

**CENTRAL BOARD OF IRRIGATION
AND POWER**

PUBLICATION NO. 43

LAND RECLAMATION

VOLUME I

BY

M. L. MEHTA

**Director, Land Reclamation, Punjab
(India)**



सत्यमेव जयते

PUBLISHED BY ORDER OF THE BOARD

U. D. CLASSIFICATION 631.61

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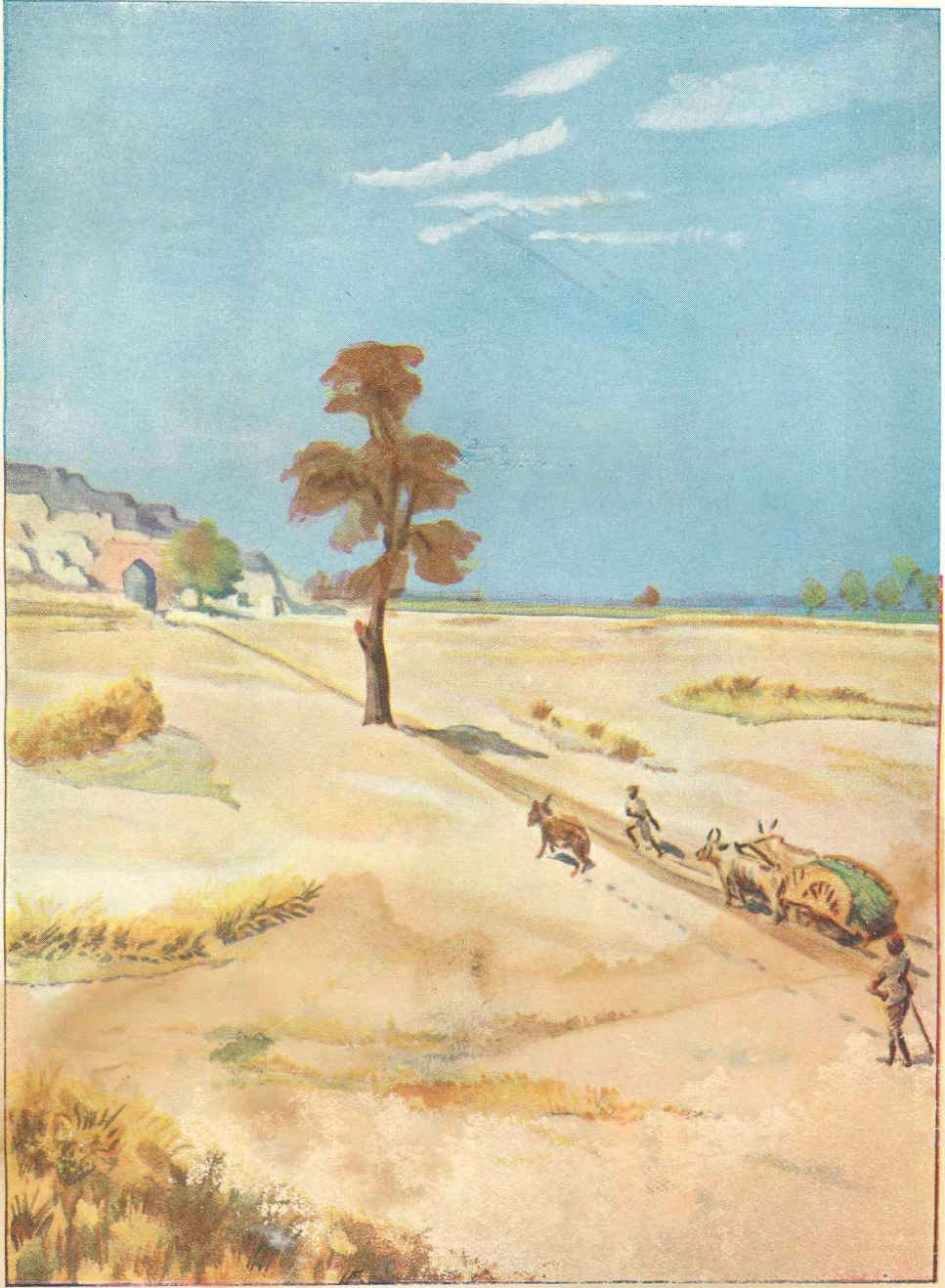
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*Good land slowly and gradually became their salt land
(Land before reclamation)*

FOREWORD

The term 'land reclamation' has been implied to mean in U.S.A. and other countries, the development of irrigation and cultivation in new and uncut lands. In India in the past the term 'land reclamation' has been used specifically for the reclamation of deteriorated and water logged lands infested with salts, but now under the pressure of growing more food, this term is being used also for bringing waste and uncultivated lands under cultivation.

In the pre-partitioned Punjab, magnificent and extensive irrigation systems were developed especially in its western portion. These resulted in intensive irrigation on new lands and brought prosperity to the State and the people, which was, however, accompanied by the evil of water logging and deterioration of lands due to rise in the water table consequent on seepage from canals, distributaries, water courses and fields. This deterioration of land due to water logging assumed a serious form and threatened the prosperity of the province. The Government of the Punjab as a result, instituted a Water Logging Enquiry Committee in 1925 to study the problem. The Irrigation Research Institute, Punjab, Lahore was also established about the same time and in addition to other studies of hydraulic and irrigation problems, the main investigation that had to be undertaken and which actually led to the inauguration of the institute, was a study of the deteriorated lands and methods to be adopted for their reclamation. Since then the Punjab Irrigation Department have done extensive work on studies on "land reclamation", both in the laboratory and the field and have been successful in reclaiming large areas which had gone out of cultivation due to salts or *thur*. As the development of irrigation was mainly confined to the western portion of the Punjab (now in Pakistan), the problem of water logging was also being studied in that portion. Shri M. L. Mehta, the author of this publication was connected with these investigations from the very beginning and to him goes the credit of development of the methods of reclamation which at the time of the partition were being successfully applied. The problem after the partition has been studied in the Indian portion of Punjab also, as there are vast areas on the Western Yamuna Canal and Sirhind Canal, which require attention, but were not being attended to before the partition. Naturally, therefore, the investigations described herein have all been carried out in the West Punjab and Shri Mehta has put them together for the benefit of all engaged on land reclamation.

The subject of land reclamation has engaged the attention of the Board since its institution in 1930 and has been discussed at every Board and Research Committee meeting. A questionnaire on land reclamation and water logging was prepared in 1935 to ascertain the

(ii)

present state of knowledge and to compare different conditions in various parts of India and a note based on the information received from various Provinces was published in 1938. The Executive Committee of the Board in 1949 felt that time had come when the Board should publish a comprehensive publication on land reclamation, based on the experience gained in different parts of the country. Shri M. L. Mehta, Director, Land Reclamation, Punjab (India), who has been connected with the subject for a long time, was requested to prepare a draft in association with Dr. R. C. Hoon, Dr. N. K. Bose and the Bombay Public Works Department. Shri Mehta has prepared his portion for the practice of reclamation, as evolved and followed in Punjab, where the problem was very acute and was studied minutely. His portion is, therefore, being published as Volume I and it is proposed to publish the contributions from others, which will deal more with the chemistry of soils, reclamation of tidal areas and reclamation of land in Deccan, in Volume II, subsequently.

Shri M. L. Mehta, the author of this volume has presented a fairly complete and upto date version of the science, as developed and followed in the Punjab. All the factors contributing to deterioration of lands, the different methods of treatment and preventive measures have been discussed in detail in Chapters 1 to 10, which will be of general interest. The remaining chapters are of local interest to the Punjab and contain details of this system, especially from administrative point of view as practised in the Punjab. It is hoped that the book will be equally useful to the soil chemist, the practical farmer and the irrigation engineer and will focus attention of all interested in the advancement of knowledge on the subject.

S. L. MALHOTRA,

Secretary,

May 21, 1951.

Central Board of Irrigation and Power.

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PREFACE

The information given in this book is based on more than twenty years' experience of work done in the laboratory and in the field, both under government control and on thousands of acres of deteriorated land reclaimed and farmed by zemindars themselves.

With the dissemination of knowledge bearing upon *thur* formation and a general recognition of the terrible risks of rise of water-table in soil profiles with a zone of salt accumulation, it is to be hoped that reclamation projects would be taken up one after the other and that the days of land deterioration will be closed for ever.

No price would be too high to pay for absolute security of land against deterioration. It is a matter of satisfaction that the costs of reclamation at the present prices of agricultural produce are not high. In fact land reclamation now is a self paying proposition.

It is now an admitted fact that there is an intimate relationship between the quality of the soil, the nutritive quality of the plants that grow on it, and the health of those who eat these plants. Poor and deteriorated land makes people poor and sickly; and poor, sickly people make poor land poorer. Every one of us, therefore, no matter where one lives, in a rural area or a suburban town or even in a big city—has a major stake in the land. Good health is primarily a matter of good nutrition.

It is the duty of all to save this great heritage (soil) from damage. If we do that, it will enable us to build a better world for our children and our children's children.

M. L. MEHTA.

CHAPTER 1

Historical and Introductory

The problem of *thur* or salt affected land in the Punjab has never been out of sight of the Punjab farmer.

The first attempt that the Punjab Government made to investigate this problem was a survey of the Lower Chenab Canal Colony area, carried out in 1908 at the instance of the late Dr. Barnes, Agricultural Chemist to the Government of Punjab.

A field experiment in the way of reclamation was started in 1914, near Narwala, Lyallpur district. This experiment involved using a mole plough with the help of steam tackle, to construct moles at regular distances in the salt affected fields. All these moles opened into a drain artificially constructed. This drain emptied itself into a tank. The idea was to apply heavy waterings to leach the soil. It was expected that the salt-laden water would enter the drain through the moles, that it would collect in the tank and become available for the manufacture of sodium sulphate on a commercial scale.

In actual working it was found that the moles all collapsed and no water entered the drain or the tank.

Soil Science was yet in its infancy and the processes involved in land deterioration and land reclamation were not well understood.

As heavy waterings had been given, there was certainly some improvement in the land, with the result that crops raised during the first year or two gave good yields. As salts had not been leached completely, patches of salt started appearing again.

The period that followed the Narwala experiment was one of rapid development of new project areas. In 1917, was completed the Triple Canal Project which involved the construction of two carrier-cum irrigation canals, viz., the Upper Jhelum and the Upper Chenab, running across the Chaj and the Rechna doabs, and of the Lower Bari Doab Canal which was designed to irrigate large areas in Montgomery and Multan districts.

By this time, surveys in connection with the proposed Sutlej Valley Canals, were put in hand—the actual construction starting in 1921. The Sutlej Valley Project comprised (a) the Bikaner Canal, the Eastern Canal and the Dipalpur Canal which were to take off at Ferozepur from the river Sutlej; (b) the Eastern Sadiqia, the Fordwah and the Pakpattan Canals which were to take off the same river at Sulemanki; (c) the Bahawal, the Qaimpur and the Mailsi Canals at Islam, from the same river again and (d) the Panjnad and Abasia Canals at Punjnad, where all the five rivers meet. These canals (a), (b), and (c) were opened in 1927-28 and the Panjnad canals in 1932.

The areas to be irrigated by the Sutlej Valley Canals in the Punjab or the adjoining states of Bikaner and Bahawalpur were yet in the course of development, when the construction of the Haveli and the Rangpur Canals was taken in hand, in 1937. When construction on this project was finished, the construction of the Kalabagh Weir on the river Indus and the Thal Canal to provide water for irrigation in the districts of Shahpur, Mianwali and Muzaffargarh was started.

It would be seen, therefore, that head-works and canals were constructed in rapid succession and vast areas of new land were brought under cultivation. On account of this, the problem of salt affected land remained largely masked and no serious notice was taken of it either by the public or the Government.

In 1918, an extremely deteriorated type of land was noticed in the Lower Bari Doab Colony. In local language this type of land was designated as 'bara'.

Briefly, *bara* land is highly arid, very closely packed and intractable. It usually cracks into hexagonal shaped clods of porous structure and it is highly charged with alkali salts. While riding across, the *bara* land gives a metallic sound. In sunlight from a distance, it looks like a mirage. The surface of the soil is generally covered with a sort of "papri" or thin cake like material, which contains about 80 per cent. clay and is impervious to water. This *papri*, although containing a very high amount of clay, is not at all sticky and if it is kept under water for an hour or so not only does it not get suspended, but can be separated into several fine leaves. If this *papri* is allowed to remain in water for a couple of days it begins to give a very offensive smell, which does not develop in the presence of mercury chloride. The profile is deep, soil crust thick, salt content is high and the pH values are usually above normal.

In appearance and chemical and physical characteristics, *Bara* land is more or less similar to the *Chit Dain* areas of the Mailsi Canal and the *Rakkar* areas on some of the older canals, viz., the Upper Chenab and Lower Chenab.

The first attempt to reclaim these soils was made in 1918, when an experimental station was established by the Agricultural department. The experiments then were unsuccessful, the main reason of the failure being that land reclamation was then ahead of research. The phenomenon of base-exchange was not clearly understood and the soil standards applicable to Punjab conditions had not been worked out.

Since 1918, considerable progress in soil science has been made; the problem of land deterioration and land reclamation is more clearly understood now. The source of harmful salts is known and the factors responsible for their movements up and down have been studied.

The problem of water-logging first came to be seriously noticed in 1915-16, but it was not till 1925, that the Government constituted

a "Waterlogging Enquiry Committee" with the object of investigating the waterlogging problem in the Province as a whole, and reporting to Government from time to time the conclusions arrived at as a result of the investigations. Originally two members were appointed, viz., the Scientific Member and the Engineer Member. In 1927, a third member was added as Civil Revenue Member, the duty of this officer being the co-ordination in each district of matters relating to the classification of waterlogged lands and methods of compensation. The main lines on which the technical work of the Committee was started were :—

(a) *Collection and Examination of Statistical data*

The object of this line of investigation was the discovery of the manner in which the equilibrium of the water-table is affected by fluctuations in rainfall, intensity of irrigation, etc., and to determine the influence of local factors, for instance soil, drainage, or the proximity of main channels, on the height of the water table.

(b) *Well surveys of tracts not covered by the Irrigation Department's canal systems*

The object of this survey was to link up on the map of the Punjab areas for which there were no contoured ground water-levels or regularly observed well lines, with the system of sub-soil water-level statistics maintained by the Canal Department.

(c) *Mapping*

The object of this work being the preparation of a general map on which all well statistics would be plotted; this being considered the most satisfactory method of studying the variation of the water-table and ascertaining its progress against time. In addition a detailed study of each doab was to be carried out by means of contoured maps on a larger scale.

(d) *Collection and examination of records dealing with remedial measures*

(e) *Laboratory and field investigations*

The object of these investigations was the examination of all available material, both from a practical and a theoretical standpoint, with a view to ascertaining the best and cheapest method of combating waterlogging, both in particular areas as well as for the Province as a whole.

An area of waterlogged and salt affected land near Hafizabad, Gujranwala district was taken over by the Irrigation Department for reclamation and experimental work. This came to be known as the "Chakanwali Reclamation Farm".

At about the same time, viz., 1925, an Irrigation Research Laboratory, was established, in a separate wing of the University Chemical Laboratory building, where investigations connected with the

chemical and physical examination of soils, examination of drainage waters, and the movement of moisture in soil columns were undertaken.

In 1928, the Waterlogging Enquiry Committee was abolished. Instead a Waterlogging Board was constituted. A new Circle called the 'Waterlogging Investigations Circle' was created within the Irrigation Branch to continue the work started by the Engineer Member of the Waterlogging Enquiry Committee. The Irrigation Research Laboratory continued the work taken up by the Scientific Member; the designation was changed to "Scientific Research Officer". The designation of the Civil and Revenue Member was changed to "Waterlogging Assistant to the Financial Commissioners".

It was laid down by the Board that the measures to be adopted to check or minimise waterlogging or *thur* belong primarily to the field of irrigation engineering; their nature and scope must, however, be determined in close collaboration with scientists trained in the study of soils and allied subjects. It was also decided that before such measures could be put into execution, they should be discussed in the 'Waterlogging Board' to ascertain what effect they will produce on the established conditions of agriculture and on the general well-being of the areas to be treated, including its health and its capacity to contribute to the revenues of the Province.

