSHED BASIS, KARUMADY

(I.C.A.R.)

1985-'86

CENTRE

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F I G U R E S

ANNUAL REPORT FOR THE YEAR 1985-86

SECTION A

1.	Title of the Scheme	: All India Co-ordinated Research Project on Agricultural Drainage under actual farming conditions on watershed basis, (ICAR), Regional Centre, (KAU), Karumady. P.O, Alleppey District, Kerala State.
2.	ICAR sanction No. and Date	: Original sanction No.F 4-5/77 AE dated 20-3-1981 of ICAR. Revised sanction No. 4-14/80 AE dated 22-10-1982 of ICAR. Further order No. 4-2/85-AE
3.	Date of commencement of the Project	: 01-12-1981
4.	Date of Completion	: 31-3-1990
5.	Sanctioned grant for the complete duration of the project	: 29.7 lakhs
6.	Sanctioned grant for the year for which the report is prepared	: 3 lakhs vide order No. 4-2/85-AE dt. 1-8-86 of ICAR.

7. Staff position as on March, 1986

Sl. No.	Name of post	No. of sanctioned post	No. of posts filled	No. of posts vacant	Name of incumbent	Scale of pay	Date of joining
1	2	3	4	5	6	7	8
1.	Assoc. Professor (Agrl.Engg)	1	1	-	Sri. E.K. Mathew, Assistant Professor	1950-2950	1-10-'84 till date
2.	Asst. Professor (Agron.)	1	1		Sri. U.Jayakumaran	1500-2685	25-3-82 to 30-4-85
3.	Asst. Professor (Agrl.Engg.)	1	1	-	Sri. T.D. Raju Junior Asst. Prof.	1500-2685	1-10-'84 till ~~date~~
4.	Farm Assistant (Agri) Senior Grade	1	1	-	Sri. A.M. Ayyappan Pillai	975-1720	26-5-82 to 9-6-85
					Sri. R.Madhavan Pillai		10-6-85 to till date
5.	Overseer (Civil) Gr.I	1	-	1	-	825-1430	Vacant since inception
6.	Draughtsman (Civil) Gr.II	1	-	1	-	700-1140	Vacant since inception
7.	Farm Assistant Gr.II	2	2	-	Sri.K.G. Muraleedharan Pillai	675-1125	1-2-82 to 16-6-85
					Sri. V.J. Rajamohan		1-2-82 to 16-6-85
					Sri. T.J. Mathew		17-6-85 to till date
					Sri. K.O. Shahul Hameed		17-6-85 to till date

1	2	3	4	5	6	7	8
8.	Surveyor	1	-	1	-	675-1125	vacant since inception
9.	Technician Gr.III	2	2	-	Sri. K.Vasudevan	675-1125	9-12-82 to till date
					Sri. K.Aravindan		10-12-82 to till date
10.	Typist Grade I	1	1	-	Sri. P. Natarajan Pillai	780-1320	17-4-82 to 31-5-85
					Smt. K.K. Mary		15-7-85 to till date
11.	Assistant Grade I	1	1	-	Sri. K. Govindan	780-1320	5-9-84 to till date
12.	Peon	1	1	-	Sri. G. Vasudevan	550-800	7-4-82 to 26-11-85
					Sri. M. Mohammed Haneef		7-12-85 to till date
13.	Watchman	2	2	-	Sri. M. Mohammed Haneef	550-800	12-4-82 to 6-12-85
					Sri. N. Raveendran		16-11-82 to till date
					Sri. C.A. Chacko		7-12-85 to till date
14.	Driver (LDV) Gr.III	1	1	-	Sri. M. Xavier	640-1000	28-2-85 to 7-1-86
					Sri. K.V. Kumaran		8-1-86 to till date

8. Financial information

i) Expenditure statement from the year of commencement to 1985-86

Sl. No.	Year	Sanctioned grant for the year	University sanction	Expenditure	Expenditure as % of the sanctioned grant
1.	1981-82	1,28,100.00	36,000.00	7,242.85	5.65
2.	1982-83	4,78,200.00	4,37,000.00	1,26,509.58	26.45
3.	1983-84	3,83,800.00	3,83,800.00	2,44,951.89	63.82
4.	1984-85	3,80,200.00	3,80,200.00	3,38,008.35	88.90
5.	1985-86	2,86,800.00	2,86,800.00	2,61,094.23	91.04%

ii) Expenditure statement of the year 1985-86 from 1-4-1985 to 31-3-1986.

Sl. No.	Budget Head	Sanctioned grant for the year	ICAR sanction	University sanction	Total Expenditure	Expenditure as % of the sanctioned grant
A.	Pay and Allowances					
1.	Pay of Officers					
2.	Pay of Estt.	1,95,300	..	1,95,300	178002.48	91.14%
3.	Allowances					
	Total	1,95,300	..	1,95,300	178002.48	91.14%
B.	TA	10,000	..	10,000	3905.80	39.05%
C.	Recurring Contingencies	31,500	..	31,500	31454.90	99.86%
D	Non-Recurring Contingencies	50,000	..	50,000	47731.05	95.46%
	Grand Total	2,86,800	..	2,86,800	261094.23	91.04%

SECTION B

PROJECT AREA - A Brief Description

B.i. Kuttanad

Kuttanad tract is a deltaic alluvium formation of four river systems viz. 'Meenachil', 'Pampa', 'Manimala', and 'Achen Coil' and the low lying area in and around 'Vembanadu Lake'. The total area of Kuttanad tract is about 870 sq.km. out of which 290 sq.km. is under garden lands, scattering all over the tract and is lying 1 to 2m above the sea level, used mainly for coconut cultivation and habitation. The remaining portion which was under submergence was progressively reclaimed as polders by constructing ring bunds. These polders lie about 0.5 to 2m below mean sea level and the impounded water is drained out by using locally manufactured axial-flow pumps. The area of each polder unit ranges from 75 to 500 ha and the total area under polder cultivation is estimated as about 520.89 sq.km. The whole area is criss-crossed by rivers, channels, canals and other waterways. The general topography of the area is flat and level.

The total watershed area of the above four rivers is nearly 5,000 sq.km. and discharge their water into Kuttanad region. After flowing through a net work of canals and channels, they join the Vembanad Lake. The catchment area has an annual rainfall varying between 280cm to 380cm. A good part of the rains, 60% to 70% are received during South West monsoon resulting in floods and most often submerging the low lands. The Kuttanad region experiences fairly uniform temperature throughout the year ranging between 21°C and 36°C. The mean relative humidity is high and is about 70%.

The Vembanad Lake which is the non reclaimed part of the Kuttanad extends between Alleppey and Cochin with an area of 80 sq.kms. This lake is connected to Arabian Sea at Cochin. The water in the lake is saline except during the monsoon season when the surface water is sweetened by flood water. When the flow in the rivers dwindles from the month of December, the saline water from the sea intrudes the entire area due to tidal action. The salinity in the northern parts of Kuttanad goes beyond limits of tolerance for rice cultivation from January onwards and it spreads rapidly to the southern parts. The surface water remains saline till the first flood washes it during the succeeding South West monsoon.

The soil is acid sulphate in nature and is having high acidity. Three major problems encountered during cultivation in this area are

1) high acidity
2) damage caused by floods and
3) intrusion of saline water during the fag end of crop period.

B.ii. Kari Lands

The whole Kuttanad tract is differentiated into three types of lands, namely Karappad, Kayal lands and Kari lands. The Kari land occupies an area o nearly 7,000 ha. They are located in the Taluks of Shertala , Ambalapuzha and Kuttanad of Alleppey District and Vaikom and Kottayam of Kottayam District.

The Kari lands are a unique agricultural tract with Kari soils - black charcol coloured organic soil. These lands are quite similar to that of Kuttanad region with respect to topography, formation, climate and vegetation, but the organic matter content of the soil is very high.

It is believed that this soil was formed and developed in the distant geologic past when the area was covered by dense forest vegetation. In the succeeding geological ages, the sea advanced and engulfed many places. After thousands of years, the sea receded exposing the coastal region and part of the present midlands. During this geological upheavals, the entire forest area was submerged far below the ground and thereafter silted upto varying levels.

The profile of Kuttanad alluvium consists essentially of alternating layer of clay and sand, admixed with varying proportions of organic matter. The clay is usually a grey, dark or bluish black in colour, This alluvial formations exist in layer varying upto 30 metres in depth underlain by sand stone and mottled clay of tertiary formation. Still distinct, the Kari soils can be readily be discerned by the deep black charcoal colour, due to high organic matter content. The top soil is admixed with well decomposed organic matter to the tune of 10-30%. But, underneath, the top layer is the partially decomposed, fibrous plant residues containing less than 50% mineral matter. Hence, these soils are both mucky and peaty in nature. In some places, large logs of wood locally known as 'Kandamaram' occur embedded in the sub soil. Beneath this layer, the soil is an admixture of sand, organic matter and clay and still deeper it becomes river sand.

Kari soils are extremely acidic in reaction with pH ranging 3-4.5 and the pH reduces further when the soil gets dried up. It is found that the extremely low pH on drying is due to the production of free sulphuric acid by oxidation of sulphur compounds in the soil. The fertility status of the soil is poor. Besides, the soil contains toxic concentrations of F_e, Al and toxic organic products.

Biii. The Project Area : Kavil Thekkumpuram Padasekharam

Biii. a. Location and Area

The project area is a typical representative tract of Kari land with an area of 89.99 ha. The project area comes under Ambalapuzha Village and Taluk of Alleppey District. It lies 4 Kms. east of Ambalapuzha Junction on National Highway 47. The padasekharam is encircled by Ambalapuzha-Thakazhy road at north, Kalathil thodu at east, Kari thodu at south and Karumady thodu at west.

Biii. b. Physiography and Hydrology

The project field is located 1 to 1.5m below mean sea level. The water collected in the project area is drained out by pumping to nearby canals using axial flow pumps (petty and parah). There are two pumping outlets, one with a 30HP and the other with 20HP axial flow pump. The former is installed on the ring bund of Karumady thodu and the latter on the ring bund of Kari thodu. Two drainage channels, with an average width of 2.5m and a depth of 0.7m, are inter connected and lead water to the pumping bays. There is a net work of small drainage channels which opens out into the main drainage channel.

The land has got almost an even topography.

The water level in the surrounding water ways will be higher by 1 to 1.5m than that in the paddy fields during the season of cultivation. The havoc of flood, over topping and breaching of bunds and flooding of paddy fields are anticipated during the period of SW monsoon. Inundation of salt water and damage of crops are experienced during the period January to March.

Biii.c. Climate

The project area experiences a typical tropical climate. The monthly mean of the weather parameters for the period from 1976 to 1984 and that for the period from 1985 January to March 1986 is given in table A. The monthly changes in climatic parameters have also been illustrated through fig. A and B.

Biii.d. Land Holding and Utilization

From the survey conducted at this station and from the records available with Revenue Department, it is found that altogether 125 cultivators are there in the project Area, farming 75.238 ha of paddy fields. When the tenureship of the land is classified based on the extent of holding, it was seen that a substantial number of holding fell below 1 acre. Out of 125 Nos. of holdings, 75 holding were with an average extent of 1 acre or below that and 35 holdings were with an average extent between 1 acre and 2.5 acre. Only 15 holdings were with mean acreage above 2.5 acre. The average size of holding is 0.601 ha (1.49 acres).

The total area of the project field is 88.919 ha and actual paddy field is 75.238 ha. The rest of the land is occupied by roads, trenches and reclaimed dry lands. The dry lands are used for human habitation and for the cultivation of perennial crops, mainly coconut.

TABLE - A

MONTHLY VARIATIONS OF WEATHER PARAMETERS IN THE PROJECT AREA

(a) Total Rainfall cm.

	JAN.	FEB.	MAR.	APRL.	MAY	JUNE	JULY	AUG	SEP.	OCT.	NOV.	DEC.	Total Mean
A	0.35	3.77	4.96	12.56	31.42	61.67	54.97	41.39	28.11	29.59	21.80	6.95	300.5
B	7.08	1.2	0.898	7.73	1.83	85.02	43.89	24.81	32.05	29.51	12.48	4.05	225.74
C	0.05	-	6.08	-	-	-	-	-	-	-	-	-	-

(b) Monthly mean maximum Temp °C

A	34.0	33.52	34.55	35.04	33.92	30.86	30.35	30.65	31.85	32.44	31.87	33.76	32.74
B	32.19	32.29	33.74	32.2	31.7	28.37	28.74	28.87	29.57	30.26	30.77	32.32	30.92
C	32.16	32.89	33.03	-	-	-	-	-	-	-	-	-	-

(c) Monthly mean minimum Temp °C

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	Total Mean
A	22.12	23.38	25.23	25.58	25.96	24.73	23.95	24.41	24.87	25.61	24.60	23.49	24.52
B	21.38	22.5	23.68	24.0	22.4	22.2	23.32	23.61	23.5	23.48	22.67	21.81	22.28
C	21.65	22.64	24.45	-	-	-	-	-	-	-	-	-	-

(d) Monthly mean evaporation (mm)

A	3.77	4.14	4.78	4.94	4.96	4.24	4.31	4.14	4.38	4.36	4.01	3.6	4.30
B	-	5.05	4.51	5.62	4.73	4.17	5.17	3.95	4.22	3.36	3.29	3.35	4.31
C	3.43	4.28	4.94	-	-	-	-	-	-	-	-	-	-

A = Monthly mean for the year 1976 to 1984

B = Monthly mean for the year 1985

C = Monthly mean for the year 1986

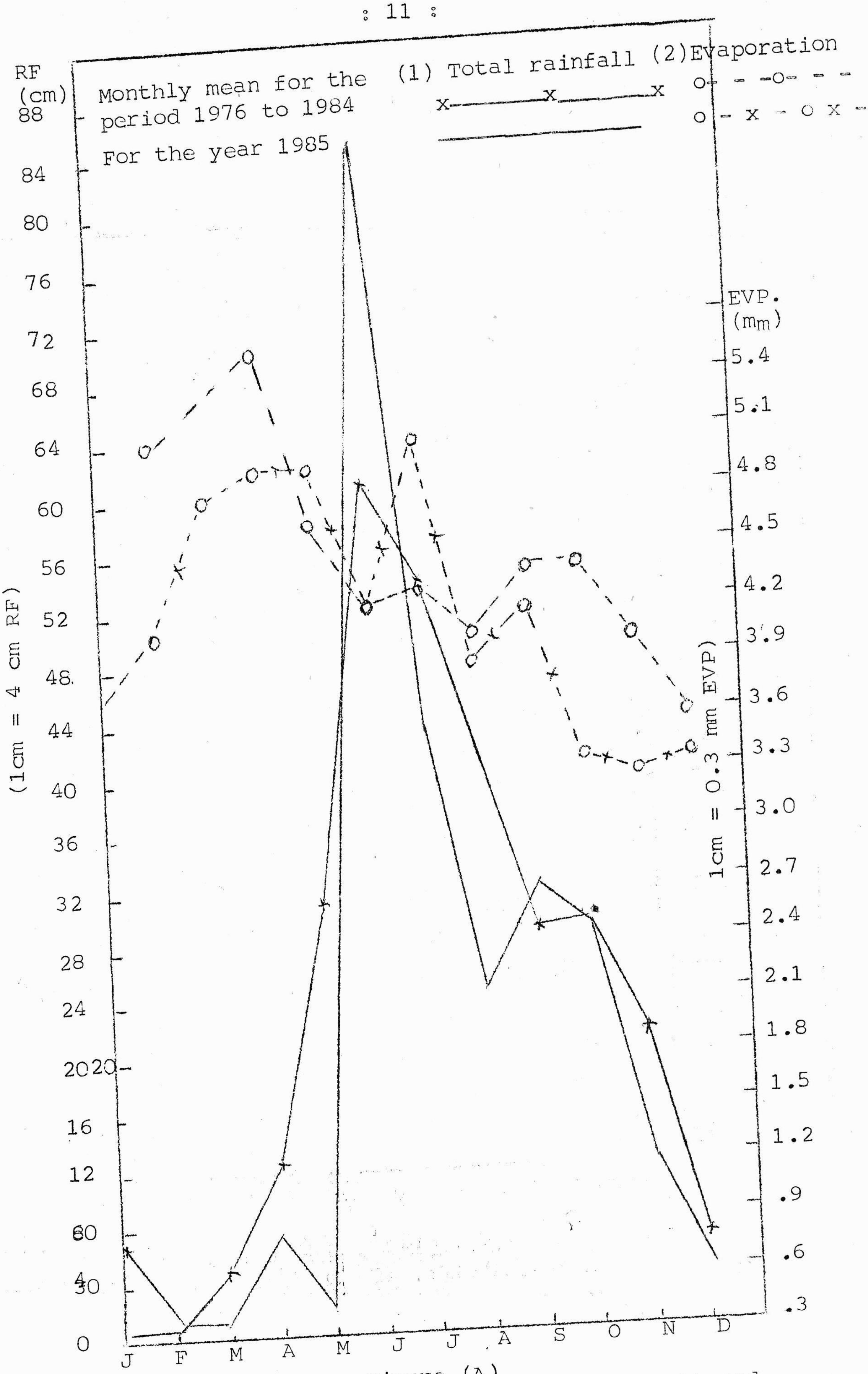


Figure (A)

Mean monthly variation in total rainfall and evaporation in the project area

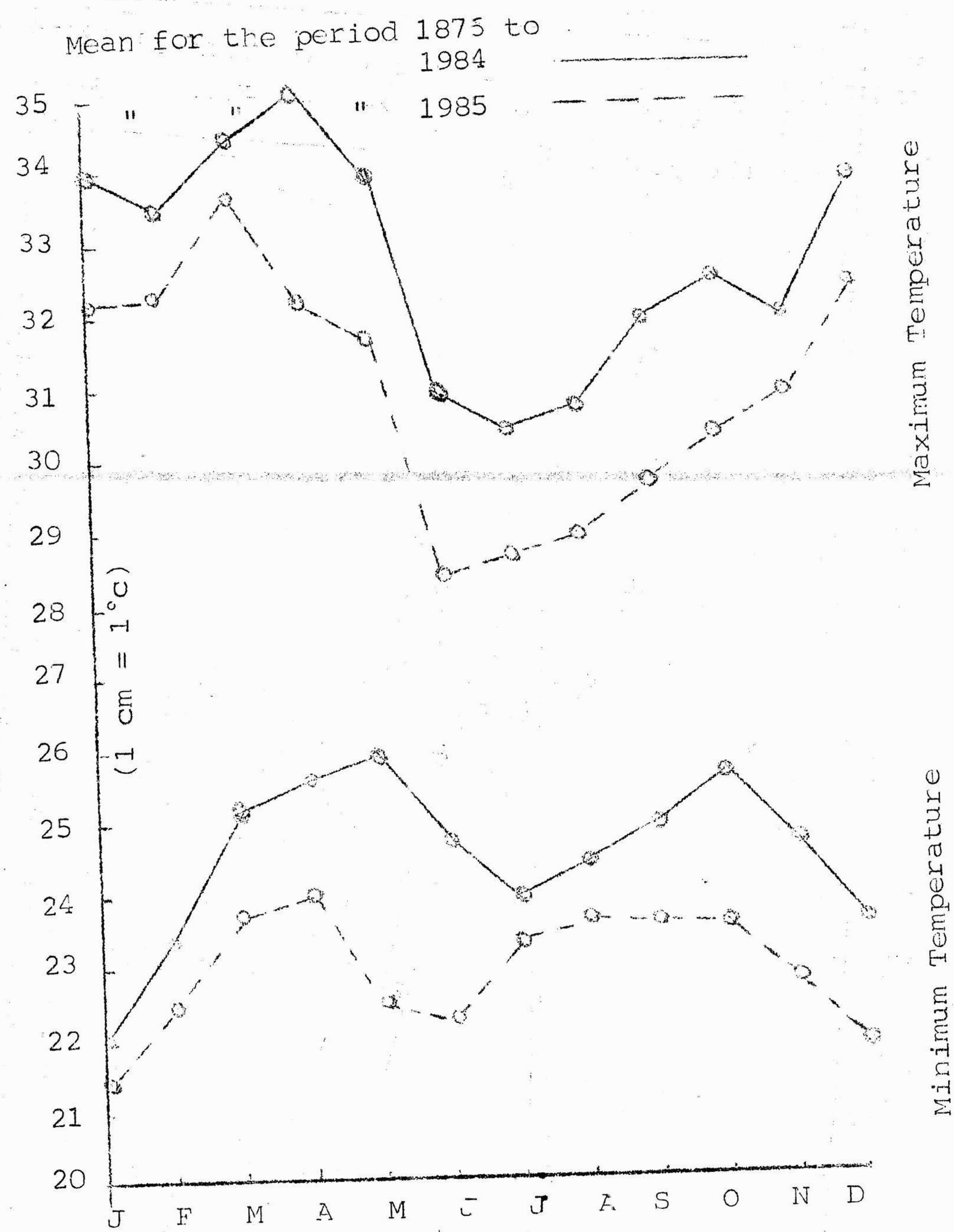


Figure (B)

Mean monthly variation in maximum and minimum temperature in the project area

Biii. e. Cropping

The one and the only crop raised in the wet land is paddy and there is 100% coverage under HYVS.

Biii f. Soil Characteristics

The soil of the project area is typical Kari soil. A soil monolith from 0-2m depth has been drawn from the project area and has been displayed in a glass/depth, the soil is clayey and black in colour due to high organic matter content. The clay type is the expanding one and large cracks are formed on drying. From 60-90m depth, lot of wooden debris, undecomposed organic material, are seen embedded. Below that, the soil is an admixture of clay, sand and organic matter. From the depth of 1.5m onwards, the soil is almost of the river sand type.

/box. From the visual observation it is seen that from 0 -60cm.

SECTION C

Objectives of the Project

1. To comprehend the effect of a surface and subsurface drainage system on the movement of soil liquids.

   i. To study the effect of surface and subsurface drains in preventing the rise of toxic products from sub-surface soil into root zone.

   ii. To study the effect of surface drains in removing the toxic products already present in the root zone.

   iii. To study the influence of sub-surface drains on lowering water table and its effect on growth and development of roots.

2. To study the pattern of hydrological cycle occuring in the water-shed area and its importance and influence on the drainage.

3. To develop a feasible technology for the layout of sub-surface drainage system suitable to peat and muck soils.

   i. To develop the criteria for the design of sub surface drains in peat and muck soils.

ii. To evaluate the types of drains (such as tile drains, PVC pipes etc.) and size and spacing of slots on drains suitable for the lay out of subsurface drains.

iii. To evaluate the filter materials to be used for the layout of subsurface drains.

iv. To decide upon the depth and spacing of the layout of subsurface drains.

v. To develop the criteria for the design of auxiliary structures of subsurface drains.

4. <u>To develop criteria for design parameters of surface drainage</u>

5. <u>To develop the drainage pattern required for different crops</u>

i. To determine the drainage requirement of rice crop under static and fluctuating conditions of water levels.

ii. To study the feasibility of changing monocropping pattern to diversified cropping and to develop agro-techniques required for the diversified cropping.

iii. To fix up the drainage requirements of the competent crops of diversified cropping.

6. To evaluate the feasibility of using the return flow from drainage for irrigation in relation to water quality ratings.

7. To evaluate the socio-economic benefits accrued from the drainage projects.

SECTION D

TECHNICAL PROGRAMME FOR THE YEAR 1985-86

I. Technical programme for the year 1985-86 as approved in the previous annual workshop.

1. Continuation of ongoing projects for collection, analysis and interpretation of data on soil properties, drain functioning, pump outlet, crop growth and yield.

2. Evaluation on the suitability of different filter materials for sub-surface drainage.

3. Analysis of drain discharge and water table data under different spacings and lengths with a view to find the diameter requirements of tile drains.

II. BRIEF TECHNICAL PROGRAMME OF THE PROJECTS TAKEN UP AT THE CENTRE DURING 1985-86.

Sl. No.	Title of the project	Title of the problem	Season	Page No.
1.	Survey and characterisation of quality of water in the project area.	Periodical changes in the quality of surface and subsurface water in the project area.	Dec. 82 to Continuing	
2.	Preparation of water contour map and hydraulic map of the project area.	Seasonal fluctuation of ground water table with reference to surface water level and characterization of aquifer in the project area	Jan. 82 to Continuing	
3.	Development of a suitable technology for the subsurface drainage system in the Kari lands of Kuttanad	a) Assessment of hydraulic properties of the tile drainage system	Dec. 84 to Continuing	
		b) Effectiveness of tile drainage system in the performances of paddy crop in the Kari land	Dec. 84 to Continuing	

RESEARCH PROJECT NO.1

1. Title of the Project : Survey and characterisation of quality of water in the project area.

2. Title of the Problem : Periodical changes in quality of surface and sub surface water in the project area

3. Objectives:

1) To assess the periodic changes in the quality of flooding water, drainage water and ground water.

2) To identify the fluctuation in the quality of water during the periods of fallowing and cultivation.

4. Practical Utility

The study will give useful information the quality of water moving in the project area and enable to study the impact of quality of water on the ecology of the area. The information thus obtained can serve effectively in the planning of cultivation in the project area.

5. Technical Programme

Water samples will be drawn at weekly intervals from the observation wells, piezometers, drainage channels and waterways and its quality such as pH and EC will be assessed.

6. Observations Taken

pH and EC of the water samples to be estimated at weekly intervals.

7. Date of Starting : December, 1982

8. Date of Completion : Throughout

9. Progress of Work

Water samples were drawn at weekly intervals from the waterways surrounding the project area and from the

Table 1(1)

pH of Water Samples at Weekly Intervals

Date	Karumady thodu	Karithodu	Kalathil thodu	Drainage channel
18-4-85	6.21	5.80	3.78	4.42
27-4-85	5.89	5.84	3.66	4.72
4-5-85	6.39	6.16	3.96	4.73
16-5-85	6.45	6.57	5.79	5.57
22-5-85	6.47	5.07	7.05	5.90
29-5-85	6.29	5.02	5,24	6.46
5-6-85	5.99	5.43	4.70	4.78
15-6-85	5.83	5.88	5.44	5.54
21-6-85	5.97	4.13	3.95	4.69
17-7-85	7.64	6.52	7.58	6.85
24-7-85	6.88	7.41	6.56	7.04
31-7-85	6.56	7.10	7.27	7.31
23-8-85	6.84	6.54	6.37	6.35
2-9-85	6.35	7.24	6.57	6.40
9-9-85	6.06	6.40	6.29	5.86
16-9-85	6.61	6.31	6.38	6.48
23-9-85	6.17	5.71	5.90	6.14
30-9-85	6.05	5.15	4.80	5.17
8-10-85	6.68	6.59	6.46	6.08
14-10-85	6.57	6.58	6.12	6.13
18-10-85	5.97	5.10	7.70	4.59
26-10-85	6.50	5.95	4.21	5.20
31-10-85	6.69	3.86	6.34	4.15
6-11-85	7.43	7.35	7.45	7.24
13-11-85	7.39	7.46	6.40	6.80
20-11-85	8.50	8.10	8.10	7.15
28-11-85	9.08	9.25	9.30	9.03
6-12-85	7.23	4.63	7.20	6.65
11-12-85	7.28	6.77	5.39	7.63
18-12-85	7.31	6.90	7.23	6.84
27-12-85	7.64	7.35	7.33	6.76
1-1-86	6.94	6.53	7.10	7.16

Date	Karumady thodu	Karithodu	Kalathil thodu	Drainage channel
8-1-86	6.23	5.80	6.13	6.25
15-1-86	6.82	6.10	6.56	6.44
30-1-86	6.86	6.79	6.55	6.33
6-2-86	7.23	7.28	6.88	6.81
13-2-86	6.94	6.30	7.01	6.91
19-2-86	6.87	6.90	6.36	6.12
27-2-86	7.12	7.29	6.00	5.46
6-3-86	6.78	6.50	6.45	5.15
13-3-86	6.55	6.36	6.40	4.21
20-3-86	6.83	6.70	6.90	5.40
26-3-86	5.99	5.60	7.36	4.43

Table 1(2)

EC of Water Samples at Weekly Intervals

Date	Karumady thodu	Karithodu	Kalathil thodu	Drainage channel
18-4-85	9.60	3.30	3.90	3.68
27-4-85	1.05	1.20	4.05	3.00
4-5-85	1.05	1.20	2.10	1.50
16-5-85	1.05	1.05	2.55	1.50
22-5-85	1.85	3.15	1.20	2.18
29-5-85	1.78	1.80	1.20	1.28
5-6-85	1.55	2.40	2.10	1.65
15-6-85	1.25	1.5	1.35	1.65
21-6-85	1.30	1.80	2.10	1.65
17-7-85	0.90	1.05	0.90	1.05
24-7-85	1.05	1.05	0.90	0.98
31-7-85	1.30	1.05	1.05	1.05
23-8-85	0.87	0.34	0.90	0.81
2-9-85	0.90	0.90	0.90	0.87
9-9-85	0.34	0.66	0.84	0.825
16-9-85	1.27	1.20	1.35	1.29

Date	Karumady	Kar. thodu	Kalathil thodu	Drainage channel
23-9-85	1.26	0.96	1.17	1.07
30-9-85	0.98	1.14	1.17	1.08
8-10-85	1.11	1.17	1.20	1.09
14-10-85	1.13	1.23	1.17	1.16
18-10-85	2.09	1.14	3.78	1.25
26-10-85	0.74	1.17	1.20	1.16
31-10-85	1.29	1.14	1.17	0.95
6-11-85	0.24	0.30	0.15	0.120
13-11-85	0.32	0.15	0.40	0.20
20-11-85	0.39	0.27	0.58	0.39
28-11-85	0.44	1.56	1.50	1.47
6-12-85	2.79	2.25	1.89	2.19
11-12-85	1.27	2.22	2.07	2.07
18-12-85	1.24	2.90	0.74	2.28
27-12-85	0.50	1.34	1.08	2.01
1-1-86	0.42	2.64	1.89	1.58
8-1-86	0.38	0.19	1.11	0.56
15-1-86	0.32	1.50	0.69	1.51
30-1-86	0.25	0.39	0.57	0.91
6-2-86	0.53	0.53	1.44	0.81
13-2-86	0.18	0.33	0.27	0.65
19-2-86	0.13	0.19	0.39	0.69
27-2-86	0.17	0.14	0.28	0.19
6-3-86	0.20	0.48	0.39	1.35
13-3-86	0.16	0.28	0.22	1.29
20-3-86	0.59	0.66	0.35	1.61
26-3-86	3.13	3.40	0.41	2.75

