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EVALUATION OF WELL PERFORMANCE AND WATER MANAGEMENT OF MONA RECLAMATION EXPERIMENTAL PROJECT (1965 — 1970)

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Synopsis

WAPDA's programme for the control of waterlogging and salinity is intended to ultimately cover the entire canal irrigated area in West Pakistan. The programme calls for intensification of agriculture rather than to merely act as means for subsurface drainage and reclamation of land. According to Regional Plan for the Northern Indus Plain, there will be 18 salinity control and reclamation projects covering an area of about 21 million acres and envisages construction of some 28,000 tubewells. In order to secure the success of this huge programme it was felt necessary to ensure effective mangement of the projects for achieving the planned objectives and to undertake investigation and research so as to develop new criteria for the optimum use of land and water resources and to formulate new concept for use in future projects. As a result of these considerations, Mona Scheme which is a part of the overall reclamation project for Chaj Doab was selected as a pilot project and is known as Mona Reclamation Experimental Project.

The project consists of 138 tubewells of 2 to 4 cusec capacity with an aggregate pumping capacity of 456 cusecs and serves an area of 1,09,700 acres of which 1,05,000 is culturable. In all wells except No. 83, the pump housing casing pipe and screens are of mild steel. The screens are mild steel slotted casing pipes, vertically slotted, with the slot size varying from $2\frac{1}{2}'' \times 1/16''$ to $2\frac{3}{4}'' \times 3/32''$, and an approximate inlet area of 27 square inches per lineal foot. The specific capacity of wells varied from 40 to 160 gpm/ft., with a median value of 87 gpm/ft. The project was constructed during 1963-64 and went into operation in July, 1965.

Hydrologic monitoring and tubewell performance studies in the project were initiated by the Central Monitoring Organization and included tubewell performance studies and the observation of sub-soil water level at strategic points. Annual reports for the project covering these aspects had been issued

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from time to time and the present paper presents an overall appraisal for the year 1965-1970. The tubewell performance studies indicate that during the first five years of operation specific capacity of 24 wells was affected and out of these in 13 wells the decrease was more than 20 per cent. Similarly the discharges of 55 wells decreased by more than 10 per cent, and out of these for 19 wells the decline could be partially attributed to the deterioration in wells' specific capacity. The pumping capacity of the scheme registered 7 per cent fall by June 1966 and 9 per cent by June, 1970. In spite of serious deterioration in many wells, only one well No. 140 was developed during this period, when its specific capacity had reduced by 70 per cent. Analysis of the well for the period January to November 1967 indicates that pumping under deteriorated condition resulted in an increase in power cost of Rs. 2,400 and 260 acre feet reduction in water supply. If 58.7 rupees is assumed as the economic value of one acre foot of water, then a further indirect loss of Rs. 15,300 occurred as a result of delay in development. The economic repercussions of late development can be easily appreciated. Economic analysis of operation and well development assuming 30 per cent reduction in specific capacity indicates that the tubewell development would be economical as compared to pumping a deteriorated well if the development remains effective for a period of one month in case of a 5 cusec well and 6 months in a case of 2 cusecs well. If the reduction in specific capacity is more, then the period for which development should remain effective further reduces.

The installed capacity of the schemes is based on the ultimate cropping intensity to be attained in the project, and during the intervening years the pumpage has to be controlled according to the crop water requirements. In order to evaluate the tubewell deliveries and the corresponding crop need, the cropping year, April 1968 to March, 1969, has been evaluated on the basis of actual crop statistics, canal supplies and the tubewell pumpage. The study indicates that against the required tubewell pumpage of nearly 1,42,000 acre feet, 1,75,000 acre feet of water was pumped, resulting in excess pumpage of 33,000 acre feet, and an increased power cost of 1,65,000 rupees, if the power cost per acre foot of the pumped water is assumed at Rs. 5. Pumping of the ground water reservoir in excess of the need, not only resulted in excess maintenance charges but also wastage of ground water potential and the likelihood of accelerating the changes in water quality. The growth of cropping intensity on many distributaries is less than 10 per cent, though the project as a whole registered an increase of 26 per cent.

INTRODUCTION

General Features of the Project Area

To assure success of large reclamation projects being undertaken, Mona scheme which is a small part of SCARP II (Chaj Doab), was selected as an ex-

perimental project. In addition to reclaiming the salinized and waterlogged land of the area, the main objectives of the project are ;

(*i*) to serve as a proving ground and pilot project for evaluating the techniques of reclamation ;

(*ii*) within the scope of operating and maintaining the scheme, there will be a continuous programme of data collection and evaluation covering all aspects of the field ;

(*iii*) concurrently with this there will be a development programme utilizing the services of a specialist to determine, implement and teach improved agricultural practices, and benefits from these aspects of the scheme will be in the form of increased productivity within the scheme area as well as the formulation of more accurate criteria on which to design and operate future reclamation projects.

The project area is situated in the north central part of Chaj Doab and is bounded on the north by Shahpur Canal, on the east by Lower Jhelum Canal and on the south by the northern branch of Lower Jhelum Canal. The gross area within the project boundary is 1,16,500 acres of which nearly 1,11,500 acres are culturable (Fig. 1).

A large part of the culturable area, nearly 92,700 acres, of which 78,900 acres is commanded, is served by eleven distributaries and direct outlets offtaking from Shahpur Branch, Lower Jhelum Canal and its northern branch. The average perennial and non-perennial diversions at the head of distributaries, based on 1960-65 record, is estimated at 1,37,000 and 27,500 acre feet respectively. The remaining culturable area was partly under dry farming and partly under private tubewell irrigation. The annual pumpage of private tubewells is estimated at 25,000 acre feet. The average annual precipitation varies from 14 to 20 inches.

The surface relief in the area is low and for storm runoff there is a fairly large network of surface drains comprising of about 80 miles of main and branch drains and 18 miles of tributary drains. The major surface drain passing through the area is Mona drain which is an extension of the Chot drain originating in the Upper Chaj Doab. The average annual inflow through this drain was 7,000 acre feet and the outflow 26,000 acre feet.

Average altitude of the subsoil water level before operation of project was about 448 feet above the mean sea level and nearly 21,000 acres were affected by salinity and waterlogging. The major source of recharge to the area were subsurface inflow from adjacent areas, seepage from the irrigation system and infilteration from precipitation; while the elements of discharge were subsurface

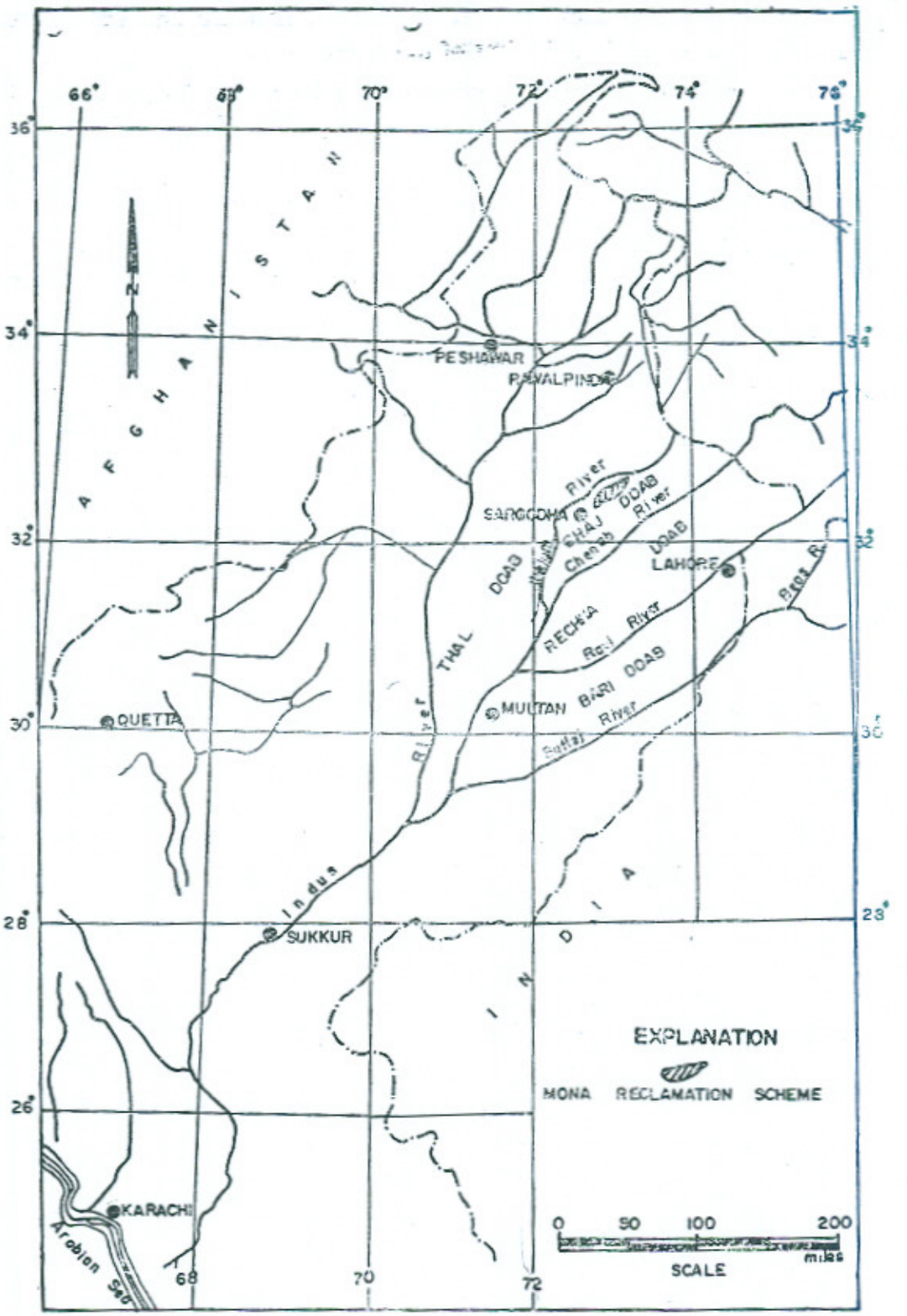


Fig. 1. Index map of West Pakistan showing the Mona Reclamation scheme

outflow, ground water pumpage, evapotranspiration and flow to drains. The aquifer was nearly in a state of equilibrium and an approximate flow chart for the pre-project conditions (1964-65) was as given in Figure 2.