The constitution of the Board was :—

- (1) Financial Commissioner Revenue (Chairman),
- (2) The Chief Engineer, Irrigation Branch,
- (3) The Director of Agriculture,
- (4) The Director of Public Health,
- (5) The Financial Secretary,

with

Superintending Engineer, Waterlogging Investigation Circle.
Scientific Research Officer, Irrigation Research Laboratory and Waterlogging Assistant to the Financial Commissioners as technical advisors.

The Board was to be an advisory body and its functions were :—

- (a) to meet quarterly;
- (b) to review the general progress of corrective or remedial measures in hand, and the progress obtained by the Scientific Research Officer in his research in waterlogging and to comment thereon;
- (c) to consider and advise the Government on proposed or projected measures for dealing with waterlogging and *thur* on broad lines, more especially in respect of the general well-being of the areas requiring treatment;
- (d) to make any suggestions or offer such advice as may seem to them desirable.

The same year when the Waterlogging Board was constituted it was decided that the position regarding land deterioration and land reclamation should be reviewed annually in a Waterlogging Conference presided over by His Excellency the Governor. These conferences were held annually.

By 1929 experimental work carried out in the laboratory and field work carried out at Chakanwali Reclamation Farm had shown that, if drainage was provided, waterlogged land could be cultivated with profit for crops like rice, sugarcane, cotton, wheat *kharif* and *rabi* fodders. It was thus demonstrated that waterlogging did not cause any permanent damage to land. To help the *zamindars* in reclaiming waterlogged lands, the Government agreed to construct the main and the branch drains; the construction of the subsidiary and the field drains being the responsibility of the *zamindars* themselves.

As a result of this recommendation, the Government launched a five year programme of drain construction.

The experimental work on land deterioration on account of salt action and land reclamation was intensified both in the laboratory and the field. While this was being intensively pursued the Waterlogging Assistant to the Financial Commissioner had obtained from his surveys conclusive evidence that some areas in canal colonies were under the process of deterioration.

Independently the Settlement Officer, Lyallpur district and Sir Malcolm Darling, Financial Commissioner, brought to the notice of Government the state of affairs in some of the worst-affected tracts.

By 1939, the laboratory and the field experiments yielded fruitful results. Methods for reclaiming salt and alkali lands were established and it was considered that the same could be applied by *zamindars* in their own fields.

In 1940, it was decided that land reclamation should be extended to *zamindars'* fields in the form of reclamation centres; the area of activity of the centre extending on all sides as reclamation progressed.

A Land Reclamation Board, as distinct from Waterlogging Board, was constituted with Sir Colin Garbett, Financial Commissioner, Revenue as its first Chairman and Chief Engineer, Irrigation as the other member. Superintending Engineer, Drainage, was the Secretary. The Land Reclamation Board was an executive body. It initiated schemes of reclamation, gave sanctions and supervised field work.

By 1942, Land Reclamation Centres had started functioning in Lower Chenab, Upper Chenab, Lower Jhelum and Lower Bari Doab Canal Circles.

In 1942, it was considered that, instead of Land Reclamation Centres, general reclamation should be taken up on whole distributaries. The entire field work was entrusted to the Irrigation Branch. The Land Reclamation Board, however, continued to review progress of work, and, lay down Government's policy.

In 1945, a separate Land Reclamation Directorate and a separate post of Director, Land Reclamation, were sanctioned. The Director of Land Reclamation was also made the Secretary of the Land Reclamation Board. Taking into consideration the diversity of land and climate, more experimental stations were established and schemes of integral land reclamation prepared.

Bara land, which did not yield to a reclamation technique in 1918 to 1928 was successfully reclaimed. Reclamation was also extended to the *Rakkar* and *Chit Dain* areas of other canals.

CHAPTER 2

The Formation of Salt (Thur) Lands

In America, attention has been devoted to the addition of salt made to the land by irrigation water and in that country Scofield (2) considers this to be an important source of salt.

In the Punjab, there has been and probably is even now, a strong opinion that the source of the salt responsible for the formation of *thur* was the water-table and that *thur* appeared as the result of the evaporation of water that is drawn from the water-table to the surface.

The investigations carried out in the Punjab do not lend support to the theory that salt contained in canal water can be responsible for the formation of salt lands. Large tracts of waste land exist even now which have never received any irrigation and which have not been cultivated so far. Soil surveys of these tracts show that almost the entire area is covered with salt at the soil surface or salt is present in the profile.

The salt content of waters in the Punjab rivers never exceeds eighteen parts per hundred thousand and this only in the *monsoon* period. During the rest of the year it remains round about seven parts per hundred thousand. Waters containing such insignificant amounts of salt are unlikely to cause any accumulations.

The belief that the source of the salt in *thur* formation was the water-table is probably due to the fact that the first serious notice of the existence of *thur* was in areas where the water-table was high.

In order to investigate the effect of the rising water-table on the formation of *thur*, soil surveys were carried out in a portion of the

Lower Chenab Canal where the water-table was rising at the rate of 1.6 feet a year. Two lines of villages (Figure 1) lying between

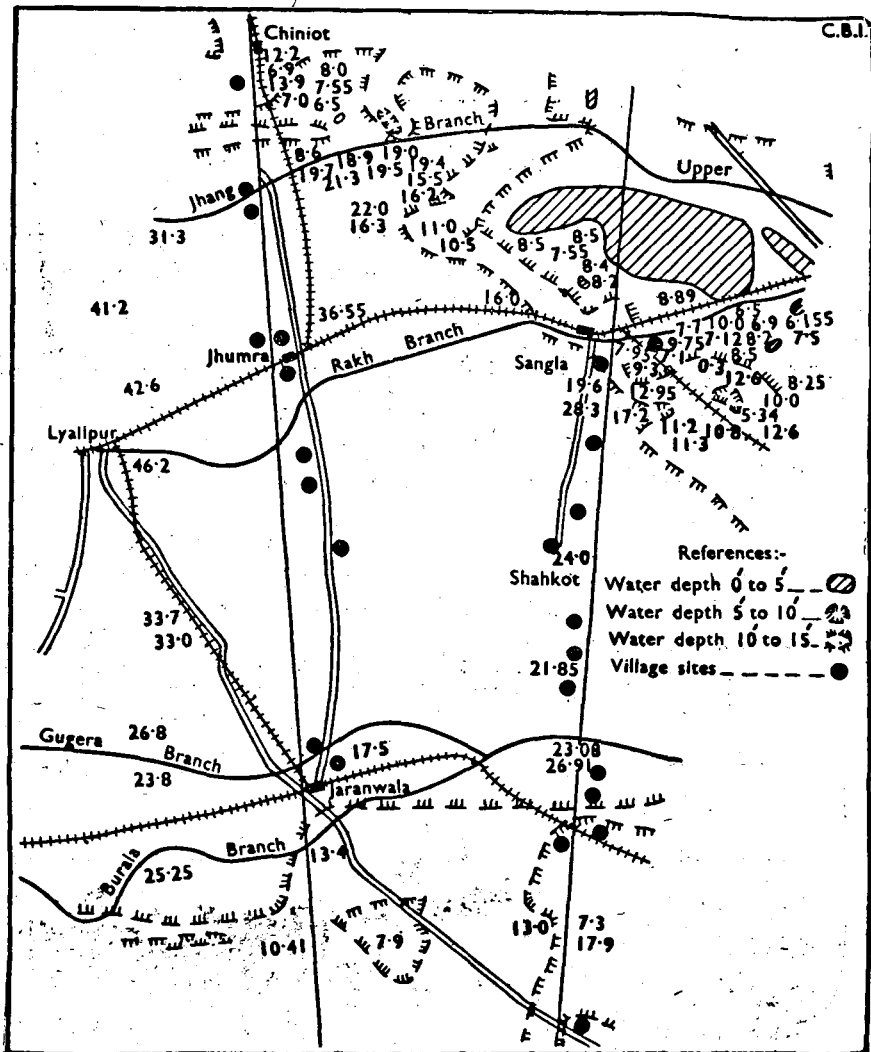


Figure 1.—A part plan of Rechna Doab showing the lines of villages under special Thur Girdawari

Pindi Bhattiana and Qila Dharam Singh and between Chiniot and Sayedwala were selected. In these villages the water-table was

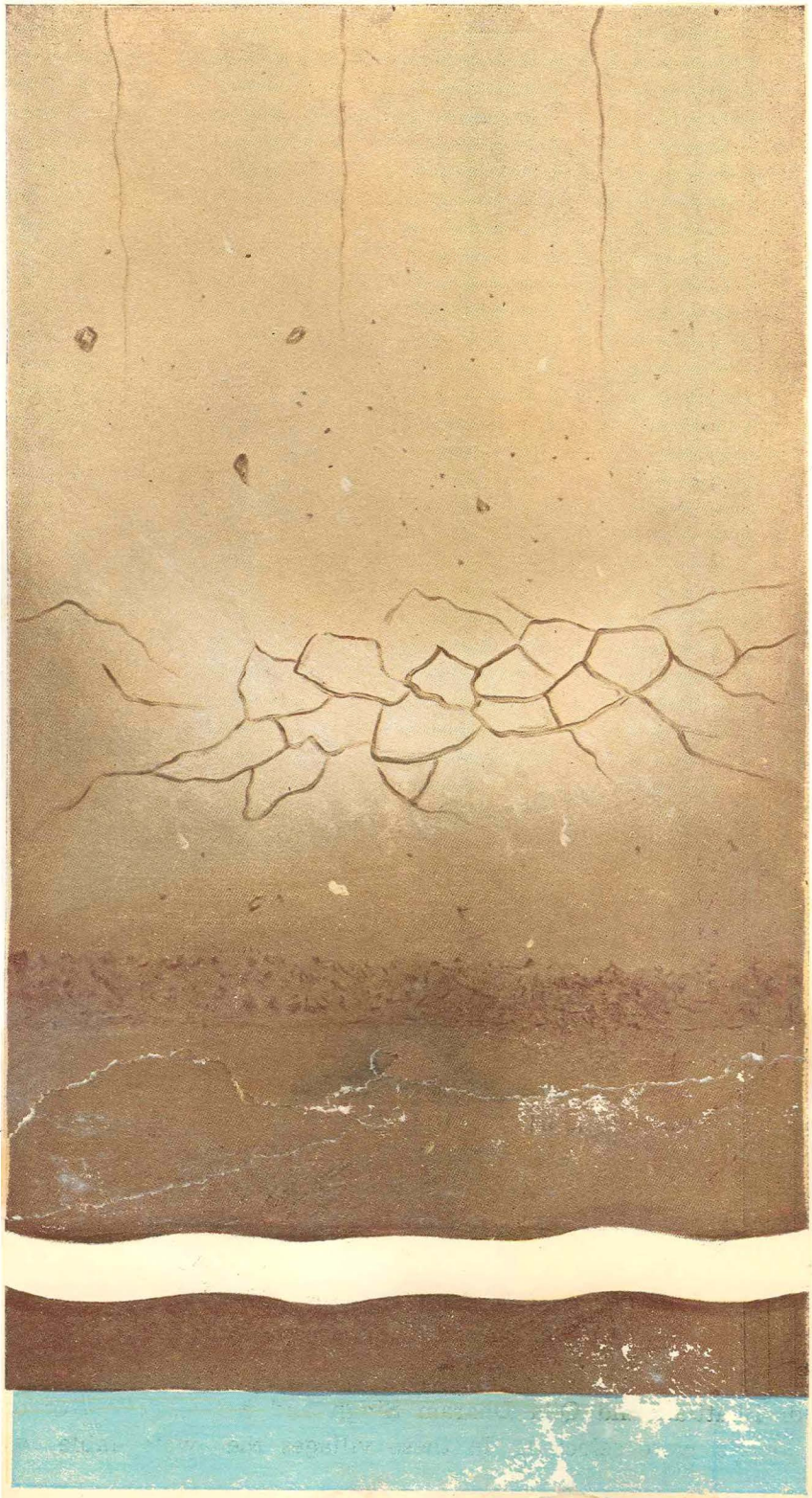


Figure 2.—Showing the multilocular form of a crust of salt in the soil profile.

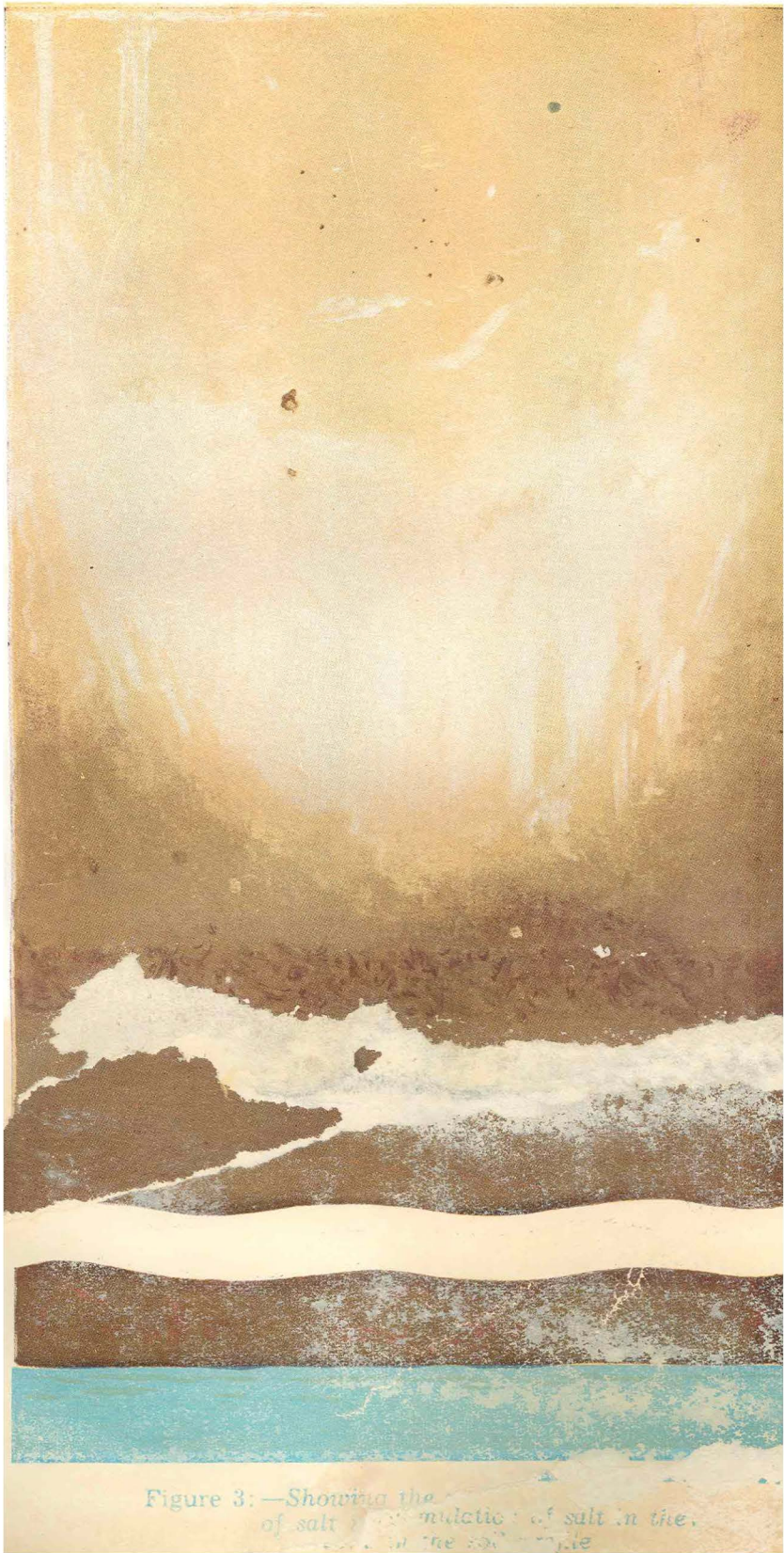


Figure 3:—Showing the
of salt accumulation of salt in the
in the soil profile

known to vary considerably in depth. The results of the survey are given in Table I.