Figure 1(1)

Periodic changes in pH of water in different water bodies wrt time
Karumady thodu and Karithodu

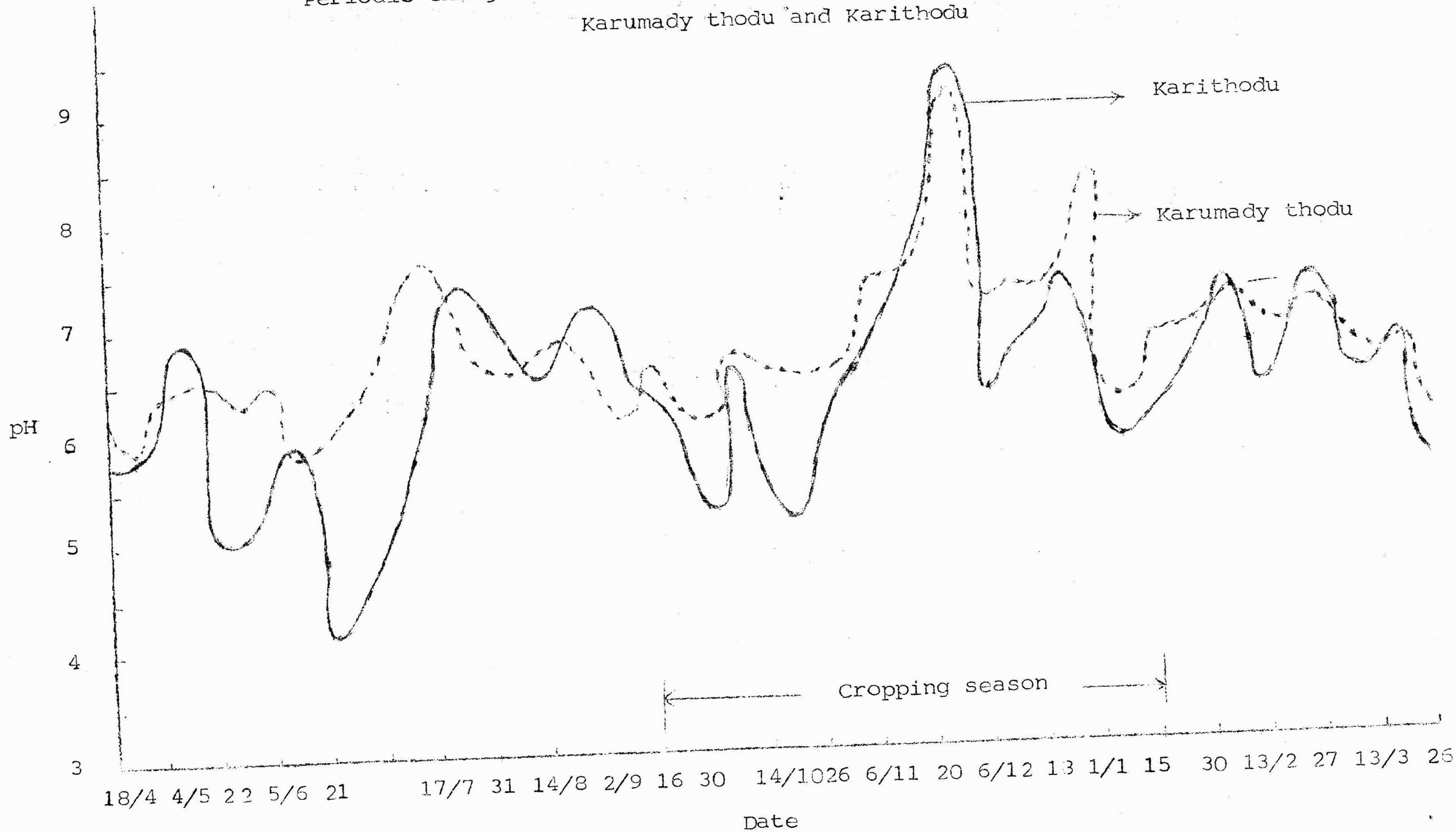


Figure 1(2)

Periodic changes in pH of water in different water bodies w.r.t time - Kalathil thodu and Drainage channel

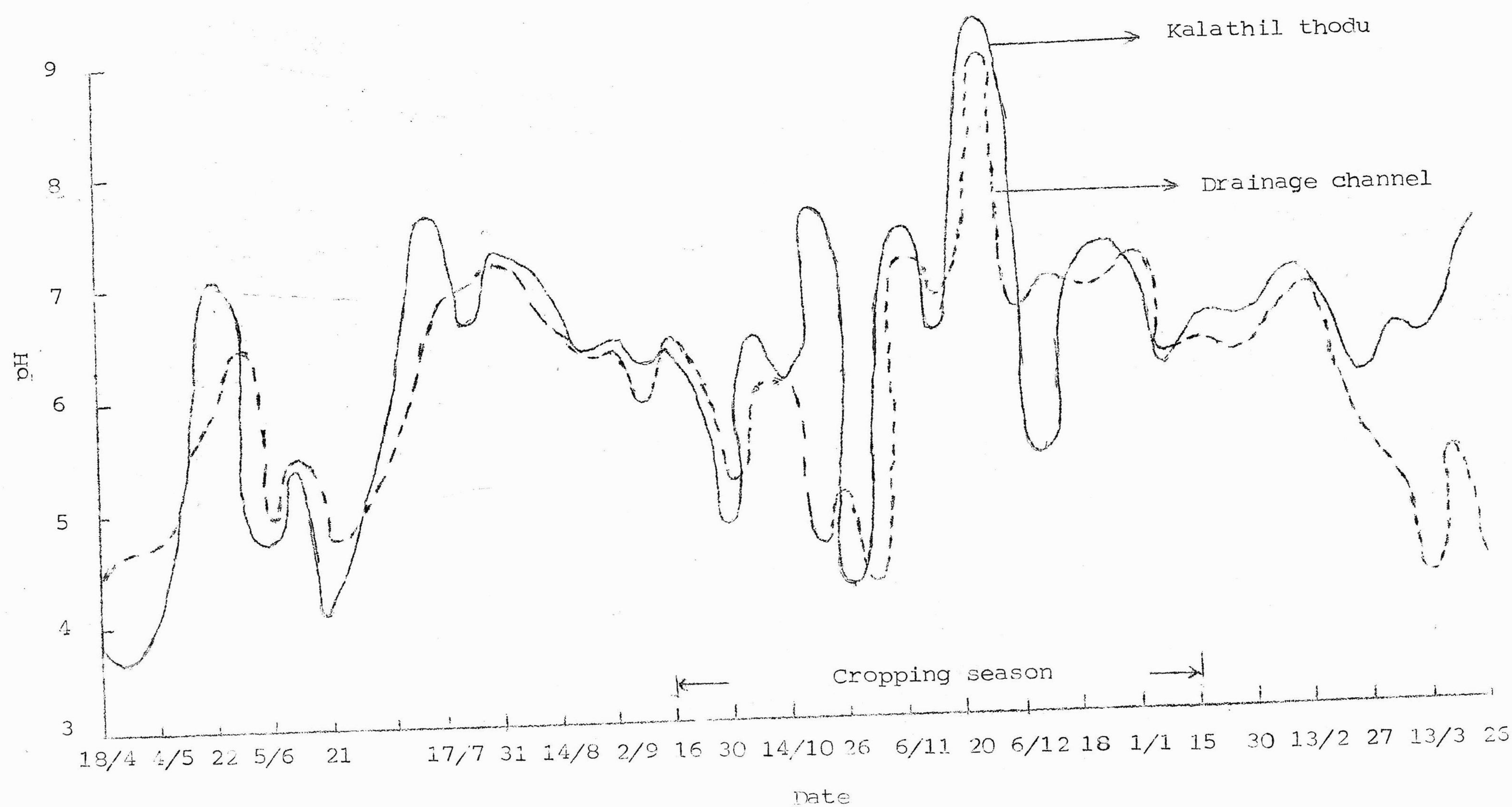


Figure 1(3)

Periodic changes in EC of water indifferent water bodies wrt time -
Karumadythodu and Karithodu

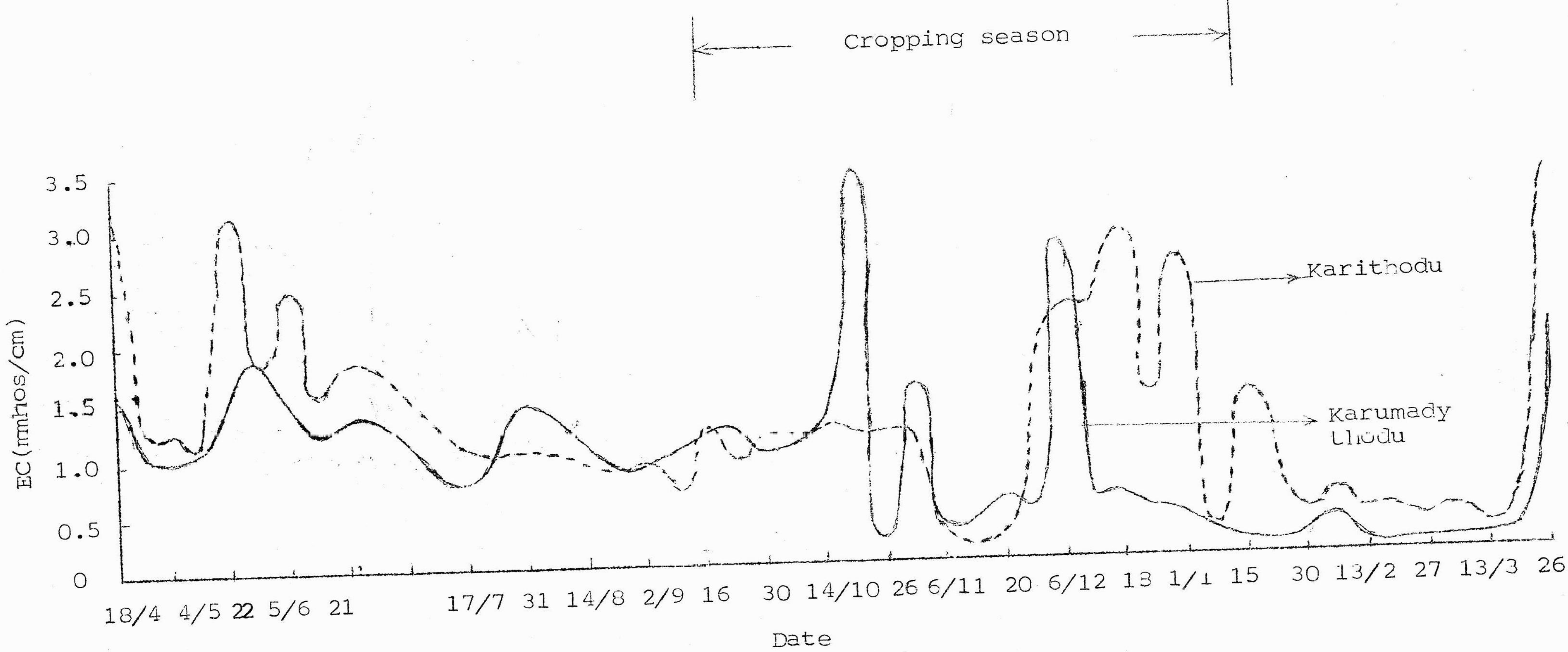
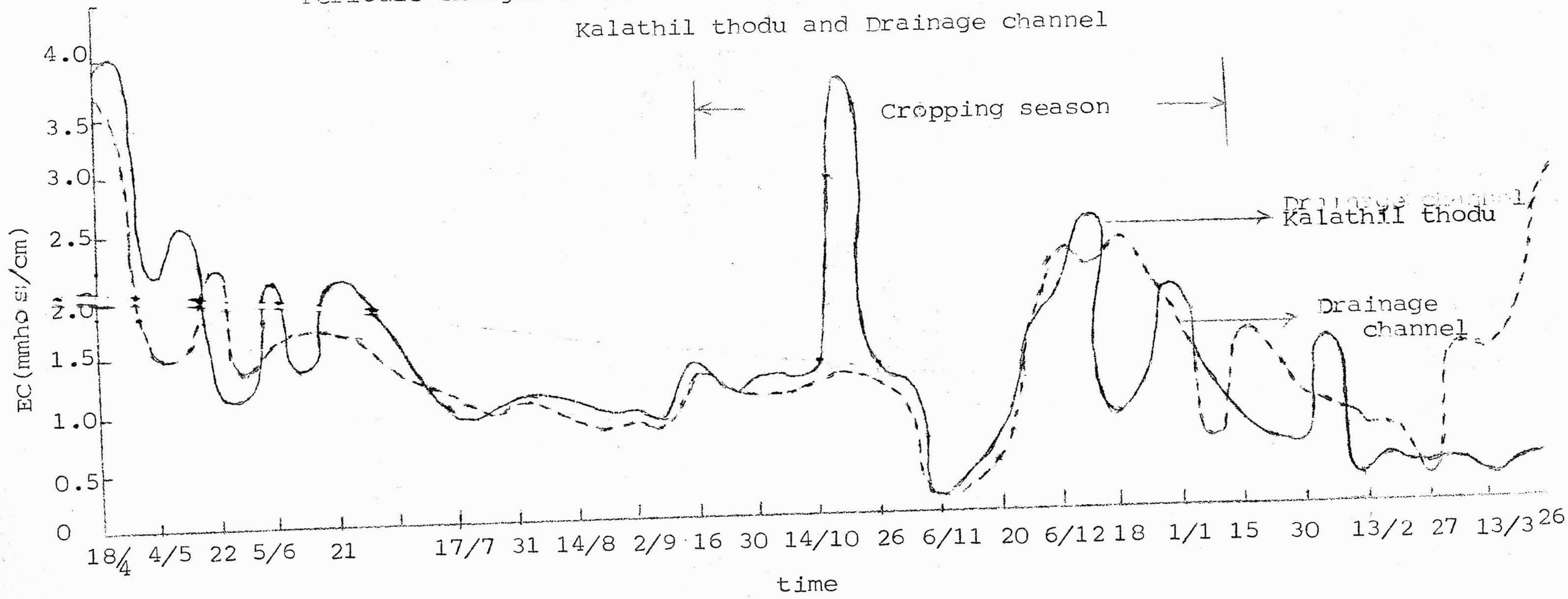


Figure 1(4)

Periodic changes in EC of water in different water bodies wrt time - Kalathil thodu and Drainage channel



field itself. They were then analysed for the pH and EC values, the data of which are presented in table 1(i) and 1(2). The graphical representation of the data is shown in fig.I(1) to I(4). The pH values fluctuated between 5.5 to 7.5 and at times crossed these limits. The pH conditions during this cropping season were better than the previous years and has reflected in the overall yield obtained from the project area. The heavy rains occured from late June to middle September has improved the soil conditions by way of leaching the acidity of the soil. The EC values fluctuated between 0.5 to 2.5 mmhos/cm while occassionally they went beyond these limits. The EC of the drainage channel was found to follow the same fluctuations of that of the outside water bodies. This could be because of the good leaching occured during the heavy rains prior to the cropping season. Flooding the field prior to the cropping season can provide better soil conditions for crop growth in Kari lands.

RESEARCH PROJECT NO.2

Title of the Project : Preparation of water table contour map and hydraulic map of the project area.

2. Title of the Problem : Seasonal fluctuations of ground water table with reference to surface water level and characterisation of aquifer in the project area "Kavil Thekkumpuram Padasekharam".

3. Objectives

a) Study on the seasonal changes in ground water with reference to surface water movement in water ways outside.

b) Seasonal changes on the level and movement of water in waterways.

c) Identification and characterization of aquifer, if any, existing in the project area.

4. Practical Utility

This study will enable to understand the changes that take place in ground water after the layout of the surface and sub surface drainage system.

5. Technical Programme

In order to record ground water table fluctuations, observation wells will be installed at a depth of 1m. using 40mm or 50mm pvc pipes at 100m apart. The pipes will be perforated with 6mm holes at 10 x 5cm. spacing and will be wound with nylon ropes/coir to prevent clogging. Water level in these wells will be recorded at weekly intervals.

6. Observation to be Taken

Water levels in observation wells, waterways and piezometers will be recorded at weekly intervals.

7. Date of Start : June 1982

8. Date of Completion : Till the scheme work is completed

9. Progress of Work

Twenty four observation wells had been installed in three bands to monitor ground water table fluctuations. Since then observation have been recorded on water levels in these tubes at weekly intervals. The locations of the observation wells are shown in fig. 2(1).

The field was flooded from April 85 to Sept.85 and hence no observation was possible during that period. However, readings were recorded from Oct. 85 to Feb. 86. The data is presented in table 2(1). The surface water level in the project area was always lower by 0.5 to 1.0m. than that of the water bodies outside the project area during the cropping season. The movement of groundwater with reference to the water level of the surrounding water body is graphically shown through fig. 2(2) and 2(3) for the cropping period. The upward

Figure 2(1)

Location of observation wells in the project area

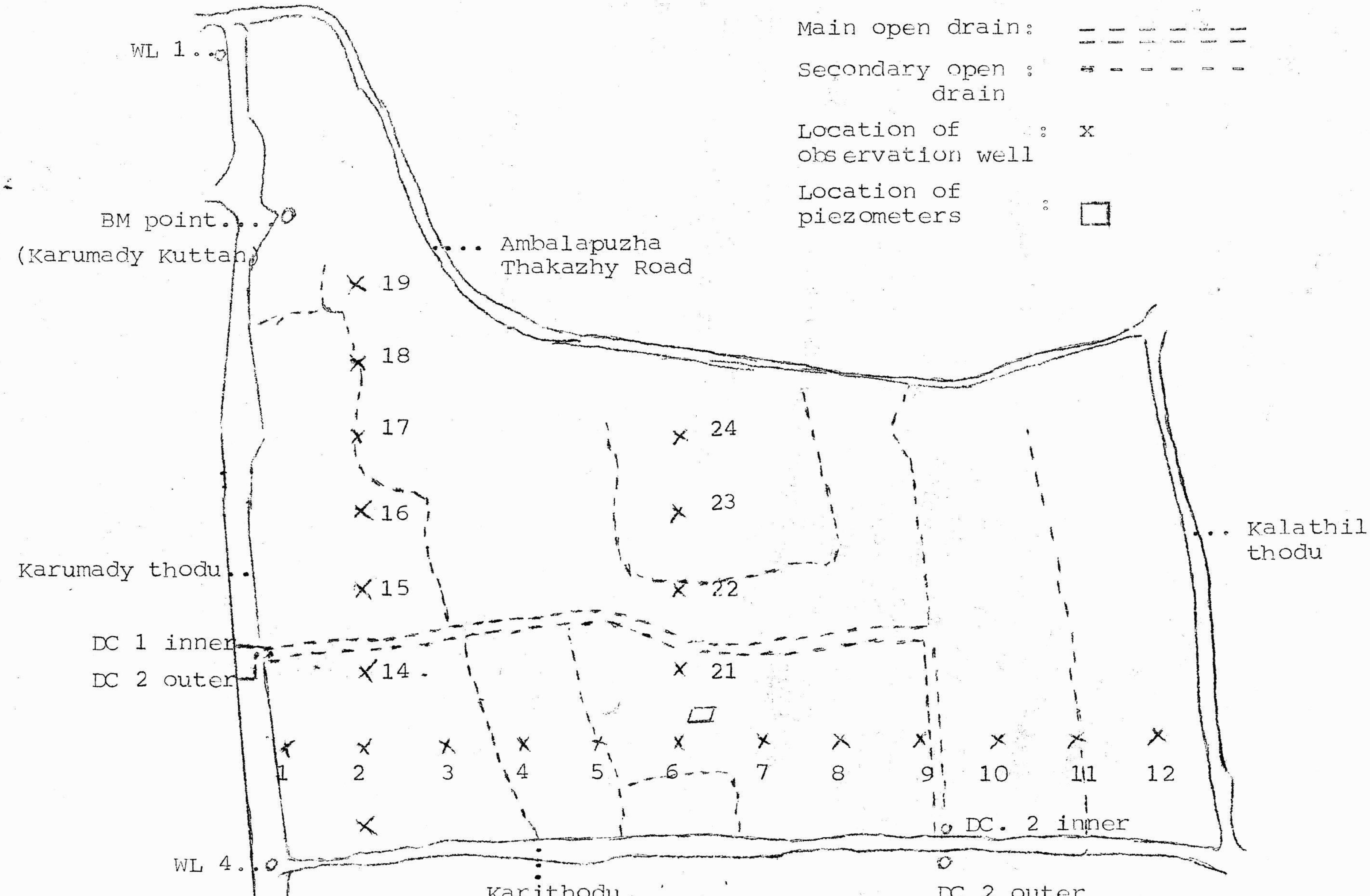


Table 2(1)

Ground Water Table level in the Project Area (as read from Surface Bench Mark Elevation = 1000 cm.)

Month	OBW1	OBW 2	OBW3	OBW4	OBW5	OBW 6	OBW 7	OBW 8	OBW 9	OBW10	OBW11	OBW12	Mean
1	2	3	4	5	6	7	8	9	10	11	12	13	14
April 85							-------- Flood Fallowing --------						
May "							"	"					
June "							"	"					
July "							"	"					
Aug. "							"	"					
Sept. "							"	"					
Oct. "	814.5	817.9	807.0	825.1	810.2	818.0	815.0	813.2	810.3	819.3	Flooded	816.2	815.2
Nov. "	814.4	820.2	811.8	829.3	811.6	824.6	820.6	820.6	812.8	821.9	"	820.9	819.3
Dec. "	819.8	824.4	815.3	813.0	815.8	824.0	823.7	822.7	819.2	821.8	"	825.5	822.0
Jan. '86	812.0	816.4	805.5	821.3	803.5	802.5	804.5	812.0	816.0	814.0	"	819.0	811.5
Feb. "	820.6	822.2	803.8	828.3	813.5	820.5	822.5	822.8	825.0	821.5	"	824.0	820.4
March "	Flooded	Flooded	Flooded	Flooded	Flooded	Flooded	Flooded	Flooded	Flooded	Flooded		Flooded	Flooded
Mean	817.1	820.2	808.7	826.8	810.9	817.9	817.3	818.3	816.7	819.7		821.0	817.7

Month	OBW 20	OBW 6	OBW 21	OBW 22	OBW 23	OBW 24	Mean
April 85	Mud	Flooded	Flooded	Flooded	Flooded	Flooded	
May "	"	"	"	"	"	"	
May "	"	"	"	"	"	"	
June "	"	"	"	"	"	"	
July "	"	"	"	"	"	"	
Aug "	"	"	"	"	"	"	
Sept. "	"	"	"	"	"	"	
Oct. "	"	818.0	Damaged	813.8	813.7	832.5	819.5
Nov. "	"	824.6	"	816.5	817.8	838.9	824.5
Dec. "	"	824.0	"	-	820.2	837.9	827.1
Jan. 86	"	802.5	"	-	800.0	Flooded	801.3
Feb. "	"	820.5	"	-	810.0	836.5	822.3
March "	"	Flooded	"	Flooded	Flooded	Flooded	-
Mean		817.9		815.2	812.3	836.3	-

Month	OBW 13	OBW 2	OBW 14	OBW 16		OBW 17	OBW 18	OBW 19	Mean
April 85					---------- Flood Fallowing ----------				
May "					"	"			
June "					"	"			
July "					"	"			
August "					"	"			
Sept. "					"	"			
Oct. "	816.0	817.9	804.7	Flooded	818.6	809.5	823.7	831.3	817.4
Nov. "	818.9	820.2	806.6	"	813.5	813.4	827.8	829.6	818.6
Dec. "	821.2	824.4	811.7	"	813.8	815.8	833.2	826.0	820.9
Jan. 86	808.5	816.4	811.0	"	806.6	817.0	823.0	813.5	813.7
Feb. "	822.0	822.2	816.8	"	815.9	821.8	831.0	839.5	824.2
March "	Flooded	Flooded	Flooded	"	Flooded	Flooded	Flooded	Flooded	Flooded
Mean	817.3	820.2	810.2		813.7	815.5	827.7	828.0	

Table 2(2)

Surface water level in waterways, which surrounds the project area (As read from surface bench mark elevation = 1000 cm)

Table 2(3)

Surface water level in the Drainage Channel (as read from Bench Mark Elevation =1000cm)

Month	WL_1	WL_4	DC_1	DC_2
April 85	858.5	854.5	855.0	864.0
May "	873.1	866.3	867.5	878.9
June "	882.0	880.7	863.7	877.8
July "	873.5	869.3	872.8	886.0
Aug. "	881.5	877.5	876.0	890.0
Sept. "	864.9	860.6	834.8	849.0
Oct. "	877.8	872.9	792.0	807.8
Nov. "	889.4	883.9	796.5	810.1
Dec. "	883.1	878.5	808.5	819.8
Jan. 86	873.6	869.9	790.0	804.9
Feb. "	859.8	854.8	819.8	831.8
March "	852.4	847.6	837.3	846.5
Mean	872.44	868.04	834.9	847.22

Figure 2(2)

Movement of Ground water table in the Project area w.r.t time and surrounding water body level (Karumadythodu)

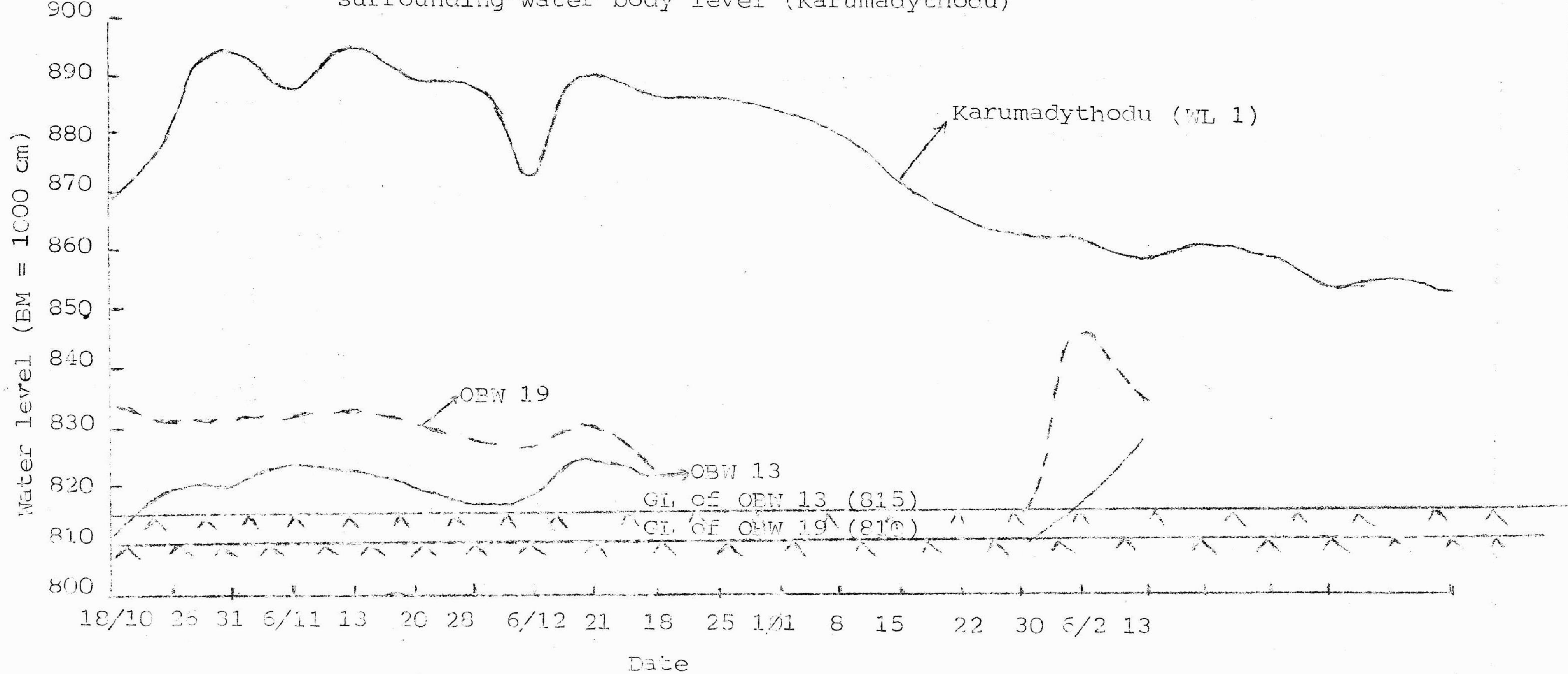
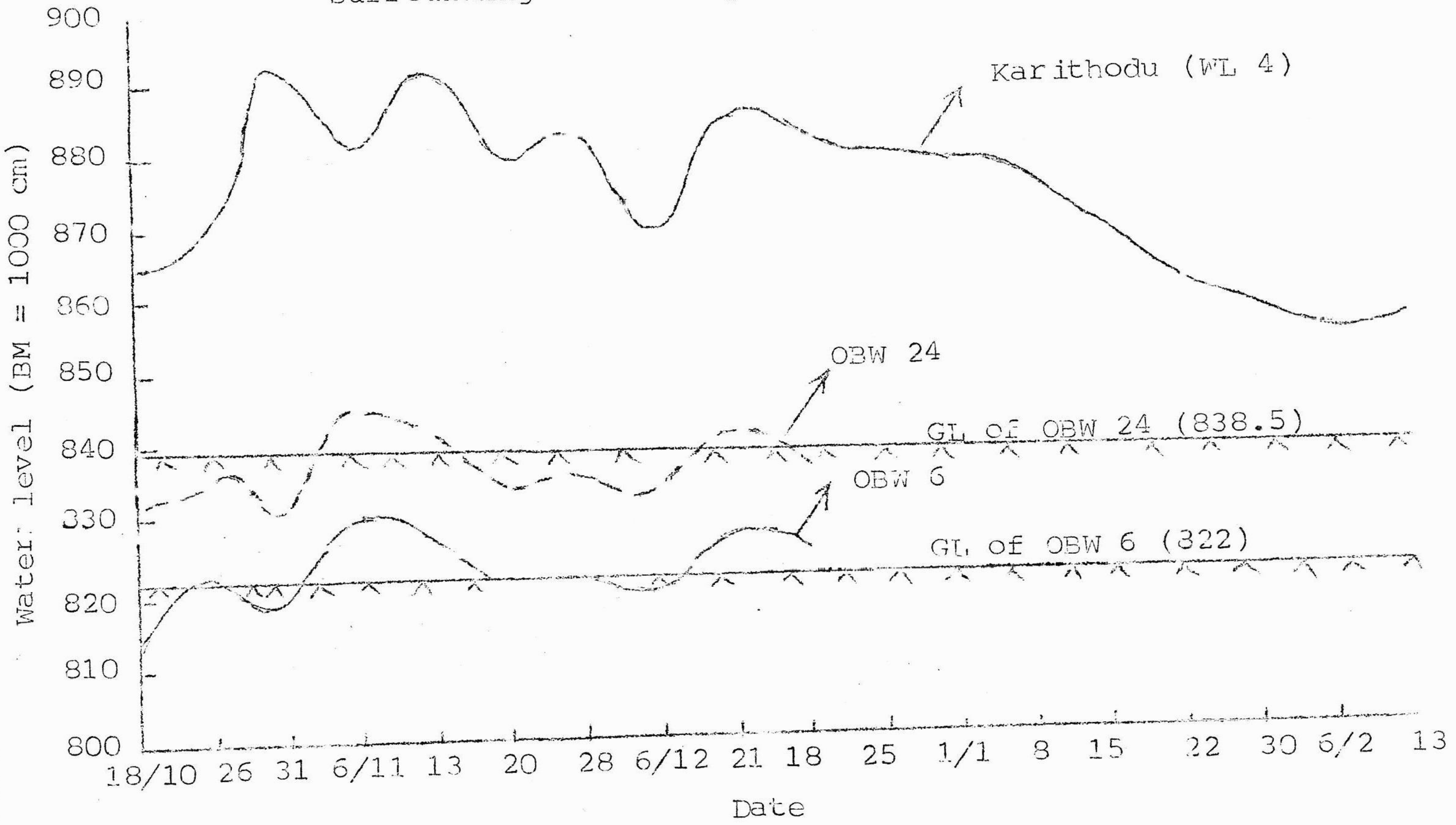