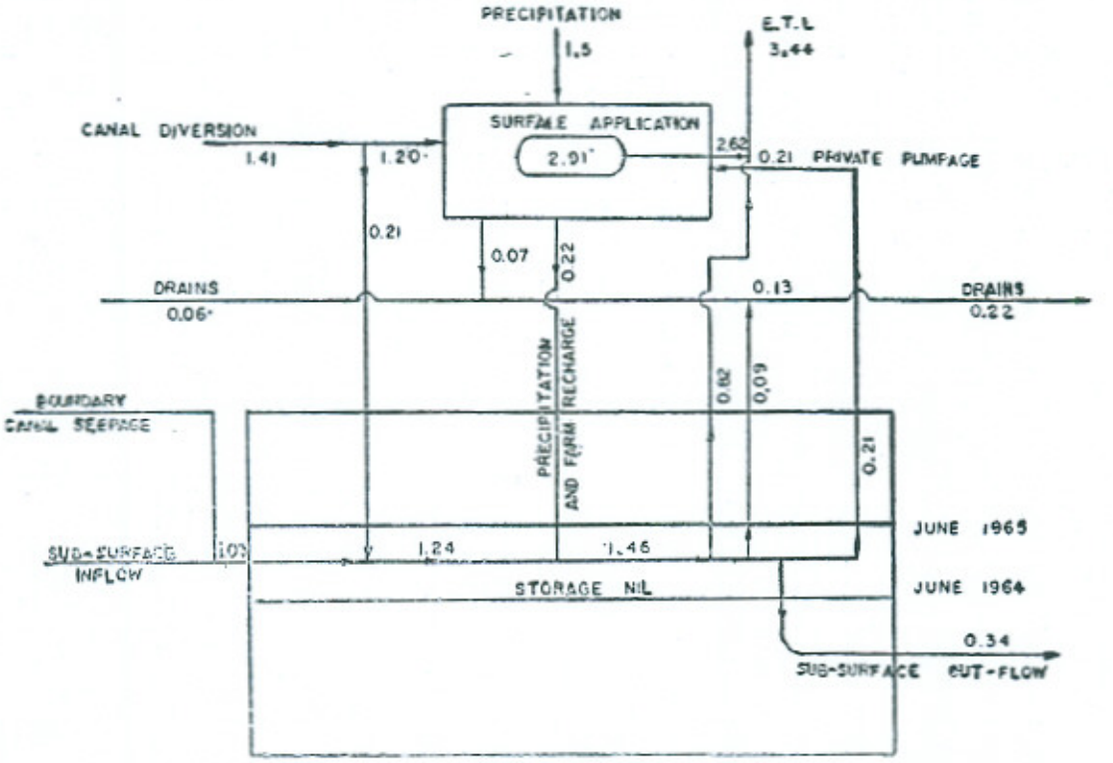


Fig. 2. Schematic flow chart showing Approximate Water Balance during period 1964-65 (All quantities in ft.)

Development Plan

There was nearly 21,000 acres of waterlogged land in the project area, and the average cropping intensity 100 per cent. The project had been designed to create favourable drainage conditions through exploitation of ground water, and supplementing the surface water supplies with extra water thus available, to remove salinity and enhance the cropping intensity to nearly 150 per cent. In addition, it was designed to extend irrigation facilities to nearly 12,000 acres of land presently under dry farming. Originally 148 project wells were proposed; however, 10 wells (Nos. 35, 38, 43, 85-90) were dropped later due to high salinity expected in the aquifer. Part of the area proposed to have been covered by these tubewells was transferred to the adjoining wells and for the remaining area (nearly 6,800 acres) supplemental canal supply (24 cusecs) was proposed. This additional canal supply has not been arranged so far thus reducing the original proposed gross project area to 109,700 acres of which 105,000 acres is culturable (Table 1).

TABLE 1.—*Break up Mona Project area according to Perennial, Non-Perennial and Uncommanded Lands*

Classification Area.		No. of T/wells	Gross Area (acre)	Ghair Mumkin (acre)	C.A. (acre)	C.C.A. (acre)
A.	(*i*) Perennial	81	77655	3650	74005	61994
	(*ii*) Non-Perennial	30	19149	414	18735	16872
	(*iii*) Uncommanded	27	12909	634	12275	—
Sub-Total(A) :—		138	109713	4698	105015	78866
	List of Areas under Tubewells not installed and where increase in canal supply is proposed					
B.	Perennial	58	903	—	903	822
		85	500	—	500	500
		86	1233	30	1203	1203
		87	1131	92	1039	1039
		88	563	1	562	562
		89	1155	—	1155	1155
		90	1275	57	1118	1118
Sub-Total (B)		7	6760	180	6480	6399
Grand Total (A) & (B)			116473	4878	111495	86265

To raise the existing cropping intensity of 100 per cent to 150 per cent, the water requirements were worked out (Tipton & Kalmbach Inc. 1962) and approximate to 3,68,000 acre feet at the head of watercourse. The historic canal supply to the area was estimated at 1,51,000 acre feet thus requiring nearly 2,17,000 acre feet of additional water from the ground water reservoir. It was further assumed that 2,50,000 acre feet of total supply will be consumed by the crops and the remaining would be losses from watercourses and the fields. Table **2** and **3** indicate the summary of future crop water requirement and additional supply required on area basis.

Layout and Well Construction

The project consists of 138 tubewells; 2 to 4 cusecs capacity, 81 situated in perennial, 30 in non-perennial and 27 in uncommanded area with aggregate designed capacity of 257, 90 and 91 cusecs respectively. Most of the wells are so located as to pump water directly into heads of water-courses. The total

pumping capacity observed at the time of acceptance was 456 cusecs, and Table 4 gives the tubewells distributary-wise along with their monthly pumping capacities for 22 hours a day basis.

TABLE 2.—*Water requirements at Head of the Watercourse*

MONTH	Perennial Area	Non-Perennial Area	Uncommanded Area
	Intensity 148%	Intensity 150%	Intensity 150%
	Crop water requirement at the Head of Watercourse	Crop water requirement at the Head of Watercourse	Crop water requirement at the Head of Watercourse
Apr.	18,442	5,353	2,263
May.	18,990	5,549	3,432
Jun.	30,586	8,487	5,312
Jul.	24,568	6,794	4,302
Aug.	20,875	5,768	3,531
Sep.	32,568	8,737	5,410
Kharif :	1,46,029	40,689	25,250
Oct.	28,671	7,300	4,438
Nov.	22,393	5,624	4,122
Dec.	16,691	4,118	2,681
Jan.	10,056	2,450	1,588
Feb.	15,794	3,977	2,563
Mar.	17,127	4,294	2,759
Rabi :	1,10,732	27,761	18,151
Annual	2,56,761	68,450	43,401

In all wells, except No. 83, the pump housing, casing and screen are of mild steel (well No. 83 has a wooden screen). The screens are slotted casing pipes with vertical slots varying in size from $2\frac{1}{4}'' \times 1/16''$ to $2\frac{3}{4}'' \times 3/32''$, with an inlet area of about 27 square inches per lineal foot. The specific capacities

TABLE 3.—*Water Supply Summary*

Type of Command	Non-Perennial Shahpur Branch	Perennial Lower Jhelum Canal	Uncommanded	Total
1. Gross Area (acres)	19,700	78,300	13,600	111,500
2. Culturable Area (acres)	18,300	73,700	12,000	104,000
3. Total water required (acre ft. (1)	40,700	146,000	25,200	211,900
Kharif (2)—	27,800	11,700	18,200	156,700
Year	68,500	256,700	43,400	368,600
4. Canal Supply (3)—				
(Acre feet) (1)—				
Kharif	23,000	69,700	—	92,700
Rabi	2,300	55,700	—	58,000
Total	25,000	125,400	—	150,000
5. Tubewell supply				
(Item 3 less item 4)				
Kharif	17,700	76,300	25,200	119,200
Rabi	25,500	55,000	18,200	98,700
Total	43,200	131,300	43,400	217,900
6. Tubewell capacity cusecs	107	285	87.5	580
A.F. per year	77,000	205,000	63,000	345,000
7. Consumptive use per cropped acre	1.69	1.60	1.64 Average	1.62

—(1) At head of watercourse — (2) Kharif and Rabi as used in this table do not exactly correspnd with normal definition; here they cover the periods April 1 to September 30 and October 1 to March 31 respectively.

— (3) Based on actual deliveries.

of the wells at the time of acceptance test ranged from 40 to over 160 gpm/ft with a median value of 87 gpm/ft. The specific capacity variation and tubewells in each range are shown in Figure 3.

