Performance of Salinity Control and Reclamation Project No. 1 Rechna Doab

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Salinity Control and Reclamation Project No. 1, in Central Rechna Doab is the first to be constructed in WAPDA's long-range program for reclamation in the Punjab. The heart of this program is a massive complex of tubewells which will serve the entire irrigated area with an average density of about one well per square mile. The tubewells are sited near the heads of watercourses and the required yield of each well is determined by the supplemental irrigation needs of the land under its command. Ground water withdrawals serve the dual purpose of satisfying irrigation requirements, and providing effective control of subsurface drainage. The system also offers a permanent solution to the effects of canal leakage because it both controls the effects of leakage, and salvages the losses from the canals.

Salinity Control and Reclamation Project No. 1 (SCARP I), went into full-scale operation in 1962. The project includes 12 contiguous scheme areas serving a gross area of 1.2 million acres in Central Rechna Doab (Fig 1). The tubewell network in operation under SCARP I comprises nearly 2,000 wells, including 1,800 constructed under WAPDA's program, and 200 existing wells which have been incorporated into the system. The total capacity of the tubewell system is over 5,600 cusecs which is equivalent to depth of water of about 3.7 feet over the gross area, or nearly 3.5 times capacity of the existing canal system in the area. Under the original project proposal the long-term operational yield would utilize, on an annual basis, about 55 per cent of the capacity of the system resulting in a three-fold increase in the supply of water

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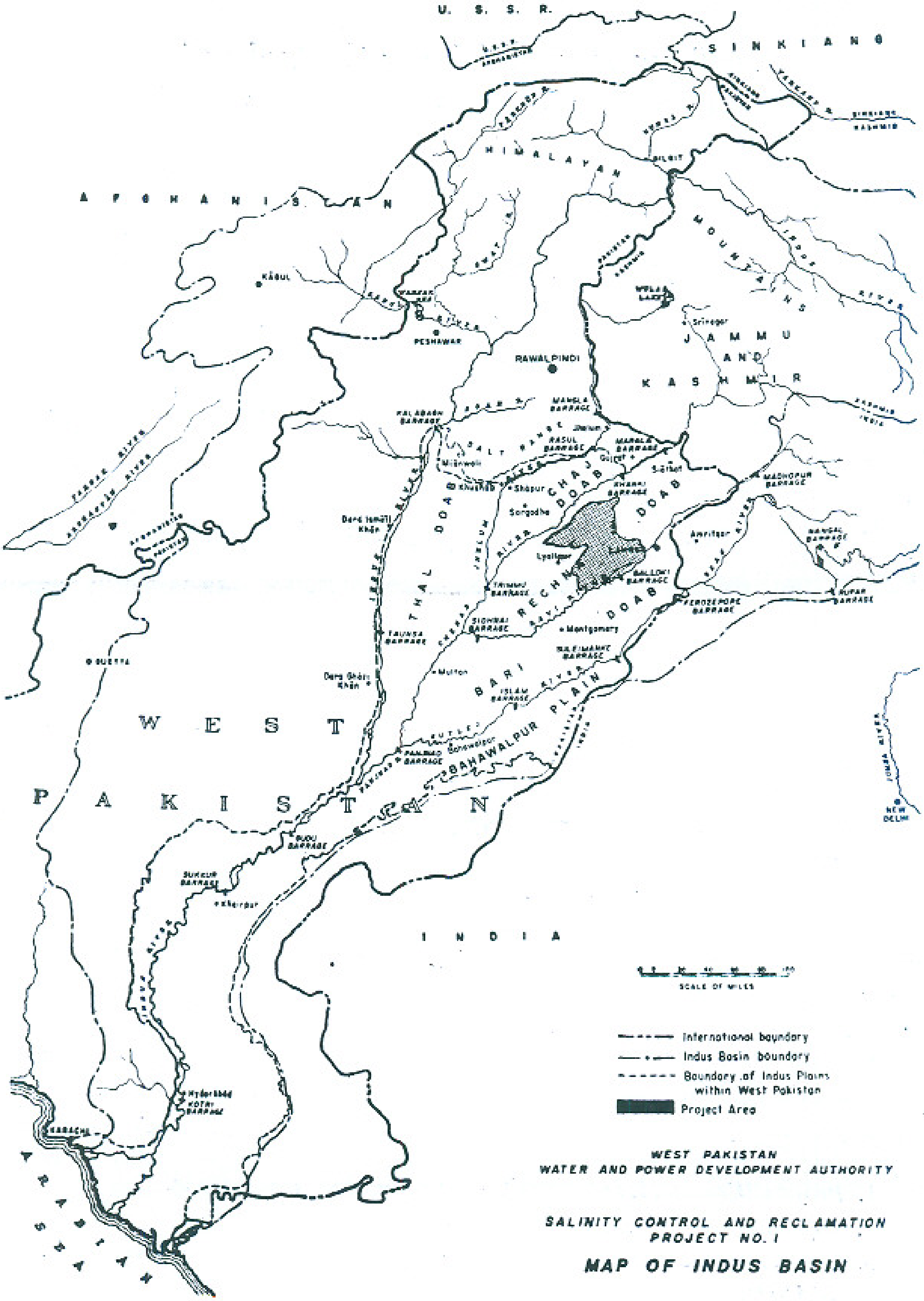
Fig. 1