Figure 2(3)

Movement of ground water table in the project area wrt time and surrounding water body level (Karithodu)



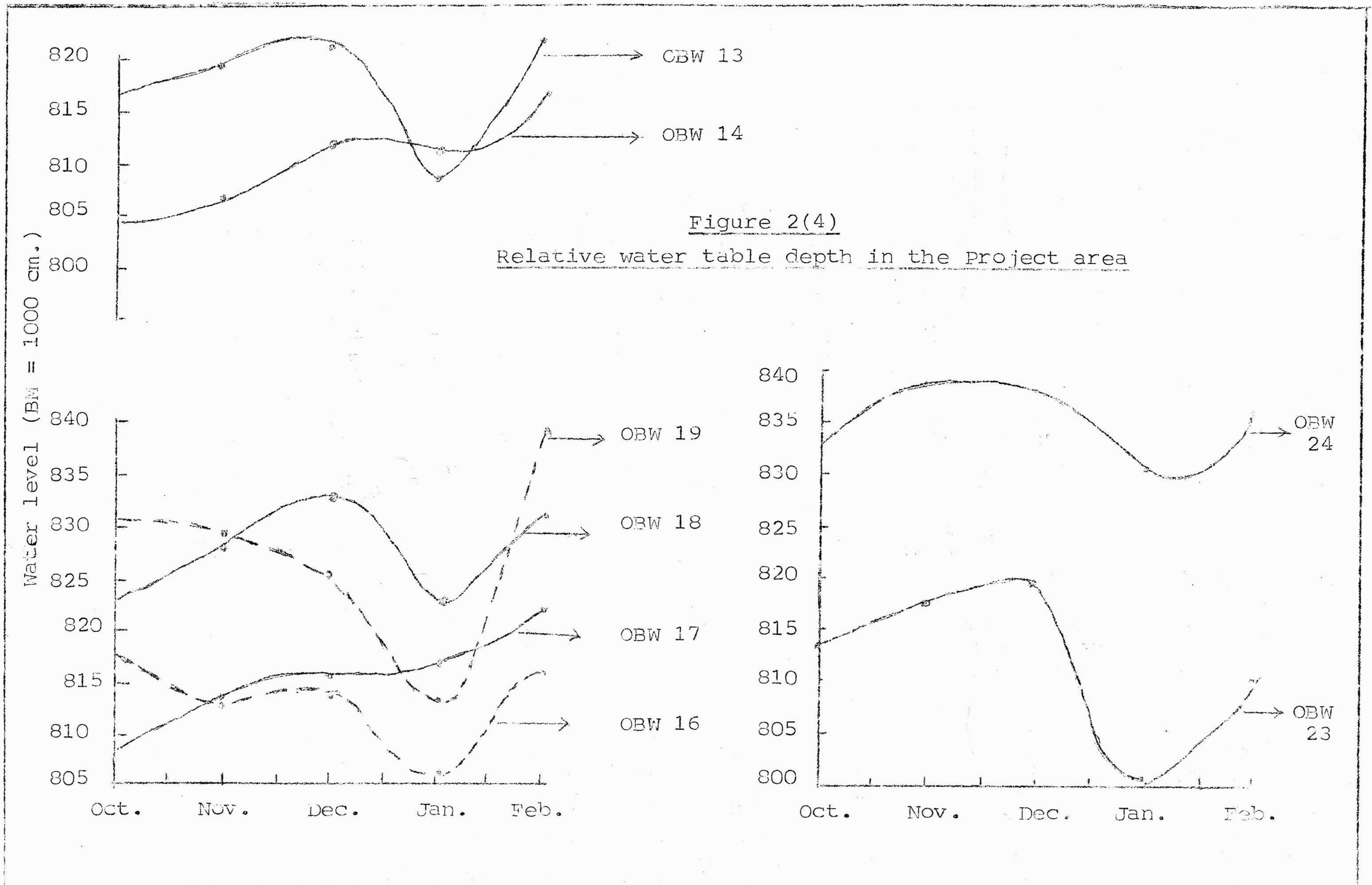


Figure 2(4)

Relative water table depth in the Project area movement of water in the soil due to the hydrostatic pressure exerted by the high water level of the outside water bodies could not be quantified because of the intermittent flooding and dewatering of the field practiced by the farmers for leaching the field during the cropping season. Thus, the contribution to the groundwater by the components of the flooding water and the contribution by the hydrostatic pressure tend to make the water level in the observation wells to an equilibrium with the water level in the field. Hence, a definite pattern of sub-surface water movement in the project area could not be traced. However, it was noticed that the water levels in the observation wells were higher as the distance of these wells increased from the main drainage channels. The above facts can be easily visualised from fig 2(4). The monthly average values of water table elevations are given in table 2(2) to 2(3).

RESEARCH PROJECT NO. 3a

1. Title of the Project : Development of a suitable technology for the sub-surface drainage system in the Kari lands of Kuttanad.

2. Title of the Problem : Assessment of hydraulic properties of the tile drainage system.

3. Objectives

   a) To estimate different parameters of hydraulics of the tile drainage system in Kari lands.

   b) To evaluate the performance of tile drainage system in the project area.

   c) To collect information to develop a viable technology for the sub surface drainage system in the project area.

4. Practical Utility

   This is the basic study for gathering all parameters of hydraulics of tile drainage system. The information collected and compiled can be utilized for deriving a suitable technology for sub-surface drainage system in Kari lands. Further, this will serve as the basic data for further field experimentation on tile drainage.

5. Technical Programme

Considering the locations and availability of farmers' field for *in situ* experimentation, it has been planned to lay 9 lines of lateral tile drains. The first six lines will be at 15m. apart (15m. spacing) and the remaining at 30m. apart. The first five lines will be of 75m. long and the rest 100m. each. The initial line designated as $1B_{15}$ will be a buffer line and so are the 6th and 9th designated as $6B_{15/30}$ and $9B_{30}$ respectively. The 2nd, 3rd, 4th and 5th lines designated as $2E_{15}$, $3E_{15}$, $4E_{15}$, $5E_{15}$ are the experimental lines of 15m. spacing. The 7th and 8th lines designated as $7E_{30}$ and $8E_{30}$ are also the experimental lines for 30m. spacing. Further replication for lateral drains of 30m. spacing or some other else cannot be planned because of the geometry of the location.

All lateral drains will run at a slope of 0.2% and at an average depth of 0.875m. The drains will be provided with a sand filter of an average thickness of 10-15 cms all around the drain. All lateral drains will open into collection drums separately. The drums will be inter connected by collector drains (PVC pipes) of 110/160mm. dia laid at 0.4% slope and this collector drain will drain into a sump from where the drainage water will be pumped out into the adjoining canal using a suitable pump.

The tile drain is of baked clay, 0.6m. long, with bell mouth at one end (125 mm. outer dia and 100mm. inner dia). They are provided with 15 nos. of 6mm. holes in three bands of 5 holes each, on the one third periphery area.

A series of observation wells will be installed in the field to record subsidence of groundwater.

6. Observations to be Recorded

a) Rate of discharge of draining water of the individual drains

c) Time elapsed for achieving steady state condition of ground water.

d) Computation of h_e, h_{tot}, K of soil, q, effective porosity (P), drainage intensity factor (a), transmissivity (t).

e) Maping of water table

f) Graphical representations (i) q vs t, h vs t, q vs h

$\frac{q}{h}$ vs h.

7. Date of Start : December 1984

8. Date of Completion : Till the scheme ends

9. Progress of Work

A suitable location was first selected in the project area 'Kavil Thekkumpuram Padasekharam' for conducting the above experiment. The representative area is of about 2.5 ha. The area was then subjected to compass survey and the alignment of tile drains, collector drain and sump etc. were demarked. The lay our of the drains is shown in fig.3(1).

Laying of Tile Drains

It was planned to lay 9 lines of lateral drains out of which 5 lines are of 75m. long and four lines of 100m. each, considering the geometry and availability of the land. Lines were marked on the field and excavations done as per specifications. The trench cross sections at initial and final points are shown in fig 3(2). The trench elevations at zero length and 75m. length of 75m. lines were fixed at 7.435 m and 7.285m. respectively, thereby giving a slope of 0.2%. The trench elevations at zero length and 100m. length of 100m. lines were fixed at 7.485 and 7.285 respectively, thereby giving a slope of 0.2% to them also. After giving a final levelling to the trench bottom, river sand was spread to a 10cm. thickness all along the trench bottom. Levels were taken at frequent intervals to see that the slope was maintained throughout. After spreading the filter, tiles drains of baked clay, 60cm. long, with bell mouth at one end (125mm. outer dia and

100mm. inner dia) provided with 15 nos. of 6mm. holes in three bands of 5 holes each, on the 1/3rd periphery area were laid with the tail of one into the bell mouth of the other. The bell mouth of the first drain was covered with gunny bag to prevent entry of soil into it. A close watch with the dumpy level was done throughout the laying process to ascertain that the correct slope was maintained. After laying the tile drains, filter was spread again over the drains to approximately a thickness of 8cm. as shown in fig. 3(2). The trench was then back filled. Nine such lines were laid as above with the first five lines having 75m. length and the rest four lines with 100m. length. The lines $1B_{15}$, $6B_{15/30}$ and $9B_{30}$ will serve as buffer lines while the rest as experimental lines. The laying of all the drains were done in such a way that their outlets are at same elevations.

Laying of Collector Drain

The collector drain was laid in a line perpendicular the drain lines. The trench was excavated and a 0.4% slope was given for the collector pipes. Based on the design calculations and the availability of pipes in the market, 110mm. pipes were used for the first 60m. and 160mm. pipes were used for the rest of the length.

Installation of Collection Drums

Empty Bitumen barrels (50cm. dia) were used as collection drums. All the tile drains (bottom) enter into the collection drum at an elevation 7.385. The point at which the collector enters at different drain line ends differ and is a function of the collector line slope. Figure 3(3) illustrates the entry of the drain line pipe and the collector line pipes into the collection drum at $5E_{15}$. Table 3(1) shows the different elevations at the collection drum and fig. 3(4) shows the vertical section of the collector line. The collection drums facilitate the measurement of drainage flow from each tile drain line. After installing the collection drums at pre-determined

: 37 :

Figure 3(3)

COLLECTION DRUM AT $5E_{15}$

Scale:

Horizontal : 1m = 12cm

Vertical : 1m = 6cm

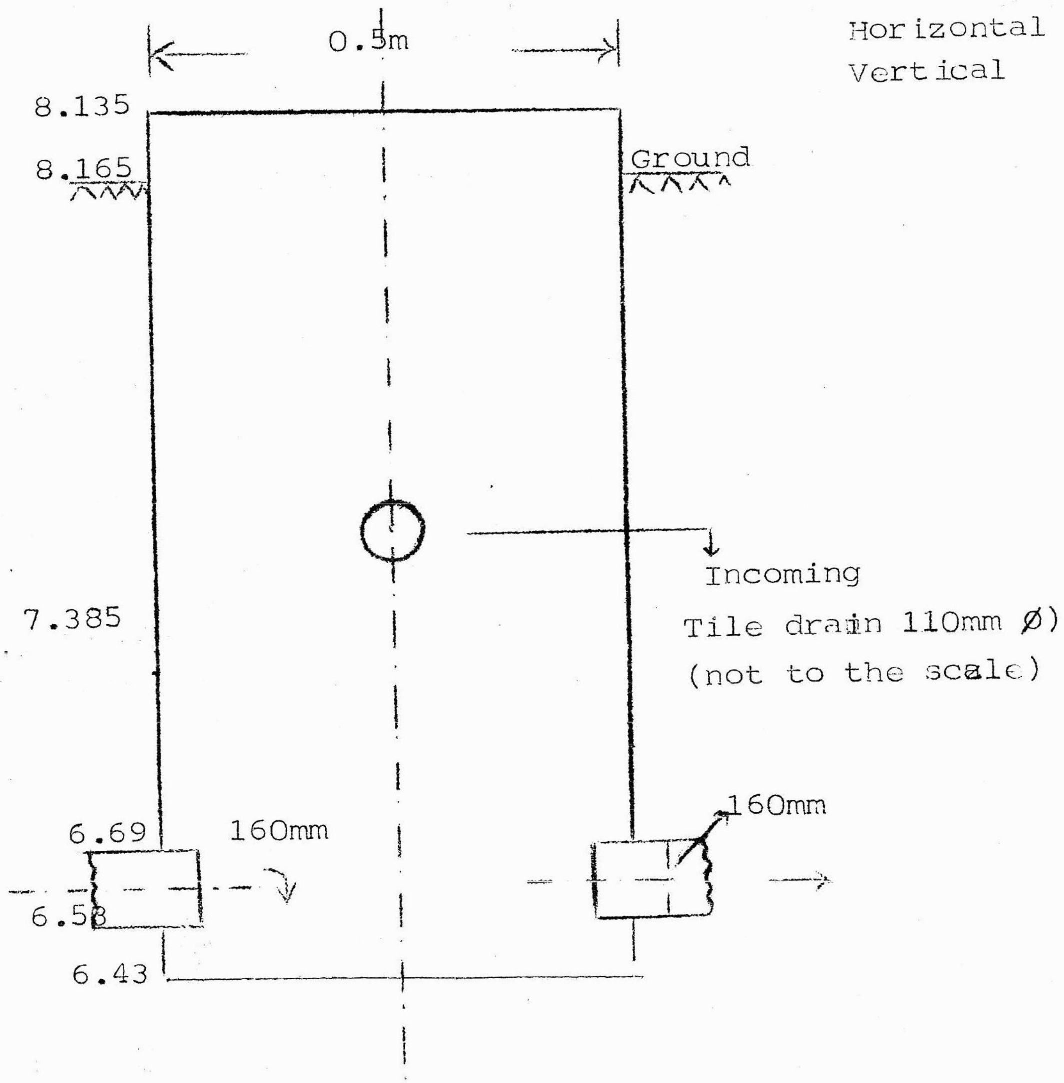
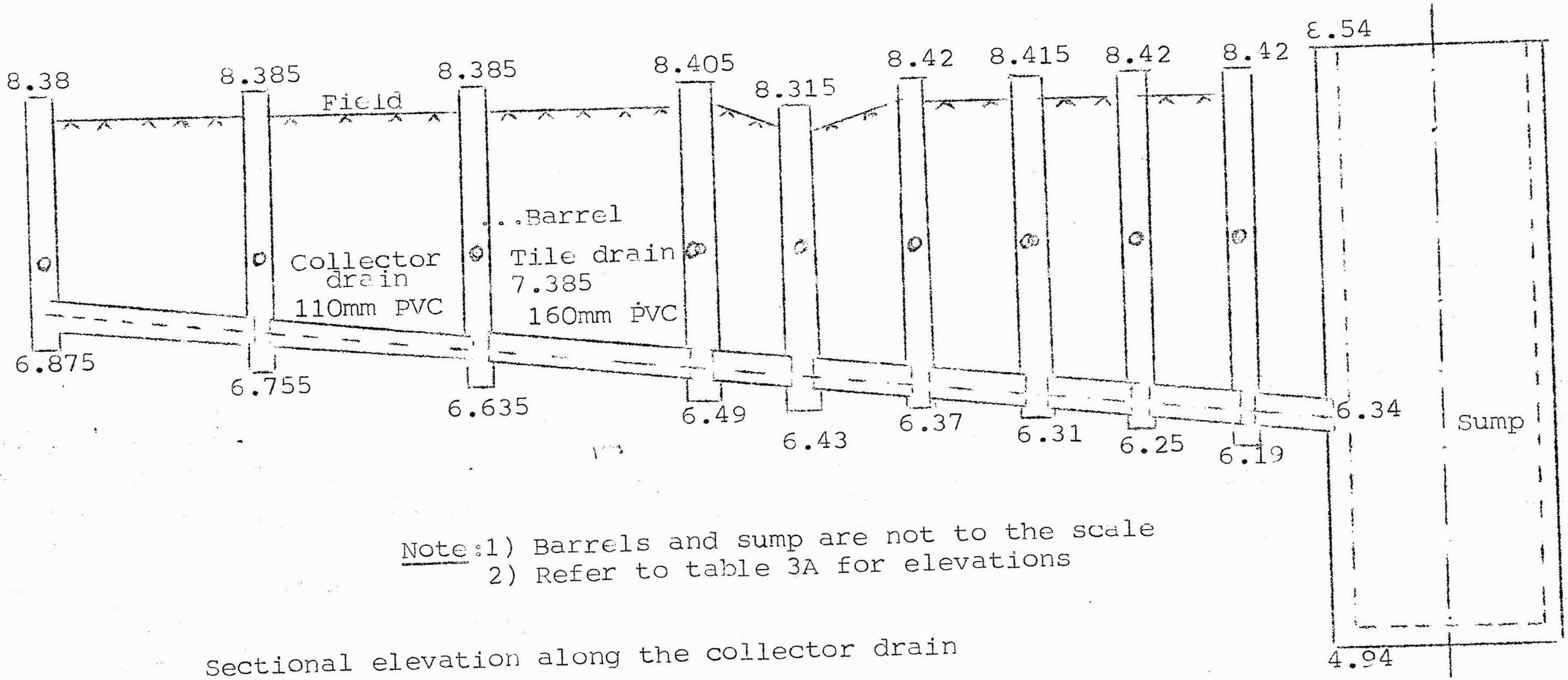


Table 3(1) Elevation on Collector Line

Distance		Collector centre	Collector top	Collector bottom	Barrel bottom	Tile Elevation (bottom)	F.E	Barrel top	Barrel length
0	$9B_{30}$	7.03	7.085	6.975	6.875	7.385	8.23	8.38	1.505
30	$8E_{30}$	6.91	6.965	6.855	6.755	"	8.235	8.385	1.63
60	$7E_{30}$	6.79	6.845/ 6.87	6.735/ 6.71	6.635	"	8.235	8.385	1.75
90	$6B_{15/30}$	6.67	6.75	6.59	6.49	"	8.255	8.405	1.915
105	$5E_{15}$	6.61	6.69	6.53	6.43	"	8.165	8.315	1.885
120	$4E_{15}$	6.55	6.63	6.47	6.37	"	8.27	8.42	2.05
135	$3E_{15}$	6.49	6.57	6.41	6.31	"	8.215	8.415	2.105
150	$2E_{15}$	6.43	6.51	6.35	6.25	"	8.27	8.42	2.17
165	$1B_{15}$	6.37	6.45	6.29	6.19	"	8.27	8.42	2.23



Note: 1) Barrels and sump are not to the scale
2) Refer to table 3A for elevations

Sectional elevation along the collector drain

Figure 3(4)

elevations, the collector pipes and the tile drains were joined to the drum and the trench was back filled.

Drainage Sump Construction

A drainage sump was constructed with a view to collect the drainage flow from the collector drain and to pump it out from there to the adjacent 'Karithodu'. The sump was designed subject to the space limitations available at the site. The collector drain enters the sump at an elevation of 6.34m. The sump was constructed with concrete rings of 110cm. outer dia and 100cm. inner dia with a height of 40cm. Figure 3(5) illustrates the installed sump. The deepest ring acts as a stilling basin (40cm.) and the effective storage depth is 1 metre. A 5 H.P electric motor pump is used to drain the water.

Installation of Observation Wells

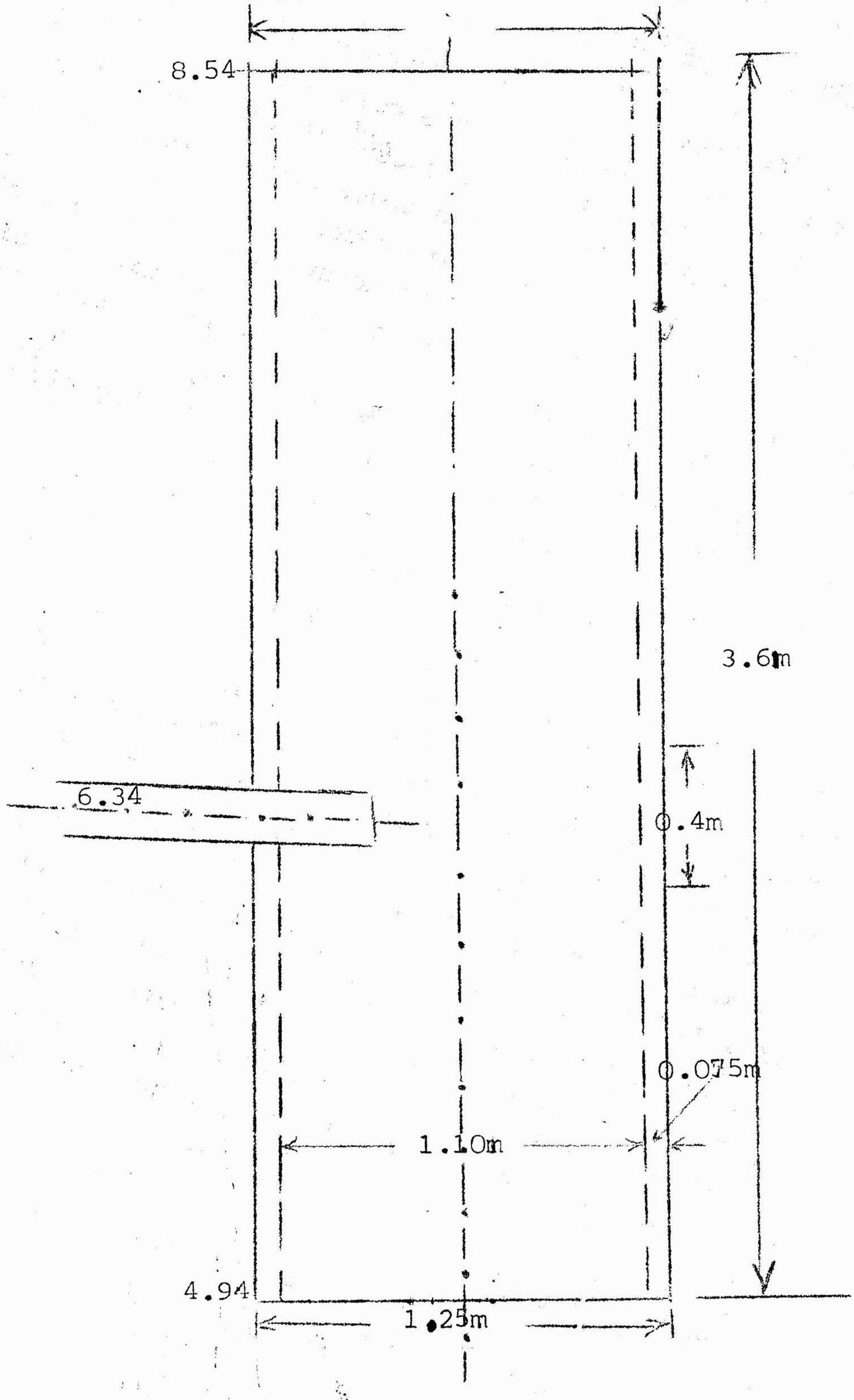
A series of observation wells were installed in the experimental site to record the fluctuations in the water table elevations on the event of drainage. The general pattern of the installation of the observation wells are shown in figure 3(6). They have been spaced perpendicular to the drain at 0.4m. S/8, and S/2 where S is the spacing. Three such lines of observation wells have been installed at L/4, L/2 and $\frac{3}{4}$ L, where L is the length of each drain line. The observation wells have been made with 1.5m. long, 40mm. PVC pipes. Five mm holes with a spacing of 10cm. have been drilled in 6 bands at the bottom 50cm. length and coir was wound around it with the bottom of the tube covered with polythene covering.

Sieve Analysis

Sieve analysis of the river sand and the base material was done in deciding the suitability of the river sand used. Tables 3(2) and 3(3) show the result of the analysis and figure 3(7) shows the grading curves drawn. Spalding (1970) suggested that the most reliable criteria for the design of filter design are those of the United States Waterways Experimental Station. The design criteria

Figure 3(5)

Sectional view of the sump



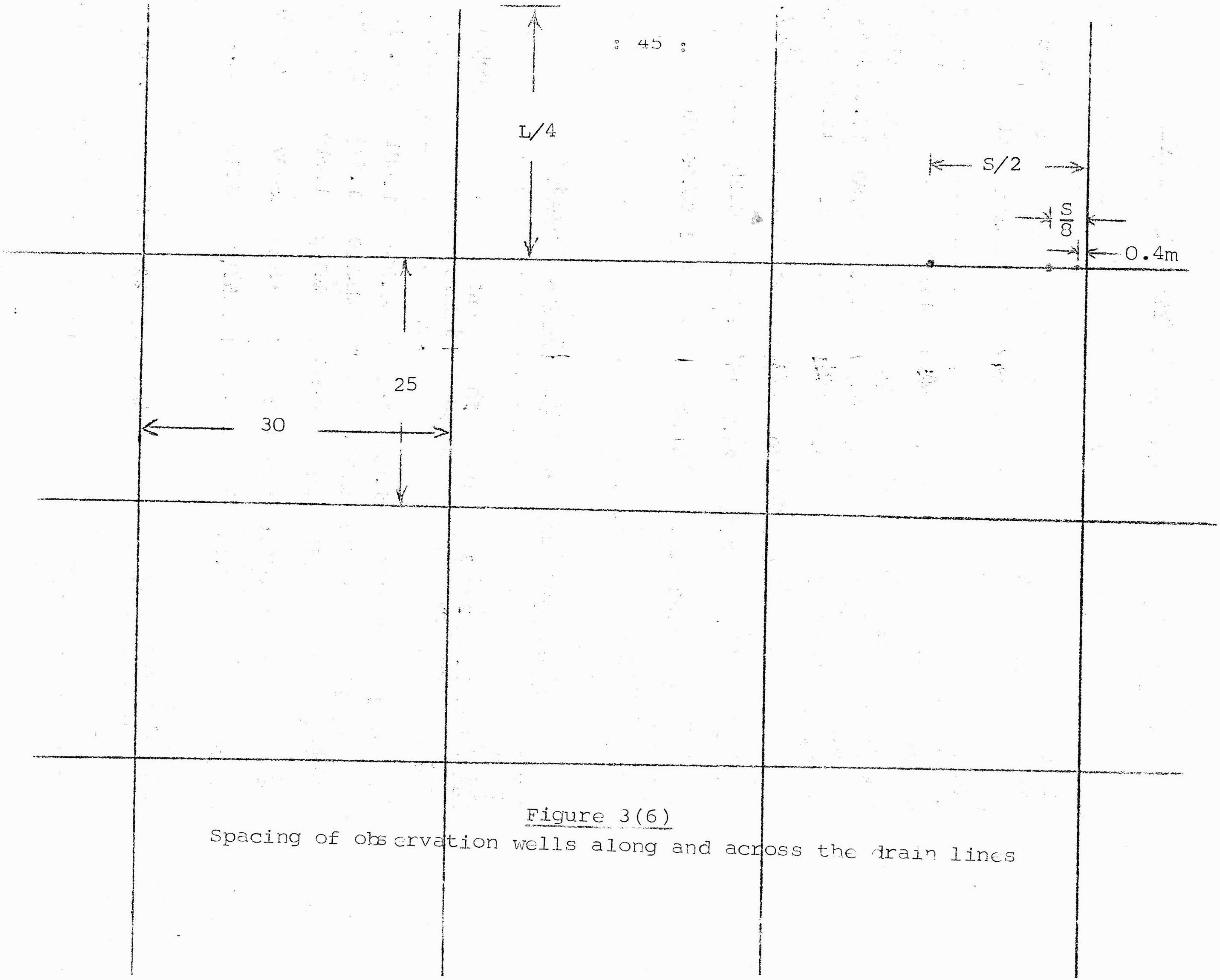


Figure 3(6)
Spacing of observation wells along and across the drain lines

Table 3(2) - Sieve Analysis of River Sand Filter

Sieve size/ wt.re-tained (gm)	5.6 mm	2 mm	1 mm	500 micron	106 micron	45 micron	45 micron	Total
Sample 1	121	207.5	380.5	245.5	457.5	4.25	13.5	1429.75
Sample 2	72.5	214.5	357	199	295.5	2.42	10.58	1151.5
Sample 3	99	229	412.5	265.5	413.5	3.83	18.17	1441.5
Sample 4	69.5	209.75	380.5	231.5	377.5	2.92	12.83	1284.5
Total	362	860.75	1530.5	941.5	1544	13.42	55.08	5307.25
% Retained	6.82	16.22	28.84	17.74	29.09	0.25	1.04	-
Cumulative % retained	6.82	23.04	51.88	69.62	98.71	98.96	100	

Table 3(3) Sieve Analysis of Base Material

Sieve size/wt. retained (gm)	5.6 mm	2 mm	1 mm	500 micron	106 micron	45 micron	45 micron	Total
Sample 1	0	0	0.045	1.875	18.114	0.597	1.681	22.314
Sample 2	0	0	0.066	1.654	19.770	1.519	1.673	24.682
Sample 3	0	0	0.555	1.410	18.871	1.540	1.719	23.595
Total	0	0	0.166	4.939	56.757	3.656	5.073	70.591
% retained	0	0	0.23	7	80.40	5.18	7.19	..
Cumulative% retained	0	0	0.23	7.23	87.63	92.81	100	..