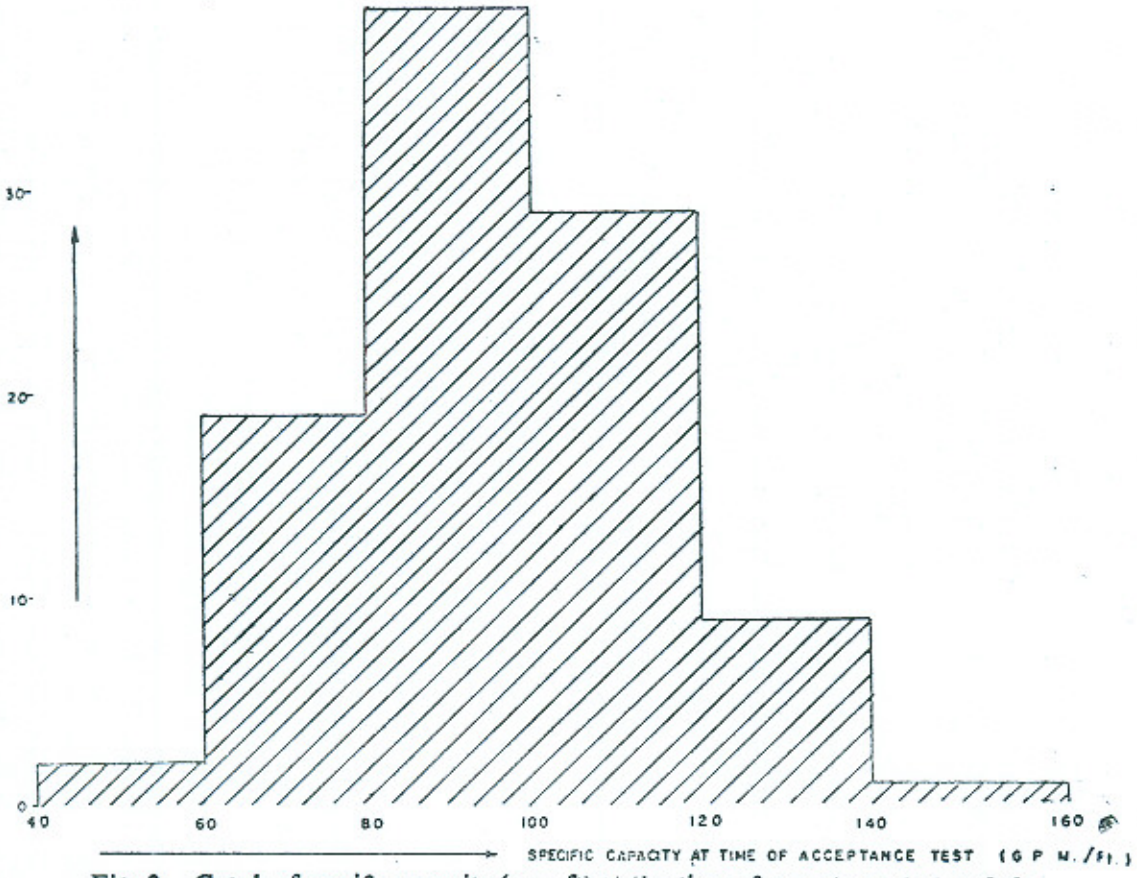


Fig. 3. Graph of specific capacity (gpm ft) at the time of acceptance test and the percent of sample

Deep well turbine pumps, driven by vertical hollow shaft electric motors, have been used in all wells. The motor starters and controls are designed to provide maximum protection to the motor from all kinds of electrical variations and faults. The above equipment was received under US-AID in 1960 but out of this only 73 pumps, 138 motors and 102 controls that were still serviceable could be used during construction, the rest of the equipment was new.

PROJECT EVALUATION

A. Tubewells

Discharges and Specific Capacities

Tubewell performance studies in Mona project were started during 1966. In the first year *i.e.* 1966-67, single step specific capacity tests were performed twice a year on all the project wells. Later on, the frequency of tests was

TABLE 4.—*Summary of Monthly Pumping Capacity of Project Wells Distributary-wise on 22 hours a Day Basis*

Name of Distributary	No. of T/wells on the Distributary	MONTHLY PUMPING CAPACITY (ACRE FEET)											
		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.
Pakhowal	1 to 9	1518	1371	1518	1469	1518	1469	1518	1518	1469	1518	1469	1518
Mona Main Line	10 to 22	2446	2209	2446	2366	2446	2366	2446	2446	2366	2446	2366	2446
Direct Outlet	23 to 27	759	686	749	734	759	734	759	759	734	759	734	759
Katto-Kala	(28 to 34,36,37,39) (40,41,44,45,46,48) to 53,55, 56, 57, 59) (60, 62 to 67.)	5819	4259	5819	5630	5819	5630	5819	5819	5630	5819	5630	5819
Chabba	68 to 73	1181	1066	1181	1066	1181	1066	1181	1181	1061	1181	1061	1181
Fatehpur	74 to 84, 91 to 95	2755	2488	2755	2665	2755	2665	2755	2755	2665	2755	2665	2755
Jewanwal	113	141	127	141	136	141	136	141	141	136	141	136	141
Bakh Miani	104 to 112	1410	1270	1410	1360	1410	1360	1410	1410	1360	1410	1360	1410
Wijhi	114, 115, 116, 134	731	660	731	707	731	707	731	731	707	731	707	731
Dewas	117 to 119	478	432	478	462	478	462	478	478	462	478	462	478
Chak Qazi Shahpur	120 to 124	928	838	928	898	928	898	928	898	928	898	898	928
Direct O/L	125 to 126	309	279	309	299	309	299	309	309	299	309	299	309
Kot Mamyana	127 to 132	1096	990	1096	1061	1096	1061	1096	1096	1061	1096	1061	1096
Uncommanded	(42, 47, 54, 61, 96) (to to 103, 133, 135) (to 148)	5060	4570	5060	4869	6060	4896	5060	5060	4896	5060	4896	5060

reduced to once a year except for deteriorating wells whose frequency of testing was raised to three or four per year.

Specific capacities and well discharges at the time of acceptance (1964) and during 1969-70 have been summarized, (Appendix 'A') and the wells showing decrease in specific capacity and discharge as compared to their acceptance test values have been grouped according to the percentage decrease (Table 5) The specific capacity of 24 wells (17 percent) have been affected, of which, for 13 wells (9 percent) the fall is more than 20 percent and can be considered as heading towards serious stage of deterioration.

Discharges of 55 wells have declined by more than 10 per cent, and of these for 19 wells it can be partially attributed to well deterioration. The decline in the remaining wells (Table 6) may be due to lowering of the subsoil water level/pump problems. The decrease in discharge of wells has resulted in an average decline of 9 per cent in the pumping capacity of the scheme, 7 per cent fall was registered up to or before June 1966, and thereafter the fall is only at the rate of 0.5 per cent per year. This small rate of decline in capacity may not be treated as a sign of satisfactory condition of the scheme, because to begin with the decline in specific capacity does not appreciably effect the pumping. If the deterioration in specific capacity is allowed to continue, the rate of decline in pumping capacity of scheme may later increase rapidly.

Operation and Maintenance

Wells in Mona project are of mild steel screens and experience in SCARP-I shows that screens are prone to incrustation and corrosion. Therefore it is not possible to save the screens altogether from the deteriorating effects, but certainly their useful life can be increased by timely corrective measures and routine cleaning and development.

Study of well performance data indicates that the tendency of mild deterioration *i.e.* fall in specific capacity less than 20 per cent, is increasing comparatively at a faster rate in the project wells than the serious deterioration, *i.e.* fall in specific capacity more than 20 per cent. In the five years operation (1965-70) only one well, No. 140 was developed and no attention was paid to many other wells which needed immediate development. This lapse on an experimental project where techniques are to be developed for use in other SCARPS cannot go unnoticed. If this situation persists the scheme is likely to face a serious deterioration in the near future.

Most of the pumps installed are of Byron Jackson with a flat head capacity curve, and if out of adjustment even by few millimeter do not pump the designed discharge. Frequent testing and adjustments by equipment engineer are very much required.

TABLE 5.—*List of wells showing percentage decrease in specific capacity and discharge since acceptance test to June '70*

Percent decrease	Wells showing decrease in	
	Specific capacity	Discharge
11-15%	17,45,72,125,134,146.	14,17,19,22,32,39,42,44,71,79,84, 91,92,107,120,130,139,141,143.
16-20%	80,94,135,139,145.	9,18,69,74,95,98,100,122,124,148.
21-25%	42,122,136	2,33,36,37,46,48,50,53,67,80,93, 115, 121.
26-30%	140	75,52,64,94,133.
31-35%	4,62	73.
36-40%	18	4,62,135,136,137,138
41-45%	52,53,92	—
45-50%	—	—
51-55%	66,69	—
56-60%	—	—
61-65%	—	—
66-70%	—	—
71-75%	—	—
76-80%	138	—

TABLE 6.—*List of wells which show percentage decrease in discharge but no change in specific capacity since acceptance to June '70*

Percentage decrease	Well No.
10-15%	14,19,32,39,44,71,79,84,91,107,120,130,141,143.
16-20%	9,74,95,98,100,124,148.
21-25%	2,33,36,37,46,48,50,67,93,115,121.
26-30%	64,133.
31-35%	73
36-40%	137.

Well Development

The solitary development carried out during the period under study was of well No. 140. The well was installed and tested for acceptance in March, 1964, and the specific capacity at that time was 109 gpm/ft. The test on the same well in September 1968, indicated specific capacity reduction to 28 gmp/ft. After development by prima cord and acid treatment the well regained its original specific capacity and was kept under observation to determine its deterioration with time after development. If it is assumed that initial rate of deterioration was the same as after development, and that it changes after certain time, and will be the same as observed during September, 1966 to November, 1967, then approximate deterioration history of the well is as given in Figure 4. From these curves it can be concluded that rate of deterioration during initial years may be small but then increases rapidly. Therefore, as soon as it is observed that the specific capacity of a well has started declining, the operating agencies must start programming for well development, so that before serious deterioration rate sets in, the wells could be developed. If this case can be termed as a representative one then increased rate of deterioration can be expected after the specific capacity of a well has reduced by 25-30 per cent of its original value. It is, therefore, desirable that wells should be developed before the reduction in specific capacity attains the above order of magnitude.

To appreciate direct and indirect losses as a result of delay in well development, the performance of this well has been further studied. Increase in power consumption (KWH) per acre foot of the pumped water and the deterioration in the pumping capacity (acre foot per day) has been plotted on Figure 4 which also depicts the deterioration history of the well. The power consumption per acre foot of the pumped water increased from 95 to 118 KWH, while the daily pumping capacity reduced from 6.72 to 5.0 acre foot. The analysis for the period January to November 1967 (when the well was developed) assuming 60 per cent operational time resulted in an increased power cost of nearly 2,400 rupees (assuming 13 paisa cost per KWH). The reduction in the water supply during the same period was 260 acre feet. Assuming an economic value of 58.69 rupees per acre foot of water, a further indirect loss of 15,300 rupees has resulted. It can, therefore, be easily appreciated that timely development of a deteriorating well is of great economic value both from point of view of operational cost as well as the economic benefits derived from the additional water.