TABLE I

Summary of Results of Special Thur Girdawari, December, 1938

No.	Name of village and district	Depth to water-table in feet	Conditions regarding <i>Thur</i>
1	Talab (Chiniot, Jhang)	9·0	<i>Thur</i> appearing
2	Chak 570 (Jaranwala, Lyallpur)	10·0	Do.
3	Mahranwala, 61 G.B. (Jaranwala, Lyallpur)	12·0	Do.
4	Chak 559 G.B. (Jaranwala, Lyallpur)	12·5	Do.
5	Chak 560 G.B. (Jaranwala, Lyallpur)	14·0	Do.
6	Sarab Kalan and Naurang Di Jhugian (Nankana Sahib, Sheikhpura)	15·0	Do.
7	Chak No. 126-G.B. (Jaranwala, Lyallpur)	16·0	Do.
8	Kotla Sant Singh Wala Chak 43-R.B. (Sheikhpura).	18·0	Do.
9	Chak 5 (Sheikhpura)	20·0	Do.
10	Chak 11-G.B. Masanda and Lalke (Sheikhpura)	20·5	Do.
11	Karyal Chak 17-G.B. (Sheikhpura)	21·0	..
12	Chak 370-G.B. (Sheikhpura)	21·0	No <i>thur</i> at the surface yet. Zone of accumulation of salts below the surface
13	Chak 126-J.B. Kokrian Da Chak (Chiniot, Jhang)	23·5	<i>Thur</i> appearing.
14	Chak 187 Baloana Jhumra (Lyallpur)	23·5	..
15	Chak 41 Marar Khurd (Sheikhpura)	23·5	<i>Thur</i> appearing
16	Chak 110 Babewala (Lyallpur)	24·5	..
16(2)	Kariwala, Chak 49 R.B. (Sheikhpura)	25·5	..
17	Raipur, Chak 658-G.B. (Jaranwala, Lyallpur)	26·0	<i>Thur</i> appearing
18	Chak 102-G.B. (Jaranwala, Lyallpur)	26·5	Do.
19	Chak 84-R.B. (Sheikhpura)	27·0	..
20	Chak 103-G.B. (Jaranwala, Lyallpur)	30·0	<i>Thur</i> appearing
21	Chak Gerri, 189-R.B. (Jaranwala, Lyallpur)	35·0	Do.
22	Khurarianwala Chak 266-R.B. (Jaranwala, Lyallpur)	37·0	Do.
23	Phulaiwala, Chak 103-R.B. (Jaranwala, Lyallpur)	40·0	Do.

From Table I it will be seen that land is going out of cultivation due to the appearance of salt at all depths of the water-table between 9 feet and 40 feet. From this the conclusion seems to be that the water-table might not be an essential factor contributing to the formation of *thur*.

Having discovered that land is going out of cultivation on account of *thur* at water-table depths from 9 to 40 feet, it was necessary to pursue the study further. During the same winter, pits to expose soil profiles were dug in all the villages. The selected points for profile observations were :—

- (a) fields where *thur* had appeared at the surface.
- (b) the adjoining fields in which normal crops of cotton were standing or wheat had been sown.

The soil profiles remained exposed for some time so that the soil characteristics could fully develop and a visual examination became possible. The observations made are shown in Figures 2 and 3 and the results of the analyses in Figure 4. From an examination

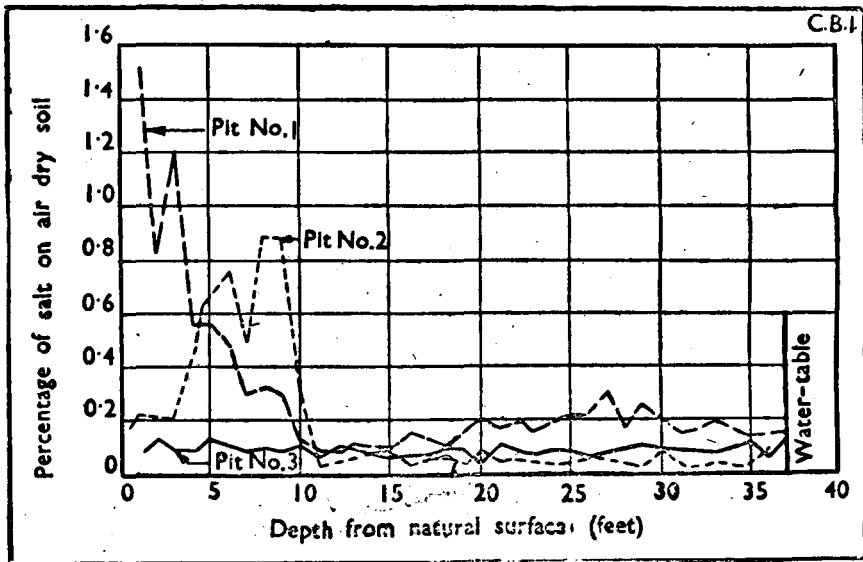


Figure 4.—Showing distribution of salt in soil profiles—Chak No. 266, Rakh Branch, Lower Chenab Canal

of Figure 4 which relates to village 266, Rakh Branch, having a watertable at a depth of 38 feet from the natural surface, it is clear that in the field (pit No. 1) which was formerly under cultivation, but had become *thur*, salt is present throughout the depth of the soil crust, that is, a depth of 10 feet from the natural surface, and that the main zone of accumulation of salt, is 0 to 5.0 feet.

In one of the two fields carrying a normal crop of cotton, the salt content of the first three feet of the soil is low. Between the

third and the tenth foot, the salt content is high and forms a zone of accumulation between these depths. Below the 10th foot, sand occurs and the salt content is low.

In another field (pit No. 3), the salt content throughout the depth of soil crust is low and no zone of accumulation of salts is present.

The three profiles represented in Figure 4 and that illustrated in Figure 2 were taken close together and were situated over similar water-tables at the same depth. Since soil profiles free from salt and containing salt occur under similar conditions regarding depth and quality of water of the water-table it follows that the water-table is not responsible for the presence of the salt in the soil crust.

The examination of soil profiles was extended to the irrigated and un-irrigated areas in other canal colonies of the Punjab. These profiles demonstrated that both in the irrigated and un-irrigated areas salts were usually present as a zone of accumulation, Figure 2, but in un-irrigated areas more even distribution of the salts throughout the soil crust was observed. It seems, therefore, that the irrigation may be responsible for the formation of the zone of salt accumulation. As these salts containing profiles were situated over varying depths of watertable and as the sand underlying them was relatively dry there could be no upward movement of moisture from the water-table to the soil crust. It must, therefore, be considered that the formation of *thur* in such areas has no connection with the rise of water-table.

The salts responsible for the deterioration of the Punjab soils are sodium sulphate, sodium chloride and sodium carbonate; sodium sulphate forms the bulk of the accumulation at least in the newer canal colonies. An examination of the soil profiles of un-irrigated areas has shown that sodium sulphate is distributed throughout the soil crust. It appears, therefore, that it must have been deposited along with the alluvium now forming the soil. A possible explanation of the presence of large quantities of sodium sulphate in the alluvium of the Punjab is indicated by the fact that sodium sulphate is deposited from a solution of mixed salts at a temperature of 3°C. Glacial conditions are known to have occurred in the Punjab, and it appears probable that the sodium sulphate was deposited along with the alluvium during a glacial period. Support is lent to this by a consideration of the extension of the alluvium into Sind where the main salts present are sodium chloride and calcium chloride and sodium sulphate is of minor importance.

Before proceeding further to discuss the factors that are responsible for the movement of the salt layer in the soil profile to the ground surface, observations made by various workers under laboratory and semi-field conditions have shown that the loss of water due to evaporation at the soil surface only affects the water in a limited depth of soil. Keen (*) states that water which has once reached the depth of six feet in a soil does not return to the surface by evaporation. The work of Veihmeyer also supports the conclusion that the return of water to the surface of a soil occurs

only from a shallow depth. More recently Ramdas and Malik ⁽³⁾ using Punjab soils have shown that the amount of water lost by evaporation decreases as the water-table recedes below the surface. The results obtained by them have been plotted in the form of a curve Figure 5. From Figure 5 it will be seen that when the water-table reaches a depth of four feet, the loss of water by evaporation from the surface ceases.

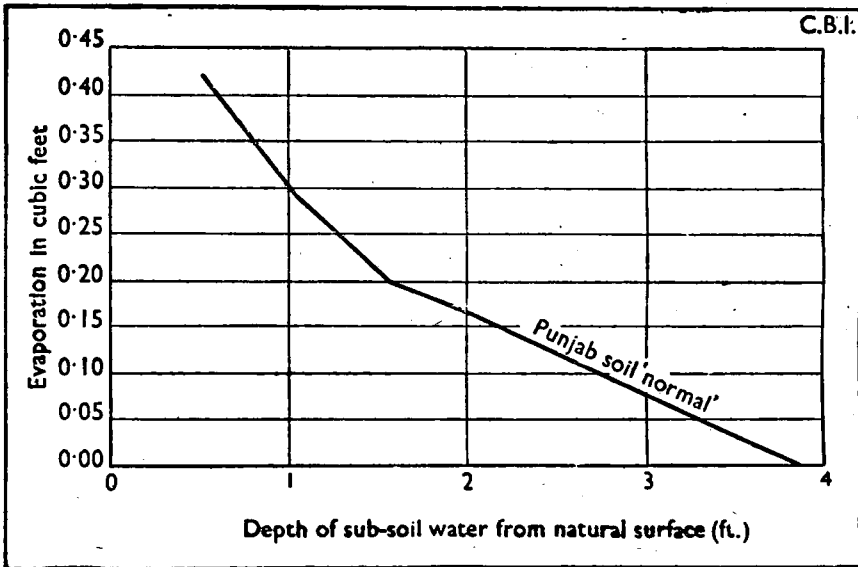


Figure 5.—Showing the evaporation of water at different water-table depths

Observations were made in Baramati area under the direction of the Poona Irrigation and Research Division ⁽⁴⁾ in which the concentration of salts at the surface was correlated with the depth of the sub-soil water. The correlation coefficient between the concentration of salts at the surface and that in the sub-soil water is significant only upto a depth of four feet. There is no relation between the surface salts and concentration in the sub-soil water when the latter is below four feet.

The study of the evidence leads to the conclusion that the water-table is unlikely to contribute salts to the soil surface when it is situated at a depth of 10 feet.

When the water-table in the Punjab is within ten feet of the surface it seems probable that it may supply water to the soil crust to replace that lost by evaporation. With soil crust less than six feet in thickness a water-table touching the bottom of this crust results in signs of waterlogging and water lost at the surface by evaporation is undoubtedly partially replaced by water from the water-table. Under these conditions of water-table it seems probable that the water-table may contribute to the formation of *thur* since there will be a tendency for the deposition of salts at the soil

surface following the evaporation of the water. In areas of high water-table, therefore, in un-cultivated fields, the source of a portion of the salt causing *thur* may be the water-table. In such cases the greatest concentration of salt occurs at the soil surface since evaporation taking place at the surface of the soil results in the deposition of the salts, Table II.

TABLE II

Showing salt content and pH values of soil from Village Uchaina, District Karnal

Description of sample	Per cent. on air dry fine earth.	
	Total soluble matter.	pH value
1st foot	2.11	8.2
2nd	0.19	8.8
3rd	0.15	9.6
4th	0.17	9.7
5th	0.13	9.7
6th	0.19	9.7
7th	0.22	9.9

Profiles in high water-table areas that are continually cultivated under irrigation generally show a zone of salt accumulation below the surface; indicating that, even in high water-table areas, the water-table may not be able to contribute towards the upward movement of the zone of salt accumulation, if cultivation and irrigation are not neglected.

Calculations have been made to estimate the amount of salt that would be added to one acre of soil-crust, ten feet in thickness, by the annual evaporation of six inches of water derived from the water-table. For a water-table containing 90 parts of total soluble matter per 100,000 parts of water the amount of salt added to the soil crust is found to be 0.5 ton per annum. Investigations of numerous soil profiles of land, that has gone out of cultivation due to *thur*, show that, on an average, more than 100 tons of salts per acre are present in a 10 feet depth of soil crust. It will be seen, therefore, that a period of something like 200 years would be necessary, if the water-table were the source of salt, to account for the presence of the quantity of salt present in *thur* land when the land has gone out of cultivation. This is an additional reason for stating that there is little connection between the rise of water-table and the appearance of *thur*.

Having eliminated the water-table as a cause of the appearance of *thur* on the soil surface in areas of deep water-table, other factors that might be responsible were brought under examination. These factors were the intensity of irrigation and the system of

cropping, which includes the use made of the irrigation water. An examination was made of the area irrigated during *kharif* and the average depth of water used for irrigating crops on all the branches of the Lower Chenab Canal where *thur* is on the increase. Taking particular instance of the Rakh Branch, the data obtained are shown in the form of curves in Figure 6. At the bottom of Figure 6 is

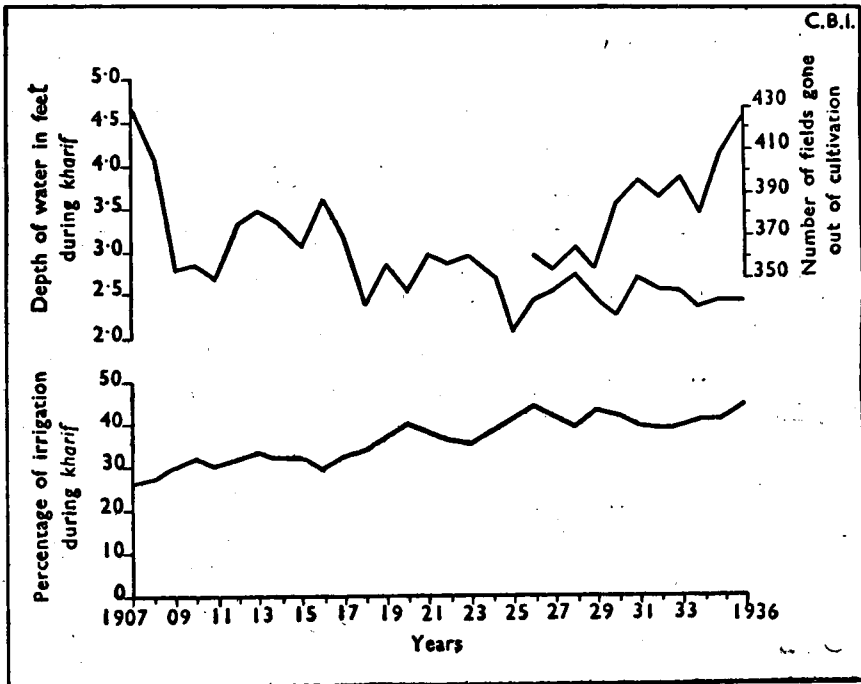


Figure 6.—Curves showing the intensity of irrigation during Kharif, the delta used during Kharif and the number of fields gone out of cultivation (Rakh Branch, Lyallpur Division)

shown the percentage area irrigated during *kharif* on the same water supply for the period 1907 to 1936. In the second curve is shown the average depth of water in feet per acre used for irrigating the *kharif* crops. In the top curve is shown the area under *banjar* (area gone out of cultivation) in village 266, Rakh Branch, the soil profiles of which have been described already. The record for the area that has gone out of cultivation is available for 12 years only.

An examination of the three curves in Figure 6 shows that the intensity of irrigation during *kharif* has increased from 26 per cent. in 1907 to 44 per cent. in 1936 which means approximately 70 per cent. more irrigation is being done now than previously on the same water supply. This increase in irrigation is reflected in the curve

for the depth of water used. The depth of water used for irrigating *kharif* crops has decreased from 4.6 feet in 1907 to 2.5 feet per acre in 1936. These figures show that a much smaller quantity of water is being used now for maturing crops than formerly. Soil surveys have shown that, during summer, salts are not so prominent at the soil surface as in winter. It may be that during summer the salts are either stationary or else there is a downward movement; an upward movement being confined to the *rabi* season. With the high delta of former years the tendency would be for the movement of salts to be downwards. With the decrease in the delta the tendency for the movement of salts downwards will have been considerably reduced. The subsequent movement of salts upwards in the *rabi* is likely to be, therefore, a much easier process than formerly. Since *thur* is appearing it must be concluded that under the present delta the balance of the salt movement is in an upward direction. This probably means that the soil is less moist at the present time than it was some years ago when the delta was higher. If, as is the case in Pit No. 2, Figure 4, salts are present in excessive quantities in the soil crust, the upward movement results in the zone of accumulation of salts approaching the surface. As soon as this upper limit of the zone of accumulation approaches such a depth from the surface that the concentration of salts can occur due to evaporation then the land becomes *thur*. The top-most curve in Figure 6 shows that with the progressive increase in *kharif* irrigation and the decrease in the amount of water used per acre the area that has gone out of cultivation has consistently increased.

The monsoon is probably also a factor determining the position of the zone of accumulation of salts in the soil profile. If the monsoon is good then the zone of accumulation will be depressed to a much greater depth than, if the monsoon is poor.