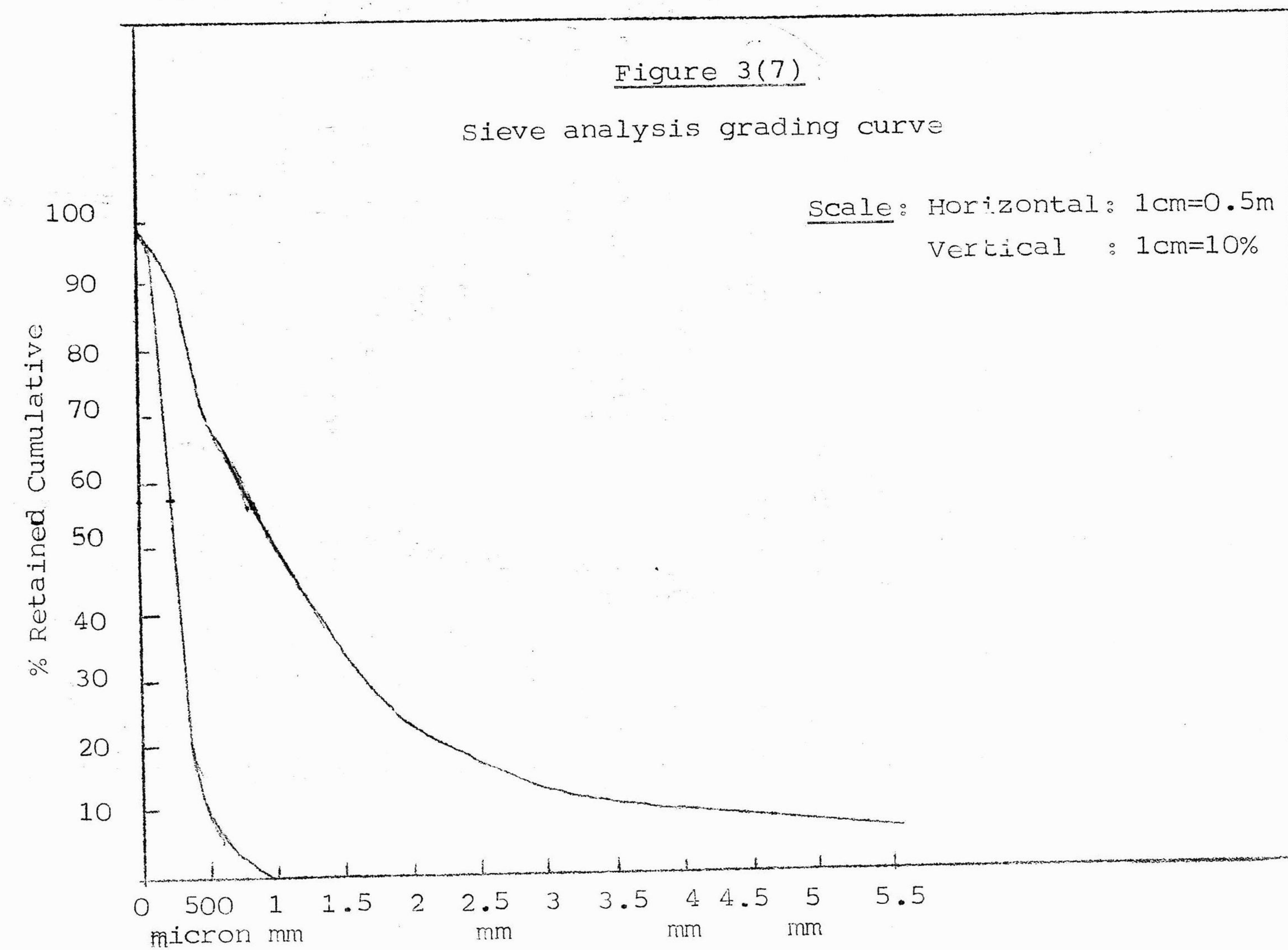


Figure 3(7)
Sieve analysis grading curve
Scale: Horizontal: 1cm=0.5m
Vertical : 1cm=10%
% Retained Cumulative
100
90
80
70
60
50
40
30
20
10
0
500
micron
1
mm
1.5
2
2.5
mm
3
3.5
4
4.5
mm
5
mm
5.5

The design criteria are

$D_{15}F \leq 5\ D_{85}S$ ---- (i)

$D_{15}F \leq 20\ D_{15}S$ ---- (ii)

$D_{50}F \leq 25\ D_{50}S$ ---- (iii)

$D_{50}F \geq 5\ D_{15}S$ ---- (iv) where $D_{15}F$ is the size of particle in filter, 15% passing sieve and $D_{85}S$ is the size of particle in soil, 85% passing sieve.

The first three criteria represent the filtration quality and the last one represents the adequacy of the hydraulic conductivity. The different particle sizes as per the above criteria is given below.

$D_{15}F$	= 0.25 mm	$D_{15}S$	= 0.125 mm
$D_{50}F$	= 1.05 mm	$D_{50}S$	= 0.25 mm
$D_{85}F$	= 2.75 mm	$D_{85}S$	= 0.40 mm

From the above particle sizes it can be seen that all the above criteria have been satisfied and the filter used is adequate in terms of filtration quality and hydraulic conductivity.

Data Processing

Just after the completion of harvest of the paddy crop in the experimental area, continuous drainage pumping started on 21-1-86 which was continued upto 26-1-86. Observations like drainage flow through the tile drains and water table recession in the 122 observation wells were recorded at hourly intervals. The readings interpolated from this data at 5-hour interval are given in appendix I. The above data was then subjected to vigourous analysis for finding the hydraulic conductivity using steady state equations since the water table movement and drain discharge conditions showed a relatively constant behaviour towards the later part of the continuous drainage. The steady state conditions are because of the continuous recharge from the outside water bodies into the experimental area which is peculiar to the Kuttanad conditions.

The analysis was based on Hooghoudt's equation which is

$$q = \frac{8\,Kdh}{s^2} + \frac{4Kh^2}{s^2} \quad \text{where}$$

q = discharge in m/day

d = equivalent depth (m)

K = hydraulic conductivity in m/day

h = hydraulic head in m at mid point of the drains

s = spacing of the drains in m

The above equation when divided by h will give an equation to a straight line which is

$$q/h = \frac{8\,Kd}{s^2} + \frac{4\,Kh}{s^2}$$

where $\frac{4K}{s^2}$ is the slope of the line from where K value can be calculated since spacing is known and $\frac{8\,Kd}{s^2}$ is the intercept from where Kd value and subsequently 'd' value can be calculated.

The observations such as discharge and hydraulic head at mid spacing were drawn against time. The discharge and the hydraulic head at mid spacing of drains were interpolated at 5-hour intervals from the above graph and typical samples are represented through fig. No. 3(8) to 3(11). The discharge versus hydraulic head relationship at corresponding time is also drawn and is shown in fig. 3(12) and 3(13). The q/h versus h relationship almost followed the Hoogoudt's equation and thus the K value and d value were calculated. A typical q/h versus h relationship is shown in fig. 3(14) and 3(15).

The computed values of different parameters are shown in table No. 3(4).

Table 3(4)

Computed values of hydraulic parameters

Parameters	Tile Line					
	$2E_{15}$	$3E_{15}$	$4E_{15}$	$5E_{15}$*	$7E_{15}$	$8E_{30}$
$\frac{4K}{s^2}$	0.0227	0.0292	0.0231	0.0272	0.0054	0.0085
$\frac{8\,Kd}{s^2}$	0.0031	0.0012	0.0023	-0.0039	3.5×10^{-5}	0.0001
K(m/day)	1.275	1.6406	1.3000	1.5312	1.2115	1.9125
Kd(m^2/day)	0.0885	0.0340	0.0633	-0.1106	0.004	0.0107
d(cm)	6.94	2.07	4.86	-7.20	0.33	0.56

* values are not taken for further analysis since d value is minus

Figure 3(8)

Discharge versus time ($3E_{15}$)

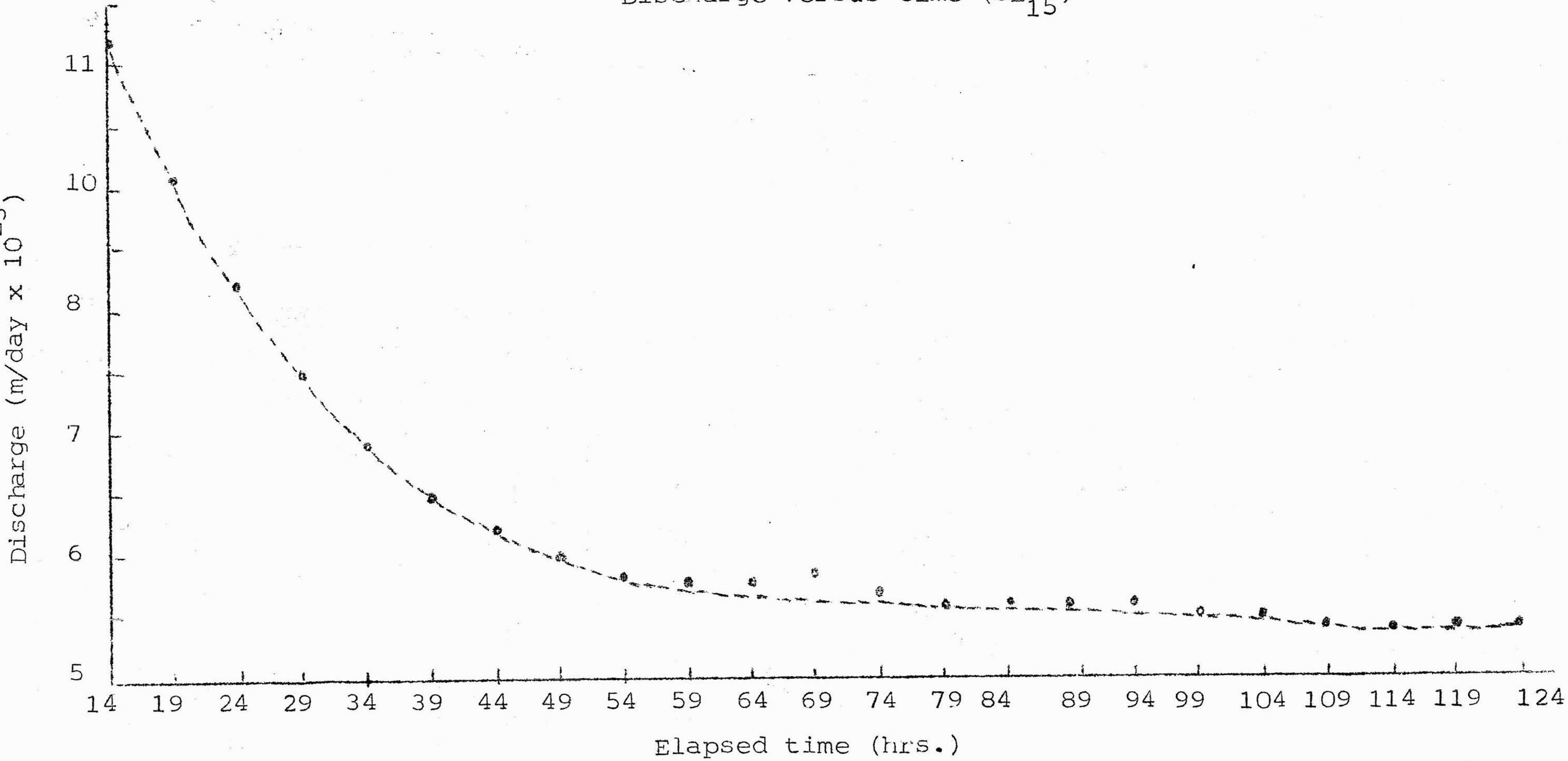
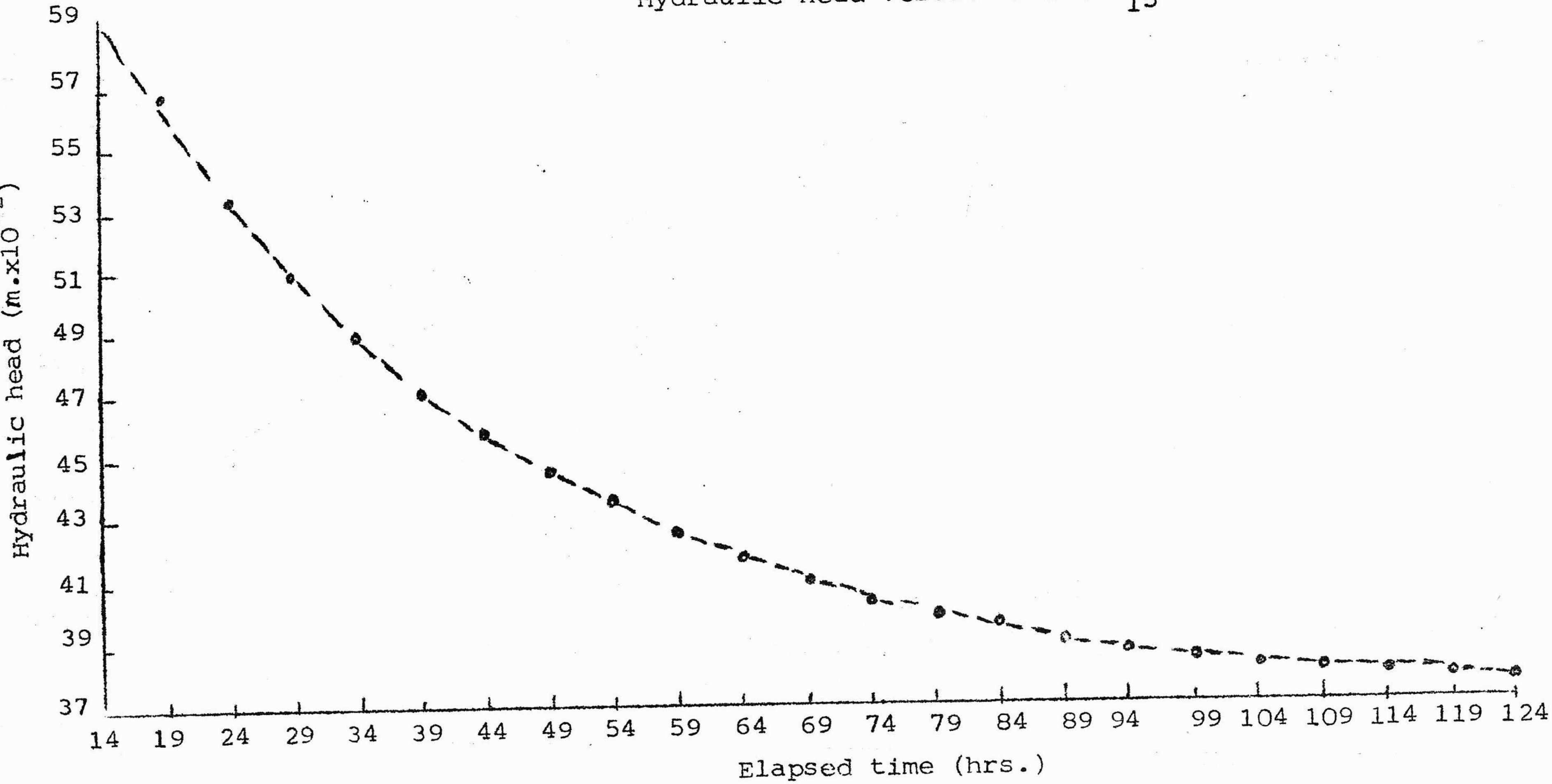


Figure 3(9)

Hydraulic head versus time ($3E_{15}$)



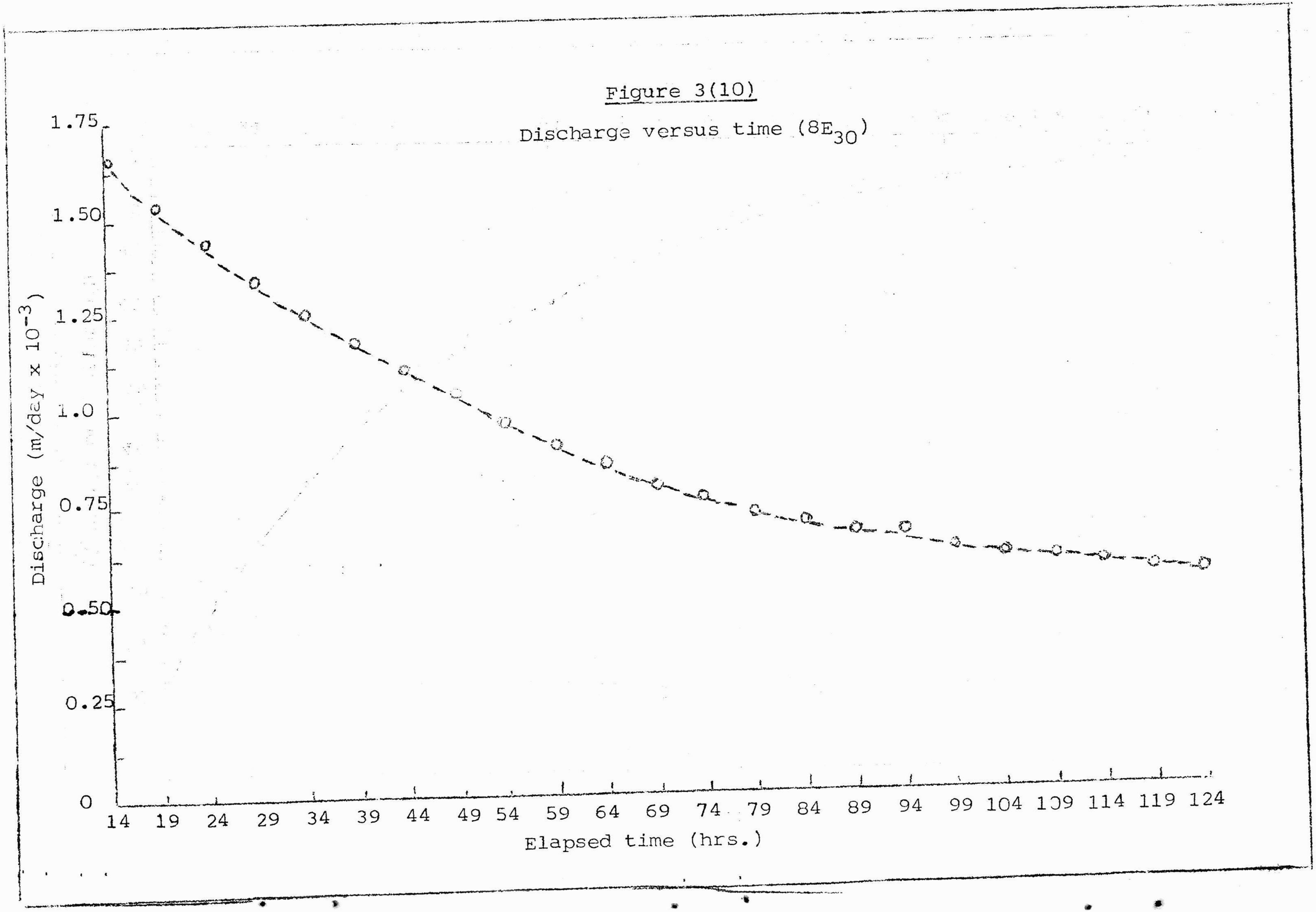


Figure 3(10)
Discharge versus time ($8E_{30}$)
1.75
1.50
1.25
1.0
0.75
0.50
0.25
0
Discharge (m/day x 10^{-3})
14 19 24 29 34 39 44 49 54 59 64 69 74 79 84 89 94 99 104 109 114 119 124
Elapsed time (hrs.)

Figure 3(11)

Hydraulic head versus time ($8E_{30}$)

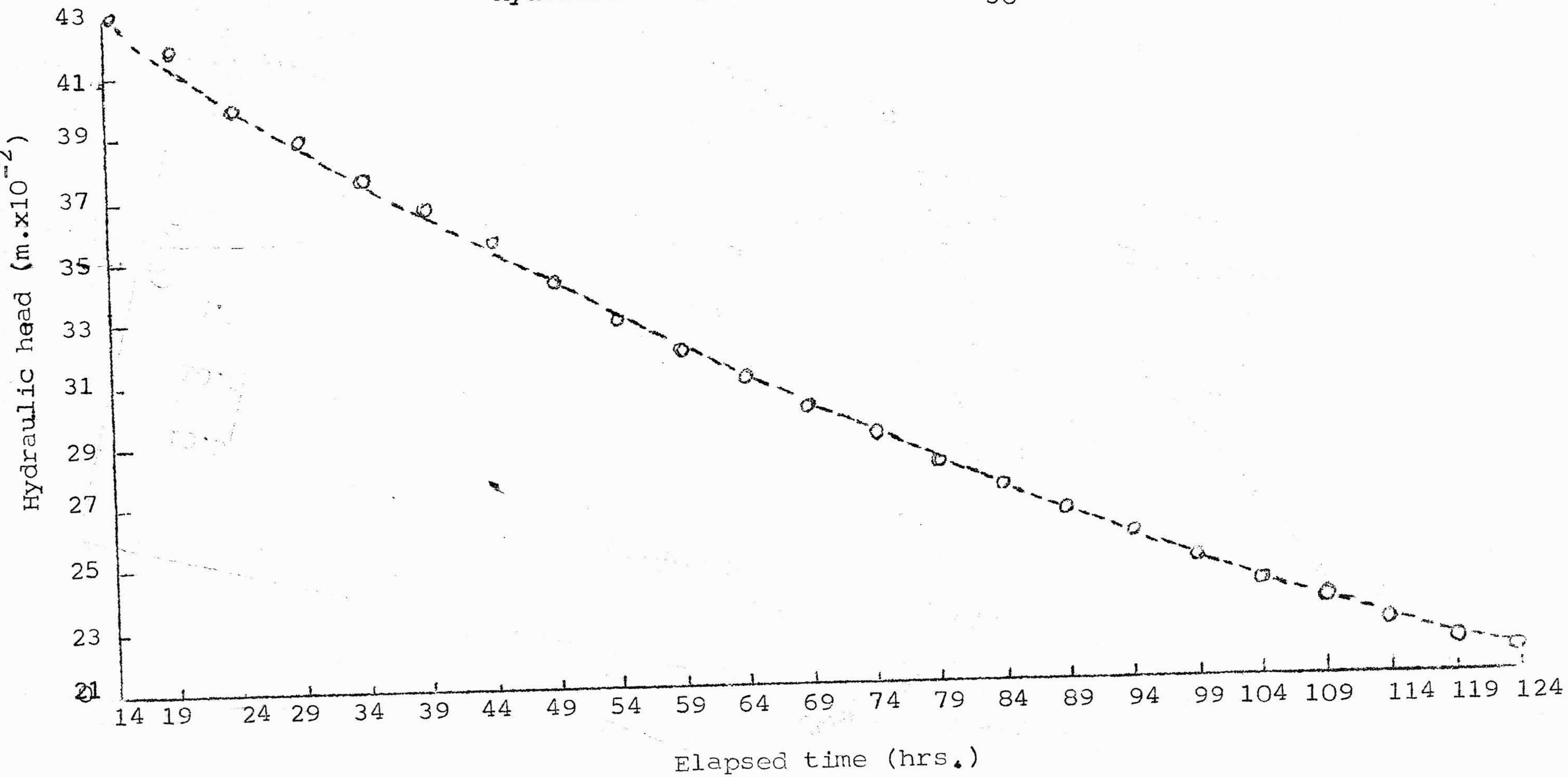
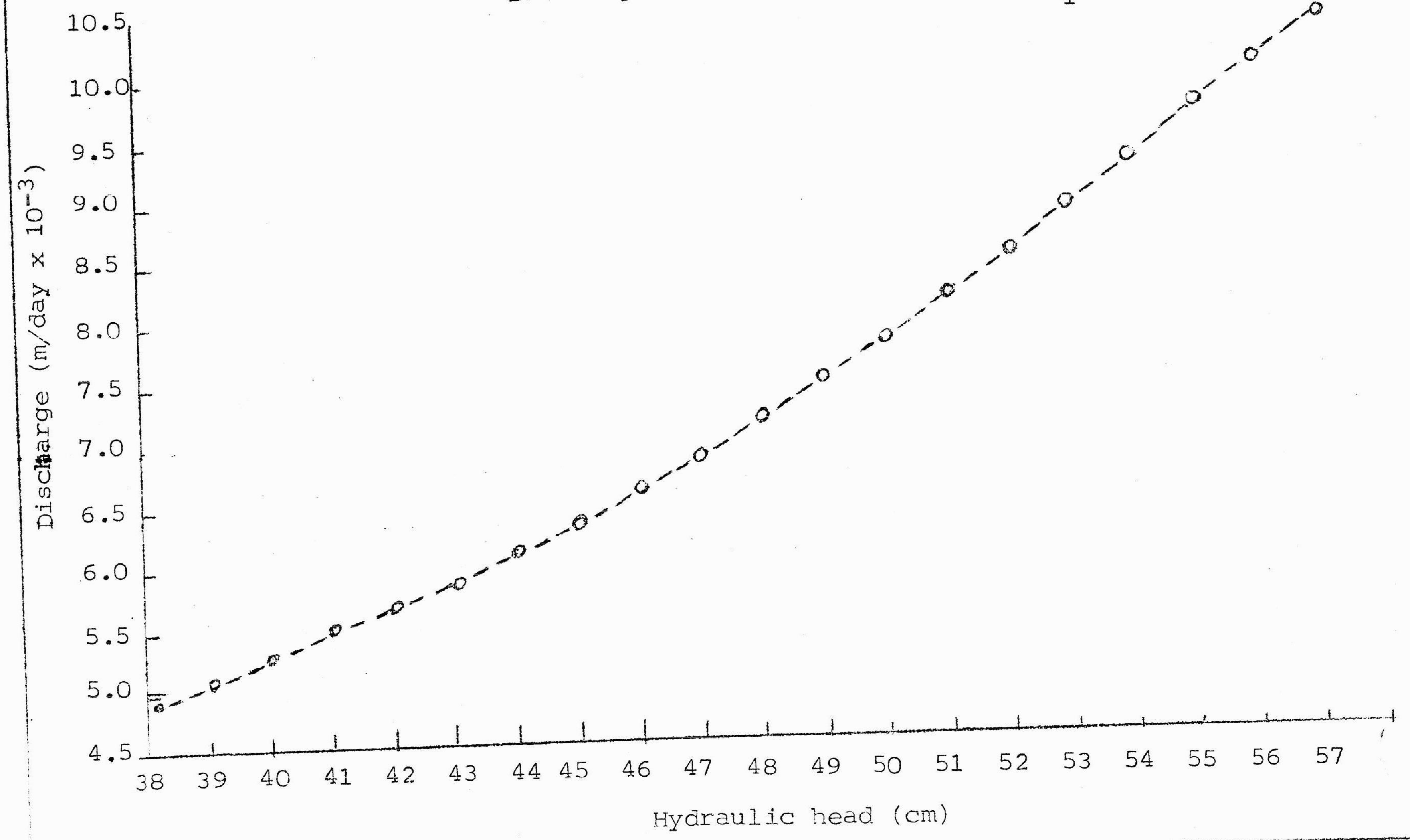


Figure 3(12)