Operational and Well Development Economics

If for a pump well the product of "q_t" *i.e.* discharge at any time "t" and the corresponding specific drawdown "S_t" remains unchanged as compared to its value (q_o S_o) at the time of acceptance test, there will be no increase in power

consumption due to well deterioration. As the well is designed to supply the specified amount of water to meet the crop needs, an effort on the part of the operating agencies to restore the original discharge by adding new pump stage, disturbs this factor and results in increased power cost. Study presented here

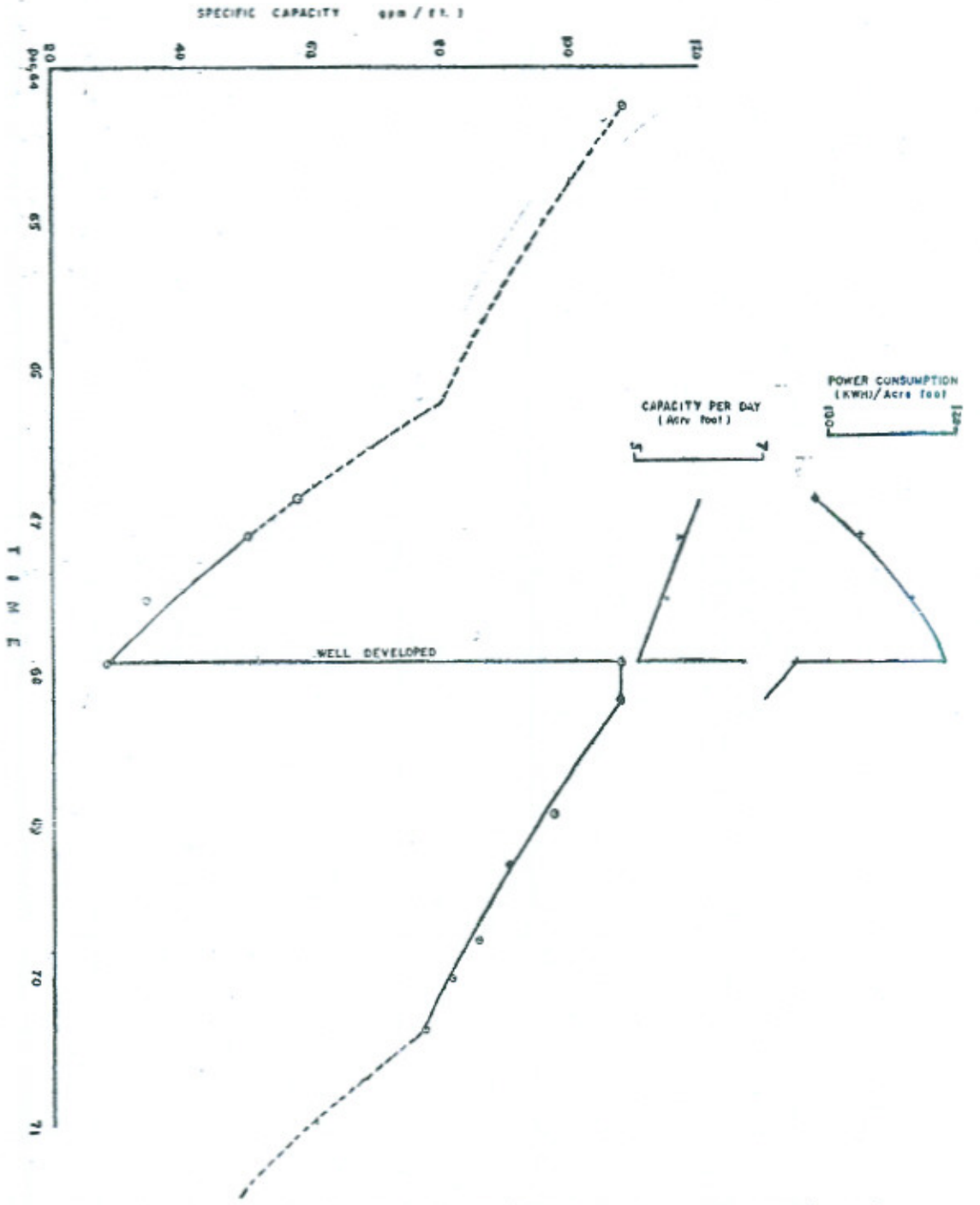


Fig. 4. Graphs showing change in specific capacity, power consumption and pumping capacity with time for Well No. 140

is based on the assumptions ;

(*i*) The well is being pumped in excess of its optimum discharge;

(*ii*) well regains its original discharge and specific capacity after development;

(*iii*) indirect economic losses which result from decreased supply not accounted for; and

(*iv*) benefit of increased tubewell life neglected.

The increase in the power cost per acre foot (Δ Caf) of pumped water at C_k paisa per kilowat hour and pumping unit efficiency of E_f is given by the equation :

$$\Delta C_{af} = 1.03 \frac{C_k}{E_f} . \quad \Delta(q.s)_t$$

where q= discharge

s= specific drawdown

Δ= change in the quantity since acceptance test to time "t".

The monthly increase in power cost has been calculated for assuming different values of (C_k/E_f), Δ (q.s), and daily pumping capacities. Assuming different costs of development, a graph between all variables has been plotted (Figure 5), to facilitate calculations. This graph helps in determining the increase in power cost per acre foot of pumped water and also the approximate length of time for which the development, if remains effective, would be economical as compared to pumping a well under deteriorated condition. The use of this graph is illustrated by the following examples :

Let take the case of a well of five cusecs capacity, which is capable of pumping ten acre feet of water daily, and its specific drawdown is 5 ft./cusecs. Suppose now that its specific drawdown has increased to 10 ft/cusec, and the discharge reduced to 4 cusecs. It is desired to estimate the increase in power cost and also to determine the period for which the development should remain effective, to be economical as compared to pumping the well under deteriorated condition. The approximate cost of development is 500 rupees. Refer to Figure 5 and draw a line parallel to "y" axis from point Δ(q.s) which is 10 in this case till it cuts the proper line of value C_k/E_f, which say in the present case is 18. From this point draw a line parallel to "x" axis till it cuts the "y" axis, read the increase in power cost per acre foot which is 1.80 rupee. Now extend it to the line of daily capacity of the well, 10 acre feet in this case. From this point draw a perpendicular on to get axis and extend it till

it cuts the curve indicating the cost of development. From this point draw a line parallel to "x" axis and read the time period on the—ve "y" axis, which in this case is less than a month".

In the above example a reduction of specific capacity of nearly 30 per cent was assumed. If the same reduction is assumed for a 2 cusecs capacity well, the time period for which the development should remain effective to be economical becomes nearly 6 months. Wells in SCARP'S are mostly in the range of 2 to 5 cusecs, and the above examples indicates that if the development remains effective for 6 months for a 2 cusecs well or 1 month in case of 5 cusecs well even then it is economical to develop the well. If the expenditure on development

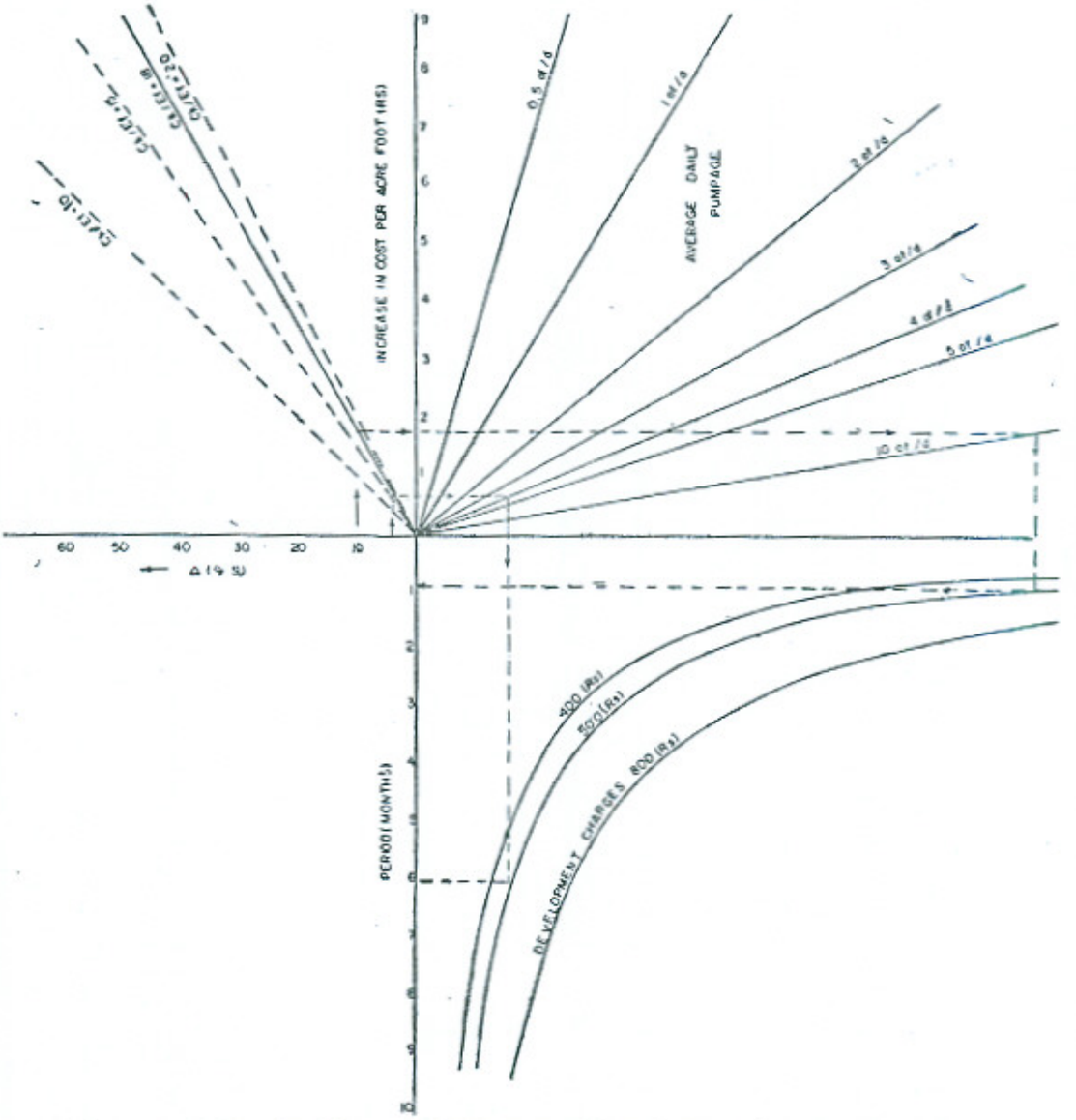


Fig 5. Relationship of cost of development of a well and period the development should remain effective to be economical

procedures can be reduced or if the decrease in specific capacity is more than 30 percent, then the period of 1 to 6 months for a well of 5 to 2 cusecs capacity will be further reduced. As an alternative other methods of development involving higher cost can be accommodated economically provided the development can be made to last for a longer period. This alternative would have the side benefit of reducing number of treatments and prolonging the life of well material.