To summarise the discussion in the preceding paragraphs it may be stated that, before the commencement of irrigation, salt is distributed throughout the depth of the soil crust and in the absence of irrigation no movement takes place. With the introduction of irrigation the salts accumulate in the form of a solution at some depth below the surface forming a zone of accumulation. The subsequent position of this zone of accumulation in the soil crust depends on the intensity of irrigation and the agriculture, which means the use made of irrigation water. If the agriculture is of such a type that the amount of water used for irrigation is sufficient to counter-balance that lost by transpiration and evaporation, then the zone of accumulation will tend to remain stationary or to move to a greater depth. If, however, the quantity of irrigation water used is insufficient to

balance the losses due to transpiration and evaporation and the zone of accumulation is within 10 feet of the surface then the tendency will be for the zone of accumulation to move upwards.

Experiments were started to examine the effect of the introduction of irrigation on the salt content of the soil profile. An area of 15 acres of government waste land which had never been irrigated was acquired near Jaranwala. Plots were laid to study the effect of different intensities of irrigation and different systems of cropping on the distribution of salt in the soil profile. The lay-out of the plots is shown in Figure 7.

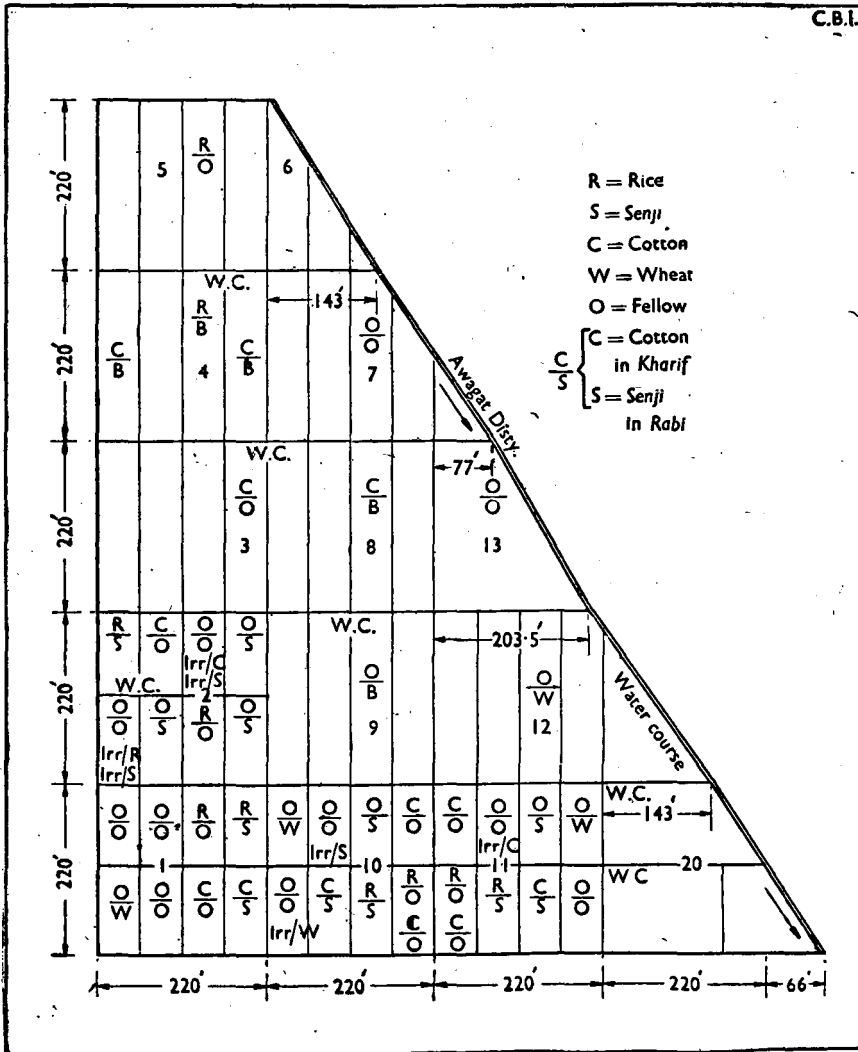


Figure 7

is shown in Figure 7. It enabled the following to be examined :—

- (a) the effect of perennial irrigation when such crops as cotton, rice, wheat and *senji* (*melilotus parviflora*) are included in the rotation ;
- (b) the effect of *kharif* irrigation only, when crops such as rice and cotton are grown ;
- (c) the effect of *rabi* irrigation only when crops such as wheat and *senji* (*melilotus parviflora*) are sown.

The water-table in the Jaranwala area is situated at a depth of 16 feet from the natural surface and the soil crust has a thickness of 10-11 feet. Figure 8 shows the distribution of salts in the soil

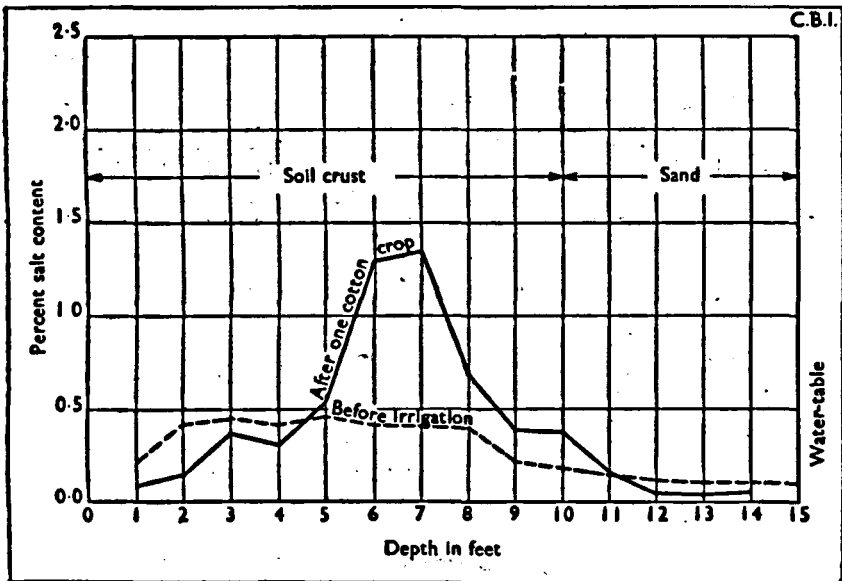


Figure 8.—Showing the distribution of salts before and after a cotton crop at Jaranwala-Maharanwala Experiment Station

profile before and after one cotton crop matured on canal irrigation. It will be seen that, before the commencement of irrigation, salts were distributed throughout the depth of the soil crust. With the irrigation applied to cotton, salts have been removed from the surface and have formed a zone of accumulation at a depth of 6-7 feet. Figure 9 shows the distribution of salts in the profile before and after the growth of one rice crop. The depth of water used for

rice is approximately three times that used for cotton. From Figure 9 it will be seen that with the heavy irrigation given to rice

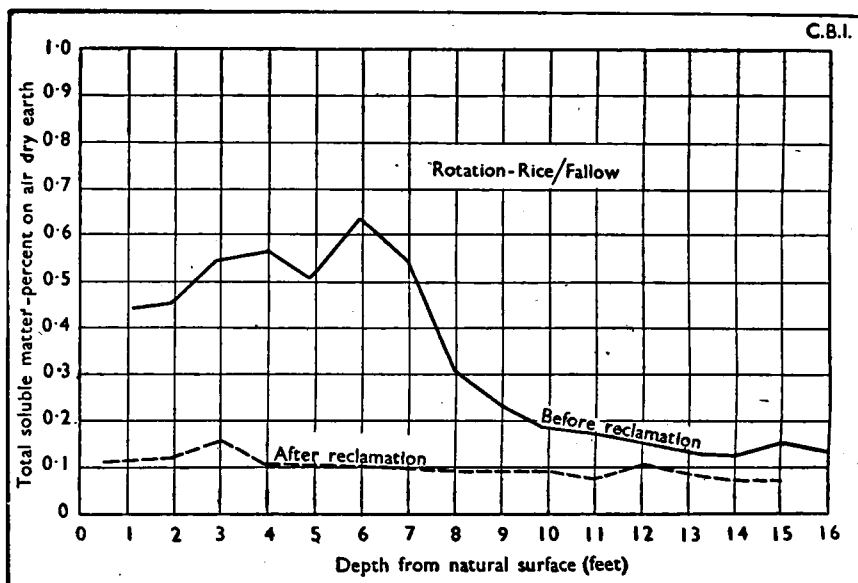


Figure 9.—Plots—Maharanwala Experimental Station

the salts have been almost completely removed from the soil crust and there is no zone of accumulation.

The differences in these profiles after irrigation have important applications. They indicate that unless salt is present in the soil crust, there is little danger of deterioration of the soil due to salt movement with a rising water-table. In the case of the profile under cotton, since the salts have not been removed from the soil crust, it would appear that there will be a tendency for the salts to again rise to the surface when conditions become suitable for this movement. In the case of the profile under rice, since the salts have been removed completely from the soil crust, deterioration in future is unlikely to take place.

The work at the Jaranwala Farm has indicated lines on which development of new project areas should be taken up and also the methods to be followed in the reclamation of salt affected lands. In an undeveloped area, if the soil has a salt bearing layer in the soil crust within 10 feet from the surface then it would be advisable to introduce a rice crop at the beginning of irrigation to remove the possibility of soil deterioration in the future. In land reclamation it seems necessary to wash the salts to the sand layer to avoid the possibility of the return of the salts to the surface.

In the North-West portion of the Province instances have come to notice where, under well irrigation, salts have not appeared at the soil surface. The question naturally arises that in the case of well irrigation, if there is a salt bearing layer in the soil crust below the natural surface, why is it that deterioration due to *thur* formation does not take place? In order to examine soil conditions under well irrigation pits were dug in recently irrigated fields under *bajra* (*Pennisetum typhoideum*) and cotton. In the case of *bajra*, it was found that the maximum depth of penetration of the irrigation water was 6.5 inches, Figure 10. Between this moist surface soil and the

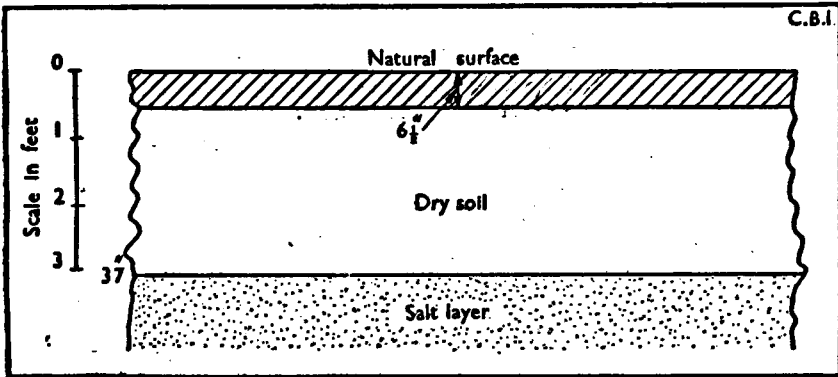


Figure 10.—Penetration of irrigation in a bajra field in the Thal area

salt bearing layer 2.5 feet of completely dry soil existed. In the case of cotton, Figure 11, the depth of the penetration of irrigation was

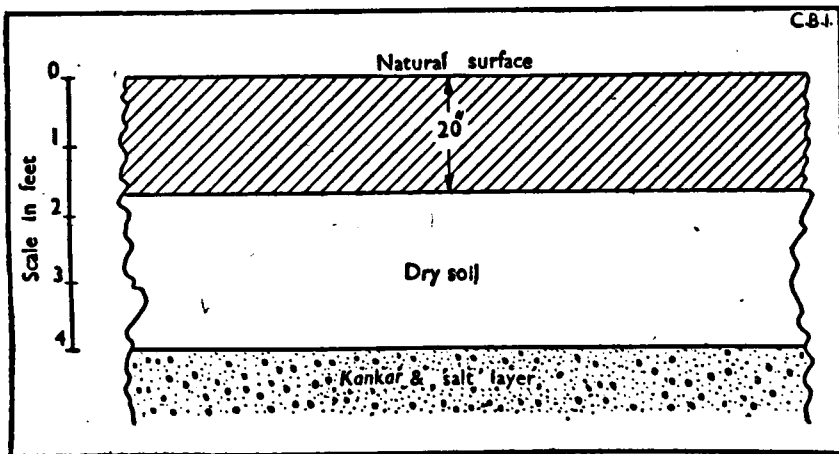


Figure 11.—Penetration of irrigation in a cotton field in the Thal area

about 20 inches since cotton receives twice the amount of water given to *bajra*. The moist soil under cotton was again separated from the salt bearing stratum by completely dry earth. The examination of these profiles has shown that under well irrigation no contact of the salt layer with the surface soil is established and, therefore, no rise of salts under well irrigation can take place.

If however, the salt bearing layer is situated within the depths to which well irrigation penetrates upward movement of salt is bound to occur and cause the land to become *thur*.

Under canal irrigation much larger quantities of water are used which establish the connection between the surface soil and the salt bearing layer in the soil crust and help in the movements up and down of the moisture and salts in the soil crust; hence the necessity for taking more precautions to avoid deterioration of land under canal irrigation than under well irrigation.

CHAPTER 3

Soil Alkali

It is now universally recognised that the presence of excessive quantities of salts is a characteristic of soils of semi-arid regions. The Punjab alluvium, therefore, in common with lands of this type, suffers from the trouble of salts. The salts usually present are sodium sulphate, sodium chloride and sodium carbonate. The presence of large quantities of such salts changes the entire physical and chemical condition of the soil. Chemical reactions take place between the salt and the clay in the soil. The clay in a normal soil is mainly present in the form of calcium clay (Ca-clay). A soil containing calcium clay is permeable to water and air, the conditions in it are aerobic and the methods to be adopted for the cultivation of such a soil are known to farmers. When a relatively concentrated solution of sodium sulphate, sodium chloride or sodium carbonate is brought in contact with a calcium clay soil, base exchange takes place, the sodium replacing the calcium in the clay, resulting in the formation of a sodium clay. The reaction is shown in the following equation :—



It will be seen that there are two stages in soil deterioration, the first stage is the accumulation of salts which is relatively less harmful; the second stage is the base exchange reaction given by the above equation, which renders the soil conditions much more difficult to ameliorate. The development of alkalinity is a gradual process and it follows that, after the first stage of *thur* appearance has been reached, the longer the land is left before reclamation, the greater will be the approach to the second stage of alkalinity. Even, if the soluble salts are completely removed by leaching, the soil will usually contain exchangeable sodium much in excess of that found in normal soil; it would, therefore, be correctly termed 'Alkali soil'. Such a soil is more difficult to reclaim than that which is highly alkaline but which contains at the same time, an excess of soluble salts.

It has already been stated that in the Punjab the main salts present are sodium sulphate, sodium chloride and sodium carbonate. Owing to the alternate wet and dry periods, and the consequent movements of moisture and salts in the soil profile, the reaction between sodium salts and calcium clay has taken place repeatedly. The result is that the Punjab plain soils tend to be sodium clays and are alkaline.

On the physical side, by the continued action of the salts, the structure or the tilth of the soil is affected, colloidal substances are altered and changes in moisture relationships occur. In a very alkaline soil the clay becomes deflocculated and the soil is impermeable to water. This soil presents difficulties in leaching and is unsuitable for the growth of normal crops. Some of these properties

are well known to Punjab farmers. They know that the cultivation of alkali lands is exceedingly difficult on account of the fact that they are too hard when they are dry and too sticky when they are wet. Besides, the surface layer does not survive rain or light irrigation but becomes a paste; and when it dries, it either becomes a hard surface pan or cracks into hexagonal shaped clods (Figure 12).

Extensive observations were made at the Chakanwali Reclamation Farm (Punjab) to study the root systems of rice plants, grown in fields having varying degree of alkalisation. After the rice was harvested, roots of representative plants were exposed and washed. These were later photographed. Typical photographs are reproduced in Figure 13. The yield of rice for the field is also given in the photograph. Although it was possible to correlate the yield of rice with the alkalinity of the soil as represented by pH values, it was not possible to find an explanation of the toxic effect that the high pH values produce. Jenney and Overstreet (⁵) hold that Ca ions, derived from the seed by the barley seedlings, are exchanged for Na ions of the soil, the result of which is that seedlings lose some at least of this Ca. Thus the seedlings are able neither to obtain Ca from the soil, nor to retain that inherited from the seed. This probably gives a satisfactory explanation for the coarse and stubby appearance of roots and also the inadequate lengths they attain in a highly alkaline soil.