Discharge versus hydraulic head ($3E_{15}$)



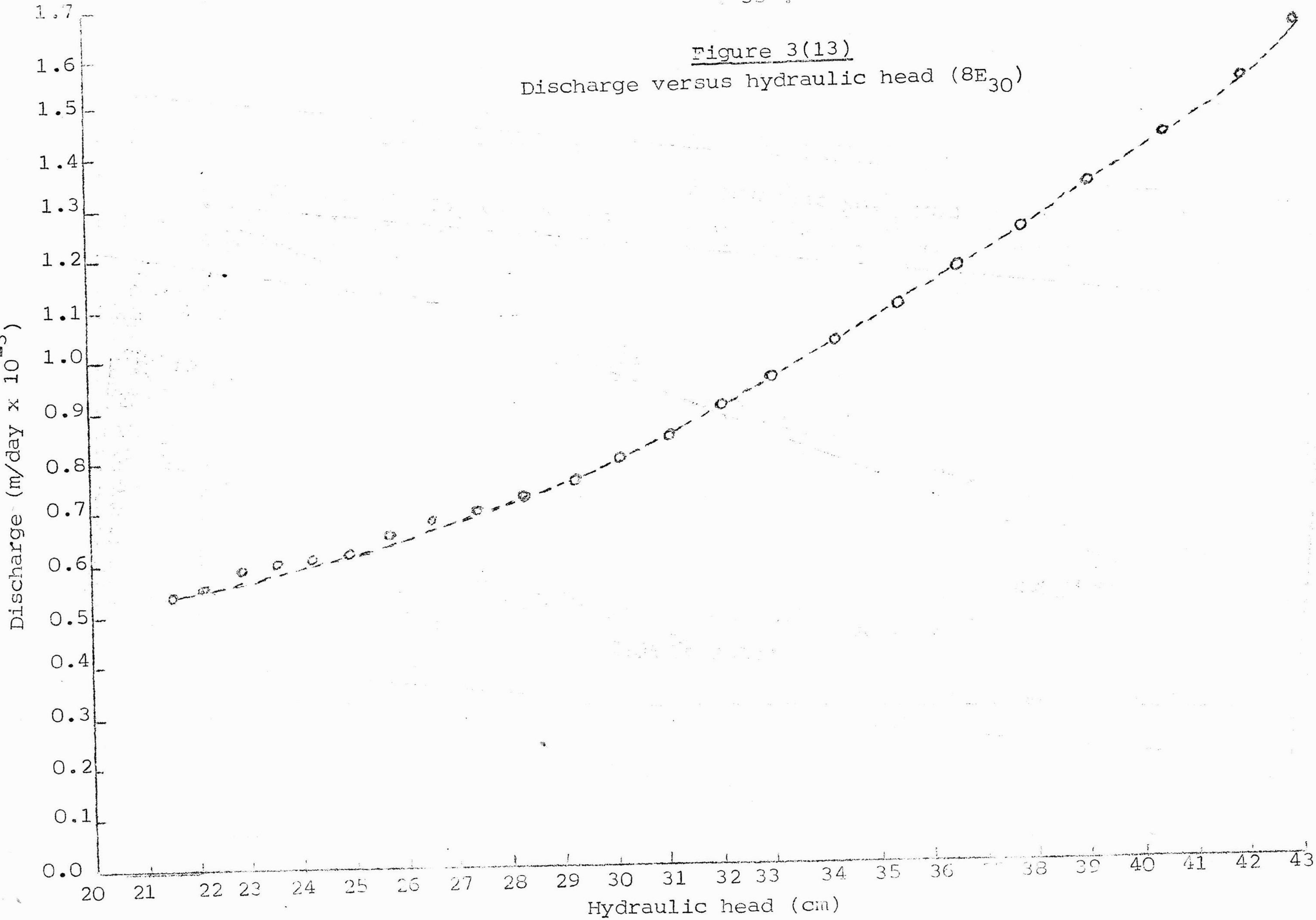


Figure 3(13)
Discharge versus hydraulic head ($8E_{30}$)
Discharge (m/day x 10^{-3})
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
38
39
40
41
42
43
Hydraulic head (cm)

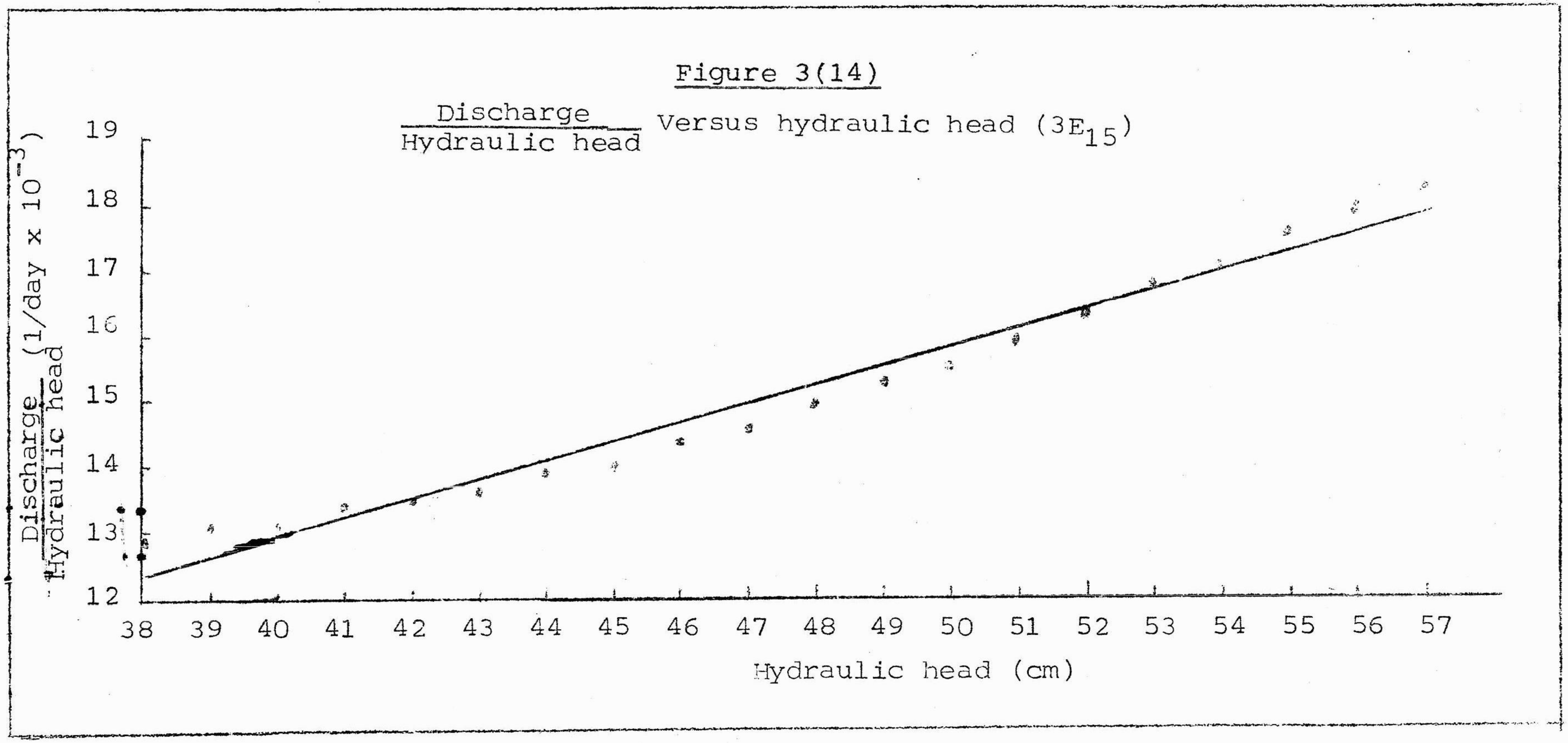


Figure 3(14)
Discharge / Hydraulic head Versus hydraulic head (3E15)
Discharge / Hydraulic head (1/day x 10^-3)
19
18
17
16
15
14
13
12
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
Hydraulic head (cm)

Figure 3(15)

$\frac{\text{Discharge}}{\text{Hydraulic head}}$ Versus hydraulic head ($8E_{30}$)

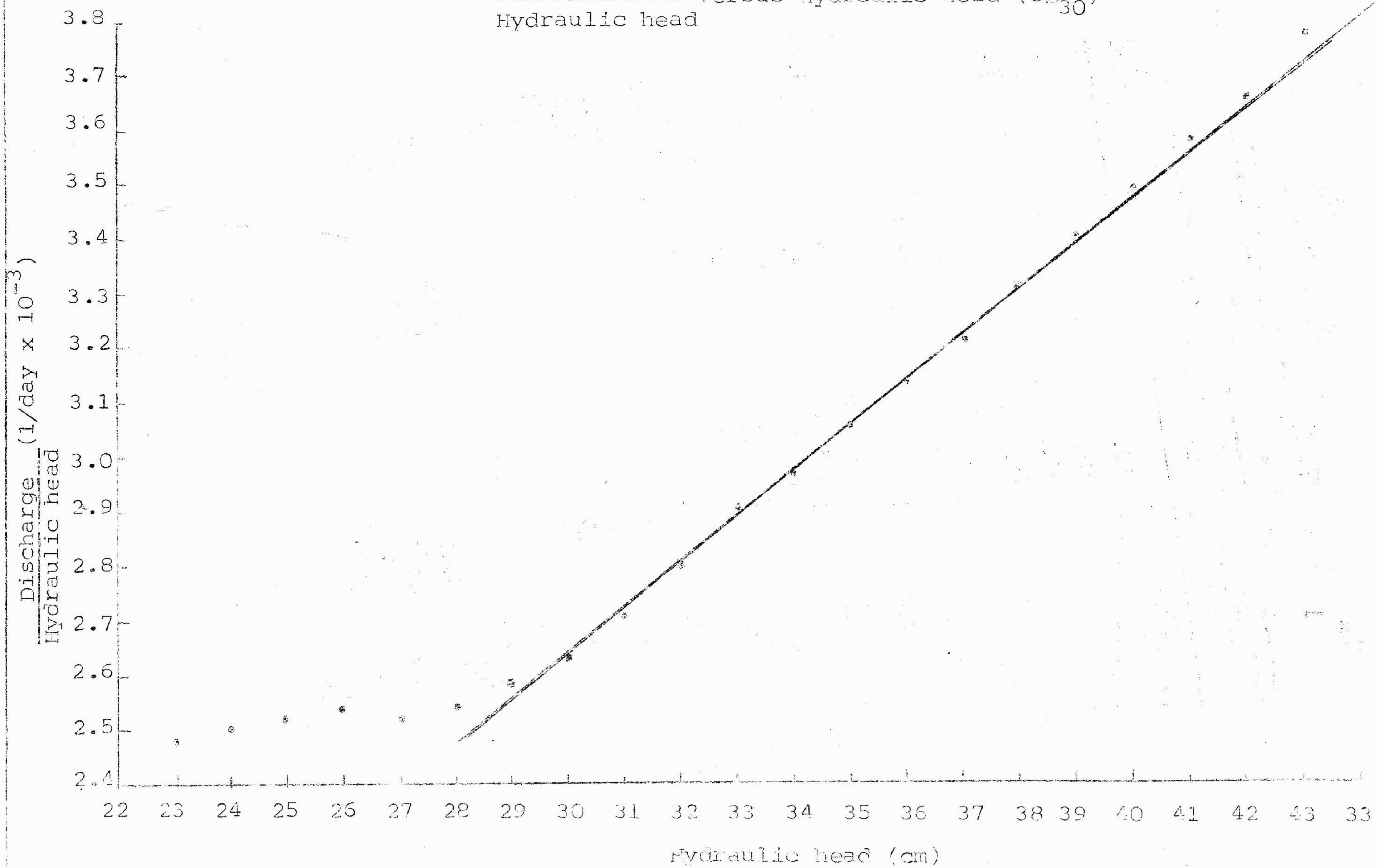


Table No.3(5)

Values of hydraulic head and discharge at different time for $2E_{15}$

Time	q mm/day	h cm	h cm	q mm/day	q lit/minute
14	-	62.4	42	6.5	5.08
19	10	60.1	43	6.65	5.19
24	9.1	56.7	44	6.78	5.30
29	8.5	53.9	45	6.95	5.43
34	8.1	51.6	46	7.1	5.55
39	7.8	49.8	47	7.23	5.65
44	7.6	48.4	48	7.43	5.80
49	7.5	47.2	49	7.58	5.92
54	7.5	46.3	50	7.73	6.04
59	7.4	45.6	51	7.88	6.16
64	7.4	44.9	52	8.08	6.31
69	7.4	44.3	53	8.28	6.47
74	7.4	43.8	54	8.48	6.63
79	7.3	43.4	55	8.68	6.78
84	7.3	43.1	56	8.90	6.95
89	7.3	42.8	57	9.13	7.13
94	7.3	42.7	58	9.38	7.33
99	7.2	42.5	59	9.68	7.56
104	7.2	42.3	60	9.75	7.62
109	7.1	42.2			
114	7.1	42.1			
119	7.1	42.0			
124	7.1	41.9			

Table No.3(6)

Values of hydraulic head and discharge at different time for $3E_{15}$

Time	Q mm/day	h cm	h cm	q mm/day	q lit/minute
14	--	59.3	38	4.85	3.79
19	10.2	56.8	39	5.05	3.95
24	9.1	53.4	40	5.25	4.1
29	8.2	51.0	41	5.45	4.26
34	7.5	49.1	42	5.65	4.41
39	6.9	47.3	43	5.85	4.57
44	6.5	45.7	44	6.05	4.73
49	6.2	44.5	45	6.3	4.92
54	6.0	43.5	46	6.55	5.12
59	5.8	42.6	47	6.8	5.31
64	5.8	41.7	48	7.1	5.55
69	5.8	40.9	49	7.4	5.78
74	5.7	40.3	50	7.75	6.05
79	5.6	39.8	51	8.1	6.33
84	5.6	39.4	52	8.45	6.6
89	5.6	39.0	53	6.85	6.91
94	5.6	38.7	54	9.2	7.19
99	5.5	38.5	55	9.6	7.5
104	5.5	38.3	56	10.0	7.81
109	5.4	38.1	57	10.35	8.09
114	5.4	37.9			
119	5.4	37.7			
124	5.4	37.6			

Table No.3(7)

Values of hydraulic head and discharge at different time for $4E_{15}$

Time	q mm/day	h cm	h cm	q mm/day	lit/ minute
14	-	55.5	36	3.7	2.89
19	7.6	51.0	38	3.95	3.09
24	6.5	47.5	38	4.15	3.24
29	5.9	45.3	39	4.35	3.40
34	5.9	43.7	40	4.55	3.55
39	5.0	42.3	41	4.78	3.73
44	4.8	41.1	42	4.98	3.89
49	4.6	40.3	43	5.20	4.56
54	4.5	39.6	44	5.48	4.28
59	4.3	38.8	45	5.73	6.48
64	4.2	38.3	46	6.03	4.71
69	4.1	37.8	47	6.38	4.78
74	4.0	37.3	48	6.52	5.33
79	4.0	36.9	49	7.35	5.74
84	3.9	36.6	50	7.93	6.20
89	3.9	36.7	51	8.53	6.66
94	3.8	36.2			
99	3.8	35.9			
104	3.7	35.8			
109	3.6	35.5			
114	3.6	35.3			
119	3.6	35.1			
124	3.6	35.0			

Table No.3(8)

Values of hydraulic head and discharge at different time for $5E_{15}$

Time	q mm/day	h cm	h cm	q mm/day	q lit/minute
14	-	58.3	41	3.23	2.52
19	6.9	54.3	42	3.4	2.66
24	6.0	52.0	43	3.58	2.80
29	5.4	50.5	44	3.73	2.91
34	4.9	49.3	45	3.95	3.09
39	4.6	48.4	46	4.20	3.28
44	4.3	47.6	47	4.43	3.46
49	4.2	46.8	48	4.7	3.67
54	4.0	46.2	49	5.0	3.91
59	3.8	45.5	50	5.38	4.20
64	3.7	45.0	51	5.73	4.48
69	3.6	44.5	52	6.18	4.83
74	3.5	43.9			
79	3.4	43.4			
84	3.3	43.0			
89	3.3	42.6			
94	3.2	42.3			
99	3.1	41.9			
104	3.1	41.5			
109	3.0	41.1			
114	3.0	40.7			
119	3.0	40.4			
124	3.0	40.4			

Table No.3(9)

Values of hydraulic head and discharge at different time for $7E_{30}$

Time	q mm/day	h cm	h cm	q mm/day	lit/ minute
14	1.53	49.8	29	0.42	0.88
19	1.41	49.2	30	0.46	0.96
24	1.31	47.9	31	0.49	1.02
29	1.21	46.6	32	0.53	1.10
34	1.14	45.5	33	0.57	1.19
39	1.08	42.2	34	0.61	1.27
44	1.01	43.0	35	0.65	1.35
49	0.96	41.7	36	0.69	1.44
54	0.91	40.5	37	0.73	1.52
59	0.86	39.4	38	0.78	1.63
64	0.81	38.4	39	0.83	1.73
69	0.76	37.5	40	0.87	1.81
74	0.71	36.5	41	0.91	1.92
79	0.68	35.5	42	0.97	2.02
84	0.64	34.6	43	1.01	2.10
89	0.60	33.8	44	1.06	2.21
94	0.58	33.0	45	1.11	2.31
99	0.54	32.2	46	1.16	2.42
104	0.51	31.4	47	1.23	2.56
109	0.49	30.8	48	1.31	2.73
114	0.46	30.1	49	1.39	2.90
119	0.45	29.5	50	1.54	3.21
124	0.44	29			

Table No.3(10)

Values of hydraulic head and discharge at different time for $8E_{30}$

Time	q mm/day	h cm	h cm	q mm/day	lit/ minute
14	1.65	43.0	22	0.55	1.15
19	1.54	42.0	23	0.57	1.19
24	1.44	40.5	24	0.6	1.25
29	1.34	39.10	25	0.63	1.31
34	1.25	37.80	26	0.66	1.38
39	1.18	36.60	27	0.68	1.42
44	1.10	35.40	28	0.71	1.48
49	1.03	34.2	29	0.75	1.56
54	0.96	33.0	30	0.79	1.65
59	0.9	32.0	31	0.84	1.75
64	0.84	31.0	32	0.9	1.88
69	0.8	30.10	33	0.96	2.0
74	0.76	29.20	34	1.01	2.10
79	0.73	28.20	35	1.07	2.23
84	0.7	27.40	36	1.13	2.35
89	0.68	26.5	37	1.19	2.48
94	0.66	25.70	38	1.26	2.63
99	0.63	24.90	39	1.33	2.77
104	0.61	24.2	40	1.4	2.92
109	0.6	23.5	41	1.47	3.06
114	0.59	22.8	42	1.54	3.21
119	0.56	22.1	43	1.63	3.4
124	0.55	21.5			

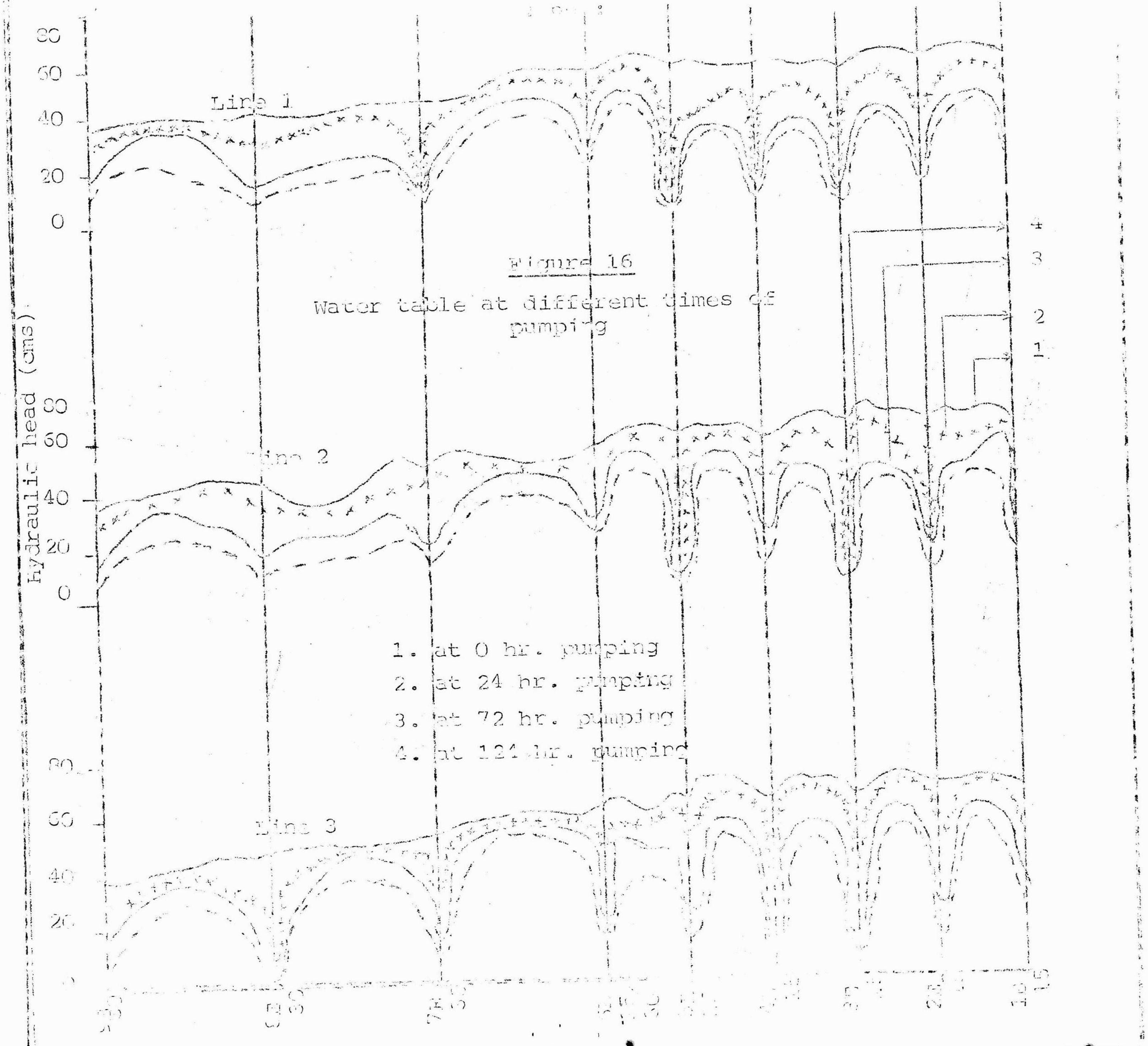


Figure 16

Water table at different times of pumping

The average value of hydraulic conductivity is thus computed as 1.468 m/day. The values of discharge and hydraulic head at identical values of time and values of q in mm/day and litres per minute at identical hydraulic heads are given for each tile drain in table No. 3(5) to 3(10). Another important feature noticed in the project area is that the water table at zero pumping is not level and showed a slope towards the farther side from the outside waterbody. When tile drains are installed in this area there is always a backflow through the drains towards the farther side since the tile drains offers relatively no resistence to flow. This can be easily identified from the fig. 3(16). The values corresponding to the figures are given in appendix II.

RESEARCH PROJECT No. 3b

1. Title of the Project : Development of a suitable technology for the sub-surface drainage system in the Kari lands of Kuttanad.

2. Title of the Problem : Effectiveness of tile drainage system in the performance of paddy crop in the Kari land.

3. Objectives

   a) To assess the incremental yield of paddy due to tile drainage system.

   b) To study the influence of the tile drainage in the pattern of growth of roots of paddy crop.

   c) To study the growth pattern of paddy crop under tile drainage system.

   d) To study the effect of tile drainage in the improvement of root zone profile of Kari lands.

4. Practical Utility:

A remarkable improvement on the growth and yield of paddy crop and also on the fertility of root zone has been revealed from the pilot study on sub surface tile drainage system in the project area. Hence, this detailed experiment will bring out the magnitude of incremental productivity of Kari lands with laying of a suitable tile drainage system. The study will also help to evaluate the economic feasibility of the project.

5. Technical Programme

Paddy crop will be raised in the field laid out with the lateral drains, giving uniform package of practices in the whole experimental area (2.5 ha). The standing crop will be divided into different strips of 5m. width along the drain line. The first strip designated as T_1 will fall 2.5 m. on either side of the centre of the drain line. The second strip, T_2, will fall between 2.5 m. and 5m. from the drain line on either side and T_3 will fall between 5m. and 7.5m. from the drain line on either side. Hence, lateral drains of 15m. spacing will have three treatments T_1, T_2, T_3 and 4 replications (4 experimental lines). For drain lines with 30m. spacing will have 6 treatments (T_1-T_6) with 2 replications. The different attributes of growth and yield of paddy crop will be recorded for each strip. The pattern of growth of roots will be studied at different stages of growth. The pre and post cropping soil qualities will be estimated to assess the improvement of soil fertility.

6. Observations to be Recorded

a) Growth and yield attributes of paddy
b) Assessment of growth of paddy roots at different intervals.
c) Physio-chemical analysis of soil.
d) Monitoring of quality of drainage and irrigation water.

7. Date of Start : December 1984
8. Date of Completion : December 1987

9. Progress of Work

The essential layout of the experiment is as given in project No. 3a except for the type of observations. Day and night pumping throughout the cultivation season was started along with the broadcasting of the paddy seeds and were continued upto 10 days before harvest. Observations like height of the plant, number of hills/Sq.m, number of panicles/Sq.m, average panicle/hill, grain weight/ha and straw weight/ha were taken and subjected to statistical analysis. The analysis was done separately for 15m. and 30m. spacing. The results of the analysis are represented through table 3(11) to 3(22).

It has been found that there was no significant variation for any parameters in between the drain lines (15m. spacing) and all the parameters except number of hills/ Sq.m. were significantly superior to the control plot. In the case of 30m. spacing the grain weight upto 15m. and straw weight upto 30m. from drain was found superior to the control plot while all other parameter were found insignificant. It could be concluded that a 15m. spacing will give an additional yield of 1.93 t/ha of grain and 10.3 t/ha of straw. The effect of drainage was statistically superior to the control plot upto 15m. and then started declining.

Water samples from each tile drain were collected at fortnightly intervals and they were analysed for its EC and pH. Figure No. 3(17) is a graph of EC versus time and it could be seen and concluded that the soils which were closer to the outside natural bodies of water drained less salts than the one which is farther. This is because of the higher water level outside the farming area creating a natural internal drainage and to some extent washes the soil. The graph of pH versus time, (fig. 3(18), gave almost identical values of pH for each drain except for $7E_{30}$ where the acidity level was comparatively very high.

Water samples from the drainage sump were also collected daily and were analysed for EC and pH. The values are drawn against time and are shown as Fig. 3(19) and 3(20). It could be seen that the EC values of the drained water were between 2 to 4.5 mmhos/cm and pH values were between 6.5 to 8.5.

A comparison of the weekly average values of EC of the drained water and the irrigation water shown in fig. 3(21) indicated that a substantial amount of salts can be leached

Table 3(11)

Item: Height of the plant in cm.(15m spacing)

	R_1	R_2	R_3	R_4	R_5	R_6	Mean
T_1	96.25	98.34	99.16	94.59	93.83	91.57	95.62
T_2	89.58	87.59	95.75	92.59	90.5	99.67	92.61
T_3	89.03	89.7	96.5	97.0	94.49	95.92	93.78
Control T_4	81.5	76.0	73.75	77.25	82.17	88.16	79.81
Total	356.41	351.63	365.16	361.43	360.99	375,32	

Gross = 2170.94

Variance Table

	DF	SS	MS	F ratio	F table	Remarks
Block	5	81.838	16.368	0.962	2.9	
Treat	3	935.156	311.719	18.320	3.29	T-Significant
Error	15	255.222	17.015			
Total	23	1272.215				

CD = 5.07 cm.