U. S. S. R.
SINKIANG
AFGHANISTAN
HIMALAYAN
MOUNTAINS
JAMMU AND KASHMIR
Kabul
Peshawar
RAWALPINDI
Srinagar
WULAR LAKE
GILGIT
MANGLA BARRAGE
KALABAGH BARRAGE
SALT RANGE
RASUL BARRAGE
MARALA BARRAGE
Jhelum
Gujrat
Sialkot
Mianwali
Khushab
Shapur
Sargodha
CHAJ DOAB
THAL DOAB
RECHNA DOAB
BARI DOAB
Lyallpur
Lahore
BALLOKI BARRAGE
MADHOPUR BARRAGE
Amritsar
NANGAL BARRAGE
RUPAR BARRAGE
FEROZEPORE BARRAGE
TRIMMU BARRAGE
SIDHNAI BARRAGE
TAUNSA BARRAGE
Montgomery
SULEIMANKE BARRAGE
ISLAM BARRAGE
Multan
Dera Ismail Khan
Dera Ghazi Khan
QUETTA
WEST PAKISTAN
BAHAWALPUR PLAIN
PANJNAD BARRAGE
Bahawalpur
GUDU BARRAGE
SUKKUR BARRAGE
Khairpur
INDIA
Hyderabad
KOTRI BARRAGE
KARACHI
ARABIAN SEA
NEW DELHI
JUMNA RIVER
INDUS RIVER
SCALE OF MILES
International boundary
Indus Basin boundary
Boundary of Indus Plains within West Pakistan
Project Area
WEST PAKISTAN
WATER AND POWER DEVELOPMENT AUTHORITY
SALINITY CONTROL AND RECLAMATION PROJECT NO. I
MAP OF INDUS BASIN

available to crops in the area. The combined tubewell-canal supplies would be sufficient to achieve an annual cropping intensity of about 150% under conditions of full supply including leaching requirements. This compares to an annual cropping intensity of about 70%, for the most part undersupplied, which was realized under canal operations.

In subsequent reviews of the SCARP I program allowances were made for certain contingencies that might restrain development of a pioneer project of this kind. Accordingly a more conservative estimate for operational yield was recommended, based on an average annual utilization of about 35% of the system capacity. This would approximately double the supply of water available to crops, and would be sufficient to support a cropping intensity of 100%.

Under both estimates ground water withdrawals would be sufficient to suppress the water table below the root zone thereby eliminating subsurface drainage problems and related salinity hazards. Also, in either case the excess pumping capacity is required to meet the peak month demands, and to provide surplus water for leaching purposes during the early years of the project.

SCARP I is not only the first project under WAPDA's reclamation program, but nowhere else in the world have tubewell reclamation methods been employed on such a large scale. The criteria for development and management of this kind of project have been devised here, and it is essential now to evaluate the performance of the project as a guide to planning not only future projects in the Punjab, but in similar terrains elsewhere.

After about one year of full-scale operations it is impossible to fully evaluate all aspects of performance of SCARP I. However, preliminary appraisals of certain critical factors of performance can be made as follows.

Well-design

A major problem in planning SCARP I was the selection of specifications for wells, especially for the screen and gravel envelope. It was obviously impracticable to attempt to customdesign each well according to local conditions so a standard set of specifications was devised which would provide highly efficient and long-lived wells in every geologic environment known to the area. The specifications for the well-screen called for the use of 10-inch mild steel casing perforated with $\frac{1}{16}'' \times 2\frac{1}{2}''$ slots at a density to provide 30 square inches of void area per lineal foot of screen, and of sufficient length that the theoretical entrance velocity does not exceed .15 feet per-second. The screen is surrounded by 4 to 8 inches of gravel shroud.