The conversion of a saline soil into an alkali soil is sometimes accompanied by the formation of a hard pan which is situated at depths varying from a foot to ten feet in the profile. The exact processes of the development of these hard pans in the Punjab plains are still the subject of study.

In the newer canal colonies they are of rare occurrence and are only found in the head reaches of canal systems where plenty of irrigation water is available for sowing rice. In these tracts the water-table is relatively high and the rainfall greater than in the lower reaches.

In older canal systems like the Upper Bari Doab Canal and the Western Yamuna Canal hard-pans in sub-soil layers are of more frequent occurrence.

In Chakanwali for example, a mole steam plough got badly bent when it passed through the middle of a field which contained an impervious sub-stratum. Attempts made to establish crops on this land were unsuccessful.

In the course of the soil survey of culturable waste of Karnal district it was noticed that the pan was so hard that even a pick axe was unable to break it. It is suspected that the pans in Karnal district are more calcareous than in canal colonies like the Lower Chenab, Lower Jhelum or the Lower Bari Doab.



Figure 12

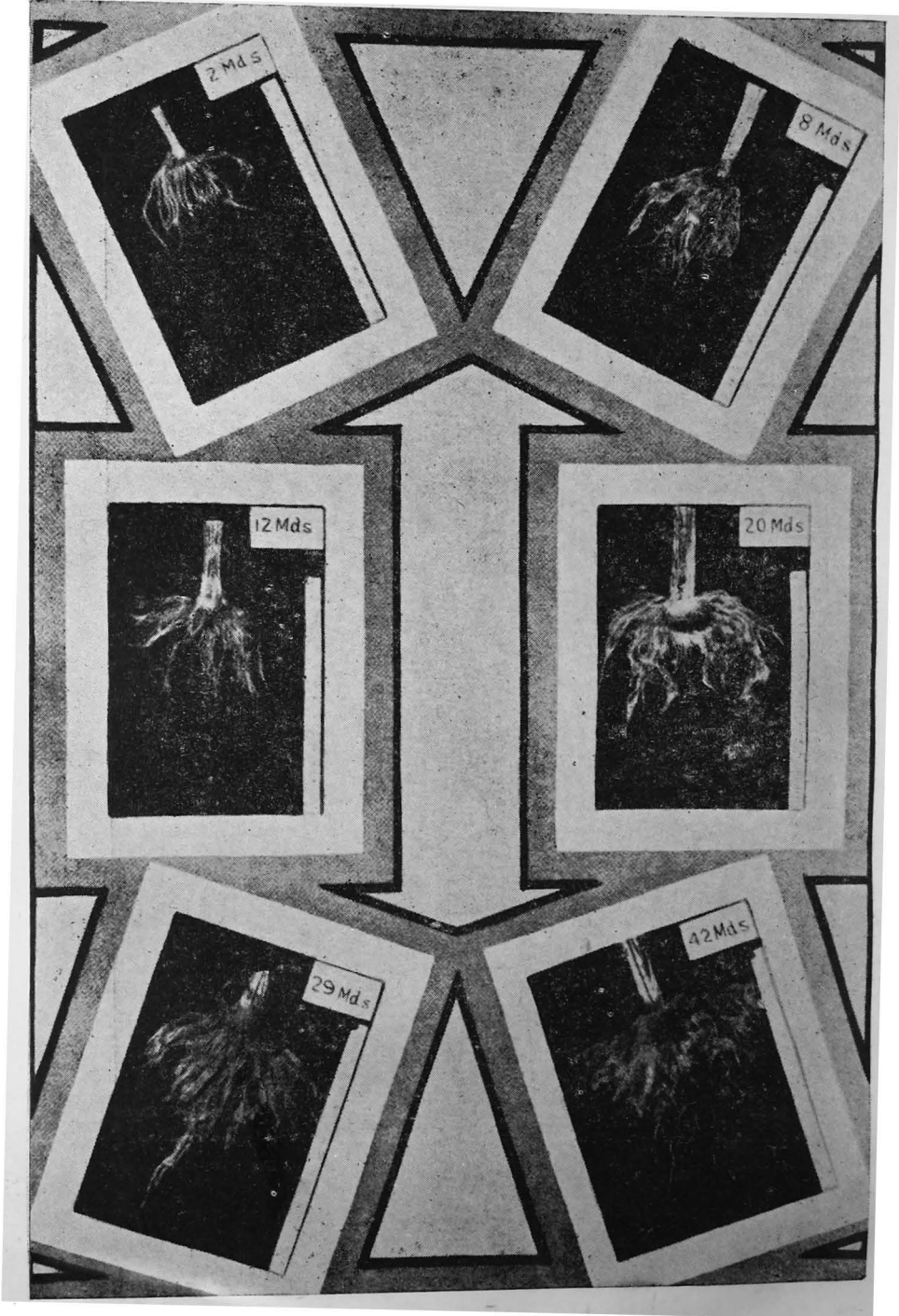


Figure 13

CHAPTER 4

Soil Standards

It is now established that, in the semi-arid portion of the Punjab plains, besides water, two other limiting factors in crop production are the salt content of the soil and its alkalinity. It is, therefore, not only necessary to make arrangements for artificial irrigation over and above what local rain can provide but also to know the limits of both the salt content and alkalinity in the soil at which yields of crops begin to decline, the limits at which crop growth becomes impossible and also the limits when amelioration of land cannot economically be carried out. To this end three types of investigations were carried out.

A large number of soil samples from wheat growing tracts were collected and examined in the laboratory. McKenzie Taylor, Puri and Asghar (*) have shown that, provided the salt content is low, the yield of wheat is not greatly affected until the pH value rises above 8.5.

Field experiments carried out at Chakanwali Reclamation Farm indicated that rice can stand a relatively higher quantity of salt in the soil and a higher degree of alkalisation than most other crops. It was also noticed that when the yield of rice had mounted to 20 *maunds* per acre a normal rotation of crops on normal water supply could be introduced.

A soil survey of the rice areas of the Upper Chenab Canal was carried out in 1933, with the co-operation of the Executive Engineers in charge of divisions. The Executive Engineers placed the services of the revenue staff at the disposal of the survey parties. The revenue staff had an intimate knowledge of the yields of rice. A very large number of soil samples were taken from fields giving varying yields of rice. Estimates for yields were verified a second time in 1934. All soil samples were examined for salt content and pH values. These results and the yields of rice, in *maunds* per acre, have been shown in the form of a solid curve Figure 14. From an examination of the solid model the following standards were laid down. (Subsequent surveys and the investigations carried out at different Experimental Reclamation Stations in the Province have confirmed these standards) .

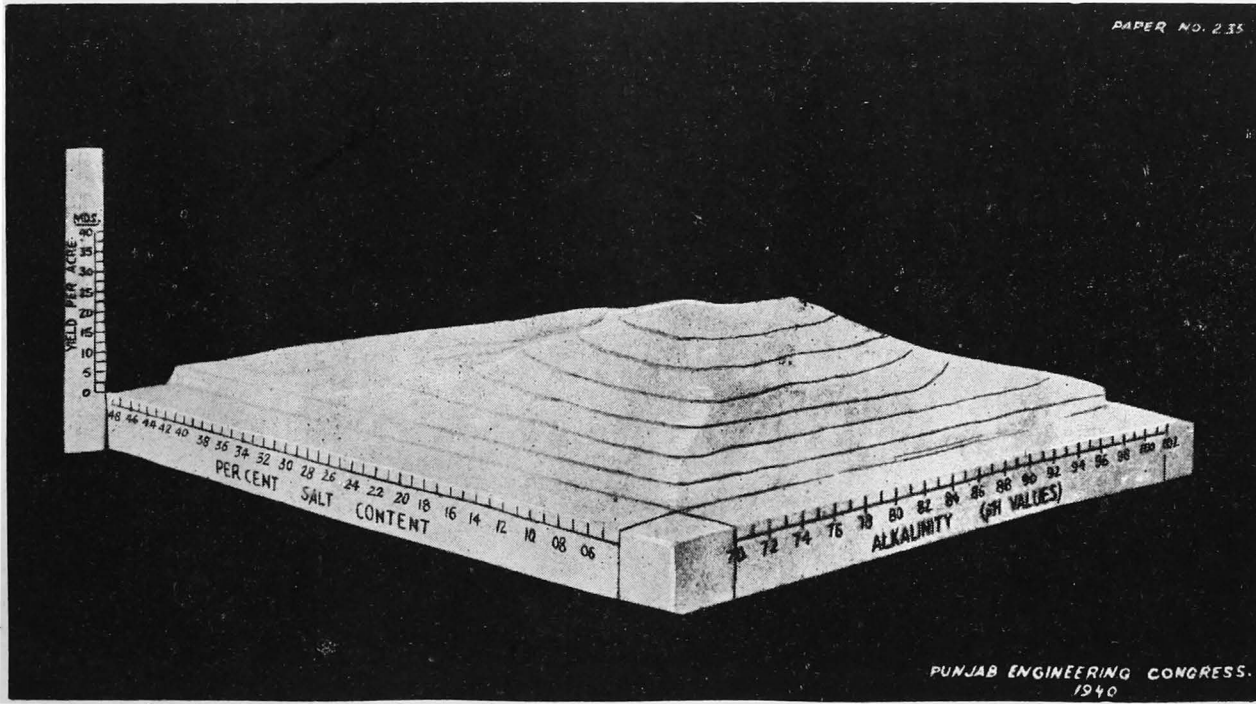


Figure 14

Type (i)—Good land capable of carrying normal crops on normal water supply and likely to give normal yields. Such soils are characterised by a total soluble salt content of 0.2 per cent. or below and a pH value not higher than 8.5.

Type (ii)—Soils which have some limiting factor, such as salts or alkalinity or both, which will tend to reduce the yields of crops below the normal. The main characteristic of this type of soil is a variable salt content, which may be higher or lower than 0.2 per cent. The pH value, however, lies between 8.5 and 9.0. Such soils should always carry a crop of rice followed by a leguminous crop like berseem or *senji* (*melilotus parviflora*). After the first year, rice can be eliminated from the rotation. Experience has shown that rice is successful even in the first year. In soil surveys of waste lands for determining advisability of new irrigation projects, therefore, the limit of pH value is laid at 9.0, i.e., if a piece of land is suitable otherwise but has a pH value ranging between 8.5 and 9.0 it is considered to be land capable of cultivation directly irrigation water becomes available.

Type (iii)—Soils in which the influence of some limiting factor is very marked so that they are only suited for a limited type of cropping in the initial stages of irrigation.

The salt content of this type is almost always above 0.2 per cent. and the pH value lies between 9.0 and 9.5. Soils of this type are unfit for general cropping and need reclamation. Two crops of rice in two summer seasons followed by a leguminous crop each winter are generally sufficient to reduce the high salt content to the normal and also reduce the pH values to enable introduction of a normal rotation of crops.

Type (iv)—Salt soils that are easy and economical to reclaim. In soils of this type the salt content is above 0.2 per cent. while the pH value is below 8.5. Soils of this type are locally known as 'Thur' soils. Usually one rice crop is sufficient for the reclamation of this type of land. After the first rice crop it is possible to sow gram, berseem and *senji* during winter and sugarcane or cotton during the following summer. If, however, the salt content is extremely high throughout the depth of the soil profile, more than one rice crop is needed to remove the whole of the salt from the root zone of the crops.

Type (v)—Saline and alkaline soils that are difficult and at the same time expensive to reclaim. These soils may or may not have a high salt content but their pH value is always higher than 9.5. These soils are locally known as 'Rakkar' soils. The reclamation of this type takes a much longer period than is the case with types (iii) and (iv). With the present prices of agricultural produce the reclamation of the 'Rakkar' type is beneficial. When prices of agricultural produce become low, then reclamation of this type is not a commercial proposition. It is advisable that this type of land should be reclaimed when prices are high so that, during depression, this land is available for increased production.

Factors that cause complications in this classification are :—

The Physical Texture of The Soil.—Sandy soils even though they are alkaline, are more easy to reclaim than those in which the clay content is relatively high. On the contrary, on account of the buffer action, some clay soils are harmless so far as their capacity to produce crops is concerned, even though their *pH* values may be high, provided the excessive amount of salt has been removed. With continued cropping and manuring the tendency for the *pH* values, however, is to decrease. With good management and careful cropping such soils ultimately become first class and continue to give increased yields.

The Type of Clay.—The second factor that causes some complication in the standards laid down is the type of clay in the soil. Some idea of the variation that can be caused on this account is obtained from work carried out in America and elsewhere. Kelley (?) for example has demonstrated that soils which contain Montmorillonitic clay are generally relatively high in exchange capacity; those in which hydrous mica is the chief type of clay, are intermediate, while Kaolinitic soils are usually low in exchange capacity.

Humus Content.—The humus content of a soil is another factor which influences the exchange capacity of clay in a soil.

Composition of the Salt.—The composition of the salt causing salinity is also a factor to be taken into consideration. Sodium carbonate, for example, is more harmful even in small amounts than relatively higher amounts of sodium chloride or sodium sulphate.

CHAPTER 5

Soil Surveys

Four types of soil surveys have been in progress in the Punjab. The first type is based on the indigenous natural vegetation that the land carries in *jungle* condition before cultivation or irrigation. Hoon and Mehta (*) and Hoon and Dhawan (*), as a result of a detailed study of the waste lands of the Province in the field and examination of soil samples in the laboratory, established the following relationships :—

- (a) '*Jand*' (*Prosopis Specigera*) indicates that constitutionally the land is fit for growing all irrigated crops. It usually carries a thick undergrowth of grass. The lower horizons of the profile are compact; the predominant constituents being silt and fine silt. Both the salt content and the pH values are low. In areas where land deterioration has been in progress the soil profile exhibits a zone of salt accumulation and high pH values. Wheat, sugarcane, cotton and rice give good yields on this type of land.
- (b) '*Wan*' (*Salvadora Oleoides*). The soils representative of this type of vegetation are characterised by a pH value of about 8.5. Calcium is the exchangeable base in almost all the horizons. When the salt content is high, such soils are developed best with leaching and rice in the first year. American cotton is particularly successful in this type of land.
- (c) '*Okan*' (*Tamarix articulata*) has a great tolerance for salt. Examination of a large number of soil profiles has shown that, even if the salt content of the profile is high throughout its depth, '*Okan*' makes normal growth and attains normal height. As land of this type is not suitable for any other purpose without irrigation this tree finds this the most suitable opportunity to establish itself and form thick colonies.

In the top layers of the soil the presence of exchangeable potassium is also a characteristic of these soils. This

may be due to the high potassium content of 'Okan' leaves.

- (d) 'Karai' (*Capparis aphylla*). The pH value of the top soil is generally on the high side. The salt content of the lower horizons is also high. Experience shows that 'Karai' soils when brought under cultivation do not give high yields.
- (e) 'Harmal' (*Peganum harmala*). This is not a very widely spread plant in the un-irrigated tracts, but, in the *zemindars'* opinion wherever it exists it indicates fair land. The presence of 'Harmal' is a positive indication of accumulation of potassium nitrate in the soil.
- (f) 'Ak' (*Calotropis procera*). 'Ak' is abundant in the arid plains of the Punjab and is considered to reach its best development on soil having a sandy substratum within about four feet from the natural surface.
- (g) 'Sarkanda' (*Sachharum munja*). *Sarkanda* grows in low sandy areas along canals and rivers subject to inundation. In these tracts it forms the chief difficulty of the agriculturists as it rapidly encroaches on the cultivation. The presence of 'Sarkanda' indicates a high water-table either continuous or occasional. In addition to a high water-table the plant may also indicate soil deterioration.
- (h) 'Lani' (*Sueda fruticosa*). 'Lani' usually grows in soils having a high content of salts and high alkalinity. Its presence indicates that the land is in a late stage of deterioration consequent on salt action.
- (i) 'Dhak' (*Butea frondosa*). *Dhak*, like 'Lani', is indicative of an advanced stage of deterioration. The salt content and the pH values are high throughout. It thrives best on heavy clay soils.
- (j) 'Bui' (*Kochia indica*). This plant grows best on excessively sandy soils. The plant is not much affected by drought.
- (k) Land devoid of vegetation belongs to the 'Rakkar' type. It is usually hard, intractable and more or less impervious to water. These lands are representative of the final stage of deterioration.

Typical analyses are reproduced in Figure 15.