Table 3(12)

Item: No. of hills/m^2 (15 m spacing)

	R_1	R_2	R_3	R_4	R_5	R_6	Mean
T_1	88	126	114	86	92	138	107.33
T_2	146	94	114	72	118	134	113.0
T_3	122	106	118	108	112	100	111.0
Control T_4	84	60	104	84	128	96	92.67
Total	440	386	450	350	450	468	

Gross = 2544

Variance table

	DF	SS	MS	F ratio	F table	Remarks
Block	5	2616	523.2	1.244	2.9	Non significant
Treat	3	1521.333	507.111	1.205	3.29	Non significant
Error	15	6310.667	420.711			
Total	23	10448.00				

Table 3(13)

Item No. of panicles/m^2 (15m spacing)

		R_1	R_2	R_3	R_4	R_5	R_6	Mean
	T1	568	752	764	592	636	760	678.67
	T_2	746	586	740	500	870	700	690.33
	T_3	606	534	664	778	772	620	662.33
Control	T_4	420	220	480	392	576	616	450.67
Total		2340	2092	2648	2262	2854	2696	

Gross = 14892

	DF	SS	MS	F ratio	F table	Remarks
Block	5	108100	21620	1.952	2.9	-
Treat	3	233120.667	77706.889	7.016	3.29	T-Significant
Error	15	166141.333	11076.089			
Total	23	507362.00				

CD = 129.48 panicles/m^2

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Table 3(14)

Item: Average panicles/hill (15 m spacing)

	R_1	R_2	R_3	R_4	R_5	R_6	Mean
T_1	6.45	5.97	6.70	6.88	6.91	5.51	6.40
T_2	5.11	6.23	6.49	6.94	7.37	5.22	6.23
T_3	7.21	5.04	5.63	7.20	6.89	6.20	6.36
Control T_4	5.0	3.67	4.61	4.67	4.5	6.42	4.81
Total	23.77	20.91	23.43	25.69	25.67	23.35	

Gross : 148.82

	DF	SS	MS	F ratio	F table	Remarks
Block	5	3.94	0.788	1.199	2.9	-
Treat	3	10.484	3.495	5.317	3.29	T-significant
Error	15	9.859	0.657			
Total	23	24.283	-			

CD = 1.00 panicle/hill

Table 3(15)

Grain wt. (t/ha) - 15m spacing

	R_1	R_2	R_3	R_4	R_5	R_6	Mean
T_1	6.89	6.88	8.10	5.57	7.83	6.77	7.01
T_2	7.67	5.66	7.09	5.47	9.73	7.42	7.17
T_3	4.33	4.65	6.88	7.21	8.16	6.05	6.21
Control T_4	4.84	2.63	5.41	4.71	5.50	6.12	4.87
Total	23.73	19.82	27.48	22.96	31.22	26.36	

Gross = 151.57

Variance table

	DF	SS	MS	F ratio	F table	Remarks
Block	5	19.72	3.94	3.97	2.9	R-Sig.
Treat	3	19.91	6.64	6.69	3.29	T-Sig.
Error	15	14.88	0.99			
Total	23	54.52				

CD = 1.23 t/ha

Table 3(16)

Straw wt (t/ha) - 15m spacing

		R_1	R_2	R_3	R_4	R_5	R_6	Mean
	T_1	19.14	26.62	28.34	20.16	22.58	20.76	22.93
	T_2	20.10	21.50	24.78	18.40	30.88	25.16	23.47
	T_3	22.00	18.75	28.32	30.60	28.72	19.74	24.69
Control	T_4	12.20	9.40	12.80	16.60	12.84	16.52	13.39
Total		73.44	76.27	94.24	85.76	95.02	82.18	

Gross = 506.91

Variance table

	DF	SS	MS	F ratio	F table	Remarks
Block	5	100.64	20.13	1.26	2.9	-
Treat	3	487.47	162.49	10.20	3.29	T-Sig.
Error	15	238.99	15.93			
Total	23	827.10				

CD = 4.91 t/ha

Table 3(17)

Height of the plant (Cm) (30m spacing)

	R_1	R_2	R_3	R_4	Mean
T_1	95.67	92.0	91.5	91.67	92.71
T_2	87.33	93.67	100.33	99.0	95.08
T_3	94.83	94.16	99.0	92.83	95.21
T_4	93.33	93.5	93.17	93.17	93.29
T_5	85.67	100.17	97.0	99.5	95.59
T_6	85.5	90.5	98.5	96.83	92.83
Control T_7	77.25	77.83	78.0	88.16	80.31
Total	619.58	641.83	657.5	661.16	

Gross = 2580.07

Variance table

	DF	SS	MS	F ratio	F table	Remarks
Block	3	153.37	51.12	2.96	3.16	NS
Treat	6	688.01	114.67	6.63	2.66	Significant
Error	18	311.20	17.29			
Total	27	1152.59				

C.D = 6.18 cm

Table 3(18)

No. of hills/m^2 - 30m spacing

	R_1	R_2	R_3	R_4	Mean
T_1	80	104	144	132	115
T_2	88	148	108	160	126
T_3	120	104	112	88	106
T_4	148	96	92	100	109
T_5	128	56	92	104	95
T_6	136	120	92	108	114
Control T_7	84	136	120	96	109
Total	784	764	760	788	

Gross = 3096

Variance Table

	DF	SS	MS	F ratio	F table	Remarks
Block	3	84.57	28.19	0.14	3.16	NS
Treat	6	2150.86	358.48	0.47	2.66	NS
Error	18	13803.43	766.86			
Total	27	16038.86				

Table 3(19)

Average panicle/hill - 30m spacing

		R_1	R_2	R_3	R_4	Mean
	T_1	9.5	4.93	5.08	5.97	6.37
	T_2	9.23	6.27	6.74	4.00	6.56
	T_3	6.43	7.42	5.43	7.18	6.62
	T_4	5.26	7.2	6.13	7.76	6.59
	T_5	6.41	9.5	6.04	5.88	6.96
	T_6	6.68	5.9	6.78	4.56	5.98
Control	T_7	4.67	2.47	4.9	6.42	4.62
Total		48.18	43.69	41.1	41.77	

Gross = 174.74

Variance table

	DF	SS	MS	F ratio	F table	Remarks
Block	3	4.36	1.45	0.53	3.16	NS
Treat	6	14.41	2.4	0.88	2.66	NS
Error	18	49.12	2.73			
Total	27	67.9				

Table 3(20)

No. of panicles/m^2 - 30m spacing

		R_1	R_2	R_3	R_4	Mean
	T_1	760	512	732	788	698
	T_2	812	928	728	640	777
	T_3	772	772	608	632	696
	T_4	778	692	564	776	702.5
	T_5	820	532	556	612	630
	T_6	908	708	624	492	683
Control	T_7	392	336	588	616	483
Total		5242	4480	4400	4556	

Gross = 18678

Variance table

	DF	SS	MS	F ratio	F table	Remarks
Block	3	64168	21389	1.32	3.16	NS
Treat	6	202573	33762	2.14	2.66	NS
Error	18	283831	15768			
Total	27	550572				

Table 3(21)

Grain wt. t/ha - 30m spacing

	R_1	R_2	R_3	R_4	Mean
T_1	7.09	8.57	6.07	7.47	7.30
T_2	9.43	10.03	6.01	8.83	8.58
T_3	8.64	7.69	6.45	5.66	7.11
T_4	7.06	4.43	5.98	7.62	6.27
T_5	6.45	5.38	5.14	6.93	5.98
T_6	9.05	7.04	8.10	8.41	8.15
Control T_7	4.71	6.07	4.33	6.12	5.31
Total	52.43	49.21	42.08	51.04	

Variance table

	DF	SS	MS	F ratio	F table	Remarks
Block	3	9.07	3.02	2.52	3.16	NS
Treat	6	33.34	5.56	4.63	2.66	Significant
Error	18	21.61	1.20			
Total	27	64.02				

C.D = 1.63 t/ha

Table 3(22)

Straw wt. t/ha - 30 m spacing

		R_1	R_2	R_3	R_4	Mean
	T_1	24.52	20.64	22.00	19.52	21.67
	T_2	31.44	30.32	25.64	24.68	28.02
	T_3	30.88	26.56	20.28	19.20	24.23
	T_4	27.40	24.32	15.20	24.60	22.88
	T_5	22.28	20.84	21.64	23.16	21.98
	T_6	26.44	25.88	21.64	23.76	24.43
Control	T_7	16.60	12.12	10.08	16.52	13.83
Total		179.56	160.68	136.48	151.44	628.16

variance table

	DF	SS	MS	F ratio	F table	Remarks
Block	3	139.21	46.40	6.3	3.16	Significant
Treat	6	453.72	75.62	10.26	2.66	"
Error	18	132.68	7.37			
Total	27	725.61				

C.D = 4.03 t/ha

Table 3(23)

Water Sample Data Taken at Fortnightly Intervals

(Collected from tile)

EC(mmhos/cm) values

Location	Date				
	21-10-85	5-11-85	26-11-85	10-12-85	6-1-86
$1B_{15}$	2.67	1.80	2.10	2.6	2.1
$2E_{15}$	3.30	2.40	2.40	2.50	2.50
$3E_{15}$	2.94	3.30	3.00	3.50	2.40
$4E_{15}$	2.13	4.20	3.90	5.20	2.40
$5E_{15}$	2.27	4.80	4.80	5.70	3.60
$6B_{15/30}$	4.80	4.510	5.10	5.0	2.70
$7E_{30}$	6.06	6.30	6.30	-	4.80
$8E_{30}$	4.92	4.80	4.80	-	4.40
$9E_{30}$	4.35	-	-	-	-

Table 3(24)

Water Sample Data Taken at Fortnightly Interval

(Collected from tiles)

pH Values

Location	Date				
	21-10-85	5-11-85	26-11-85	10-12-85	6-1-86
$1B_{15}$	6.6	7.42	8.30	6.20	-
$2E_{15}$	6.10	7.65	7.35	6.40	-
$3E_{15}$	6.10	7.88	7.30	6.20	-
$4E_{15}$	7.30	8.49	9.35	6.10	-
$5E_{15}$	5.90	8.37	8.34	4.10	-
$6B_{15/30}$	6.49	8.61	9.30	-	-
$7E_{30}$	2.43	2.40	4.60	5.80	-
$8E_{30}$	3.56	8.80	8.65	5.60	-
$9B_{30}$	6.11	-	-	-	

Figure 3(17)

Water samples from drain at fortnightly interval - EC analysis

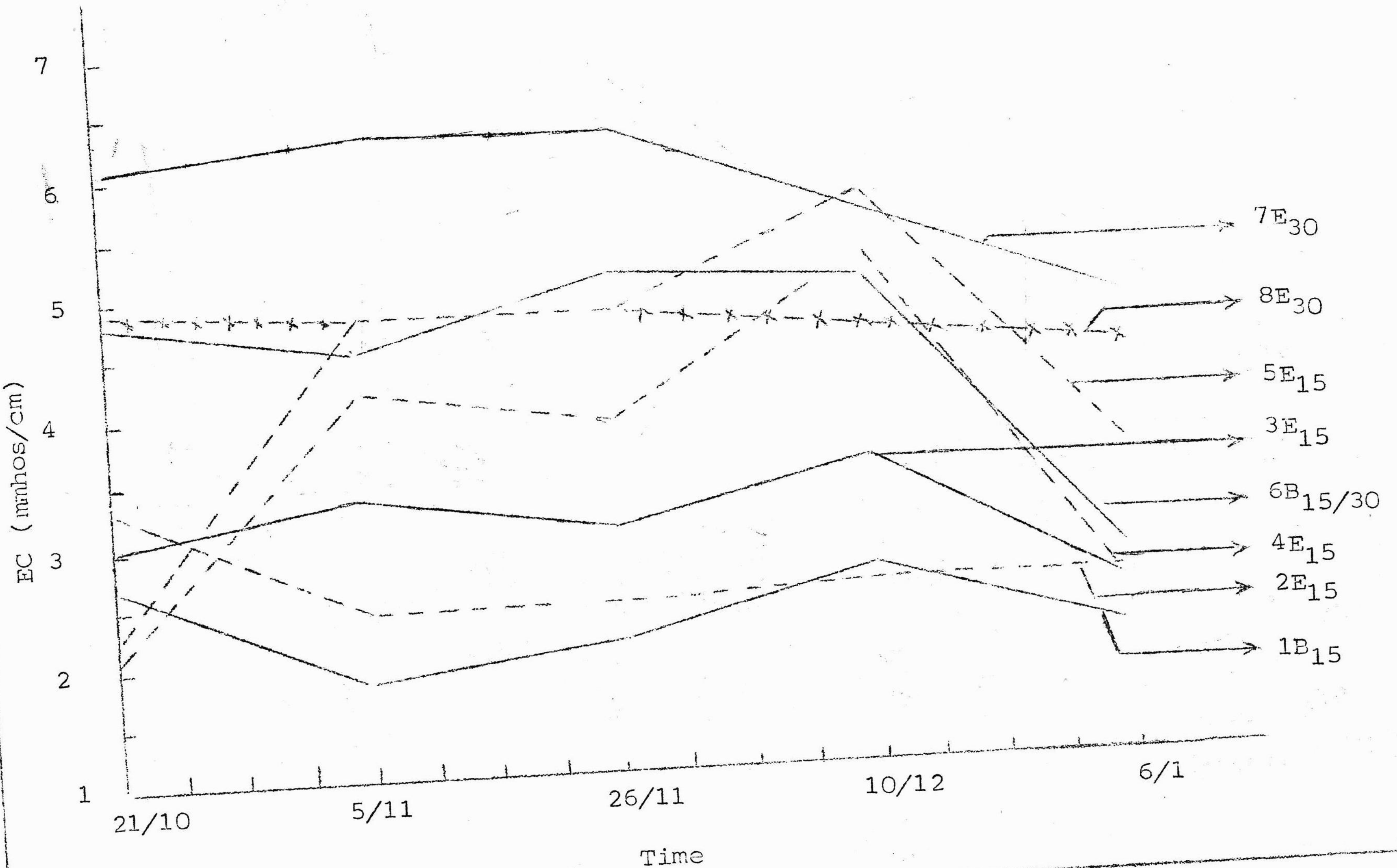


Figure 3(18)

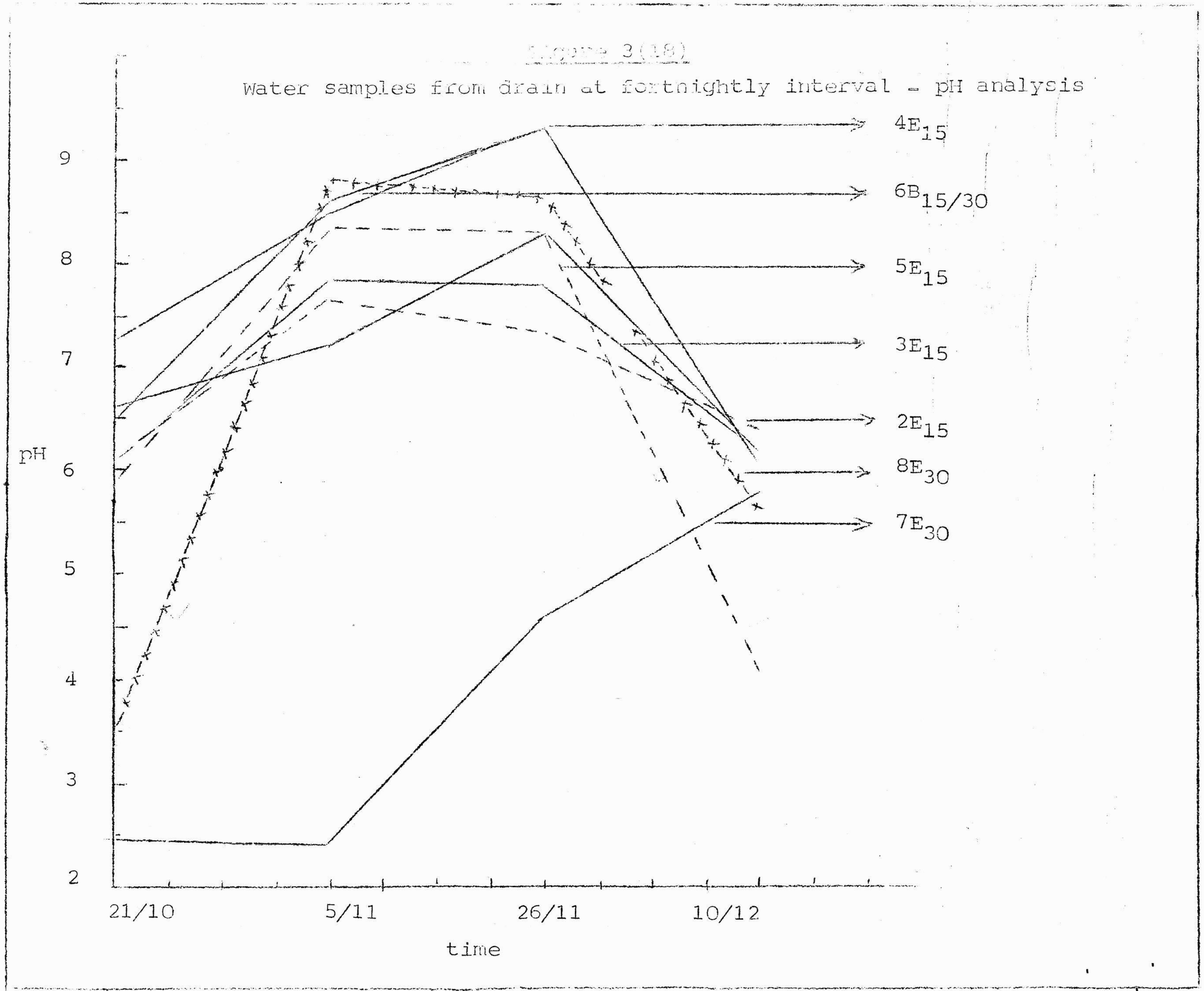

Water samples from drain at fortnightly interval - pH analysis
4E15
6B15/30
5E15
3E15
2E15
8E30
7E30
pH
9
8
7
6
5
4
3
2
21/10
5/11
26/11
10/12
time

Table 3(25)

Water sample data taken daily from the drainage sump

EC (mmhos/cm)

Date	EC	Date	EC	Date	EC
21-10-85	-	21-11-85	3.30	22-12-85	4.5
22-10-85	-	22-11-85	4.05	23-12-85	4.55
23-10-85	2.45	23-11-85	3.75	24-12-85	4.75
24-10-85	4.1	24-11-85	3.06	25-12-85	4.45
25-10-85	1.8	25-11-85	4.20	26-12-85	4.38
26-10-85	2.4	26-11-85	3.70	27-12-85	4.10
27-10-85	0.69	27-11-85	3.85	28-12-85	4.23
28-10-85	2.17	28-11-85	3.8	29-12-85	4.55
29-10-85	4.0	29-11-85	3.9	30-12-85	4.90
30-10-85	1.8	30-11-85	3.75	31-12-85	4.55
31-10-85	1.98	1-12-85	3.95	1-1-86	3.95
1-11-85	2.93	2-12-85	3.19	2-1-86	3.83
1-11-85	1.8	3-12-85	2-94	3-1-86	-
3-11-85	2.63	4-12-85	4.8		
4-11-85	2.70	5-12-85	4.95		
5-11-85	2.01	6-12-85	4.65		
6-11-85	2.20	7-12-85	4.60		
7-11-85	2.84	8-12-85	4.70		
8-11-85	2.77	9-12-85	4.48		
9-11-85	-	10-12-85	4.85		
10-11-85	-	11-12-85	4.25		
11-11-85	2.78	12-12-85	4.55		
12-11-85	2.54	13-12-85	4.25		
13-11-85	3.38	14-12-85	3.78		
14-11-85	3.60	15-12-85	4.33		
15-11-85	-	16-12-85	4.60		
16-11-85	3.9	17-12-85	4.15		
17-11-85	3.88	18-22-85	3.44		
18-11-85	3.98	19-12-85	-		
19-11-85	3.90	20-12-85	2.87		
20-11-85	4.05	21-12-85	4.45		

Figure 3(19)

EC of daily water samples collected from drainage sump during cultivation

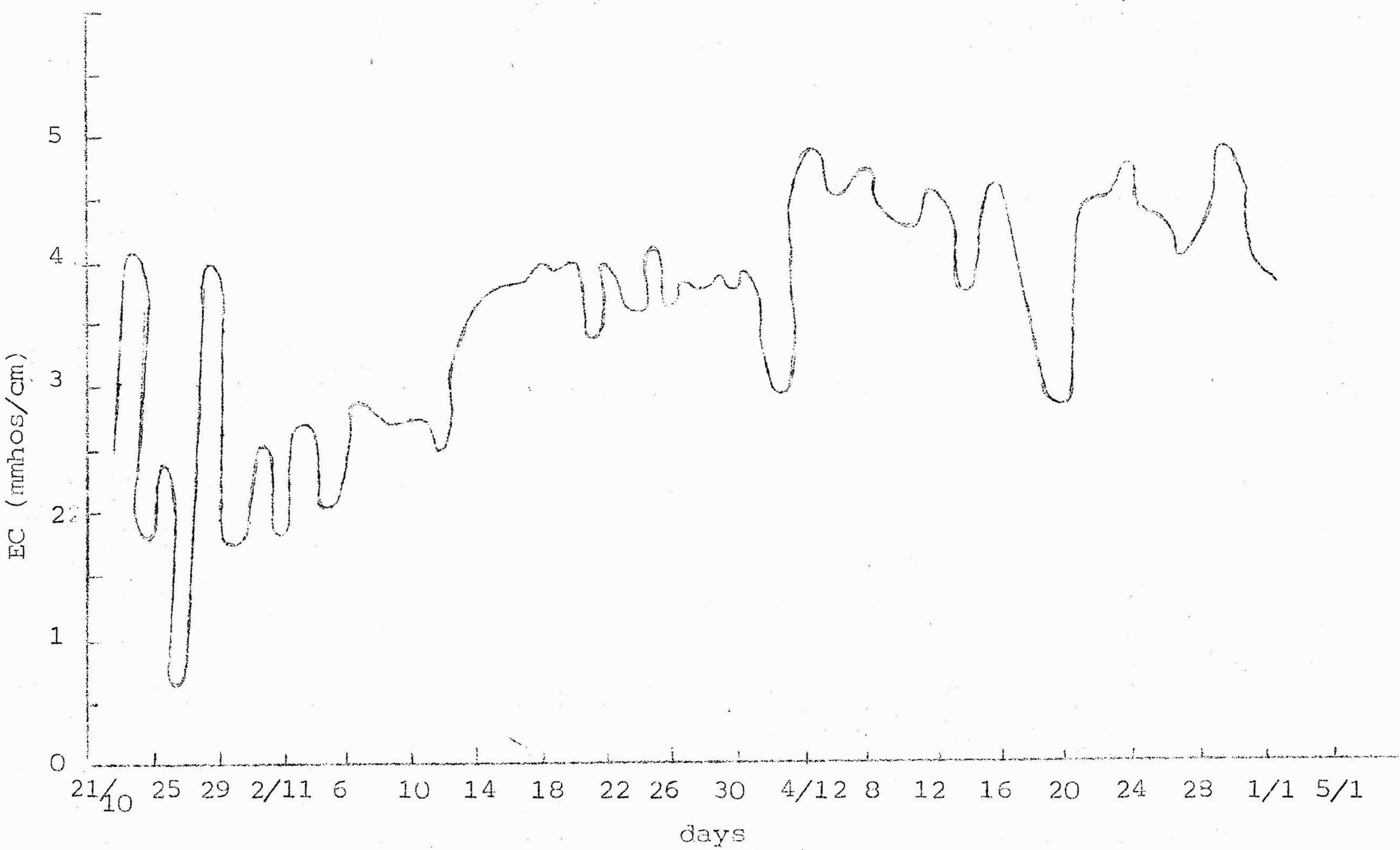


Table 3 (26)

Water sample data taken daily from the drainage sump

pH values

Date	pH	Date	pH	Date	pH
21-10-85	-	15-11-85	-	9-12-85	6.9
22-10-85	6.51	16-11-85	6.4	10-12-85	7.5
23-10-85	5.67	17-11-85	7.8	11-12-85	7.1
24-10-85	6.4	18-11-85	8.6	12-12-85	6.8
26-10-85	7.1	19-11-85	7.6	13-12-85	6.6
27-10-85	7.5	20-11-85	7.6	14-12-85	6.4
28-10-85	7.07	21-11-85	7.9	15-12-85	6.5
29-10-85	7.1	22-11-85	7.5	16-12-85	6.3
30-10-85	7.2	23-11-85	7.7	17-12-85	7.1
31-10-85	7.9	24-11-85	7.9	18-12-85	6.7
1-11-85	7.8	25-11-85	7.5	19-12-85	5.9
2-11-85	8.2	26-11-85	7.7	20-12-85	6.6
3-11-85	7.7	27-11-85	7.7	21-12-85	7.3
4-11-85	8.1	28-11-85	7.3	22-12-85	7.2
5-11-85	8.4	29-11-85	6.9	23-12-85	7.5
6-11-85	8.0	30-11-85	7.0	24-12-85	6.7
7-11-85	7.6	1-12-85	7.6	25-12-85	6.7
8-11-85	7.7	2-12-85	6.7	26-12-85	6.6
9-11-85	7.4	3-12-85	7.1	27-12-85	6.5
10-11-85	-	4-12-85	7.6	28-12-85	7.0
11-11-85	7.6	5-12-85	7.6	29-12-85	7.2
12-11-85	7.4	6-12-85	7.1	30-12-85	6.6
13-11-85	8.1	7-12-85	6.6[illegible]	31-12-85	6.8
14-11-85	7.8	8-12-85	7.3	1-1-86	6.9
				2-1-86	7.1
				3-1-86	-

Figure 3(20)

pH of daily water samples collected from drainage sump during cultivation

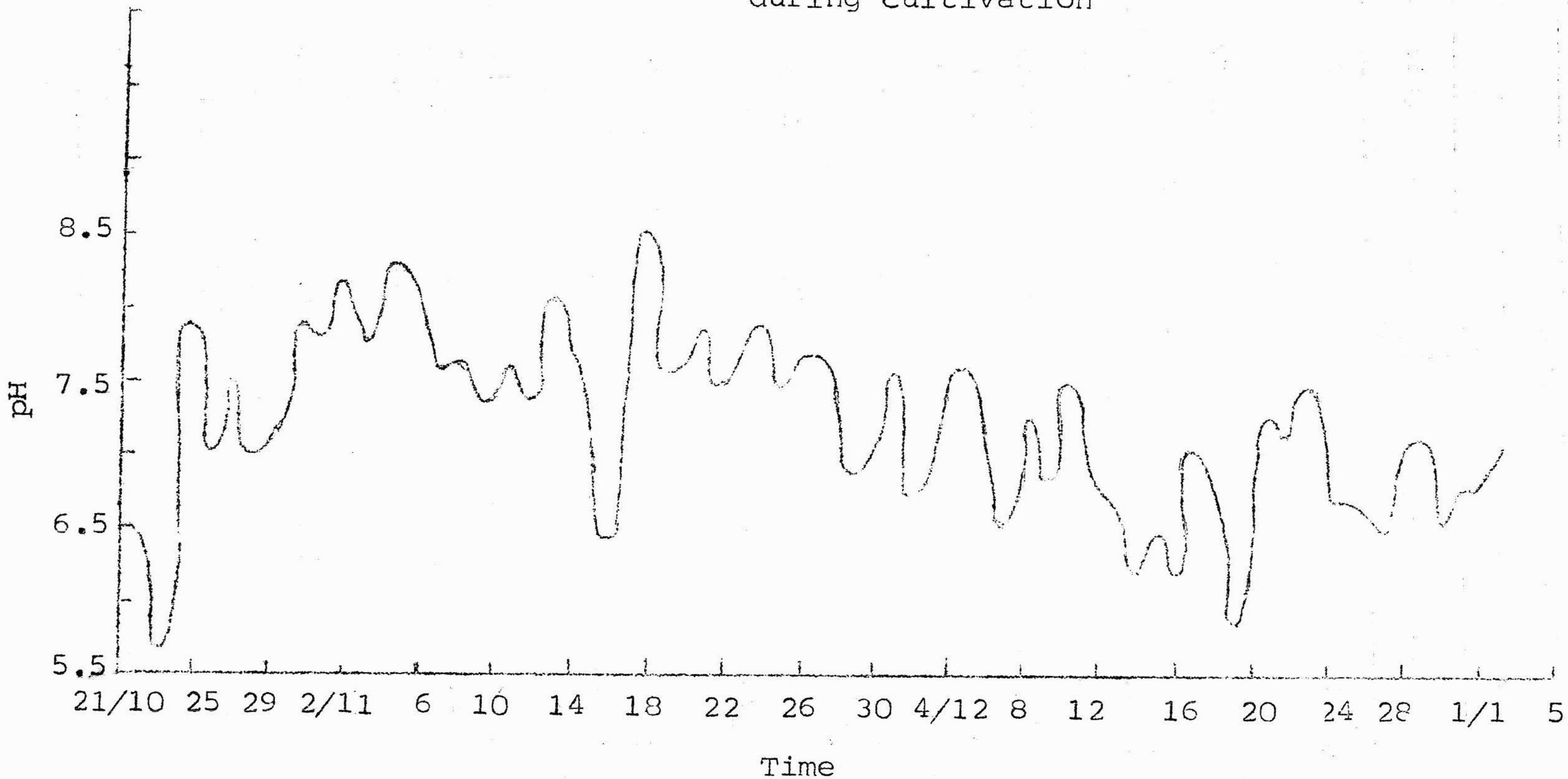


Table 3(27)

Weekly averages of EC and pH of irrigation and drained water

Date	Irrigation water		Drained water	
	EC mmhos/cm	pH	EC mmhos/cm	pH
26-10-85	1.86	5.79	2.41	6.94
3-10-85	1.14	3.86	2.46	7.55
6-11-85	0.32	6.63	2.42	7.84
13-11-85	0.36	7.61	2.85	5.47
20-11-85	0.88	7.60	3.84	7.81
28-11-85	1.68	9.23	3.82	7.38
6-12-85	2.24	6.35	4.71	7.17
11-12-85	2.13	6.54	4.35	6.94
18-12-85	2.45	7.00	3.43	6.50
27-12-85	1.51	7.38	4.48	6.88
1-1-86	2.45	5.87	3.71	6.87