The hydraulic efficiency of the tubewells design and the effectiveness of the development technique were largely confirmed by the initial yields achieved in the acceptance tests. The average specific capacity of 1,014 wells drilled by reverse circulation methods is about 116 gpm/ft. of drawdown, and a typical well yields between 110 and 130 gpm/ft. of drawdown. The wells that were drilled by cable tool methods have somewhat lower specific capacities—averaging about 80gpm/ft. In any event, the yields obtained for SCARP I wells are high by any standards of comparison. They compare most favourably with typical conventional tubewells in the Punjab which commonly yield less than 40 gpm/ft. of drawdown.

Operating experience with the tubewells has fortified our confidence in the original design criteria. Since the inception of pumping the tubewells have been carefully monitored by periodic sampling of specific capacity of representative wells. Some 138 wells have been sampled twice at six month intervals and the results show no perceptible general trend of declining yields, or marked incidence of well failures either on a local or regional basis. The average specific capacity of these wells was 106 gpm/ft. at the time of acceptance, 103 gpm/ft. in October 1961, and 103 gpm/ft. in March, 1963. Some individual wells showed large variations, but most of these probably reflect errors in the measurement which are inevitable when soundings are taken in operating wells. As the errors presumably balance the average cited above probably provide a more reliable estimate of conditions than studies of individual wells.

It should be noted that about forty wells experienced a marked decline in yield during the interval of several months between the date of their completion and the time the acceptance tests were made. Screens were removed from several of the wells and the incrustation was determined by X-ray analysis to consist chiefly of iron carbonate. The wells were then redeveloped by explosive treatment and have performed satisfactorily since.

As the incrustation occurred while the wells were idle, it cannot be related to hydraulics of the wells. Furthermore, although most of these wells are located in the Zafarwal area and were drilled by cable-tool methods, there are no obvious common features of their environment—such as a characteristic quality of water, or a unique geologic situation. Thus the occurrence of the incrustration probably is related to some external cause, most likely organic material which was introduced into the wells during or after construction. Studies of this phenomena are continuing; in the meantime in the new construction all wells are being sterilized with calcium hypochlorite upon completion, and no cases of incrustation have occurred in wells so treated.

Notwithstanding the excellent performance achieved by the tubewells in SCARP I, the Ground Water and Reclamation Division, in co-operation with the Water and Soils Investigation Division, instituted detailed experimental studies in an effort to further improve the basic design criteria, and also to devise appropriate specifications for unusual conditions. The first of these studies consisted of a series of step-drawdown tests in five newly commissioned wells in the Lalian Project area in Chaj Doab. The objectives were to evaluate entrance losses in wells constructed according to the current design as used in SCARP I, and to determine whether the well-efficiency can be enhanced by the use of still larger openings in the screens.

The preliminary results of these studies provide virtually final confirmation of the basic design. Head loss through the well-screen was negligible at all rates of discharge; head loss through the gravel envelope could not be evaluated quantitatively, but it was of the same or lesser order of magnitude than occurred in the surrounding formation. Flow meter studies showed that water entered the wells through the entire length of slotted screen at rates of flow which varied more-or-less according to the texture of the formation.

Everything considered, the current specifications for construction and development of tubewells appear to be a reasonable compromise between efficiency on one hand, and the economy of standardization on the other. Additional studies are planned to test the feasibility of employing an improved gravel envelope in conjunction with screens perforated with 3/32" and 1/8" slots. It is questionable whether appreciably greater well efficiencies can be obtained because there is little margin for further improvement; but considering the large number of tubewells that will ultimately be involved in the reclamation program for the Punjab, any improvement in well hydraulics, however slight, may have important economic implications.

System Operation

Table I summarizes tubewell operations and utilization of tubewell supplies from the inception of pumping through the 1962-63 Rabi season. A significant feature of this table is the progressive decrease in lost time owing to mechanical breakdowns and power failure. Evidently the initial "breaking-in" period has been negotiated and the project operations now are involved only with matters of more-or-less routine maintenance.

Equally significant is the marked increase in utilization of the tubewell supplies between the 1961-62 and 1962-63 Rabi seasons. This is in part due to the decrease in lost time from mechanical and power failure, but it is primarily a reflection of a decrease in "no demand" as cultivators gained confidence in the tubewell supplies.