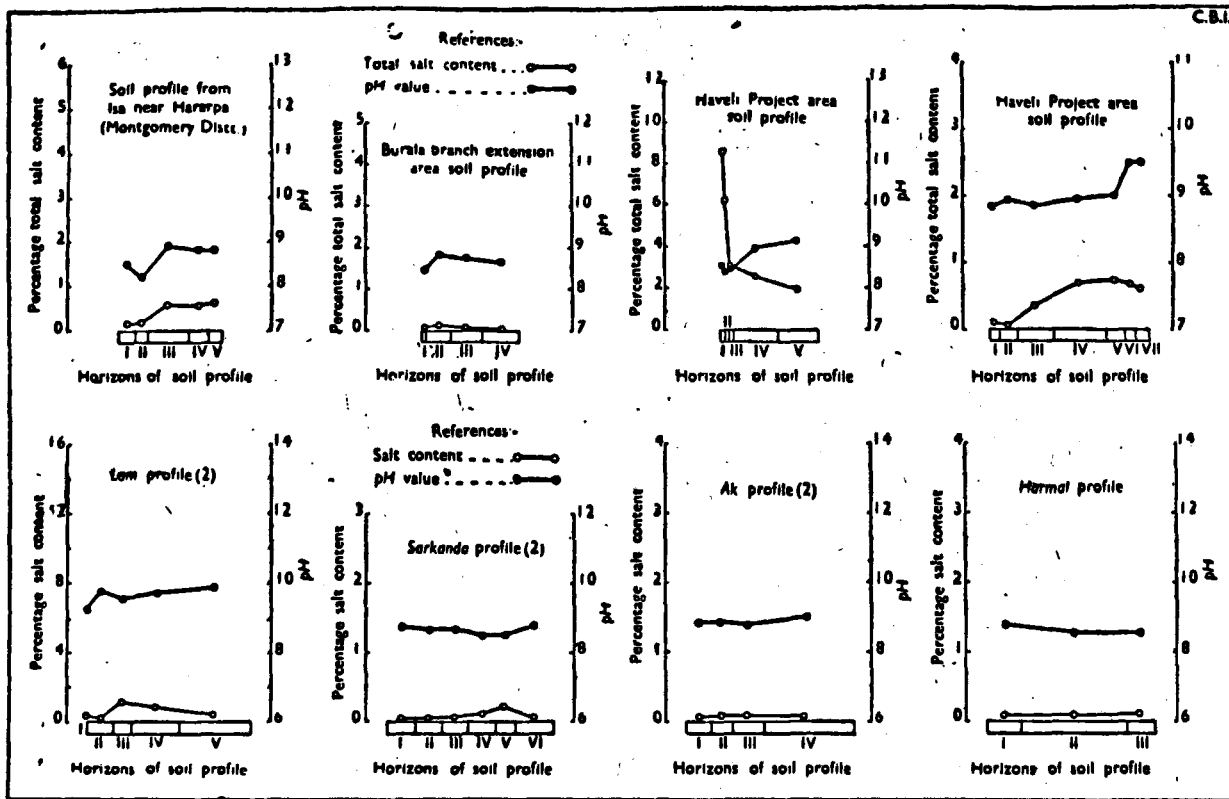


Figure 15.—Showing percentage salt contents in various types of Govt. waste lands such as Jand, Wan, Okan, Karai, Lani, Sarkanda, Ak, and Harmal respectively.

Scientific soil surveys based on examination of representative soil samples in the laboratory were not carried out for the earlier irrigation projects. Special revenue staff attached to the Civil Department were deputed to make reconnaissances on the basis of native vegetation. Soil conditions for the pre-irrigation period of such areas can, therefore, be surmised from these records. The practical farmer, even now, uses these standards for assessing values for purchasing, selling and leasing land.

There is no gain saying the fact that natural vegetation is often an excellent guide to soil fertility. Particularly is this so where one species is used to compare different areas. But the method must be used with caution. Many a time one is deceived by supposing that a relatively dense forest growth of a certain species indicates a very fertile soil. Instances are available where such forests exist on poor or deteriorated soils. This happens by virtue of a closed cycle in which fertility is maintained by the decay of their own litter; thus when the forests are cleared the fertility is rapidly dissipated.

The second type of soil survey is carried out by the village revenue official (*patwari*). The standard adopted by the *patwari* is the yield of crop in each individual field. These surveys are primarily meant either for assessment of land revenue and charges for irrigation or recording the extent of damage to land on account of waterlogging, salts and alkalinity.

For assessing charges for water the '*patwari*' is constantly touring in the area under his charge and maintains a record of all areas irrigated, crops sown, areas matured and areas failed. The charges for irrigation are assessed according to the crops sown, the rates for which have been previously fixed by government. All fields that have been irrigated are assessed. If the farmer considers that his crop has failed, he can apply for the remission of the water-rate to the Divisional Canal Officer. A crop is considered a failure when the field is less than 25 per cent. of the normal for the district.

When, however, damage to land on account of waterlogging, salts and alkalinity is to be recorded, the *patwari*, although he uses the same yard stick, that is more than 75, per cent. damage, has to specifically mention that the damage is due to these causes. Till 1945 these surveys formed the official statistics and were the basis for discussions in waterlogging board meetings and waterlogging conferences.

The surveys carried out from the year 1928 to 1944 showed that the land damaged on account of waterlogging was not large. It was more or less insignificant compared to that damaged by salts.

It is not proposed to deal here at length with surveys dealing with waterlogging. The extent of the damage is given in Chapter 8.

It must, however, be remembered that long before damage to crops on account of waterlogging is caused, salts appear at the soil surface on account of which land is classed as '*thur*'.

The drawbacks in these surveys were :—

- (a) The survey was confined to selected villages and selected estates and not extended over whole districts.
- (b) No notice was taken of land deterioration until damage to land exceeded 75 per cent.
- (c) Figures for damage were available by villages and not by canal systems.

In 1944 the definition for the classification of damage to land was changed and the work of the survey was transferred to the Irrigation Branch of the Revenue Ministry. The new classification is :—

- (i) Uncultivated *thur*.
- (ii) Ex-cultivated *thur*.
- (iii) Cultivated *thur*.
- (iv) *Bara* or *Rakkar* areas.
- (v) *Thur* areas under reclamation.
- (vi) *Thur* areas reclaimed.

These classifications require defining and the adoption of the following definitions was accepted.

(a) *Thur*.—Soil which is affected by salt efflorescence at the surface, whether the surface be white-ash coloured, black or brown, or not discoloured but presenting an oily appearance.

All areas locally known as *Kallar*, *Shor*, *Reh*, will be classed as *thur*.

The best months for judging whether soil is *thur* or not are December, January and February; and consequently the visual *thur* test is carried out during these months, and classification of land as *thur* is then made.

(b) *Uncultivated thur* : *thur* affected areas which have remained uncultivated since the advent of canal irrigation.

(c) *Ex-cultivated thur* : areas which have been under cultivation since the advent of canal irrigation, but have gone out of cultivation on account of (*thur*) salt efflorescence.

(d) *Cultivated thur* : *thur* affected fields which are under cultivation.

(e) *Bara* and *Rakkar* : areas which are known by the terms *Bara*, *Bari*, *Rakkar*, *Rappar*, *Kappar*.

(f) *Thur* area under reclamation : *thur* affected land on which reclamation operations are proceeding.

(g) *Thur* area reclaimed : an area declared reclaimed after having been included in the type defined under (f) above.

Note :—(1) in the case of (b), (c), (d) and (e), the whole of the field which is visibly affected (as found by the visual test *girdawari* during the cold weather) by *thur* to the extent of 20 per cent. or more will be recorded as *thur*. If the field is affected to a lesser extent than 20 per cent the area will not be recorded as *thur*.

For the purpose of discussion all types of *thur* are taken together.

From the surveys carried out in accordance with the new classification it was found that the extent of damage to land varied from 10 per cent upwards.

3. As a result of checks made, it was known that, in some cases, the *patwaris'* figures were not reliable and cent per cent check by higher revenue officers was not possible. It was considered that a more accurate method of recording '*thur*' should be devised.

As an alternative, Bigsby (Chief Engineer, Punjab) suggested that aerial photographs might be of use and arranged for a test of three different areas on the Upper Chenab Canal. With the help of these photographs (Figures 16, and 17), a check was made in the field in tracts representing the following :—

1. A tract in which the intensity of cropping is high.
2. A tract in which the area is predominantly *thur*.
3. A tract in which the main crop during kharif is rice.

As a result of the observations in the field it was shown that :—

- (i) The cropped area stands out well in the photograph. The intensity of the green colour of the crop is shown by the intensity of the dark shade in the photograph. It is possible to distinguish by the difference in shading between wheat and gram during the *rabi* season.
- (ii) The areas occupied by ponds are also well defined. These are usually very irregular in shape.
- (iii) All fallow fields appear white in the photograph and the bunds in these fields are well defined showing that they are maintained.
- (iv) Fields that have become '*thur*' appear white in the photograph but the *bunds* are not clearly defined showing that they are not maintained and therefore, the fields are not under cultivation. The remains of these *bunds* persist for a considerable period and, therefore, it is possible by means of the photograph to distinguish between *thur* land that has been cultivated and original *thur* land which has never been broken. In the *Thur* areas small black dots of irregular occurrences may be seen. These small black dots represent bushes of *Lani* (*Sueda fruticosa*) and *karai* (*Capparis aphylla*) or other wild vegetation which is colonising the *Thur* area.
- (v) *Kallar* patches in cultivated areas can be readily distinguished.

On the basis of the information collected in the field, an interpretation of one complete village was made in the Institute from the aerial photograph. In order to compare the results obtained from the photograph with the actual, a party was sent out in the field to



Figure 16



Figure 17.

make a survey of the same village without the help of the photograph. All these maps were given for checking to still another party who were not connected with any of these surveys either in the field or in the Institute. The results obtained are given in Table III. In this table, the number of fields examined is divided into three classes, *viz.*, *Thur*, *Thur*-patches and good land. An examination of Table III shows close agreement between the survey done in the field and that done on the photograph.

TABLE III

Sheet No.	Units <i>Thur</i>		Units patches of <i>Thur</i>		Units Good	
	Field	Photograph	Field	Photograph	Field	Photograph
1	..	..	..	..	..	..
2	1	1	..	..	..	..
3	98	94	20	14	..	10
4	233	233	81	51	10	40
5	68	59	64	63	10	30
6	141	146	182	148	43	72
7	129	168	170	97	72	106
8	26	37	150	49	114	204
9	137	133	96	88	19	31
10	172	150	125	110	22	5
11	116	130	63	39	8	18
12	10	10	..	..	..	..
13	..	..	..	..	..	..
Total	1,131	1,161	961	659	298	570

No effort has so far been made to calculate the actual areas under *Thur*, *Thur*-patches and good land for the two surveys mentioned above, but for purposes of comparison a portion of the area surveyed has been reproduced in Figures 18, 19 and 20. Figure 18 is a copy of the aerial photograph of this area. Figure 19 shows the classification made from the photograph in the Institute. Figure 20 gives the soil survey of the same area carried out in the field without the help of the photograph. It will be seen that Figures 19 and 20 agree closely.

From the work described above it is evident that the aerial photographs offer a method of obtaining a permanent record of the following :—

- (1) The area still in cultivation.
- (2) '*Thur*' areas that have been in cultivation in the past.



Figure 18.

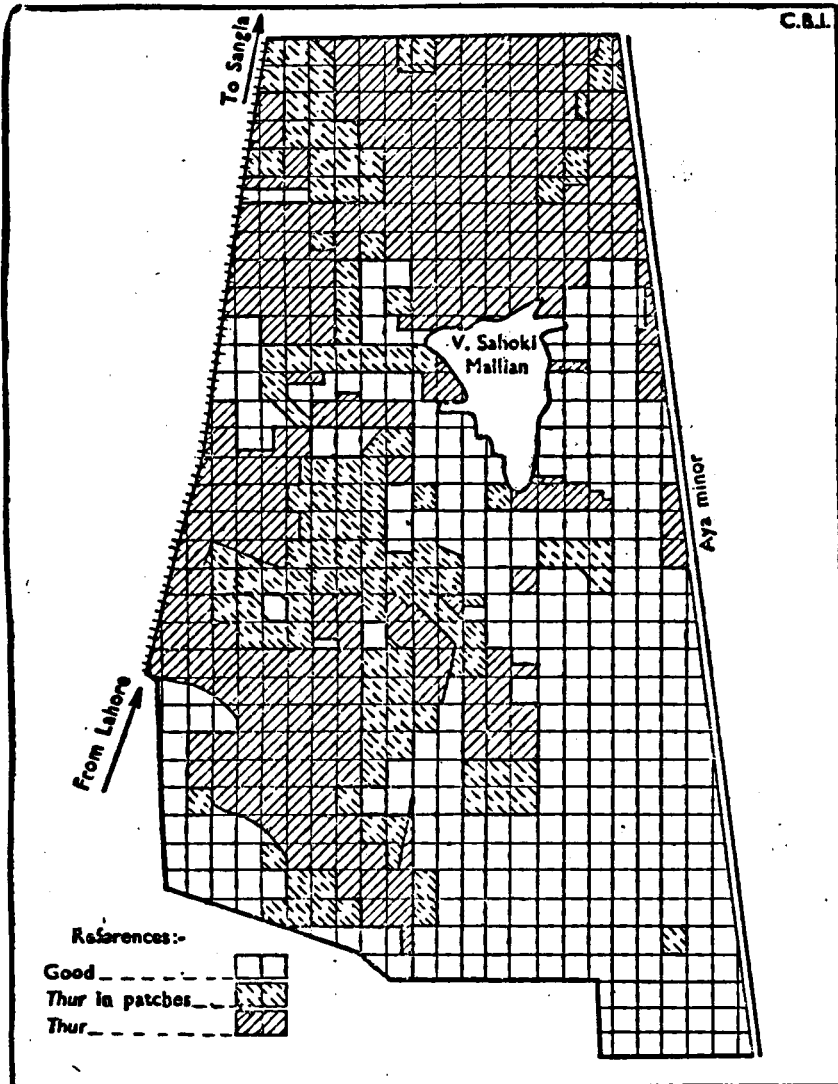


Figure 19

- (3) The areas that have never been cultivated.
- (4) The extent of 'Thur' in cultivated fields.
- (5) The types of crops and the total area under crops in any one season.
- (6) Record of habitations, roads and railway tracks, also irrigation channels and other topographical features which may be of importance in connection with investigations.