Presently the wells are being developed by the prima cord blasting operations, which are carried out from top to bottom of the screen without properly locating the section, which needs development. Developing only the choked section of screen, identified through velocity surveys, may reduce the cost of development.

B. CROPWATER REQUIREMENT AND TUBEWELL PUMPAGE

General

During the project planning, the installed capacity of a scheme is determined on the basis of ultimate cropping intensity planned for the area, which requires many years to attain its final value. In the intervening period the water is required to be pumped according to the crop need. An assessment of crop water requirement for the year April 1968 to March, 1969 and the corresponding tubewell deliveries during the period has been compared. The analysis has been made distributary-wise, to identify areas of discrepancy. The yearly growth of the cropping intensity has been determined both for the project as a whole and for each distributary.

Cropwater Requirements (1968-69)

To assess the water needs the crop statistics for each distributary have been collected from the record of Mona Reclamation Experimental Project for the year April 1968 to March 1969. Cropwater requirements in the field have been estimated by Blanney-Criddle formula utilizing the temperature and rainfall data of Phulerwan weather station situated in the project area. To calculate the requirement at the head of watercourses, 30 per cent losses have been assumed both in the field and the watercourses. Monthly requirement of water supply at the head of watercourses for each distributary thus arrived at is given in Appendix II.

Canal Supply

The monthly canal supply at the head of each distributary during the same period has been collected from the records of the Irrigation Department. Assuming 15 percent seepage and other losses canal supply at the head of watercourses has been estimated and given in Appendix II.

Tubewell Pumpage

Monthly tubewell pumpage required to supplement the canal supply for satisfying the crop needs during the period under study has been summarized along with actual pumpage in Appendix II. The required annual tubewell pumpage and the actual pumpage distributary-wise has been summarized in Table 7 and indicates that during the period under study (1968-69) pumpage has been in excess of the crop water needs. Nearly 1,42,000 acre feet of additional water was required, while tubewells pumped 1,75,000 acre feet *i.e.* 33,000 acre feet in excess of the demand. The cropping intensity during 1968-69 was 121.4 per cent and increased to 126.2 per cent in 1969-70. Assuming that the crop water requirements vary linearly with the cropping intensity, the additional

TABLE 7.—*Showing required Tubewell Pumpage and the actual Pumpage—Distributary-wise* (1968-1969)

Name of the Distributary	Tubewell Water required (acre feet)	Tubewell Water pumped (acre feet)
Mona	10,479	15,011
Pakhowal	10,706	15,062
Rattokala	43,456	42,472
Chabba	8,927	8,287
Fatehpur and Nabi Shah Minor Main Line	17,729	15,699
Dir. Outlets	1,526	5,904
Chak Qazi	6,737	5,201
Kot Mamyana	3,759	7,524
Dewas	2,423	4,589
Wijhi	2,740	3,802
Jiwanwal	1,417	1,028
Rakh Miani Shahpur Br.	3,982	10,564
Dir. Outlets	498	3,833
Uncommanded Area	27,716	25,904
Total	142,095	174,880

water required during 1969-70 was 1,55,300 acre feet against the actual pumpage of 204,400 acre feet, *i.e.* 49,100 acre feet in excess of the demand. If Rs. 5 is assumed as the electricity charges per acre foot of water, then excess pumpages resulted in an unnecessary expenditure of 1,65,000 rupees in 1968-69 which rose to 2,45,500 rupees in 1969-70. The actual losses are much more, as the excess pumpage resulted in more wear and tear of equipment, more recharge to reservoir making reclamation of waterlogged lands difficult and wastage of electricity which could be used for better purposes.

Cropping Intensity

The cropping intensity both distributary-wise and for the whole project have been determined from the crop statistics (Table 8). The table indicates that with the exception of few distributaries, the increase in cropping intensity is less than 10 per cent in five years though the project as a whole is registering an increase of nearly 26 per cent.

TABLE 8.—*Channel-wise annual Cropping Intensity of Mona Reclamation Experimental Project since* 1965-70
(*Year April to March*)

Name of Channel	Culturable Area	Annual Cropping Intensity					Percentage increase/decrease (—) in intensity (1965-70)
		1965-1966	1966-1967	1967-1968	1968-1969	1969-1970	
Pakhowal	8187	92	107	112	112	101	9
Mona	11317	105	113	113	104	110	5
Rattokala	33996	115	121	122	124	128	13
Chabba	5325	165*	149	150	152	155	6
Fatehpur	13357	104	123	127	126	133	29
Direct Outlets	3191	123	104	107	116	92	—31
Wijhi	2124	—	120	116	131	125	5
Dewas	1972	101	110	110	116	110	9
Chak Qazi	3989	132	159*	140	146	151	19
Rakh Miani	4371	196	96	107	100	118	—18
Kot Mamyana	3941	106	120	119	128	130	24
Jewanwal	894	—	100	113	134	151	51
Direct Outlets							
Shahpur Br.	1047	49	64	89	64	—	—
Uncommanded	10729	—	75	105	119	142	142
Total	104440	100.4	115.3	119.7	121.4	126.2	25.8

*Raoni acreage not taken into account. Sugarcane area has been added twice

TABLE 9.—*Monthly Tubewell Pumpage and Utilization Percentage (Designed Capacity and 22 hours a day Basis) of Project Wells Mona Reclamation Experimental Project (October 1965 to June 1970)*

Month	1965-66		1966-67		1967-68		1968-69		1969-70	
	Pumpage (A.F.)	Utiliza-tion %age	Pumpage (A.F.)	Utiliza-tion %age	Pumpage (A.F.)	Utiliza-tion %age	Pumpage (A.F.)	Utiliza-tion %age	Pumpage (A.F.)	(Utiliza-tion %age
July	—	—	9652	38.78	14585	58.59	10836	43.53	16091	64.64
Aug.	—	—	8336	33.57	7963	31.99	11700	47.00	14898	59.85
Sep.	—	—	14012	58.16	10356	42.98	15684	65.1	18174	75.44
Oct.	2955	71.2	9171	36.84	14004	56.25	17978	72.22	18839	75.68
Nov.	13090	62.3	9889	41.03	10343	42.93	16110	66.78	16179	67.16
Dec.	14960	61.68	10202	40.98	6326	25.41	14994	60.23	17415	69.96
Jan.	15700	63.07	5952	23.91	5993	24.07	18854	75.74	17964	72.16
Feb.	6041	26.91	46.2	20.47	8996	40.01	12682	56.40	16435	73.09
Mar.	5848	23.68	3652	14.67	10468	42.05	17437	50.05	15281	61.38
Apr.	9033	37.49	11312	46.95	12763	52.98	18174	75.44	17529	72.76
May	10289	41.33	12686	50.96	14871	59.74	16285	64.42	17862	71.75
June	10636	44.15	13482	55.96	13575	56.35	56.35	18683	17380	72.14
Yearly Pump-age.	88560		112948		130243		186579		204047	
Average Utiliza-tion :		45.48		38.53		44.43		63.65		69.61

Note : (1) The pumpage given above may be 5-10 percent less than actual value due to orifice plate effect.

(2) All tubewells commissioned by end of December 1965. The progressive total of commission tubewells by end of October was 95, by end of November 126, and by end of December, 138.

The period to achieve planned intensity can be fairly reduced if the weak spots in the project are located and maximum attention paid by the extension services and agriculture staff to that area. If possible, the crop statistics be maintained and studied preferably outlet-wise or at least ditributary-wise.

C. GROUND WATER

Water Table Decline

Since the completion and operation of the project, ground water has become the major source of irrigated agriculture. During 1969-70 the pumpage from ground water reservoir was 204,407 acre feet (Table 9) against the canal water diversion of 1,38,700 acre feet. As a result of development of ground water resources the subsoil water level has registered a declining trend (Table 10).

TABLE 10

Years	Average water level	Total Lowering
July 1965	... 647.88 ft.	0 ft.
June 1966	... 645.37 "	2.51 "
June 1967	... 645.04 "	2.84 "
June 1968	... 646.34 "	1.54 "
June 1969	... 644.98 "	2.90 "
June 1970	... 644.13 "	3.75 "

The average lowering since July 1965 to June 1970 is in the order of 3.75 feet. Figures 6 to 8 show water table contours for June 1970, the areal distribution of change in water level since July 1965 to June 1970 and the average depth below N.S.L. in June, 1970.

Water Budget Analysis (1969-70)

The hydrologic balance equation for an area in its simplest form is; "inflow—outflow=change in storage". Analysis of the water budget based on

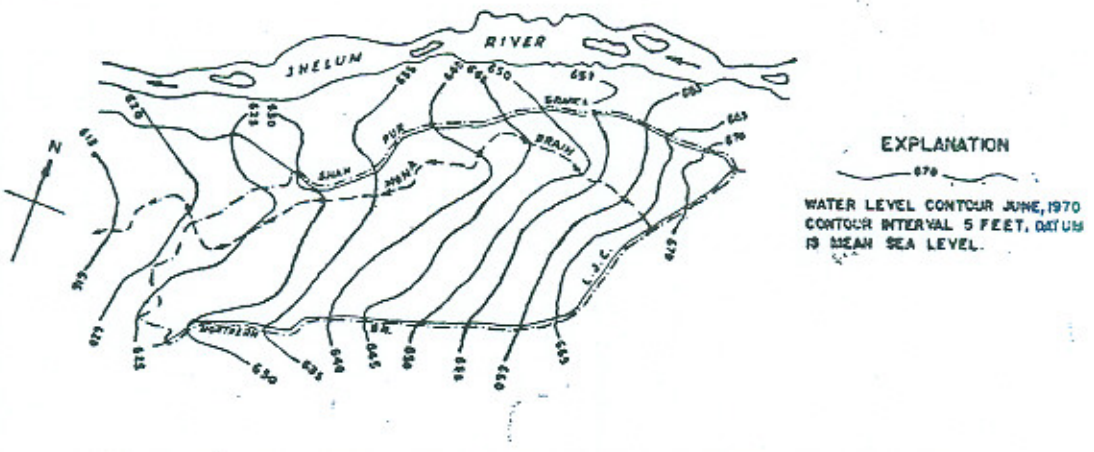


FIGURE - 6 MAP SHOWING THE APPROXIMATE ALTITUDE OF THE WATER TABLE IN THE MONA RECLAMATION SCHEME IN JUNE, 1970.