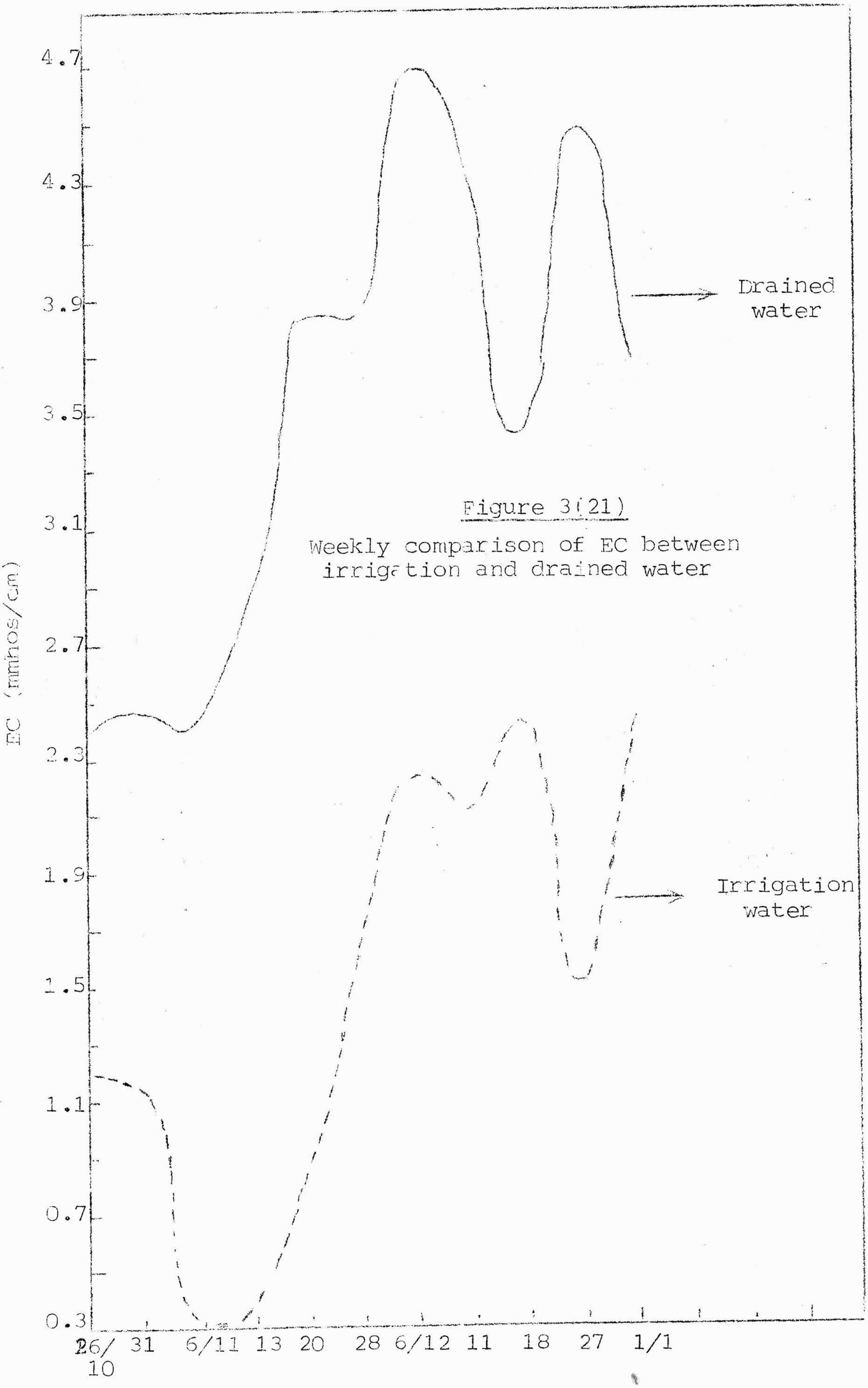


Figure 3(21)

Weekly comparison of EC between irrigation and drained water

Figure 3(22)

Weekly comparison of pH between irrigation and drained water

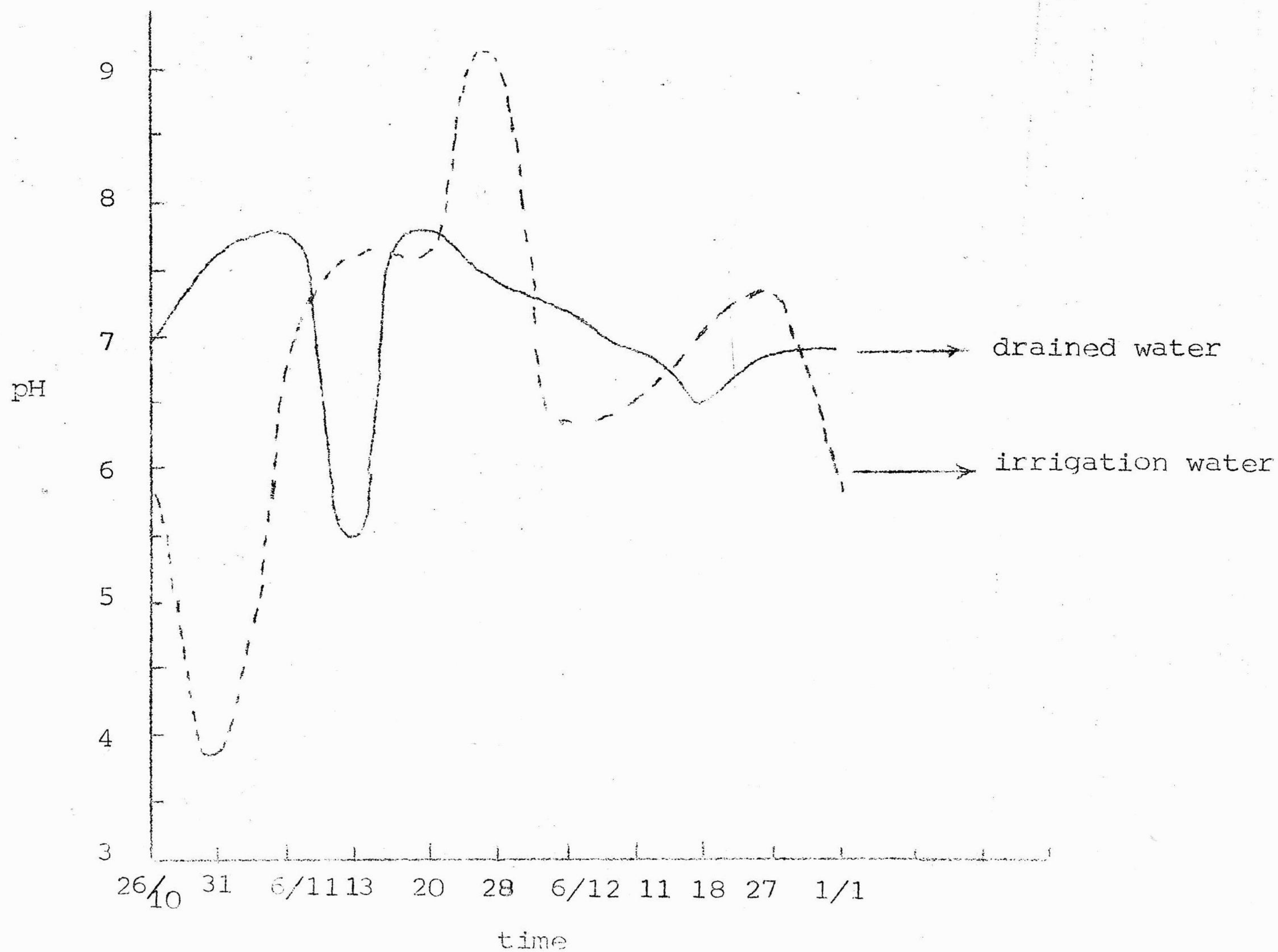


Table 3(28)

Soil sample data taken at different time

EC(mmhos/cm)

	Date				
	21-10-85	5-11-85	26-11-85	10-12-85	1-1-86
$1B_{15}$ on the line	1.14	0.62	0.50	0.75	0.84
$1B_{15}$ moddle	0.96	0.88	0.30	0.61	1.03
$2E_{15}$ on the line	1.17	0.50	0.35	0.72	1.08
$2E_{15}$ middle	1-20	0.695	0.54	0.87	0.93
$3E_{15}$ on the line	1.17	0.325	0.26	0.83	0.99
$3E_{15}$ middle	1.20	0.385	0.34	0.77	1.11
$4E_{15}$ on the line	1.20	0.485	0.25	0.85	0.84
$4E_{15}$ middle	0.99	0.485	0.42	0.82	0.48
$5E_{15}$ on the line	0.99	0.73	0.28	0.87	1.11
$5E_{15}$ middle	0.99	0.39	0.37	0.89	0.90
$6B_{15/30}$ on the line	0.99	0.725	0.50	0.74	0.93
$6B_{15/30}$ middle	1.05	0.61	0.26	0.91	0.90
$7E_{30}$ on the line	1.23	0.525	0.35	0.91	1.02
$7E_{30}$ middle	1.05	0.90	0.40	0.92	1.02
$8E_{30}$ on the line	0.96	0.[illegible]8	0.28	0.74	0.96
$8E_{30}$ middle	0.96	0.395	0.32	0.65	0.90
$9B_{30}$ on the line	1.17	0.71	0.27	0.70	0.93
Control	1.20	0.795	0.46	0.75	1.41

Figure 3(23)

EC of soil samples taken at different time

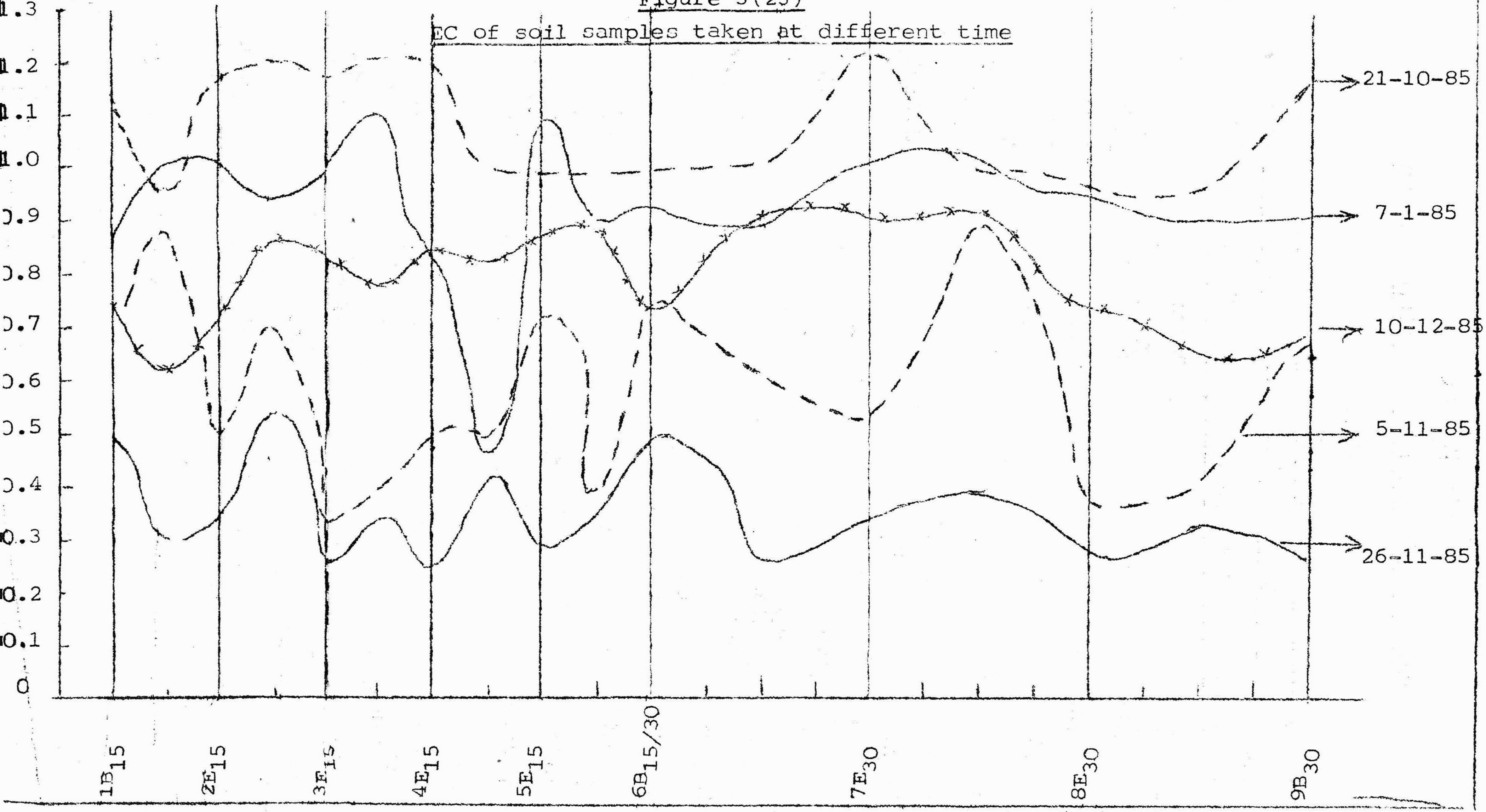


Table 3(29)

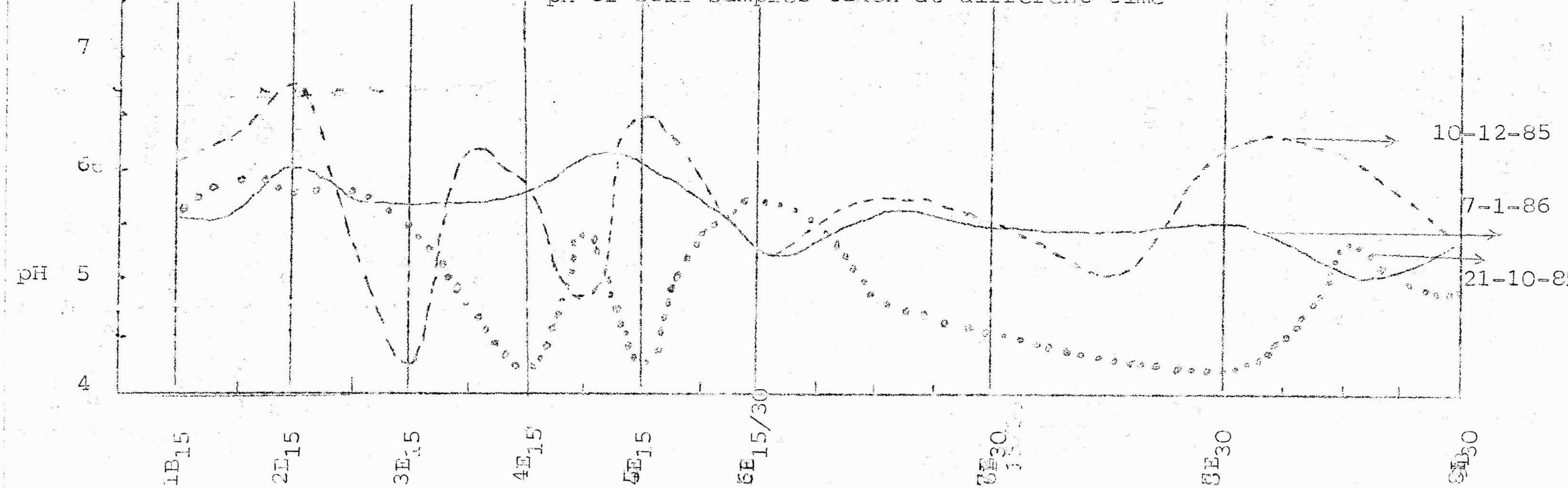
Soil sample data taken at different time

pH values

Location	Date		
	21-10-85	10-12-85	7-1-86
$1B_{15}$ on the line	6.05	5.60	5.54
$1B_{15}$ middle	6.32	5.90	5.57
$2E_{15}$ on the line	6.75	5.80	6.06
$2E_{15}$ middle	5.39	5.80	5.78
$3E_{15}$ on the line	4.32	5.50	5.70
$3E_{15}$ middle	6.21	4.80	5.69
$4E_{15}$ on the line	5.90	4.20	5.80
$4E_{15}$ middle	4.88	5.50	6.14
$5E_{15}$ on the line	6.52	4.30	6.10
$5E_{15}$ middle	5.94	5.50	5.66
$6B_{15/30}$ on the line	5.26	5.80	5.26
$6B_{15/30}$ middle	5.77	4.90	5.70
$7E_{30}$ on the line	5.56	4.60	5.50
$7E_{30}$ middle	5.15	4.40	5.50
$8E_{30}$ on the line	6.26	4.30	5.56
$8E_{30}$ middle	6.20	5.40	5.05
$9E_{30}$ on the line	5.32	4.80	5.43
Control	4.50	5.90	5.05

Figure 3(24)

pH of soil samples taken at different time



through the sub surface drainage system. While the EC of the irrigation water fluctuated between 0.3 mmhos/cm to 2.2 mmhos/cm the EC of the drained water ranged between 2.4 to 4.7 mmhos/cm. The same comparison of pH values, as can be seen from fig.3(22), shows relatively same pH values which ranged between 6 to 7.5.

Soil samples were also collected at fortnightly intervals from pre determined spots to monitor the changes in its quality. They were taken from a 15 cm depth. The EC and pH values are drawn against time and are shown in fig. 3(23) and 3(24). The EC values continued to reduce since pumping and started rising towards the end of the season as the pumping intensity reduced. It was also noted that the EC values for the soil samples on the drain line were comparatively less than the EC values of soil samples at the mid spacing. The pH values of the soil, though remained at acidic level, were not very harmful for rice production. It could be noticed that the pH was comparatively more acidic at drain locations than that at the mid spacing which might be because of the aeration at drain locations due to the drastic lowering of water tables at that location on pumping.

SECTION E

SUMMARY

Investigation on the quality variation of the water in the project area was continued. The assessment was mainly focussed on the acidity and salinity of flooding water and the groundwater. The pH values fluctuated between 5.5 to 7.5 and the EC values fluctuated between 0.5 to 2.5 mmhos/cm and at times crossed these limits. Seasonal fluctuations of groundwater table with reference to surface water level was also monitored during the reporting year. The field was flooded from April 85 to Sept. 85 and hence no observation was possible during that period. During the cropping period the field was almost saturated and the surface and the ground water in the field was found to keep the same elevation and hence a clear cut groundwater movement was not traceable. The water le...

levels in the polders were always lower by 0.5 to 0.75 m than that in the nearby waterways.

The experiment on the "Development of a suitable technology for the sub surface drainage system in the Kari lands of Kuttanad" has revealed that the average hydraulic conductivity of the area is 1.468 m/day. The discharge and the hydraulic head relationships were established. It was found that there was no significant variation for any crop growth parameters in between the drain lines for a 15m spacing and all the parameters except number of hills/m^2 were significantly superior to the control plot. In the case of 30 m spacing only the grain weight upto 15m from the drain line and the straw weight upto 30m from the drain line was found superior to the control plot. It could be concluded that the 15 m spacing will give on additional yield of 1.93 tons/ha of grain and 10.3 tons/ha of straw. The effect of drainage was statistically superior to the control plot upto 15m and then started declining.

It was found during the analysis of data that the soils which were closer to the outside natural bodies of water drained less salts that the soils which were farther. This could be because of the higher water level outside the farming area creating a natural internal drainage.

The analysis of the water samples from the drainage sump has shown that the EC values of drained water were between 2 to 4.5 mmhos/cm and the pH values were between 6.5 to 8.5.

A comparison of weekly average of EC of the drained water and irrigation water has indicated that a substantial amount of salts can be leached through the subsurface drainage system. While the EC of the irrigation water fluctuated between 0.3 mmhos/cm to 2.2 mmhos/cm, the EC of drained water ranged between 2.4 to 4.7 mmhos/cm.

Soil samples were also collected at fortnightly intervals from the experimental area to monitor the changes in the quality. The EC values continued to reduce since pumping and started rising towards the end of the season as the pumping intensity reduced. It was also noted that the EC values on the drain lines were comparatively less than that at the mid spacing. The pH values of soil, though remains at acidic level, were not very harmful for rice production.

SECTION F

Problems Encountered during the year under report

There was only one cropping season due to the flood during June-Sept. and hence the research activities in the field had to be limited to during that period. The field activity was mainly centered around the observations on crop data and drainage data of the already laid tile drains. The experiment on filter studies could not be taken up for the want of favourable time.

SECTION G

Technical Programme 1986-87

1) Continuation of the ongoing projects.

   a) Monitoring of periodical changes in the quality of surface and sub-surface water in the project area.

   b) Monitoring of seasonal fluctuations of ground water table with reference to surface water level.

   c) Assessment of hydraulic properties of the tile drainage system.

   d) Theoretical prediction of drain performance in terms of water entry quality of the drain.

   e) Effectiveness of tile drainage system in the performance of paddy crop in the Kari land.

2) Evaluation of the suitability of different filter materials for the sub-surface drainage.

Since the experiments conducted by sub-surface tile drains were found effective, it is very essential to deepen the existing channels to serve as a collector drain for the tile drains. The tile drains are laid at a depth of 75-90 cm below the ground level and the existing open channels are below 1m depth. An approximate estimate of Rs.80,000/- has already been submitted for approval.

APPENDIX I

Discharge at 5hour interval in mm/day for different tile drains

Time	Tile No.					
	$2E_{15}$ *	$3E_{15}$ *	$4E_{15}$ *	$5E_{15}$ *	$7E_{30}$ @	$8E_{30}$ @
14	11.4	11.8	10.2	8.9	2.9	2.2
19	10.0	10.2	7.6	6.9	1.8	1.5
24	9.1	9.1	6.5	6.0	1.5	1.4
29	8.5	8.2	5.9	5.4	1.4	1.3
34	8.1	7.5	5.4	4.9	1.2	1.2
39	7.8	6.9	5.1	4.6	1.1	1.1
44	7.6	6.5	4.8	4.3	1.0	1.0
49	7.5	6.2	4.6	4.1	1.0	1.0
54	7.5	6.0	4.5	4.0	0.9	0.9
59	7.4	5.9	4.3	3.9	0.9	0.9
64	7.4	5.8	4.2	3.7	0.8	0.9
69	7.4	5.8	4.1	3.6	0.7	0.8
74	7.4	5.7	4.1	3.5	0.7	0.8
79	7.4	5.6	4.0	3.4	0.7	0.7
84	7.3	5.6	3.9	3.4	0.6	0.7
89	7.3	5.6	3.9	3.3	0.6	0.7
94	7.3	5.6	3.8	3.2	0.5	0.7
99	7.2	5.6	3.7	3.1	0.5	0.7
104	7.2	5.5	3.6	3.1	0.5	0.7
109	7.1	5.4	3.6	3.0	0.5	0.7
114	7.1	5.4	3.6	3.0	0.5	0.7

* 15 m spacing

@ 30 m spacing

Hydraulic heads at 5 hour interval

Time	Head (cm)				
	OBW 111	OBW 112	OBW 113	OBW 114	OBW 115
14	51.4	62.1	62.8	59.2	56.2
19	44.0	59.7	60.8	51.5	49.0
24	38.6	57.4	57.6	45.6	43.5
29	34.9	55.5	54.3	41.5	38.7
34	32.0	54.0	51.8	39.2	35.0
39	29.6	52.6	50.0	38.6	32.0
44	28.0	51.2	48.6	37.8	29.5
49	26.9	50.0	47.4	37.1	27.5
54	26.0	49.0	46.6	36.4	25.6
59	25.5	48.0	45.9	36.0	24.2
64	25.2	47.1	45.3	35.6	22.8
69	25.0	46.2	44.9	35.4	21.9
74	24.7	45.5	44.5	35.2	21.0
79	24.5	44.8	44.2	35.1	20.2
84	24.3	44.2	43.9	34.9	19.6
89	24.0	43.6	43.8	34.8	19.0
94	23.8	43.1	43.7	34.8	18.4
99	23.3	42.7	43.5	34.7	18.0
104	23.3	42.3	43.4	34.7	17.5
109	23.2	42.0	43.3	34.7	17.2
114	22.9	41.7	43.2	34.7	16.8
119	22.7	41.5	43.1	34.6	16.4
124	22.5	41.3	43.0	34.6	16.1

The subscrips of observation wells denotes the following

1) First digit indicates the OBW line.
2) Second digit indicates the drain line.
3) Third digit indicates the position of the OBW from the drain line towards the left.

Time	Head (cm)				
	OBW 121	OBW 122	OBW 123	OBW 124	OBW 125
14	55.9	57.5	62.0	57.4	57.0
19	45.5	48.8	59.3	52.3	51.8
24	39.0	43.6	55.7	47.0	46.0
29	34.0	40.2	53.4	43.0	42.0
34	30.4	37.7	51.4	39.7	38.8
39	27.4	35.8	49.6	37.3	36.4
44	25.0	34.4	48.1	35.3	34.0
49	23.0	33.2	46.9	33.7	32.0
54	21.5	32.4	46.0	32.5	30.4
59	20.2	32.0	45.2	31.4	29.0
64	19.0	31.6	44.4	30.5	27.6
69	18.3	31.4	43.7	29.8	26.6
74	17.6	31.1	43.1	29.4	25.4
79	17.2	31.0	42.6	28.9	24.4
84	16.8	30.8	42.3	28.4	23.4
89	16.2	30.7	41.8	28.1	22.6
94	15.8	30.6	41.6	27.7	21.8
99	15.7	30.4	41.4	27.4	21.2
104	15.2	30.3	41.2	27.2	20.5
109	15.0	30.0	41.1	27.0	20.0
114	14.7	29.9	40.9	26.8	19.5
119	14.4	29.8	40.8	26.7	19.0
124	14.0	29.8	40.7	26.7	18.6

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Time	Head (Cm)				
	OBW 131	OBW 132	OBW 133	OBW 134	OBW 135
14	27.8	54.8	56.5	55.6	22.2
19	17.4	46.2	54.2	50.3	20.8
24	13.7	40.1	51.0	47.2	20.6
29	11.5	36.2	48.6	44.9	20.4
34	10.4	33.7	46.7	42.6	20.0
39	10.2	31.8	44,9	40.5	19.6
44	9.9	30.4	43.3	38.6	18.8
49	9.7	29.2	42.1	37.0	18.5
54	9.5	28.6	41.0	35.4	18.2
59	9.3	28.2	39.9	34.2	17.8
64	9.2	27.9	38.9	33.0	17.7
69	9.1	27.6	38.1	31.6	17.6
74	9.1	27.4	37.4	30.5	17.4
79	9.0	27.0	36.9	29.5	17.3
84	9.0	26.8	36.5	28.6	17.3
89	8.9	26.6	36.1	28.0	17.2
94	8.9	26.5	35.8	27.3	17.2
99	8.9	26.4	35.5	26.7	17.0
104	8.9	26.2	35.4	26.2	17.0
109	8.9	26.0	35.1	25.7	17.0
114	8.9	25.9	34.8	25.2	17.0
119	8.9	25.8	34.6	25.0	16.8
124	8.9	25.7	34.4	24.8	16.8

Time	Head (Cm)				
	OBW 141	OBW 142	OBW 143	OBW 144	OBW 145
14	25.0	56.8	54.5	55.7	50.8
19	17.5	53.7	47.7	43.0	44.2
24	16.0	49.8	44.0	37.9	40.8
29	14.8	46.7	42.0	34.6	38.04
34	14.0	44.2	40.6	32.6	36.2
39	13.4	42.1	39.6	31.1	34.3
44	12.6	40.2	38.9	30.0	32.7
49	12.3	38.5	38.4	29.1	31.0
54	11.8	37.0	38.1	28.6	29.5
59	11.3	35.6	37.7	28.2	28.2
64	11.1	34.4	37.6	27.8	26.8
69	11.0	33.3	37.4	27.4	25.4
74	10.8	32.4	37.1	27.2	24.0
79	10.8	31.5	36.9	27.0	22.6
84	10.4	30.7	36.7	26.9	21.4
89	10.3	30.0	36.6	26.7	20.2
94	10.2	29.3	36.5	26.5	19.2
99	10.0	28.6	36.3	25.4	18.4
104	9.9	28.0	36.1	26.1	17.9
109	9.8	27.4	35.9	25.9	17.7
114	9.8	27.0	35.7	25.7	17.0
119	9.7	26.7	35.6	25.4	16.8
124	9.6	26.4	35.5	25.3	16.5

Time	Head (Cm)				
	OBW 151	OBW 152	OBW 153	OBW 154	OBW 155
14	12.2	56.0	62.0	56.2	53.0
19	9.4	49.4	60.9	54.5	48.7
24	8.9	44.6	59.9	52.8	45.1
29	8.7	40.8	59.0	51.4	42.3
34	8.3	37.8	58.0	50.0	40.1
39	8.2	35.4	57.1	48.7	38.3
44	8.2	33.6	56.2	47.3	36.4
49	8.0	31.8	55.2	46.2	34.8
54	7.9	30.4	54.3	45.1	33.5
59	7.8	29.2	53.3	44.1	32.3
64	7.8	28.4	52.4	43.2	31.1
69	7.8	27.6	51.5	42.3	30.0
74	7.8	26.8	50.7	41.4	29.0
79	7.8	26.2	49.9	40.5	28.0
84	7.8	25.8	49.3	39.8	27.2
89	7.8	25.4	48.6	39.2	26.5
94	7.8	25.0	48.0	38.5	25.7
99	7.8	24.8	47.4	37.9	25.1
104	7.8	24.7	46.8	37.3	24.5
109	7.8	24.4	46.2	36.8	24.0
114	7.8	24.0	45.7	36.3	23.6
119	7.8	24.0	45.7	36.3	23.6
124	7.8	23.6	44.6	35.5	22.7

Time	Head (Cm)				
	OBW 161	OBW 162	OBW 163	OBW 164	OBW 165
14	51.3	54.8	55.6	44.3	46.2
19	47.4	53.3	55.4	42.6	42.2
24	44.6	52.1	54.7	40.8	39.1
29	42.0	50.9	53.9	39.4	36.5
34	40.0	49.5	53.1	38.2	33.2
39	38.2	48.3	52.2	37.0	31.0
44	36.5	47.2	51.2	35.8	29.2
49	35.2	46.2	50.1	34.7	27.6
54	33.7	45.3	49.1	33.8	26.1
59	32.5	44.5	48.1	32.8	24.7
64	31.4	43.8	47.2	31.7	23.5
69	30.4	43.0	46.4	30.9	22.5
74	29.5	42.3	45.5	30.0	21.6
79	28.5	41.6	44.6	29.3	20.9
84	27.8	41.0	43.7	29.6	20.2
89	27.1	40.6	43.0	28.0	19.5
94	26.5	40.0	42.2	27.4	18.9
99	25.8	39.5	41.5	26.7	18.3
104	25.3	39.1	40.7	26.2	17.8
109	24.8	38.6	40.0	25.7	17.3
114	24.4	38.3	39.4	25.3	17.0
119	24.0	38.0	38.7	25.0	16.6
124	23.5	37.7	38.2	24.6	16.3