In any event, the use of the tubewell supplies is developing about as anticipated. Project planning estimates were based on a lower annual yield than is

TABLE 1

Tubewell Operating Statistics

Growing Season	Rabi		Kharif		Rabi	
Quarter/Year	4/61	1/62	2/62	3/62	4/62	1/63
Number of Tubewell	1104	1210	1233	1534	1711	1740
Percent lost hours due to Power Supply Failure.	16.00	9.81	8.89	7.68	5.78	3.70
Mechanical Failure	7.87	7.42	9.53	7.33	4.35	5.04
No demand	23.59	13.99	4.61	3.10	14.87	10.30
Total	47.46	21.22	23.03	18.11	25.00	19.04

now being realized, but it was recognized that greater utilization of the system capacity would be desirable during the early years of operation to hasten the suppression of the water-table and reclamation of saline lands. The current rate of pumpage yielding a tubewell delta of over 2.5 feet represents this transient, but vital initial phase of reclamation and development.

Quality of Tubewell Supplies

The tubewells comprising the SCARP I network were sampled for chemical analysis during their acceptance tests and resampled by WASID under their monitoring program for SCARP I at about six month intervals since the inception of pumping. This comprehensive program was necessary, in the first instance, to confirm the project quality of water estimates which were based on a broad interpretation of investigational data; and subsequently to monitor the effects, if any, of pumping on the quality of ground water supplies.

Analytical data for 1,022 wells that have been sampled three times under the monitoring program indicate that to date there has been no significant change in the quality of water. Ground water from these wells had an average mineral concentration of 690 ppm at time of the acceptance tests, 687 ppm after about six months of operation, and 663 ppm after about 12 months. Individual wells experienced more pronounced variations. Between successive sampling periods the mineral content of water from about half of the wells changed by a factor of 10% or more. But there is no obvious trend in the data because there was an equal distribution of samples showing increasing as opposed to decreasing concentrations.

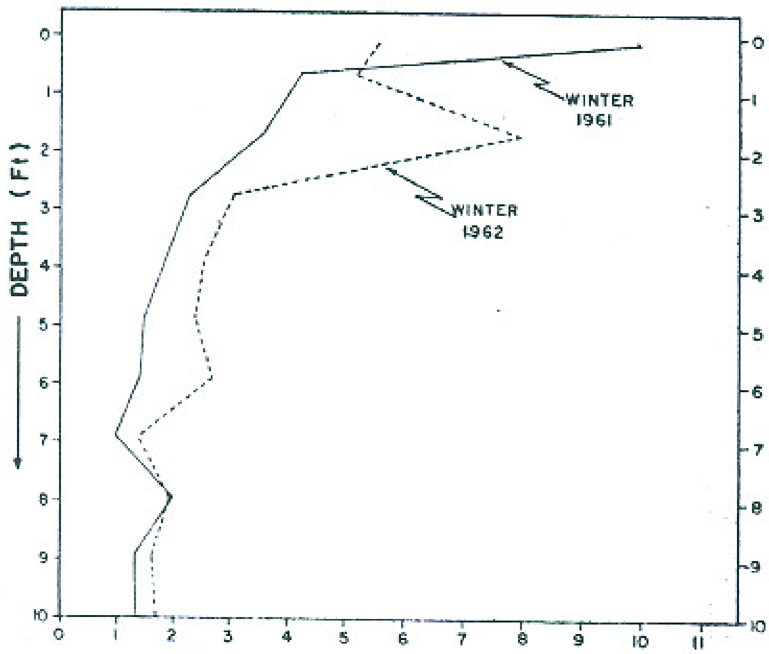
Salinity Control

WASID has established about 400 test plots in the SCARP I area to monitor the response of the soils to the project reclamation activities. The plots were selected to represent virtually every combination of soil texture, salinity status, and chemical quality of reclamation supplies that will occur under the project. The monitoring program consists of periodic examination of the soil profile to a depth of ten feet to describe significant changes in the chemical and physical properties of the soils. Various kinds of determinations are made. For the purposes of this review the most significant are electrical conductivity (Ec) of the soil extract which measures the salinity status of the soil; and sodium adsorption ratio (SAR) of the soil extract which reflects the alkalinity status of the soil.

The first complete sampling of the test plots was made prior to the 1961-62 Rabi season, and a second survey was begun in the winter of 1962. The results are shown graphically in figures 2 and 3 which compare average values of

FIG. 2

CHANGES IN Ec OF SOIL PROFILE
AVERAGE FOR 48 TEST PLOTS
IN SCARP I AREA



Ec and SAR for all plots for which data are available for two sampling periods; and in figures 4, 5 and 6 which depict changes that have occurred in typical plots representing potential problem environments.