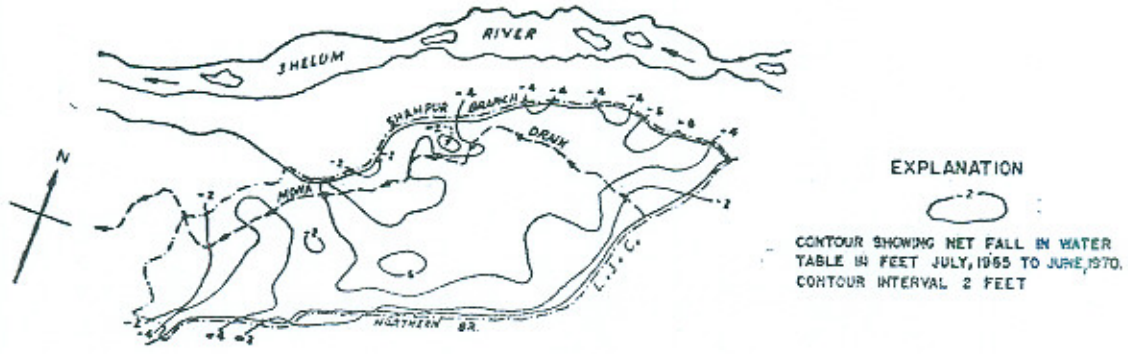


FIGURE - 7 APPROXIMATE CHANGE IN ALTITUDE OF THE WATER TABLE IN THE MONA RECLAMATION SCHEME DURING JULY, 1965 TO JUNE, 1970.

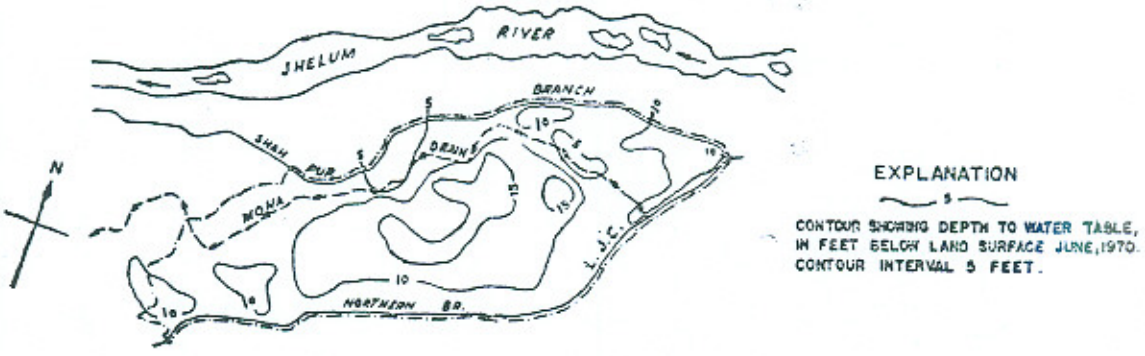


FIGURE - 8 MAP SHOWING THE APPROXIMATE DEPTH TO THE WATER TABLE BELOW LAND SURFACE IN THE MONA RECLAMATION SCHEME IN JUNE, 1970

this equation has been attempted (Figure 9) to indicate order of magnitude for each component. The accretion to ground water reservoir from boundary canal seepage and regional inflow, and the subsurface outflow from the project are determined from flownet analysis assuming the regional transmissibility of 2 ft²/sec.

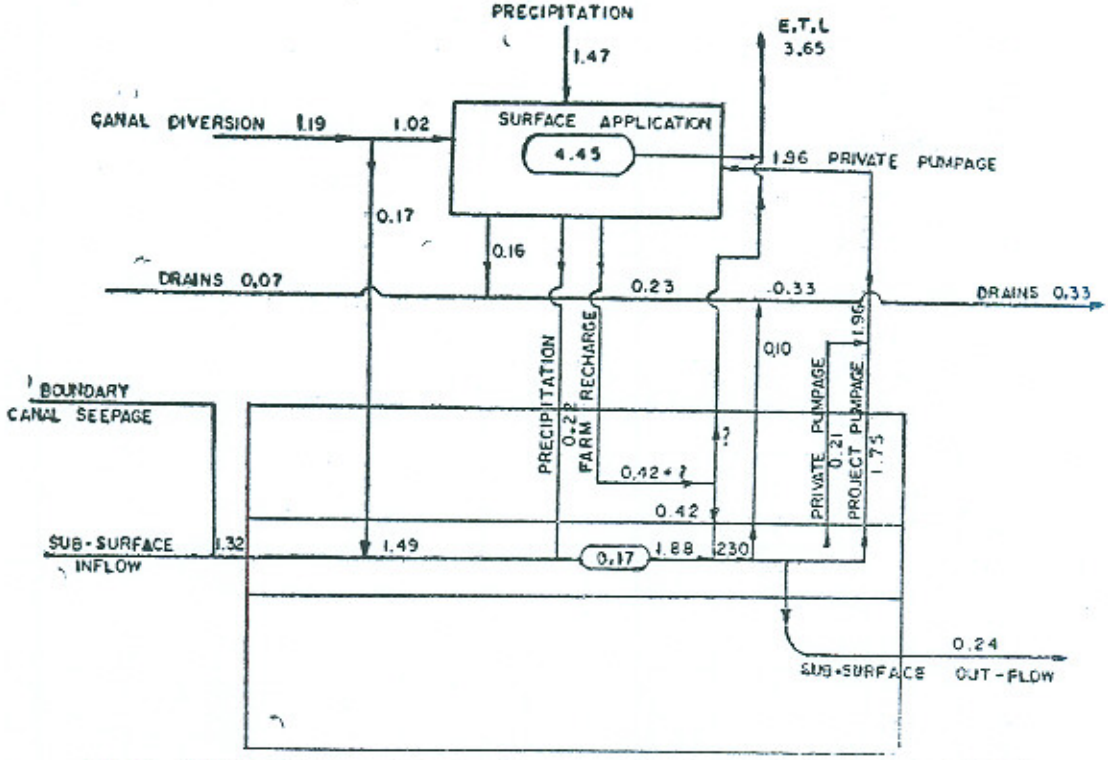


Fig. 9. Schematic Flow chart showing approximate water balance during period 1969-70 (All quantities in ft).

Ground water budget :

Inflow :

Ground water	...	1.32	ft.
Infilteration from precipitation	...	0.22	ft.
Seepage from canal diversion	...	0.17	ft.
Infilteration from farm irrigation	...	x	ft.
		1.71+x	ft.

Outflow :

Ground water	...	0.24	ft.
Pumpage	...	1.96	ft.
Drains	...	0.10	ft.
Evapotranspiration	...	y	ft.
		2.30+y	ft.
Change in Storage (C)		0.17	ft.

(E.T.L.—Infilteration)=(1.7+0.17—2.30)=—0.42 ft.

Total water budget :

Inflow :

Ground water	...	1.32	ft.
Canal diversion	...	1.19	ft.
drains	...	0.07	ft.
Precipitation	...	1.47	ft.
Total (A)	...	4.05	ft.

Outflow :

Ground water	...	0.24	ft.
Drains	...	0.33	ft.
Total (B)	...	0.57	ft.
Change in Storage (C)	...	0.17	ft.
Approximate direct evapotranspiration and evaporation losses	...	3.65	ft.

It is found from this analysis that the usable recharge to the ground water reservoir has increased from 0.21 feet during 1964-64 to 1.75 feet in 1969-70.

CONCLUSIONS

The project in addition to many other objectives was destined to develop techniques for proper maintenance and operation of project wells and management of water supply, for application to other projects. Following are the main conclusions :

(1) The specific capacity of 24 wells have decreased by more than 10 per cent and out of these in thirteen wells the decrease was more than 20 per cent. The rate of deteriorating wells is on increase and requires efforts for timely well development.

(2) Discharge of 55 wells have decreased by more than 10 per cent and out of these for 19 wells the decline can be partially attributed to deterioration in the wells' specified capacities. The overall decline in pumping capacity of scheme up to June 1970 is 9 per cent, of which 7 per cent fall was before June, 1966. The small rate of decline in the pumping capacity cannot be considered as a sign of satisfactory condition, because to begin with, the effect of decline of specific capacity on discharge is not perceptible.

(3) The solitary well development carried out in the project during five years is on well No. 140. The well was developed when its

specific capacity had reduced by 70 per cent. This untimely development of a single well resulted in an increase in power cost of Rs. 2,400 during the period January 1967 to November 1967 and an indirect loss of Rs. 15,300.

(5) The concept of economic use of additional water is altogether non-existent. Nearly 33,000 and 49,100 A.F. of water was pumped in excess of demand during 1968-69 and 1969-70 respectively. This excess pumpage resulted in increased power cost of 1,65,000 rupees in 1968-69 and 2,45,500 rupees in 1969-70.

(6) Pumping of ground water reservoir in excess of the need, not only resulted in excess power and maintenance charges but also wastage of ground water potential and is likely to accelerate the changes in water quality.

(7) The average decline in the water table since operation of project (July 1965) is 3.75 feet.

(8) The usable recharge to the project area is 1.79 feet or 208,000 acre feet.

(9) The overall cropping intensity of the project has increased from 100.4 to 126.2 per cent. The increase on Pakhowal, Mona, Wijhi and Dewas is less than 10 per cent.