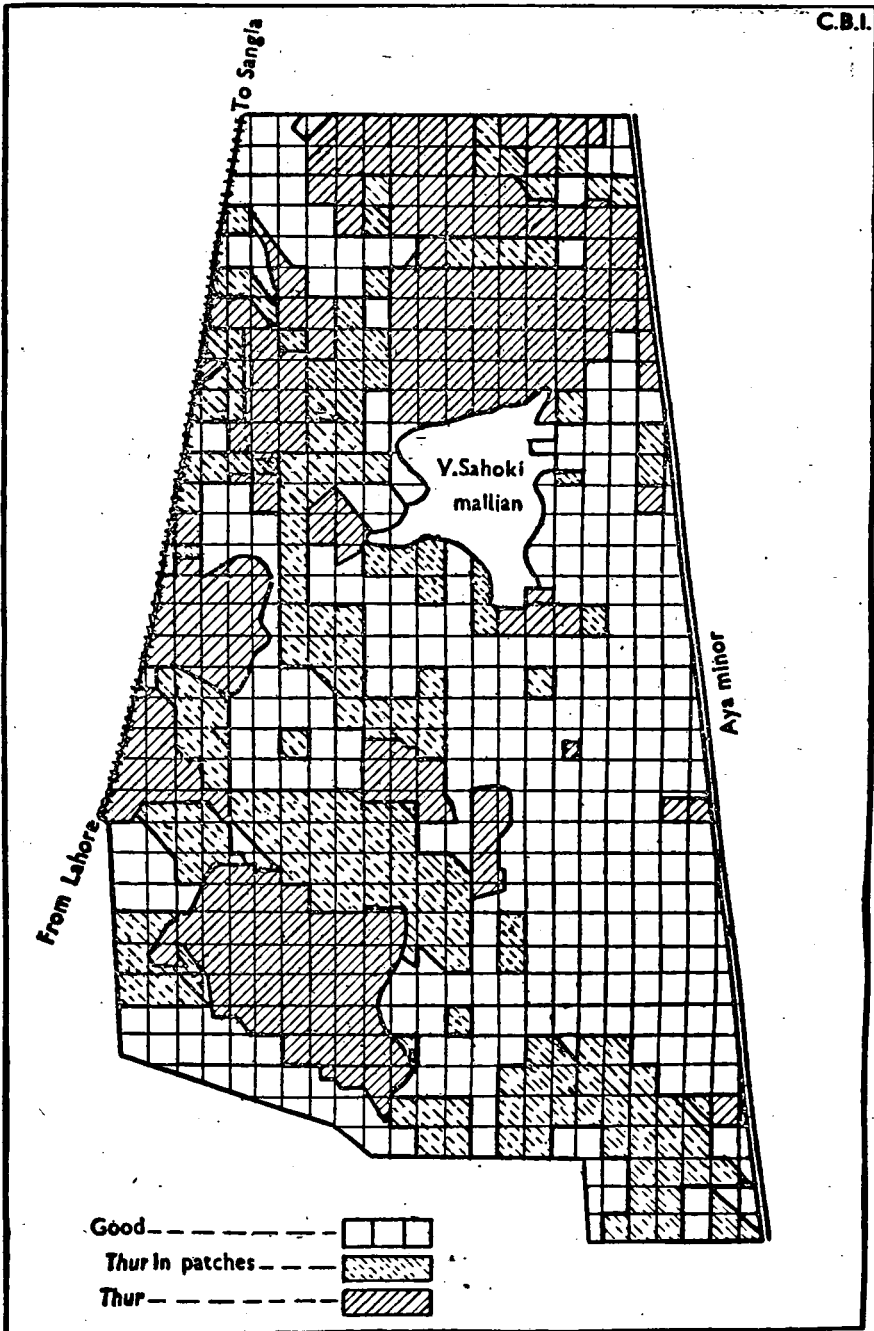


Figure 20

A very important use of the aerial photographs is in connection with the development of new projects. So far soil surveys carried out for such areas have been done on a grid system. In the Haveli Project Area, for example, the grid consisted of 400 acre units. Grid sampling, although it may give sufficient information with respect to the advisability of a project, does not give complete information for purposes of colonisation. If the ordinary sampling of soils is extended to individual fields the amount of labour and expense involved is tremendous and is not justified. Combined with the grid system, an aerial survey offers the possibility of obtaining a fairly accurate record of the condition of individual fields before the commencement of irrigation. As has been mentioned already, a complete record of the initial condition of virgin soil is essential for tracing the changes that take place after the introduction of canal irrigation. It will give early information regarding the progress of soil deterioration and enable measures to be taken to control it.

Economy in labour, space and the materials required is also a consideration in the preservation of records. In an aerial photograph maximum information is contained in the minimum amount of space.

The study of the aerial photographs of the Upper Chenab Canal areas has raised several other problems which require investigation. In Figure 17 for example, 'Thur' has appeared in the form of swirls. Careful observations were made to find the cause of the appearance of "Thur" in this shape. The area is situated along the Deg Nallah and has been subject to floods before the construction of the canal.

Soil samples from alternate strips of 'thur' and unaffected soil were taken and examined in the laboratory. The results are given in Table IV.

TABLE IV
Appearance of "Thur" in swirls

Description of soil	Depth	pH value	Salt content per cent.	Clay per cent.
Soil samples from Chak No. 21 <i>Thur</i> patch	0-6"	9.40	0.59	26.62
	6"-1'-3"	9.84	0.64	29.56
	1'-6"-2'-6"	9.96	0.52	32.68
	2'-6"-3'-6"	10.00	0.47	33.86
	3'-6"-4'-6"	10.00	0.31	22.40
	4'-6"-5'-6"	9.90	0.16	8.36
	5'-6"-6'-6"	0.08	0.11	1.92
	6'-6"-7'-6"	9.00	0.07	2.96
7'-6"-8'-6"	7.70	0.03	2.24	

TABLE IV—contd.

Appearance of "Thur" in swirls—contd.

Description of soil	Depth	pH value	Salt content per cent.	Clay per cent.
Soil samples from Chak No. 21, normal patch	0"—6"	7.90	0.14	19.56
	6"—1'-6"	8.24	0.14	14.90
	1'-6"—2'-6"	7.84	0.18	8.02
	2'-6"—3'-6"	7.94	0.13	7.74
	3'-6"—4'-6"	7.64	0.11	3.82
	4'-6"—5'-6"	8.24	0.07	4.62
	5'-6"—6'-6"	8.24	0.07	5.70
	6'-6"—7'-6"	7.76	0.03	3.40
7'-6"—8'-6"	7.76	0.01	3.62	

It will be seen that the clay content of the *thur* soil profile is high to a depth of 4 feet 6 inches whereas in the unaffected strip the clay content is low and the sand high.

The mechanical composition of the soil, therefore, is a determining factor in the peculiar shape of the appearance of 'thur'. If the water-table in this area continues to rise and comes very near the natural surface portions which are growing crops now may also develop "thur".


4. The fourth type of survey involves soil sampling in the field and the examination of soil samples in the laboratory.

In anticipation of construction of canal systems the area proposed for irrigation is surveyed by the Survey Department of the Government of India. One of the functions of the survey is to divide the area in rectangles—the four corners of each rectangle being marked at site by pitching a stone or a brick. Soil samples are taken by the Irrigation Branch soil survey staff on a grid basis—the size of the grid varying from 400 to 1,000 acres, depending on the object that is in view. If the purpose of the survey is to determine the advisability of proceeding with a project, and the area to be irrigated is large, then soil sampling on a grid of even 1,000 acres each gives sufficient information to form an opinion. If however, the object of the survey is to determine soil characteristics which would yield information on the effects of canal irrigation on the sub-soil water-table, the probable quantities of water required for maturing crops and the possible methods by which irrigation water can be conserved and soil fertility maintained, then a more closer sampling is needed; the grid is reduced to 400 or even 100 acres each.

Soil samples are examined in the laboratory for total soluble matter, *pH* values, clay content, *kankar* percentage and soil moisture. In particular samples complete analyses, both chemical and mechanical of the soil and the clay fraction are made.

Very recently an area of approximately 180,000 acres of waste land in Karnal district has been surveyed. The results of analysis show that a good deal of the land is of a type of which the salt content or alkalinity is high and which, therefore, is unfit for cultivation without reclamation.

From the results of the *patwaris* survey, which is confined to the areas within the irrigation boundaries of canal systems, and the scientific soil surveys of some of the project areas likely to come under irrigation, it is possible to make an estimate of the extent of damage to land and the work involved in reclaiming and bringing these lands back to normal fertility.



CHAPTER 6

Movement of Moisture and Salts in the Soil Profile

A characteristic Punjab alluvium consists of a soil crust of varying thickness overlying sand.

For a proper conception of the mechanism of moisture movements in the soil profile, let us first start with a picture of the distribution of moisture in deep soil profiles, both in the irrigated and the adjoining unirrigated tracts of land. Wilsdon and Mehta (¹⁰), (Figure 21), took soil samples from a series of bores made in un-

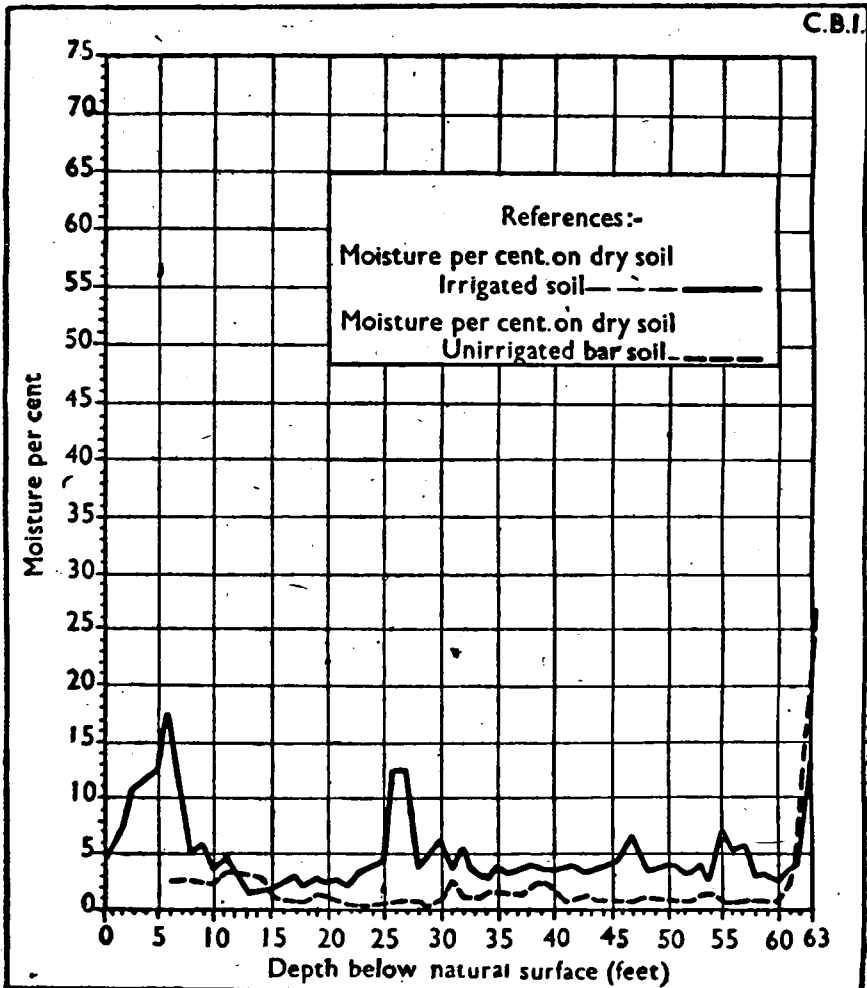


Figure 21

irrigated tracts and the adjoining irrigated fields near Lyallpur and found that, even though the tract was situated far away from any canal, the irrigated profile was consistently wetter than the adjoining unirrigated profile. As the moisture percentage was never near saturation in any portion of the profile it was concluded that the additional moisture in the irrigated profile was a contribution from surface irrigation. This was a direct evidence of the downward movement of water in the unsaturated phase.

The same authors (11) performed experiments with the object of determining the distribution of water in the sub-soil under a water-course. To ensure that the water distribution in the soil below had attained a steady state the water-course was kept full of water long enough. In order to reduce the experimental error of a single vertical boring and to obtain simultaneous values for moisture concentrations at various depths soil samples were taken from borings made radially in an unlined well dug at a distance of eight feet from the water-course (Figures 22 and 23). Figure 22 shows

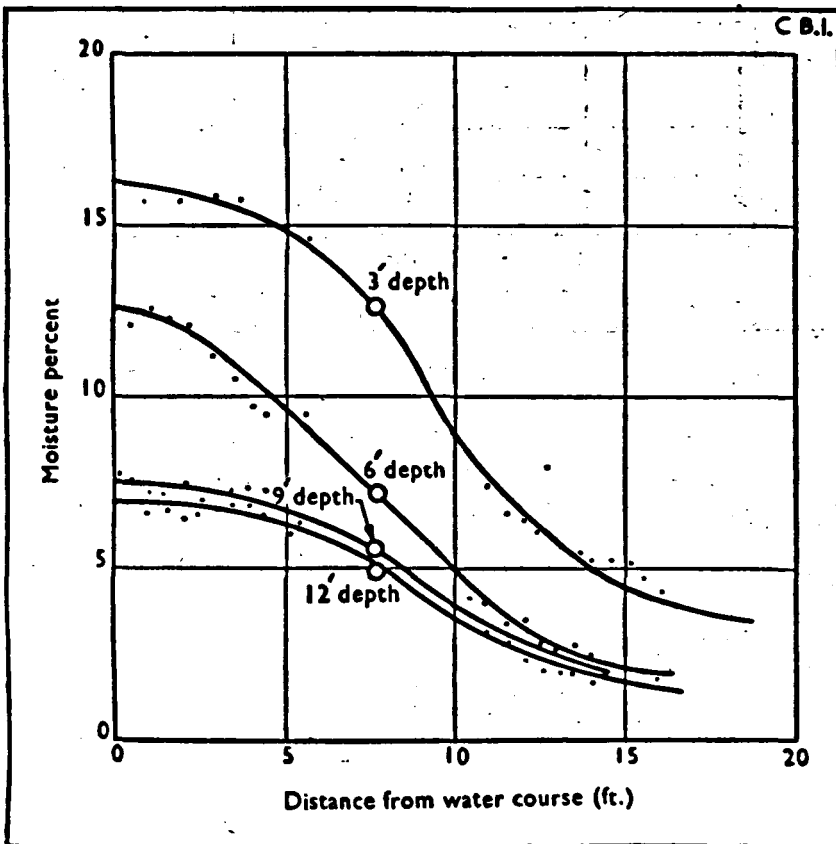


Figure 22

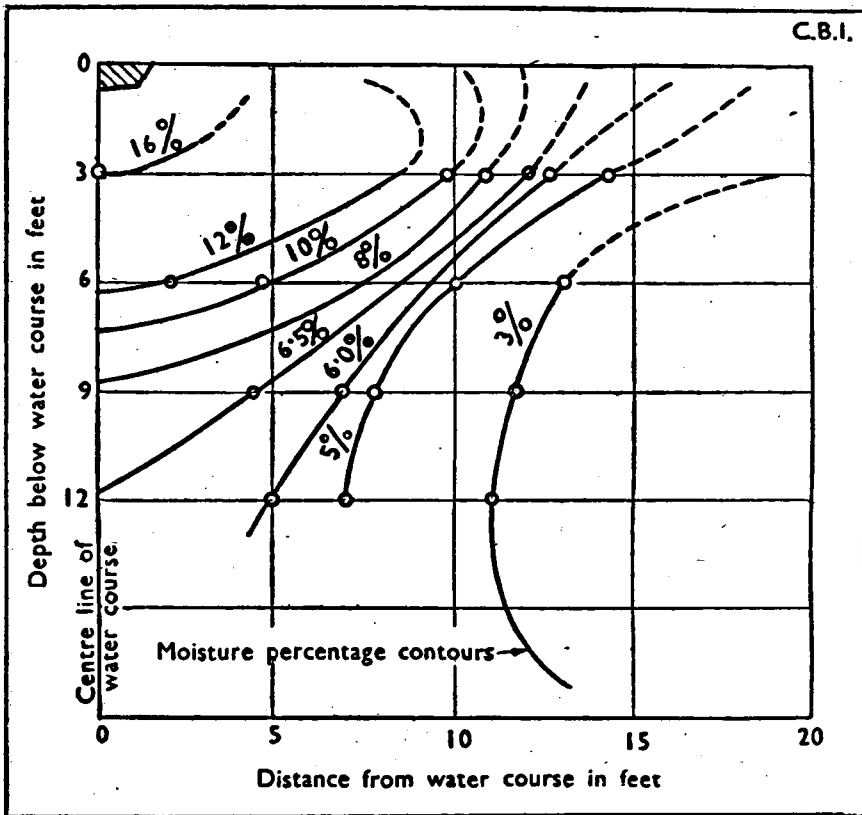


Figure 23

the results of moisture estimations plotted and diagram 23 is a contour diagram obtained by interpolation on Figure 22. It will be seen that the motion of water in soil column below the bed of a water-course also is in the unsaturated phase and all movements are more or less vertical there being very little horizontal movement.

McKenzie Taylor and Mehta repeated these experiments in 1937 and 1938. Their results for one set of profiles in the Samundri area of Lyallpur District are reproduced in Table V.

TABLE V

Showing distribution of moisture in a whole soil profile. Chak
468 G.B. Samundri, district Lyallpur

Depth from N.S. at which soil sample was taken.	Per cent. moisture on dry soil	
	Field which has never been irrigated.	Field which has been under irriga- tion and cultivation since 1902.
1st foot	1.4	1.6
2nd "	3.2	5.8
3rd "	2.7	6.9
4th "	2.2	9.6
5th "	1.9	11.2
6th "	2.8	12.3
7th "	1.3	13.6
8th "	1.0	16.7
9th "	0.8	14.6
10th "	1.0	8.2
11th "	1.1	7.2
12th "	1.0	5.2
13th "	0.7	3.4
14th "	0.7	3.6
15th "	0.8	4.2
16th "	0.9	4.5
17th "	0.7	5.2
18th "	0.9	3.2
19th "	0.6	3.0
20th "	0.7	3.7
21st "	0.6	2.8
22nd "	1.1	4.4
23rd "	3.2	2.7
24th "	9.0	3.3
25th "	8.7	3.5

TABLE V—contd.