FIG. 3

CHANGES IN SAR OF SOIL PROFILE
AVERAGE FOR 47 TEST
PLOTS IN SCARP I AREA

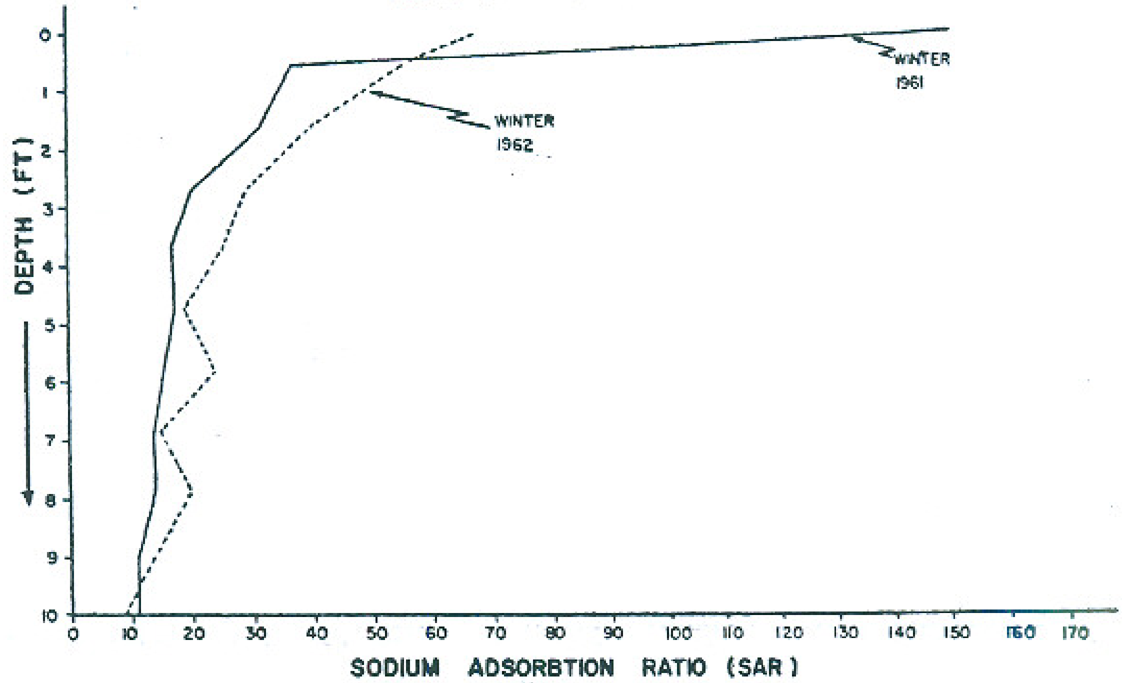


FIG. 4

CHANGES IN EC_e OF SOIL PROFILE FOR FINE-TEXTURED SOIL
AVERAGE FOR 8 TEST PLOTS
IN SCARP I AREA