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Appendix I

Discharges and specific capacities of Project Wells

Tubewell No.		Acceptance Test			Subsequent Test			
		Date	Discharge (gpm)	Specific capacity (gpm/ft)	Date	Discharge (gpm)	Specific capacity (gpm/ft)	Type of Pump.
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)
!!	1	4/64	1574	104	5/70	1526	100	BE
	2	4/64	1554	81	5/70	1228	84	BJ
	3	4/64	1473	73	9/69	1526	78	BE
!!!	4	6/64	1613	87	4/70	1025	66	BJ
	5	4/64	1194	72	9/69	1193	73	BE-J
	6	4/64	1270	99	4/70	1280	100	BE-J
	7	6/64	1633	91	9/69	1609	84	BE
	8	5/64	1493	79	3/70	1393	90	BJ
!!	9	5/64	1410	62	3/70	1119	57	BJ
	10	4/64	1574	91	9/69	1752	92	BJ
	11	5/64	1431	92	2/70	1526	103	BJ
	12	5/64	1513	115	9/69	1589	127	BJ
	13	4/64	1613	82	8/69	1554	78	BE
!!	14	4/64	1493	96	8/69	1280	113	BJ
	15	4/64	1574	98	12/69	1575	95	BE
	16	4/64	1554	107	8/69	1595	96	BE
!!!	17	4/64	1246	114	8/69	1079	98	BE-J
!!!	18	4/64	1245	94	12/69	1038	60	BE-J
!!$	19	4/64	1452	115	8/69	1246	128	BJ
!$	20	4/64	1534	110	4/70	1393	123	BJ
$	21	4/64	1294	107	3/70	1313	126	BJ
!!$	22	4/64	1431	110	2/70	1280	115	BJ
	23	4/64	1318	74	4/70	1362	75	BE-J
	24	1/64	1534	92	4/70	1439	92	BE
	25	4/64	1633	105	2/70	1568	100	BE
	26	1/64	1270	108	2/70	1246	121	BE-J
	27	1/64	1270	91	2/70	1246	97	BE-J
	28	1/64	1652	109	9/69	1725	101	BJ
	29	1/64	1613	123	2/70	1498	131	BJ
	30	1/64	1574	164	9/69	1609	176	BJ
	31	1/64	1613	129	9/69	1946	150	BJ
!!	32	1/64	1613	131	9/69	1378	123	BE
!!	33	1/64	1574	157	10/69	1017	172	BJ
	34	5/64	1725	119	—	—	—	BJ
	35							
!!	36	6/63	1113	88	2/70	831	181	BEJ
!!	37	5/64	1593	117	4/70	1211	110	BJ

Tubewell No.		Acceptance Test			Subsequent Test			
		Date	Discharge (gpm)	Specific capacity (gpm/ft)	Date	Discharge (gpm)	Specific capacity (gpm/ft)	Type of Pump.
(1)		(2)	(2)	(4)	(5)	(6)	(7)	(8)
!!	39	5/64	1574	95	4/70	1378	90	BE
$	40	5/64	1431	79	10/70	1362	72	BJ
	41	5/64	1182	61	12/69	1156	60	BE
!!!$	42	5/64	1387	72	14/70	1228	156	BJ
!!	44	5/64	1742	130	10/69	1483	122	BJ
!!!	45	3/64	1294	147	9/69	906	127	BE
!!	46	3/64	1725	134	2/70	1370	140	BJ
!!	47	3/64	1514	93	10/60	1469	85	BJ
!!	48	3/64	1594	126	3/70	1263	127	BJ
	49	3/64	1574	92	3/70	1636	102	BJ
!!	50	3/64	1613	115	6/69	1280	121	BJ
!!!$	51	3/64	1603	107	5/70	1622	112	BJ
	52	3/64	1622	96	4/70	1175	56	BJ
!!!$	53	3/64	1594	90	4/70	1228	48	BJ
	54	3/64	1554	105	8/69	1760	104	BJ
	55	3/64	1260	103	9/69	1246	109	BE
	56	3/64	1564	107	4/70	1540	102	BJ
	57	3/64	1593	106	11/69	1763	118	BJ
	59	2/64	1725	127	10/69	1595	133	BJ
	60	2/64	1680	122	10/69	1156	119	BE
	61	3/64	1270	110	11/69	1059	102	BE
!!!	62	2/64	1725	114	10/69	997	79	BJ
	63	3/64	1318	108	1/70	1156	105	BE-J
!!	64	2/64	1613	91	11/69	1725	90	BJ
	65	2/64	1613	104	3/70	690	118	BJ
!!!	66	2/64	1622	98	4/70	1346	44	BJ
!!	67	3/64	1743	110	3/70	1498	125	BJ
	68	1/64	1534	92	2/70	1346	93	BJ
!!!	69	1/64	1652	108	4/70	1313	52	BJ
	70	2/64	1282	113	12/69	1454	82	BE-J
!!	71	2/64	1670	131	9/69	1725	124	BJ
!	72	2/64	1725	123	9/69	1228	116	BJ
!!	73	2/64	1795	90	9/69	1346	127	BJ
!!	74	2/64	1594	85	2/70	1595	97	BJ
	75	2/64	1670	88	3/70	1346	79	BJ
	76	2/64	1294	78	2/70	1554	90	BJ
	77	2/64	1594	71	3/70	1211	80	BE-J
	78	2/64	1195	88	2/70	1446	69	BJ
!!	79	2/64	1633	84	8/69	974	90	BJ
!!!	80	2/64	1232	99	3/70	1622	70	BJ

Tubewell No.		Acceptance Test			Subsequent Test			
		Date	Discharge (gpm)	Specific capacity (gpm/ft)	Date	Discharge (gpm)	Specific capacity (gpm/ft)	Type of Pump.
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)
	81	6/64	1670	98	5/70	1655	99	BJ
	82	2/64	1688	51	8/69	1228	105	BJ
	83	2/64	1169	88	9/69	1362	50	BE-J
!!	84	6/64	1534	80	8/69	1001	84	BJ
!!	91	6/64	1141	97	11/69	1439	73	BE
!!!	92	6/64	1632	93	4/70	1246	56	BJ
!!	93	2/64	1633	115	11/69	1237	95	BJ
!!!	94	2/64	1688	98	5/70	1424	97	BJ
!!	95	2/64	1688		11/69		107	
	96	4/64	1539	94	8/69	1540	105	BJ
	97	4/64	1554	110	4/70	1409	110	BE
!!	98	4/64	1593	112	11/69	1280	125	BJ
	99	4/64	1462	112	4/70	1595	125	BJ
!!	100	4/64	1707	105	8/69	1393	111	BE
	101	4/64	1652	108	9/69	1719	111	BE
	102	4/64	1622	124	9/69	1512	122	BE
	103	6/64	1410	110	10/69	1346	121	BJ
	104	4/64	1245	69	11/69	1313	55	BE-J
	105	4/64	1220	73	9/69	1346	80	BE-J
	106	5/64	1270	71	11/69	1362	75	BE-J
	107	4/64	1574	95	11/69	1362	108	BJ
	108	4/64	1574	79	11/69	1662	88	BE
	109	4/64	1245	75	5/70	1246	70	BE-J
	110	5/64	1220	69	2/70	1193	65	BE-J
	111	5/64	1564	72	11/69	1554	73	BE
	112	5/64	1554	68	12/69	1483	67	BE
	113	6/64	1113	40	5/70	1038	38	BE-J
$	114	5/64	1472	73	5/70	1362	64	BJ
!!	115	6/64	1458	53	5/70	1119	56	BE-J
	116	5/64	1573	78	10/69	1346	75	BE-J
	117	5/64	1554	83	12/69	1469	89	BJ
	118	5/64	1270	87	9/69	1297	91	JB
	119	5/64	1574	74	10/69	1554	77	BE-J
!!	120	5/64	1574	81	12/69	1330	89	BE
!!	121	5/64	1593	94	12/69	1211	96	BJ
!!!	122	6/64	1760	104	4/70	1454	81	BJ
	123	5/64	1670	93	12/69	1675	93	BJ
!!	124	5/64	1688	97	11/69	1385	101	BE
!	125	3/64	1670	101	4/70	1636	87	BJ
	126	3/64	1220	87	4/70	1280	78	BE

Tubewell No.		Acceptance Test			Subsequent Test			
		Date	Discharge (gpm)	Specific capacity (gpm/ft)	Date	Discharge (gpm)	Specific capacity (gpm/ft)	Type of Pump.
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)
	127	3/64	1633	81	12/69	1568	91	BJ
	128	3/64	1688	105	9/69	1774	99	BE
	129	3/64	1534	69	5/70	1636	68	BE
!!	130	3/64	1593	79	12/69	1378	89	BE
	131	3/64	1294	87	12/69	1297	93	BJ
	132	3/64	1652	96	12/69	1675	101	BE
!!	133	3/64	1725	116	5/70	1263	116	BJ
!	134	5/64	1220	82	12/69	1211	72	BE
!!!	135	3/64	1513	82	5/70	906	68	BJ
!!!	136	3/64	1594	92	10/69	997	70	BJ
!!	137	3/64	1594	109	5/70	1017	110	BJ
!!!	138	3/64	1232	102	4/70	881	22	BE
!!!	139	5/64	1514	97	11/69	1280	81	BJ
!!$	140	3/64	1574	108	4/70	1483	77	BE
!!	141	3/64	1472	123	10/69	1263	129	BJ
@	142	3/64	1511	100	3/70	1540	105	BJ
!!	143	3/64	1462	91	3/70	1280	87	BJ
	144	3/64	1194	111	9/69	1193	111	BE-J
!	145	4/64	1127	83	9/69	1099	67	BE-J
!	146	4/64	1220	90	10/69	1305	79	BE-J
@	147	4/64	1127	79	9/69	1193	84	BE-J
@!!	148	5/64	1155	73	9/69	951	76	BJ

Note—1. Acceptance tests were carried out by Tipton and Kalmbach Inc. with 8⅛" orifice plate and 10" discharge pipe. Subsequent tests were performed using 61" orifice plate and 8" discharge pipe.

2. ! Tubewells showing decrease in specific capacity more than 10% since acceptance test.
3. !! Tubewells showing decrease in discharge more than 10% since acceptance test.
4. !!! Tubewells showing decrease in discharge and specific capacity more than 10% since acceptance test.
5. $ Tubewells where second stage impellers have been added.
6. BJ—, BE, BE-J :—Tubewells fitted with Byron Jackson, Beco and Beco-Jacuzzi pumps respectively.