Time	Head (Cm)				
	OBW 171	OBW 172	OBW 173	OBW 174	OBW 175
14	19.1	43.9	44.0	41.0	41.9
19	17.4	39.5	43.0	38.2	37.2
24	16.5	35.9	41.0	35.1	32.6
29	15.9	33.4	39.3	32.8	29.0
34	15.5	31.6	37.8	31.0	26.6
39	15.4	30.0	36.2	29.4	24.6
44	15.2	28.6	34.7	27.7	22.8
49	14.9	27.5	33.2	26.1	21.2
54	14.7	26.6	31.8	24.7	19.9
59	14.5	25.7	30.6	23.4	18.6
64	14.3	25.2	29.5	22.3	17.5
69	14.1	24.5	28.5	21.2	16.5
74	13.9	24.0	27.4	20.3	15.7
79	13.7	23.5	26.4	19.3	14.9
84	13.6	23.0	25.5	18.6	14.1
89	13.4	22.5	24.6	17.9	13.5
94	13.2	22.1	23.7	17.3	12.8
99	13.0	21.7	22.9	16.7	12.3
104	12.8	21.4	22.1	16.2	11.7
109	12.6	21.1	21.5	15.7	11.4
114	12.5	21.0	20.8	15.2	11.0
119	12.5	20.7	20.2	14.8	10.6
124	12.5	20.6	19.7	14.5	10.5

Time	Head (Cm)				
	OBW 181	OBW 182	OBW 183	OBW 184	OBW 185
14	42.2	40.5	42.0	39.3	36.5
19	38.8	36.8	41.0	38.3	34.6
24	35.6	34.1	40.0	37.4	32.8
29	32.7	31.8	38.9	36.4	31.0
34	30.5	29.8	37.8	35.5	29.4
39	28.6	28.1	36.9	34.2	28.0
44	27.0	26.5	36.0	33.8	26.7
49	25.4	25.2	35.1	33.0	25.5
54	24.1	24.0	34.2	32.1	24.3
59	22.7	23.0	33.3	31.3	23.2
64	21.3	22.0	32.5	30.4	22.1
69	20.1	21.1	31.6	29.5	21.1
74	19.0	20.3	30.9	28.6	20.1
79	18.0	19.5	30.0	27.8	19.1
84	17.0	18.9	29.2	27.0	18.2
89	16.0	18.3	28.4	26.2	17.4
94	15.2	17.7	27.6	25.4	16.5
99	14.5	17.2	26.9	24.8	15.6
104	13.8	16.6	26.2	24.3	15.0
109	13.2	16.0	25.5	23.8	14.4
114	12.7	15.6	24.8	23.4	13.7
119	12.3	15.2	24.0	23.0	13.3
124	12.0	14.8	23.3	22.7	13.0

The subscrips of observation wells denotes the following

1) First digit indicates the OBW line
2) Second digit indicates the drain line
3) Third digit indicates the position of the OBW from the drain line towards the left

Time	Head (Cm)				
	OBW 211	OBW 212	OBW 213	OBW 214	OBW 215
14	37.0	68.4	66.5	67.0	74.2
19	27.2	66.4	63.7	61.6	71.8
24	23.0	65.1	61.0	59.0	69.8
29	21.2	64.5	58.7	57.2	68.8
34	20.2	64.2	56.8	56.0	68.0
39	20.0	64.2	55.4	54.9	67.4
44	20.0	64.0	54.0	54.0	66.9
49	20.0	64.0	52.8	53.1	66.6
54	20.0	64.0	51.8	52.3	66.2
59	20.0	63.6	51.1	51.5	66.0
64	19.8	63.3	50.5	50.7	65.5
69	19.8	62.6	50.0	50.0	65.0
74	19.7	61.6	49.5	49.2	64.2
79	19.6	60.2	49.0	48.4	63.4
84	19.5	57.4	48.5	47.6	62.2
89	19.5	54.5	48.2	46.9	59.6
94	19.5	52.2	47.9	46.2	53.0
99	19.4	50.4	47.8	45.4	47.4
104	19.4	49.0	47.6	44.7	42.0
109	19.4	47.7	47.5	44.0	38.0
114	19.3	46.4	47.4	43.4	34.6
119	19.3	45.1	47.4	42.7	32.0
124	19.3	44.1	47.4	42.1	29.9

Time	Head (Cm)				
	OBW 221	OBW 222	OBW 223	OBW 224	OBW 225
14	22.8	45.2	67.0	71.9	63.6
19	21.1	38.0	63.5	69.9	58.5
24	20.4	35.0	60.2	68.2	54.4
29	20.1	33.0	57.2	66.7	50.5
34	19.8	32.0	55.1	65.1	47.0
39	19.7	31.6	53.3	63.4	44.2
44	19.5	31.4	52.0	61.6	41.6
49	19.2	31.2	50.8	59.8	39.4
54	19.0	31.0	49.9	58.2	37.2
59	18.7	30.8	49.2	56.5	35.5
64	18.2	30.7	48.6	54.5	33.8
69	17.0	30.4	48.2	52.4	32.4
74	15.5	30.2	47.8	50.2	31.2
79	14.3	30.0	47.5	48.0	30.0
84	13.4	29.6	47.3	46.1	29.0
89	12.8	29.4	47.0	44.5	28.0
94	12.3	29.3	46.7	42.9	27.[illegible]
99	12.0	29.2	46.6	41.5	26.8
104	11.8	29.0	46.5	40.5	26.0
109	11.4	28.7	46.5	39.5	25.5
114	11.2	28.5	46.5	38.7	25.0
119	11.0	28.4	46.5	38.4	24.8
124	10.8	28.4	46.4	38.3	24.4

Time	Head (Cm)				
	OBW 231	OBW 232	OBW 233	OBW 234	OBW 235
14	13.0	63.0	68.0	57.4	58.6
19	9.8	57.8	65.9	52.4	51.7
24	9.0	53.6	63.8	47.3	44.0
29	9.0	50.2	61.9	44.0	39.0
34	9.0	47.0	60.2	41.4	33.8
39	9.0	44.4	58.7	39.1	31.4
44	9.0	42.0	57.2	37.3	29.0
49	9.0	40.0	55.8	35.8	26.8
54	9.0	38.2	54.5	34.6	25.0
59	9.0	36.4	53.2	33.5	23.4
64	9.0	35.2	52.0	32.7	22.4
69	9.0	34.2	51.0	32.2	21.4
74	9.0	33.2	50.0	31.7	20.6
79	9.0	32.4	49.2	31.3	19.8
84	9.0	31.4	48.3	30.9	19.2
89	9.0	30.8	47.5	30.6	18.8
94	8.8	30.0	46.7	30.4	18.4
99	8.8	29.4	45.9	30.2	18.0
104	8.8	28.9	45.3	30.0	17.8
109	8.7	28.4	44.6	29.7	17.5
114	8.7	28.0	44.1	29.6	17.0
119	8.6	27.4	43.6	29.5	16.9
124	8.5	27.3	43.2	29.4	16.9

Time	Head (Cm)				
	OBW 241	OBW 242	OBW 243	OBW 244	OBW 245
14	54.6	61.5	63.7	64.6	50.0
19	50.4	59.5	63.0	62.5	38.6
24	46.8	57.6	62.4	59.5	33.0
29	43.4	55.5	61.8	55.8	29.0
34	40.0	53.4	61.2	52.6	26.0
39	36.8	51.4	60.6	49.8	23.6
44	34.2	49.4	59.9	47.4	21.6
49	31.9	47.6	59.2	45.4	20.4
54	29.6	45.7	58.6	43.4	19.6
59	27.4	44.2	57.9	41.6	19.0
64	25.5	42.8	57.3	40.2	18.6
69	23.9	41.5	56.6	38.6	18.2
74	22.4	40.2	55.9	37.3	17.9
79	21.0	39.0	55.1	36.2	17.5
84	19.6	37.8	54.4	35.2	17.4
89	18.4	36.9	53.7	34.2	17.2
94	17.2	35.9	53.0	33.5	17.0
99	16.2	35.2	52.4	32.9	17.0
104	15.4	34.5	51.6	32.3	17.0
109	14.6	33.8	51.1	31.7	16.9
114	13.8	33.3	50.5	31.1	16.9
119	13.1	32.8	49.9	30.6	16.8
124	12.5	32.5	49.4	30.1	16.8

Time	Head (Cm)				
	OBW 251	OBW 252	OBW 253	OBW 254	OBW 255
14	11.0	63.8	64.5	59.1	60.9
19	9.6	61.0	64.2	57.2	56.8
24	9.6	56.8	63.7	53.7	53.7
29	9.6	53.0	63.1	54.3	50.7
34	9.5	49.8	62.4	52.8	48.4
39	9.4	47.0	61.7	51.4	46.2
44	9.4	44.6	60.9	50.2	44.4
49	9.4	42.5	60.3	48.9	42.5
54	9.4	40.6	59.5	47.6	41.0
59	9.4	39.2	58.6	46.5	39.6
64	9.4	37.7	57.7	45.5	38.5
69	9.4	36.4	57.1	44.5	37.4
74	9.4	35.0	56.4	43.6	36.4
79	9.4	34.0	55.6	43.8	35.5
84	9.4	33.0	54.8	42.0	34.6
89	9.4	32.0	53.9	41.3	33.9
94	9.4	31.2	53.1	40.5	33.2
99	9.4	30.4	52.3	39.9	32.5
104	9.4	29.6	51.5	39.2	31.8
109	9.4	29.0	50.6	38.7	31.3
114	9.4	28.6	49.7	38.2	30.8
119	9.4	28.0	48.8	37.8	30.4
124	9.4	27.6	48.0	37.5	30.0

Time	Head (Cm)				
	OBW 261	OBW 262	OBW 263	OBW 264	OBW 265
14	51.3	51.9	57.5	50.2	47.2
19	48.1	51.0	56.7	48.8	43.8
24	45.0	50.2	55.9	47.2	40.2
29	42.4	49.4	55.1	45.8	37.1
34	40.4	48.6	54.4	44.4	34.5
39	38.5	47.8	53.6	43.1	32.2
44	36.8	47.0	52.8	41.8	30.3
49	35.3	46.0	52.0	40.6	29.0
54	34.0	45.2	51.2	39.2	27.4
59	32.9	44.4	50.4	38.0	26.0
64	32.0	43.6	49.8	36.8	24.6
69	31.2	42.7	48.9	35.5	23.4
74	30.4	41.9	48.1	34.2	22.4
79	29.8	41.0	47.4	33.2	21.6
84	29.2	40.3	46.6	32.2	21.0
89	28.6	39.4	45.8	31.2	20.4
94	28.2	38.6	45.1	30.3	19.7
99	27.7	37.8	44.3	29.6	19.2
104	27.2	37.0	43.5	28.7	18.7
109	26.9	36.2	42.7	27.9	18.3
114	26.6	35.4	41.9	27.2	17.8
119	26.3	34.5	41.1	26.5	17.5
124	26.1	33.7	40.4	25.9	17.2

Time	Head (Cm)				
	OBW 271	OBW 272	OBW 273	OBW 274	OBW 275
14	51.0	47.0	39.4	41.0	44.0
19	49.5	45.8	37.9	39.1	39.4
24	47.6	44.5	36.6	37.4	36.4
29	45.3	43.2	35.4	35.8	33.9
34	43.1	42.0	34.2	34.1	31.4
39	41.0	40.8	33.2	32.5	29.2
44	39.2	39.7	32.1	31.0	27.4
49	37.4	38.6	31.1	29.4	25.6
54	36.0	37.5	30.1	28.0	24.0
59	34.5	36.3	29.2	26.8	22.4
64	33.1	35.3	28.3	25.5	21.4
69	32.0	34.5	27.5	24.5	20.2
74	30.8	33.2	26.8	23.5	19.3
79	29.6	32.3	26.0	22.6	18.4
84	28.6	31.5	25.2	21.5	17.5
89	27.7	30.7	24.4	20.8	16.6
94	26.7	29.9	23.7	20.0	15.7
99	25.8	29.1	23.0	19.3	15.0
104	25.0	28.5	22.3	18.7	14.3
109	24.1	27.7	21.6	18.0	13.7
114	23.4	27.0	20.9	17.4	13.1
119	22.8	26.3	20.2	16.8	12.6
124	22.1	25.7	20.1	16.3	12.1

Time	Head (Cm)				
	OBW 281	OBW 282	OBW 283	OBW 284	OBW 285
14	46.2	46.9	46.3	40.2	37.6
19	43.1	45.1	45.3	39.3	35.0
24	40.2	43.2	44.3	38.3	32.3
29	37.0	41.3	43.3	37.0	30.0
34	34.3	39.4	42.4	35.6	29.6
39	32.0	37.9	41.5	34.4	25.7
44	30.2	36.4	40.5	33.1	24.0
49	28.4	34.8	39.6	32.0	22.6
54	26.4	33.4	38.6	31.0	21.1
59	25.0	32.1	37.8	30.0	19.8
64	23.6	30.9	37.0	29.1	18.5
69	22.3	29.7	36.2	28.3	17.3
74	21.0	28.6	35.2	27.5	16.2
79	20.0	27.6	34.3	26.8	15.3
84	19.0	26.7	33.4	26.1	14.3
89	18.2	25.7	32.6	25.4	13.4
94	17.4	24.8	31.8	24.8	12.8
99	16.6	24.0	31.0	24.2	12.2
104	16.0	23.1	30.2	23.6	11.2
109	15.3	22.4	29.4	23.0	11.0
114	14.6	21.6	28.6	22.6	10.4
119	14.0	21.0	27.8	22.0	9.8
124	13.4	20.2	27.0	19.8	9.3

Time	Head (Cm)				
	OBW 311	OBW 312	OBW 313	OBW 314	OBW 315
14	64.8	69.2	74.7	70.6	71.0
19	56.8	66.5	73.6	66.3	66.0
24	51.4	63.9	72.7	61.1	61.8
29	47.6	61.1	71.8	56.9	57.6
34	44.8	58.8	70.8	53.2	54.2
39	42.5	56.5	69.8	49.6	50.6
44	40.5	54.4	68.9	46.8	47.6
49	39.0	52.7	68.1	44.4	44.8
54	37.5	51.1	67.2	42.5	42.4
59	36.3	49.6	66.3	40.8	40.4
64	34.8	48.3	65.4	39.6	38.4
69	33.8	47.0	64.7	38.8	36.6
74	32.8	45.8	64.1	38.0	35.0
79	31.9	44.6	63.4	37.2	33.4
84	31.0	43.6	62.8	36.6	32.0
89	30.2	42.8	62.2	35.8	30.6
94	29.5	42.1	61.7	35.2	29.4
99	28.9	41.5	61.3	34.6	28.4
104	28.3	40.9	60.8	34.2	27.5
109	27.9	40.4	60.5	33.7	26.5
114	27.6	38.9	60.0	33.4	25.7
119	27.2	39.4	59.6	33.0	25.0
124	27.0	39.0	59.3	32.8	24.4

Time	Head (Cm)				
	OBW 321	OBW 322	OBW 323	OBW 324	OBW 325
14	65.6	72.3	75.4	70.2	67.0
19	57.8	70.9	74.5	67.2	61.0
24	51.9	68.4	73.6	63.6	55.6
29	47.5	66.1	72.7	60.2	50.6
34	43.8	64.1	71.7	57.1	46.4
39	40.0	62.0	70.8	53.9	42.5
44	36.6	60.0	69.8	51.0	39.2
49	33.8	58.1	68.8	48.2	36.0
54	31.3	56.3	67.9	45.9	33.4
59	29.0	54.6	66.9	43.6	30.8
64	27.0	52.9	66.0	41.8	28.8
69	25.0	51.5	65.0	40.0	27.0
74	23.6	50.1	64.2	38.7	25.3
79	22.1	48.8	63.3	37.4	24
84	20.6	47.7	62.5	35.2	22.6
89	19.3	46.7	61.8	35.2	21.6
94	18.3	45.7	61.1	34.2	20.5
99	17.4	44.8	60.4	33.4	19.6
104	16.6	44.0	59.8	32.4	18.8
109	16.0	43.3	59.1	31.9	18.0
114	15.4	42.6	58.4	31.4	17.4
119	14.8	42.0	57.7	31.0	16.8
124	13.9	41.5	57.0	30.8	16.4

Time	Head (Cm)				
	OBW331	OBW 332	OBW 333	OBW 334	OBW 335
14	62.3	70.3	74.5	72.1	61.0
19	50.2	67.3	73.2	70.3	54.0
24	43.7	63.5	71.7	68.6	46.0
29	38.6	60.0	70.6	65.9	40.0
34	34.2	56.6	69.3	65.3	35.4
39	30.5	53.4	68.1	63.7	31.6
44	27.3	50.4	66.9	62.2	28.4
49	24.2	47.5	65.7	60.7	25.4
54	21.7	44.7	64.4	59.1	23.0
59	19.8	42.4	63.0	57.5	21.0
64	18.0	40.5	61.6	56.0	19.0
69	16.7	38.6	60.2	54.5	17.8
74	15.6	37.0	59.0	53.2	16.8
79	14.6	35.6	57.9	51.9	15.8
84	13.9	34.1	56.9	50.7	15.0
89	13.4	32.9	56.0	49.4	14.2
94	12.8	31.9	55.2	48.2	13.8
99	12.3	30.9	54.3	47.0	13.2
104	11.8	30.0	53.7	45.9	12.6
109	11.3	29.2	53.2	44.8	12.3
114	10.8	28.4	52.7	43.8	12.0
119	10.4	27.7	52.2	42.9	11.5
124	10.0	27.3	51.8	42.3	11.2

Time	Head (Cm)				
	OBW 341	OBW 342	OBW 343	OBW 344	OBW 345
14	56.0	68.4	74.7	66.8	64.4
19	43.0	64.3	73.0	62.5	59.2
24	34.0	60.6	71.7	58.8	54.5
29	27.0	57.2	70.2	55.3	49.6
34	22.8	54.0	69.0	52.1	45.4
39	19.2	50.8	67.8	49.0	42.0
44	16.7	48.0	66.5	46.3	38.6
49	14.6	45.4	65.3	43.6	35.7
54	13.2	43.0	64.0	41.4	33.0
59	12.0	41.0	62.8	39.2	30.6
64	11.0	39.0	61.6	37.0	28.4
69	10.2	37.2	60.5	35.4	26.5
74	9.8	35.6	59.5	31.7	25.0
79	9.4	34.0	58.5	32.3	23.4
84	9.0	32.5	57.5	30.8	22.2
89	8.8	31.9	56.5	29.6	21.0
94	8.8	30.4	55.6	28.4	20.0
99	8.5	29.5	55.0	27.3	19.0
104	8.4	28.7	54.5	26.3	18.4
109	8.2	28.2	54.2	25.4	17.6
114	8.0	27.5	54.1	24.5	16.7
119	8.0	26.9	54.1	23.6	16.0
124	7.8	26.5	53.9	22.8	15.6

Time	Head (Cm)				
	OBW 351	OBW 352	OBW 353	OBW 354	OBW 355
14	65.6	68.8	59.4	68.9	66.4
19	61.6	67.3	58.6	68.3	65.3
24	57.3	65.6	57.9	67.8	64.4
29	53.4	63.8	57.1	67.1	63.3
34	50.0	62.0	56.4	66.2	62.1
39	47.2	59.9	55.5	64.9	60.7
44	44.4	57.8	54.7	63.4	59.0
49	41.8	55.9	53.8	62.0	57.2
54	39.6	54.2	53.0	60.4	54.8
59	37.5	52.4	52.0	59.0	53.0
64	35.4	50.6	51.0	57.2	51.0
69	33.4	48.9	49.9	55.5	48.8
74	31.7	47.2	48.8	53.9	47.0
79	30.0	45.7	47.8	52.3	45.2
84	23.4	44.3	46.7	50.7	43.3
89	26.8	43.0	45.6	49.0	41.7
94	25.4	41.6	44.4	47.4	39.8
99	24.0	40.4	43.3	46.1	38.2
104	23.0	39.2	42.3	44.3	36.7
109	21.8	38.2	41.2	42.6	35.4
114	21.0	37.2	40.2	41.0	34.1
119	20.0	36.2	38.9	39.3	33.0
124	19.4	35.2	37.7	27.6	32.2

Time	Head (Cm)				
	OBW 361	OBW 362	OBW 363	OBW 364	OBW 365
14	61.1	60.6	60.5	57.0	58.2
19	53.6	60.2	60.5	56.0	54.9
24	48.5	59.8	60.5	55.0	51.4
29	43.8	59.4	60.5	54.0	48.0
34	40.0	58.8	60.5	53.2	44.9
39	36.8	58.3	60.5	52.6	42.0
44	33.8	57.9	60.5	52.2	39.4
49	31.5	57.1	60.5	51.9	37.5
54	29.5	56.5	60.5	51.6	35.7
59	27.7	55.8	60.5	51.3	34.2
64	26.3	55.1	60.5	51.0	32.7
69	24.7	54.3	60.5	50.5	31.4
74	23.3	53.6	60.5	49.8	30.0
79	22.2	52.8	60.5	49.1	28.7
84	21.0	51.8	58.5	48.5	27.6
89	20.0	50.9	58.5	47.5	26.4
94	19.2	50.0	58.5	46.5	25.4
99	18.5	49.2	58.5	45.4	24.4
104	17.8	48.2	58.5	44.2	23.4
109	17.1	47.2	58.5	43.1	22.6
114	16.7	46.3	58.5	42.1	21.9
119	16.4	45.4	57.5	41.0	21.2
124	16.1	44.2	56.3	40.0	20.5

Time	Head (Cm)				
	OBW 371	OBW 372	OBW 373	OBW 374	OBW 375
14	49.8	55.0	52.0	48.8	16.0
19	39.4	53.0	51.6	44.6	10.8
24	33.0	51.2	51.3	41.6	8.2
29	28.2	49.5	51.2	39.1	7.3
34	25.4	47.8	50.8	37.2	7.0
39	23.0	46.5	50.6	35.8	6.8
44	21.0	45.2	50.4	34.6	6.4
49	19.4	44.0	50.0	33.2	6.1
54	20.2	43.0	50.0	32.0	6.0
59	17.2	42.0	49.5	30.8	5.8
64	16.5	40.8	49.0	29.6	5.6
69	15.8	39.7	48.4	28.6	5.4
74	15.2	38.7	47.8	27.5	5.2
79	14.8	37.6	47.4	26.6	5.0
84	14.4	36.8	46.8	25.8	4.8
89	14.0	35.9	46.2	25.0	4.7
94	13.4	35.0	45.6	24.5	4.6
99	13.0	34.2	45.0	23.9	4.5
104	12.5	33.3	44.2	23.4	4.5
109	12.2	32.4	43.4	23.0	4.4
114	11.8	31.6	42.7	22.7	4.4
119	11.5	30.8	41.6	22.4	4.2
124	11.2	30.0	40.4	22.0	4.0

Time	Head (Cm)				
	OBW 381	OBW 382	OBW 383	OBW 384	OBW 385
14	8.6	43.3	45.2	37.6	39.0
19	6.8	38.4	44.7	35.7	35.6
24	5.8	34.6	44.0	34.4	32.6
29	5.2	31.9	43.3	33.1	30.0
34	4.8	29.7	42.6	32.2	27.5
39	4.7	28.1	42.0	31.5	25.3
44	4.5	26.8	41.6	30.9	23.1
49	4.5	25.8	41.2	30.4	21.2
54	4.5	24.9	40.8	29.9	19.4
59	4.5	24.1	40.3	29.2	17.9
64	4.5	23.4	39.6	28.7	16.5
69	4.5	22.6	38.9	28.2	15.2
74	4.4	21.8	38.2	27.6	14.0
79	4.4	21.2	37.5	27.1	13.1
84	4.4	20.5	37.0	26.4	12.2
89	4.4	20.0	36.3	25.9	11.5
94	4.4	19.5	35.7	25.4	10.9
99	4.3	19.0	35.1	24.9	10.3
104	4.0	18.6	34.6	24.3	9.7
109	3.8	18.2	34.1	23.7	9.1
114	3.7	17.9	33.4	23.2	8.5
119	3.6	17.6	32.7	22.7	8.0
124	3.4	17.5	32.1	22.2	7.5

APPENDIX II

Hydraulic heads at different times of pumping

OBW No.	0 hrs.	24 hrs	74 hrs.	124 hrs
111	61.25	38.6	24.7	22.5
112	63.25	57.4	45.5	41.3
113	63.75	57.6	44.5	43.0
114	63.25	45.6	35.2	34.6
115	62.50	43.5	21.0	16.1
121	61.75	39.0	17.6	14.0
122	62.75	43.6	31.1	29.8
123	62.75	55.7	43.1	40.7
124	61.25	47.0	29.4	26.7
125	55.75	46.0	25.4	18.5
131	62.25	13.7	9.1	8.9
132	61.25	40.1	27.4	25.7
133	57.50	51.0	37.4	34.4
134	60.25	47.2	30.5	24.8
135	58.75	20.6	17.4	16.8
141	58.25	16.0	10.8	9.6
142	59.25	49.8	32.4	26.4
143	58.25	44.0	37.1	35.5
144	60.25	37.9	27.2	25.3
145	--	40.8	24.0	16.6
151	59.75	8.9	7.8	7.8
152	60.75	44.6	26.8	23.6
153	62.75	59.9	50.7	44.6
154	58.00	52.8	41.4	35.5
155	56.00	45.1	29.0	22.7
161	54.00	44.6	29.5	23.5
162	55.50	52.1	42.3	37.7
163	56.00	54.7	45.5	38.2
164	45.50	40.8	30.0	24.6
165	48.50	39.1	21.6	16.3
171	47.50	16.5	13.9	12.5
172	47.50	35.9	24.0	20.6
173	44.00	41.0	27.4	19.7
174	42.50	35.1	20.3	14.5
175	44.50	32.6	15.7	10.5
181	45.50	35.60	19.0	12.0
182	42.50	34.1	20.3	14.8
183	42.50	40.0	30.9	23.3
184	40.00	37.4	28.6	22.7
185	38.00	32.8	20.1	13.0

OBW No.	0 hrs.	24 hrs.	74 hrs.	124 hrs
211	63.0	23.0	19.7	19.3
212	70.0	65.1	61.6	44.1
213	68.5	61.0	49.5	47.4
214	70.0	59.0	49.2	42.1
215	55.0	69.8	64.2	29.9
221	65.5	20.4	15.5	10.8
222	68.0	35.0	30.2	28.4
223	68.5	60.2	47.8	46.4
224	74.0	68.2	50.2	38.3
225	68.0	54.4	31.2	24.4
231	64.0	9.0	9.0	8.5
232	68.5	53.6	33.2	27.3
233	68.0	63.8	50.0	43.2
234	61.5	47.3	31.7	29.4
235	63.0	44.0	20.6	16.9
241	61.5	46.3	22.4	12.5
242	62.5	57.6	40.2	32.5
243	64.5	62.4	55.9	49.4
244	65.0	59.5	37.3	30.1
245	60.0	33.0	17.9	16.8
251	53.5	9.6	9.4	9.4
252	65.0	56.3	35.0	27.6
253	64.5	63.7	56.4	48.0
254	60.5	53.7	43.6	37.5
255	60.0	53.7	36.4	30.0
261	64.5	53.0	30.4	26.1
262	53.0	52.0	41.9	33.7
263	52.0	58.5	48.1	40.4
264	58.5	50.5	34.2	25.9
265	50.5	49.0	22.4	17.2
271	51.5	47.6	30.8	22.1
272	46.0	44.5	33.2	25.7
273	40.0	36.6	26.8	20.1
274	40.5	37.4	23.5	16.3
275	47.0	36.4	19.3	12.1
281	48.0	40.2	21.0	13.4
282	47.5	43.2	28.6	20.2
283	44.0	44.3	35.2	27.0
284	40.0	38.3	27.5	19.8
285	38.5	32.3	36.2	9.3

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OBW No.	0 hrs.	24 hrs.	74 hrs.	124 hrs.
311	70.25	51.4	32.8	27.0
312	70.75	63.9	45.8	39.0
313	74.75	72.7	64.1	59.3
314	73.25	61.1	38.0	32.8
315	73.75	61.8	35.0	24.4
321	72.25	51.9	23.6	13.9
322	72.75	68.4	50.1	41.5
323	75.75	73.6	64.2	57.0
324	71.25	63.6	38.7	30.8
325	70.75	55.6	25.3	16.4
331	69.75	43.7	15.6	10.0
332	72.25	63.5	37.0	27.3
333	73.25	71.7	59.0	51.8
334	73.25	68.6	53.2	42.3
335	67.25	46.0	16.8	11.2
341	66.75	34.0	9.8	7.8
342	71.25	60.6	35.6	26.5
343	74.25	71.7	59.5	53.9
344	75.75	58.6	31.7	22.8
345	67.25	54.5	25.0	15.6
351	68.25	57.3	31.7	19.4
352	69.75	65.6	47.2	35.2
353	60.50	57.9	48.8	37.7
354	69.00	67.8	53.9	27.6
355	67.00	64.4	47.0	32.2
361	66.50	48.5	23.3	16.1
362	60.50	59.8	53.6	44.2
363	61.00	60.5	60.5	56.3
364	57.50	55.0	49.8	40.0
365	57.50	51.4	30.0	20.5
371	59.50	33.0	15.2	11.2
372	54.00	51.2	38.7	30.0
373	52.50	51.3	47.8	40.4
374	52.00	41.6	27.5	22.0
375	53.00	8.2	5.2	4.0
381	52.50	5.8	4.4	3.4
382	48.00	34.6	21.8	17.5
383	45.50	44.0	38.2	32.1
384	39.50	34.4	27.6	22.2
385	42.50	32.6	14.0	7.5

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