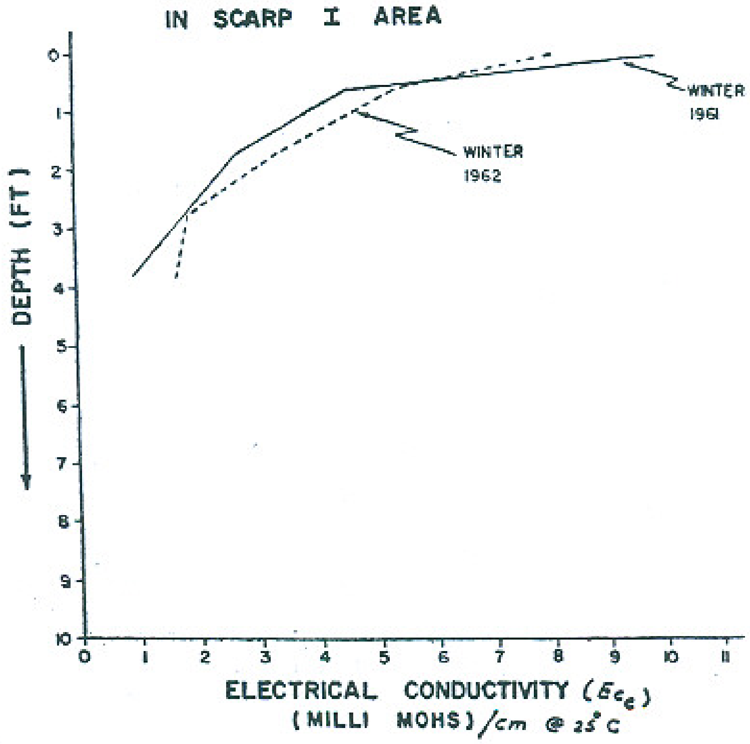


FIG. 5

CHANGES IN SAR OF SOIL PROFILE FOR FINE-TEXTURED SOIL
AVERAGE FOR 8 PLOTS IN
SCARP I AREA

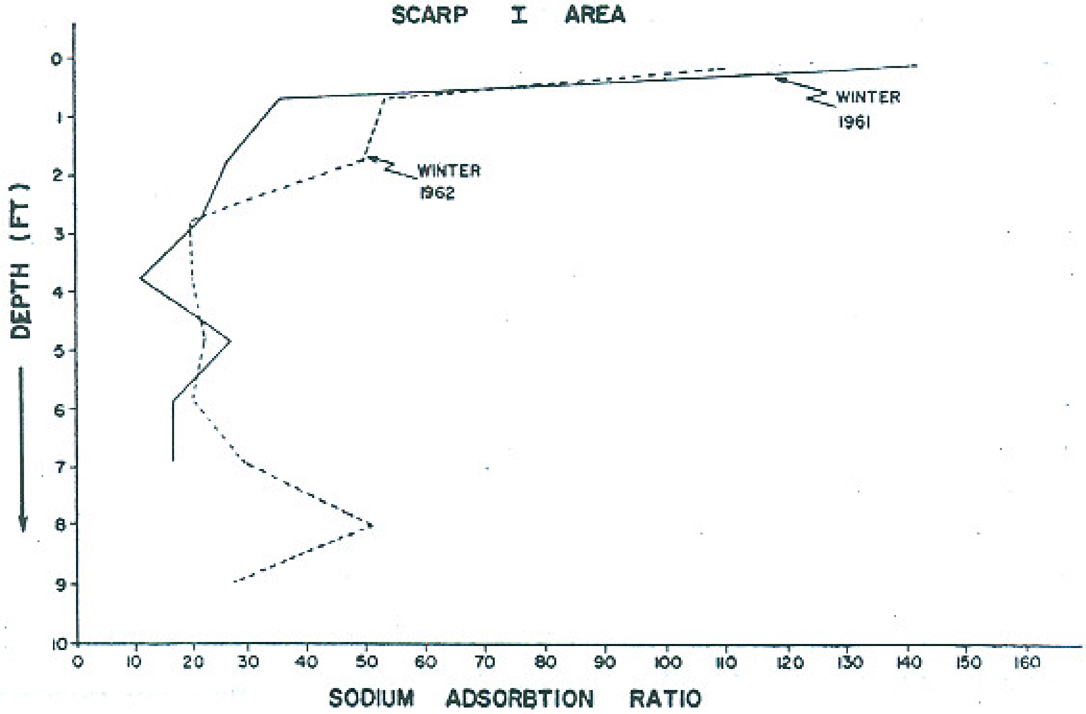
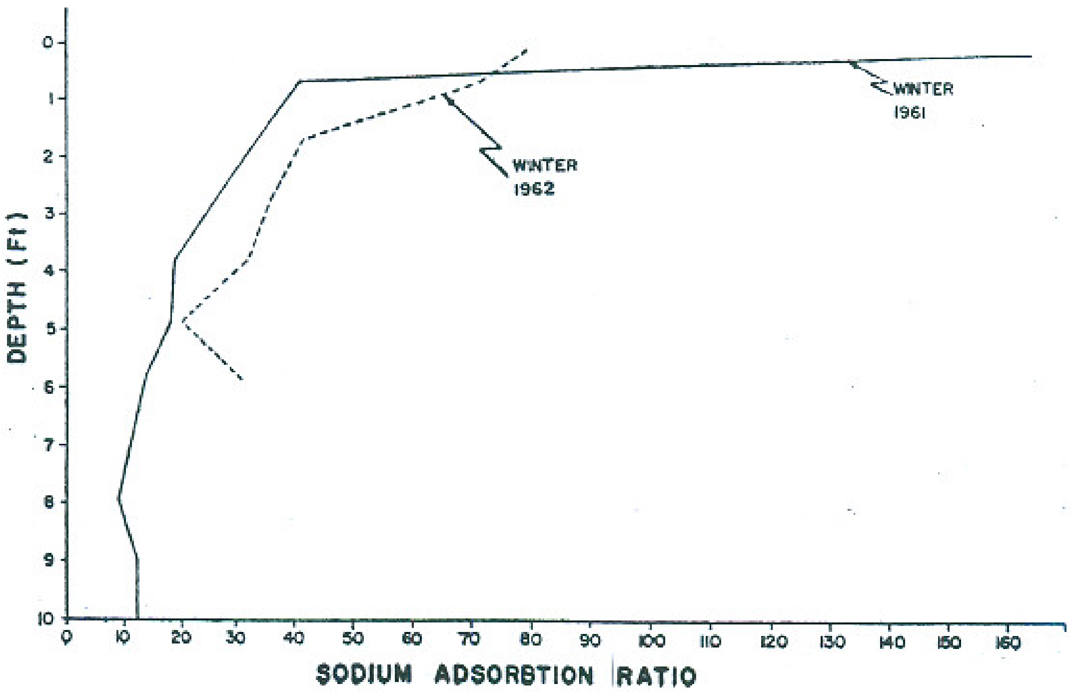