Appendix II

TABLE.—*Water requirements and Tubewell Pumpage (April 1968 to March 1969)*

(all values in acre-feet at head of watercourse)

MONTHS	Pakhowal Distributary				Mona Distributary			
	G.A. 8,677 (acres) C.A. 8,187 (acres) CCA. 8,187 (acres) AFS (Canal) 23 Cfs. *Intensity* : Kharif 50 Rabi 62 (%) T/well inst. capacity 27 Cfs.				G.A. 11,975 (acres) C.A. 11,317 (acres) CCA. 9,529 (acres) AFS (Canal) 31 Cfs. *Intensity* : Kharif 49 Rabi 61 (%) T/well inst. capacity 27 Cfs.			
	Crop water requirement	Canal Supplies	T/well water required	T/well water pumped (68-69)	Crop water requirement	Canal Supplies	T/well water required	T/well water pumped (68-69)
Apr.	1340	910	430	1166	1520	1458	62	1262
May	990	738	252	1250	985	1614	—	1327
Jun.	1816	711	1105	1206	1903	1507	396	1294
Jul.	1886	734	1152	1049	2431	1614	817	652
Aug.	1680	734	964	1287	1955	1614	341	669
Sep.	2744	726	2018	1350	3804	1662	2242	1422
Oct.	2754	734	2020	1394	3635	885	2750	1517
Nov.	2092	1043	1049	1387	2824	1354	1470	1248
Dec.	1458	617	841	1279	1996	833	1163	1240
Jan.	1067	694	371	1436	1486	781	705	1663
Feb.	1882	1082	—	986	1179	1354	—	1113
Mar.	1604	1082	522	1270	2011	1458	533	1604

Appendix II

TABLE.—*Water requirements and Tubewell Pumpage (April 1968 to March 1969)*

(all values in acre-feet at head of watercourse)

MONTHS	Fatehpur Distributary				Battokala Distributary			
	G.A. 13,629 (acres) C.A. 13,357 (acres) CCA. 10,653 (acres) AFS (Canal) 54 Cfs. *Intensity* : Kharif 58 Rabi 69 (%) T/well inst. capacity 49 Cfs.				G.A. 35,436 (acres) C.A. 33,996 (acres) CCA 31,474 (acres) AFS (Canal) 98 Cfs. *Intensity* : Kharif 56 Rabi 66 (%) T/well inst. capacity 103.5 Cfs.			
	Crop water requirement	Canal Supplies	T/well water required	T/well water pumped (68-69)	Crop water requirement	Canal Supplies	T/well water required	T/well water pumped (68-69)
Apr.	2614	1707	907	939	5897	4032	1865	3302
May	2158	1828	330	1355	4683	4166	517	3874
Jun.	3861	1769	1912	1263	8114	3933	3948	3255
Jul.	3443	1907	1536	1187	8237	4166	4071	2738
Aug.	2760	1997	763	1163	6624	4166	2458	2200
Sep.	4806	1933	2873	1592	11800	4132	7668	3618
Oct.	4706	1057	3649	1757	11700	2873	8837	4034
Nov.	3630	1529	2101	1311	9276	4082	5194	3920
Dec.	2650	943	1662	1253	6581	2419	4162	3513
Jan.	1916	1002	914	1783	4709	2722	1957	4585
Feb.	1543	1651	—	887	3940	1234	—	3379
Mar.	2733	1651	1082	1209	7013	4234	2779	4054

Appendix II

TABLE.—*Water requirement, and Tubewell Pumpage (April 1968 to March 1969)*

(all values in acre-feet at head of watercourse)

MONTHS	Chabba Distributary G.A. 5,373 (acres) C.A. 5,325 (acres) CCA. 5,316 (acres) AFS (Canal) 17.0 Cfs. *Intensity* : Kharif 72 Rabi 80 (%) T/well Inst. capacity 21.0 Cfs.				Wijhi Distributary G.A. 2,139 (acres) C.A. 2,124 (acres) CCA. 1,764 (acres) AFS (Canal) 9 Cfs. *Intensity* : Kharif 56 Rabi 74(%) T/well inst. capacity 13 Cfs.			
	Crop water requirement	Canal Supplies	T/well water required	T/well water pumped (68-69)	Crop water requirement	Canal Supplies	T/well water required	T/well water pumped (68-69)
Apr.	1294	848	446	659	408	422	—	365
May.	1118	914	204	759	256	566	—	183
Jun.	1693	575	818	681	513	516	—	234
Jul.	1733	897	836	464	588	554	34	191
Aug.	1436	855	581	492	508	499	9	167
Sep.	2508	796	1712	738	815	529	286	419
Oct.	2347	559	1788	793	831	193	638	379
Nov.	1720	796	924	716	616	171	445	384
Dec.	1220	472	748	629	452	—	452	350
Jan.	829	531	298	839	342	37	305	364
Feb.	749	825	—	665	286	114	172	252
Mar.	1363	791	572	752	528	129	399	514

Appendix II

TABLE.—*Water requirement, and Tubewell Pumpage (April 1968 to March 1969)*

(all values in acre-feet at head of watercourse)

MONTHS	Rakh Miani Distributary				Kot Mamyana Distributary			
	G.A. 4,550 (acres) C.A. 4,371 (acres) CCA. 3,910 (acres) AFS (Canal) 19 Cfs. *Intensity* : Kharif 46 Rabi 56 (%) T/well inst. capacity 25 Cfs.				G.A. 4,062 (acres) C.A. 3,941 (acres) CCA. 3,941 (acres) AFS (Canal)—Cfs. *Intensity* : Kharif 56 Rabi 72 (%) T/well inst. capacity 19.5 Cfs.			
	Crop water requirement	Canal Supplies	T/well water required	T/well water pumped (68-69)	Crop water requirement	Canal Supplies	T/well water required	T/well water pumped (68-69)
Apr.	490	899	—	588	632	857	—	282
May.	280	990	—	631	525	937	—	333
Jun.	774	894	—	783	902	847	55	497
Jul.	1021	953	68	666	889	907	—	391
Aug.	901	830	71	613	706	655	51	251
Sep.	1437	958	479	1003	1226	897	329	587
Oct.	1361	412	949	1022	1138	517	621	861
Nov.	980	319	661	1134	941	296	645	766
Dec.	684	—	684	902	666	—	666	935
Jan.	518	64	454	1075	462	24	438	1087
Feb.	413	267	146	846	430	118	312	666
Mar.	725	255	470	1311	748	106	642	768

Appendix II

TABLE.—*Water requirements and Tubewell Pumpage* (*April* 1968 *to March* 1969)

(all values in acre-feet at head of watercourse)

MONTHS	Chak Qazi Distributary				Jiwanwal Distributary			
	G.A. 4,223 (acres) C.A. 3,989 (acres) CCA. 3,927 (acres) AFS (Canal) 19 Cfs. *Intensity* : Kharif 64 Rabi 81 (%) T/well inst. capacity 16.5 Cfs.				G.A. 934 (acres) C.A. 894 (acres) CCA. 894 (acres) AFS (Canal) 4 Cfs. *Intensity* : Kharif 68 Rabi 66 (%) T/well inst. capacity 2.5 Cfs.			
	Crop water requirement	Canal Supplies	T/well water required	T/well water pumped (68-69)	Crop water requirement	Canal Supplies	T/well water required	T/well water pumped (68-69)
Apr.	719	756	—	331	132	230	—	17
May	459	937	—	483	60	260	—	51
Jun.	1017	847	170	402	222	235	—	66
Jul.	1254	870	384	223	350	240	110	69
Aug.	1031	208	823	220	332	166	166	72
Sep.	1645	860	785	303	478	239	239	116
Oct.	1617	464	1153	415	409	119	290	103
Nov.	1247	292	955	552	240	84	156	86
Dec.	924	—	924	549	170	—	170	115
Jan.	694	52	642	748	129	17	112	123
Feb.	559	457	102	367	107	74	33	78
Mar.	994	195	799	608	193	52	141	132

Appendix II

TABLE.—*Water requirement and Tubewell Pumpage (April 1968 to March 1969)*

(all values in acre-feet at head of watercourse)

MONTHS	Shahpur Br. Dir. Outlets. G.A. 1,050 (acres) C.A. 1,047 (acres) CCA. 866 (acres) AFS (Canal) 3.86 Cfs. *Intensity* : Kharif 29 Rabi 35 (%) T/well inst. capacity 5.5 Cfs.				Dewas Distributary G.A. 2,029 (acres) C.A. 1,927 (acres) CCA. 1,972 (acres) AFS (Canal) 9 Cfs. *Intensity* : Kharif 49 Rabi 67 (%) T/well inst. capacity 8.50 Cfs.			
	Crop water requirement	Canal Supplies	T/well water required	T/well water pumped (68-69)	Crop water requirement	Canal Supplies	T/well water required	T/well water pumped (68-69)
Apr.	162	188	—	327	306	356	—	404
May	236	234	2	283	156	469	—	351
Jun.	302	234	68	304	398	423	—	312
Jul.	263	203	60	315	518	370	148	277
Aug.	213	93	120	329	468	398	70	214
Sep.	373	234	139	335	708	437	271	402
Oct.	146	117	29	356	702	232	470	416
Nov.	88	70	18	334	503	136	367	447
Dec.	49	—	49	336	376	—	376	455
Jan.	21	8	13	370	279	15	264	510
Feb.	17	102	—	215	237	163	74	289
Mar.	23	39	—	329	435	52	383	512

Appendix II

TABLE.—*Water requirements and Tubewell Pumpage* (*April* 1968 *to March* 1969)

(all values in acre-feet at head of watercourse)

MONTHS	Main Line Direct Outlets				Uncommanded Area			
	G.A. 3,197 (acres) C.A. 3,191 (acres) CCA. 2,766 (acres) AFS (Canal) 9.4 4Cfs *Intensity* : Kharif 45 Rabi 65(%) T/well inst. capacity 13.50 Cfs.				G.A. 11,341 (acres) C.A. 10,729 (acres) CCA. (acres) AFS (Canal) Cfs. *Intensity* : Kharif 48 Rabi 69 (%) T/well inst. capacity 90 Cfs.			
	Crop water requirement	Canal Supplies	T/well water required	T/well water pumped (68-69)	Crop water requirement	Canal Supplies	T/well water required	T/well water pumped (68-69)
Apr.	360	565	—	363	2033	—	2033	2829
May	309	579	—	575	1357	—	1357	3299
Jun.	596	565	33	548	2304	—	2304	2710
Jul.	582	579	3	225	2302	—	2302	2545
Aug.	413	579	—	100	1888	—	1888	2041
Sep.	788	565	223	486	3422	—	3422	3302
Oct.	817	347	443	693	3604	—	3604	3196
Nov.	755	449	306	693	2990	—	2990	3127
Dec.	596	233	363	623	2169	—	2169	2682
Jan.	446	291	155	738	1623	—	1623	3535
Feb.	309	474	—	297	1381	—	1381	2960
Mar.	498	534	—	563	2643	—	2643	3678