FIG. 6

CHANGES IN SAR OF SOIL PROFILE FOR LANDS SERVED BY
TUBEWELL SUPPLIES WITH RSC VALUES GREATER THAN 5 ML/L
(AVERAGE RSC 10.17 ML/L)

AVERAGE FOR 20 TEST PLOTS IN SCARP I AREA



According to these data there has been a definite improvement in the salinity status of the soil. Prior to the tubewell operations the highest salinity commonly occurred within the surficial six inches of the profile. After one year of reclamation the concentration of salts in this zone decreased appreciably. This was accompanied by a more-or-less proportional increase in salinity of the soil profile below a depth of about one foot. Evidently the combined effect of ground water pumpage and increased irrigation delta has been to reverse the flux at the water-table. In the pre-reclamation hydrologic environment the direction of ground water movement was upward towards the land surface where discharge occurred as evapo-transpiration losses resulting in accumulation of salt at land surface. Under the pumping regimen ground water is moving downward and laterally towards the wells which are now the principlal factors of discharge from the water table. This, in turn, has promoted downward migration of the accumulated salts, which, if continued, will ultimately flush the soil profile of harmful concentrations of saline residues.

A significant feature of these data is the almost universal response of the soils to the reclamation measures, regardless of their texture, slinity status, or the quality of the tubewell supplies. As anticipated, the fine-grained soils (figures 4 and 5) appear to be responding more lowly, but they are showing progressive improvement and there is no evidence that additional amendments will be required. Most significant perhaps is the favourable response of the soils which are served by tubewell supplies characterized by high values of "Residual Sodium Carbonate" (figure 6). RSC is a method of expressing the sodium hazard of irrigation supply. Although the RSC values of the tube-well supplies represented in figure 6 average 10.17 me/1—more than four times the commonly accepted standard for a hazardous supply—there is no evidence of deterioration of the soils that would occur if the RSC factor were operating.

Subsurface Drainage

The response of the water-table to tubewell pumpage is being monitored by periodic measurement of static water levels in the tubewells, and through a network of observation wells and automatic depth recorders maintained by WASID. These data are now being analysed by WASID. Their studies are incomplete, but preliminary findings indicate that for the one year period ending April 1962 the water table declined an average of about 3.45 feet in most areas where the tubewells were in operation for the full year. Correlation of data for these areas with antecedent conditions indicates an average decline of about 5 feet since the inception of pumping. Exceptions were the Chuhar-kana and Jaranwala areas; these are served by previously existing tubewells which were incorporated into SCARP I management, but are underdesigned by SCARP I standards.

The preliminary findings are encouraging for two reasons. Firstly, they prove that subsurface drainage can be controlled by ground water pumpage. In this connection it is significant that the water table showed a progressive decline through all seasons of the year including the monsoons. That suggests that recharge from precipitation is insignificant compared to ground water withdrawals in the project area, and is not an important factor in the hydrologic balance. Secondly, they tend to confirm the project planning estimates for sustained long-term withdrawals. The 3.5 foot decline in one year was accomplished while the water table lay sufficiently close to land surface to be subject to non-beneficial evapotranspiration losses, and while the rate of ground water pumpage was much in excess of the long-term operational yield planned for the project. In time as the water levels decline non-beneficial evapotranspiration losses will become negligible; and as reclamation operations are completed pumping will be cut back to about the project design estimate. Under those conditions withdrawals probably will closely approximate recharge, and the water-table will tend to stabilize.

Agriculture

The technical accomplishments cited previously are interesting and significant, but in the last analysis, the most important aspect of the reclamation program is the response of agriculture. At this early stage of operation the agricultural effects are difficult to evaluate, but some measure of the impact of the tubewell operation can be taken from the cropping statistics for the areas which have received full tubewell supplies since the fall of 1961. (Table 2).

TABLE 2

Summary of Cropping Statistics for Area Served by Full Tubewell Supplies Since Fall, 1961

Culturable Area (Acres)	Area Irrigated and Intensity			Increase in Irrigated Acres
	..Average	1962	1963	
	Rabi			
	166890 33%	198598 39.2%	136958 46.8%	700680 42%
506109	*Kharif*			
	187872 37%	205206 40.5%	220000* 43%	32000* 17%
	Annual			
	354762 70%	403794 80%	456958* 90.2%	102068* 29.7%

*Estimated.

According to these data the cropping intensity during Rabi increased from about 33% for the pre-reclamation period to 39% for the 1961-62 season, and 47% for 1962-63. This represents a 42% increase in the acreage under irrigation during Rabi. For Kharif the cropping intensity increased from about 37% for the pre-reclamation period to 40% in 1962, and a similar or larger increase is anticipated for the current (1963) season. This will represent nearly a 17% increase in the acreage under irrigation during Kharif. Thus after two years of full supplies the annual cropping intensity will have increased from about 70% to about 90%, representing an increase in irrigated area of nearly 30%. This is a significant accomplishment: by any reasonable projection of these data we can anticipate that a cropping intensity of 100% will be achieved in 1964, and far exceeded in subsequent years, and in the long run may well approach the target of 150% intensity as originally proposed.

Marketing statistics furnished by the Chuharkana Marketing Committee provide another index of the effects of the reclamation activities on agricultural production. According to these data (table 3), there has been a marked increase in the production of agricultural commodities for the Chuharkana market each year since 1961 when the reclamation program went into full scale operation in that area. Prior to 1961 there was a more modest annual increase while the reclamation activities were being established. Thus between 1958 and 1963 there was an overall increase of 80% in the commodities marketed with 85% of the increase occurring between 1961 and 1963.

TABLE 3

Chuharkana Market Statistics

	Farm Commodities Marketed (Maunds)						
Year	Wheat	Rice	Sugar	Cotton	Oilseeds	Fodder	Gram
1958	60000	83800	24000	8900	10000	1000	700
1959	63000	83000	22909	9000	9500	690	
1960	69892	90000	26012	11998	100112	1090	895
1961	82107	96997	38006	14011	13025	1200	1200
1962	92672	132000	48788	17015	15988	1400	1350
1965	97996	140015	60093	18988	17895	1509	1488

There are no data to directly relate the effects of the reclamation activities on yields of crops. However, individual cultivators report 100 per cent or more appreciation in yields of some crops and even casual observers are impressed with the obviously improved condition of all agriculture in the area. Notwithstanding the absence of detailed data, it is safe to say that there has been an appreciable increase in yields—very likely of an order of magnitude that exceeds the original project estimates.

SUMMARY

SCARP I has yielded impressive results. From an operational standpoint the project has equalled or exceeded the goals set for every aspect of performance during the initial period of development; if this trend is continued it must be ranked as an outstanding success by any reasonable standards. In an experimental sense SCARP I has confirmed both the technical feasibility of tubewell reclamation methods, and the basic design criteria adopted for the projects under development program. It is also providing an experimental basis for modification of some details of planning and design which will enhance the economic utility of future projects.

It is not intended to suggest here that all of the problems of reclamation and development of the water and soil resources of the Punjab have been solved. On the contrary, some of the most vexing problems of management and regional planning and development remain. But SCARP I has demonstrated that application of science and technology are the keys to successful reclamation in the Punjab. Continued application of these principles will undoubtedly yield solution to virtually every problem that may arise in connection with management and development. And considering the inherent operational flexibility and favourable economic bias of tubewell methods, there is little doubt that any technically feasible activity can be accommodated within the program. Thus we have every reason to be optimistic about the future prospects of maintaining permanent irrigated agriculture in the Punjab.