Showing distribution of moisture in a whole soil profile. Chak
468 G.B. Samundri, district Lyallpur

Depth from N.S. at which soil sample was taken.	Per cent. moisture on dry soil	
	Field which has never been irrigated.	Field which has been under irriga- tion and cultivation since 1902.
26th "	3.6	2.8
27th "	4.2	3.6
28th "	6.0	2.1
29th "	11.3	14.0
30th "	30.0	30.0

From an examination of Figure 21 and Table V it is concluded that, on account of continued cultivation and irrigation over a period of years, the soil profile has developed three distinct zones of moisture contents.

The Pellicular Stage Zone.—This zone extends from the natural surface to a depth varying between 6 and 10 feet. The moisture distribution in this zone depends on the date when the field was last irrigated. If irrigation had been recent the moisture percentage in this zone will be high. If, however, evaporation at the soil surface had taken place for sometime after irrigation, the moisture contents would be relatively low.

Below the "Pellicular zone" is a zone at "Field Moisture Capacity". "Field Moisture Capacity" can, therefore, be defined as the amount of water retained by a soil column against gravity in actual field conditions.

Below the "Field Moisture Capacity Zone" is the "Capillary Zone", the "Capillary Zone" is influenced by the water-table. As almost always the water-table is in the sand layer the capillary zone is of small depth.

Under irrigation conditions, water applied to the soil surface establishes a moisture gradient, the surface soil having the greatest percentage of moisture. If the amount of water applied is more than is required to bring the "Pellicular Zone" to "Field Moisture Capacity", the excess water enters the "Field Moisture Capacity Zone" and gradually travels downwards till it gets added into the "Capillary Zone", thereby raising the water-table. In actual practice, however, evaporation commences soon after irrigation is applied. The "Pellicular Zone", which may have attained field moisture capacity soon begins to lose moisture—the surface soil

quickly coming back to the pellicular stage. As evaporation proceeds, the depth of the pellicular stage zone gradually increases until a certain maximum depth of development is reached. During the development of the pellicular stage zone the soil above the shallow capillary zone will still be at field capacity.

The field observations described above were supplemented by experiments in the laboratory. In the first experiment, glass tubes were fitted with wire gauzes at one of the open ends. One glass tube was filled with dry sand and a second with sand saturated with water. The saturated sand column was allowed to drain, so that the column came to field capacity. The two columns of sand were then placed vertically in a trough of coloured water (representing salt water) and the movement of water in the sand columns observed. It was found that a rapid rise occurred in the dry sand column but that there was no tendency for the coloured water to enter the sand column at field capacity. Evaporation was allowed to take place from the field capacity sand column but even after 15 days no water had risen from the water-table into this tube, though there was a small amount of diffusion of the dye into the base of the sand column. From this the indication is that, during the development of the pellicular stage zone the water being evaporated at the sand surface is not replaced by water drawn from the water-table.

In order to obtain further information on the effect of the field capacity zone on evaporation and the water-table, a series of sand columns of varying depths and at field capacity were set up in troughs of coloured water. It was noted that no water entered the sand columns at the commencement of the experiment. In order to rapidly establish pellicular stage zones, dry sand was added to the top of the field capacity zones and the time taken before coloured water entered the tubes was noted. It was observed that water rapidly passed from the top of the field capacity zones into the dry sand forming pellicular stage zones. The results are shown in Table VI, and Figure 24.

TABLE VI

Time taken before water passes into columns of sand at field capacity after the establishment of a surface pellicular stage zone

Original depth of field capacity zone in inches	Time in minutes
6	6
9	60
12	720
27	No rise in 15 days

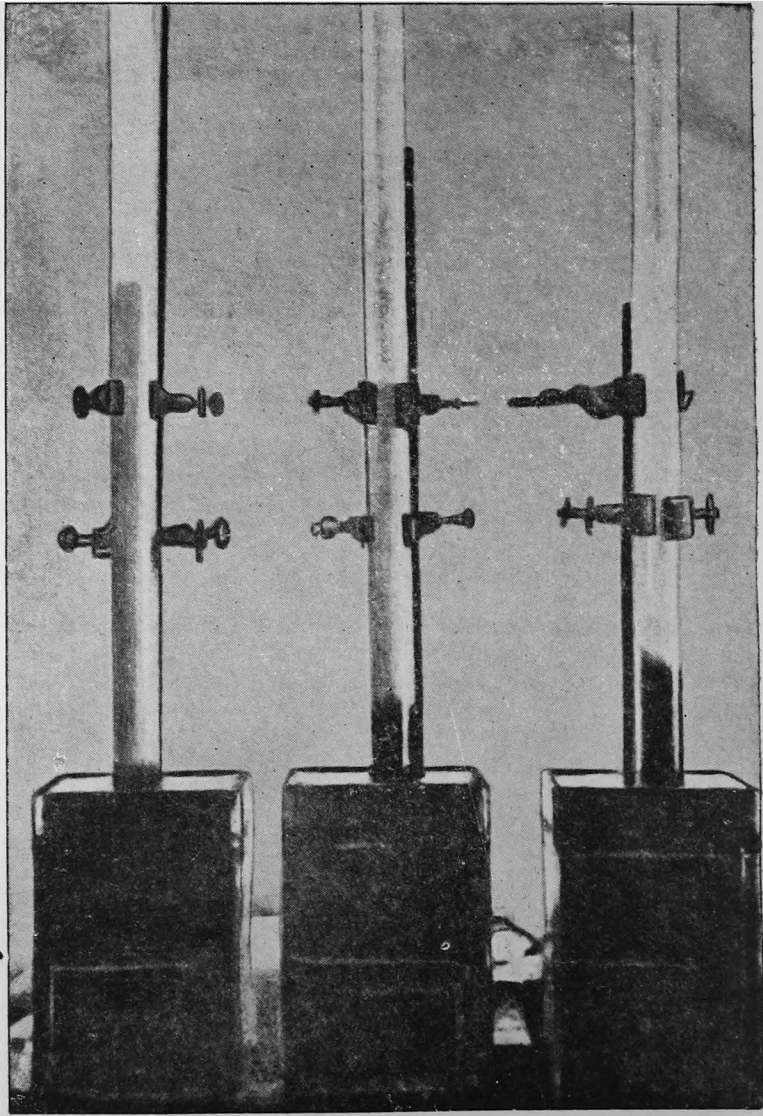


Figure 24

The results in the above table clearly show that, as the depth of the field capacity stage zone is increased, the time taken for the effect of the establishment of the pellicular stage zone to be felt on the water-table also increases. It was noticed that the movement of the coloured water into the sand columns only occurred after the complete conversion of the field capacity zone into a pellicular stage zone. The conditions in this experiment are extreme, since under field conditions it is impossible to have an air dry zone directly in contact with a field capacity stage zone.

These experiments lead to some important conclusions and applications :—

1. Field irrigation is responsible for raising the moisture content of the soil right down to the water-table which may be as much as 68 feet below the natural surface.
2. That this movement of water into the soil column takes place in an unsaturated phase.
3. Under profuse irrigation such as is required for leaching salt land or for growing rice the "Pellicular Stage Zone" is raised to even above field capacity thus enabling moisture and salts to move down to the water-table.
4. So long as the "Field Capacity Stage Zone" exists between a pellicular stage zone and the water-table, evaporation at the soil surface can have no effect upon the water-table and, therefore, the control of the water-table level cannot be established by evaporation.
5. During land reclamation, salts are washed into the subsoil. Under irrigated conditions an examination of soil profiles has shown that, a zone of permanent field moisture capacity exists. If the salts are washed into the zone of permanent field capacity, it follows from the properties of this zone that they cannot return to the surface. Under these conditions reclamation must be permanent.
6. Since under irrigation, the presence of a field moisture capacity zone between the water-table and the surface has been demonstrated, it follows that salt having been washed to the water-table cannot again return to the surface in an adjoining area. The reclamation of one area will, therefore, not endanger other areas in its neighbourhood.

7. If it were possible to establish a zone of field moisture capacity in the soils of low rainfall areas, a reserve of water could be accumulated in the soil from which crops could draw. The development of a zone of field capacity under low rainfall conditions depends upon the concentration of the total rainfall on a given area upon a smaller area and below its surface. This can be achieved by trenching, as illustrated in Figure 25. The soil dug from the trenches will be placed between them so as to form ridges. The water falling on the ridges will flow into the trenches and get absorbed by the soil. By this means rain can all be conserved in the soil profile, and in this manner it may be sufficient to produce a crop on a smaller area.

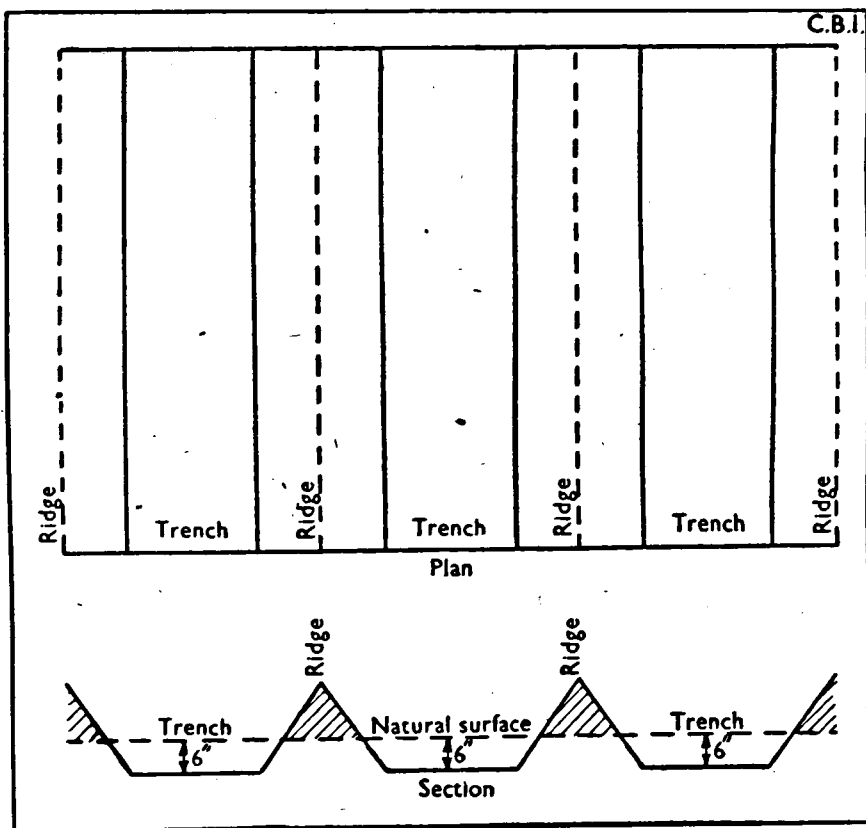


Figure 25.—Showing the arrangement of trenches and ridges to accumulate rainfall in inches.

It has been noticed that gram after rice is very successful and gives higher yields as compared with that grown under ordinary irrigation or without irrigation.

CHAPTER 7

Rise of the Water-table

A series of lines of wells distributed over the whole of the irrigation system in the Punjab have been under observation since 1870 to obtain a record of the variations in the water-table levels. These observations have shown that the introduction of canal irrigation is almost invariably followed by a rise of the water-table which may under certain conditions lead to waterlogging.

According to standard practice, observations of the water-levels in the wells are made twice a year, in June and in October. In June, following a long dry period, the water-table is at its greatest depth from the surface. The variations in June to June readings of the water-level therefore, give a measure of the permanent additions to the water-table. The readings of the well levels in October are made when the water-table is at its minimum depth from the surface following the monsoon period. Additions to the water-table made by the monsoon are obtained by comparing the June and October records of the well levels.

Wilsdon and Bose⁽¹²⁾ carried out a geodetic survey of certain portions of the Punjab plains and have shown that a subterranean rock ridge is present. This ridge is composed of rhyolite and it divides the Punjab into two areas, so far as its underground characteristics are concerned. It has been suggested that the presence of the underground ridge has resulted in the heading up of the sub-soil stream and that the rise of the water-table in the lower portions of the doab is now taking place due to the underground water flowing over the crest.

A large number of rain gauge stations have been established by the Irrigation Department in the areas commanded by the canals. Discharge measurements at control points in canal systems are available and river gauges are recorded daily. With the data available from measurement of well levels, rainfalls, and canal and river water supplies, it has been possible to examine the rise of the water-table with reference to the factors that may be operating.

Wilsdon and Sarathy⁽¹³⁾ made a systematic study of the available data. They came to the conclusion that both the rainfall and irrigation contributed to the rise in water-table. As a result of their work they recommended canal closures in order to reduce the seepage component of the irrigation load.

The well observations, rainfall and canal discharge data for the Upper Chenab Canal area were examined by McKenzie Taylor, Malhotra and Mehta⁽¹⁴⁾. The conclusions they reached confirmed those of Wilsdon and Sarathy regarding the importance of the monsoon rainfall as a factor in the rise of the water-table.

As a result of the study of the Upper Chenab Canal Area they suggested a drainage system to reduce the rainfall component of the total load of water on the land.

An investigation of the rise of the water-table in the lower portion of the Rechna Doab has been carried out by Malhotra (¹⁵). He concluded that either the same factors were operating upstream and downstream of the rock ridge or that the water-table upstream of the rock-ridge was influencing that downstream.

In 1945 Malhotra (¹⁶) made an investigation of the rise of water-table in a low rainfall area irrigated by a distributary of the Haveli Lined Canal. He came to the conclusion that, in this tract there was a consistent rise of 0.10 foot a month since the canal opened, and there was no fall of the water-table in the winter months. The conclusion reached was that the lining of the main canal *alone* was not sufficient to prevent a rise of the water-table in this area.

The canal water supply load may be divided into two parts with reference to additions to the water-table. A certain amount of water is lost by seepage from canals and added to the water-table. Of the water used for the irrigation of crops a certain amount passes from the "Pellicular zone" into the "Field Moisture Capacity Zone" and ultimately to the "Capillary Zone" thereby raising the water-table.

Using entirely different methods for the measurement of absorption losses from canal channels Crump, Malhotra, Vaidhianathan and Blench have more or less agreed that the average absorption loss is eight cusec per million square feet of wetted perimeter. From this, the conclusion is that canals may make considerable additions to the water-table by means of absorption losses. This means that, if absorption could be prevented, the water-table would be stabilized. Superficially this may seem a reasonable conclusion.

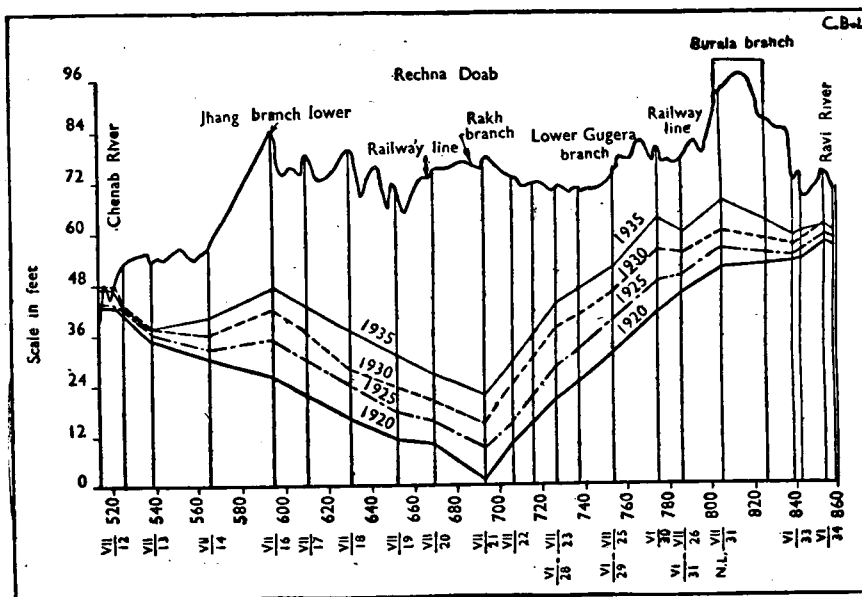


Figure 26.—A Section of Provincial Well Line No. XII.

A detailed examination of the general rise of water-table in a doab made by Mehta⁽¹⁷⁾ has shown that it is so uniform over the whole area of the doab that it seems unlikely that the additions to the water-table on a series of isolated lines can be an important factor in the general rise. Figures 26 and 27 show the uniformity of

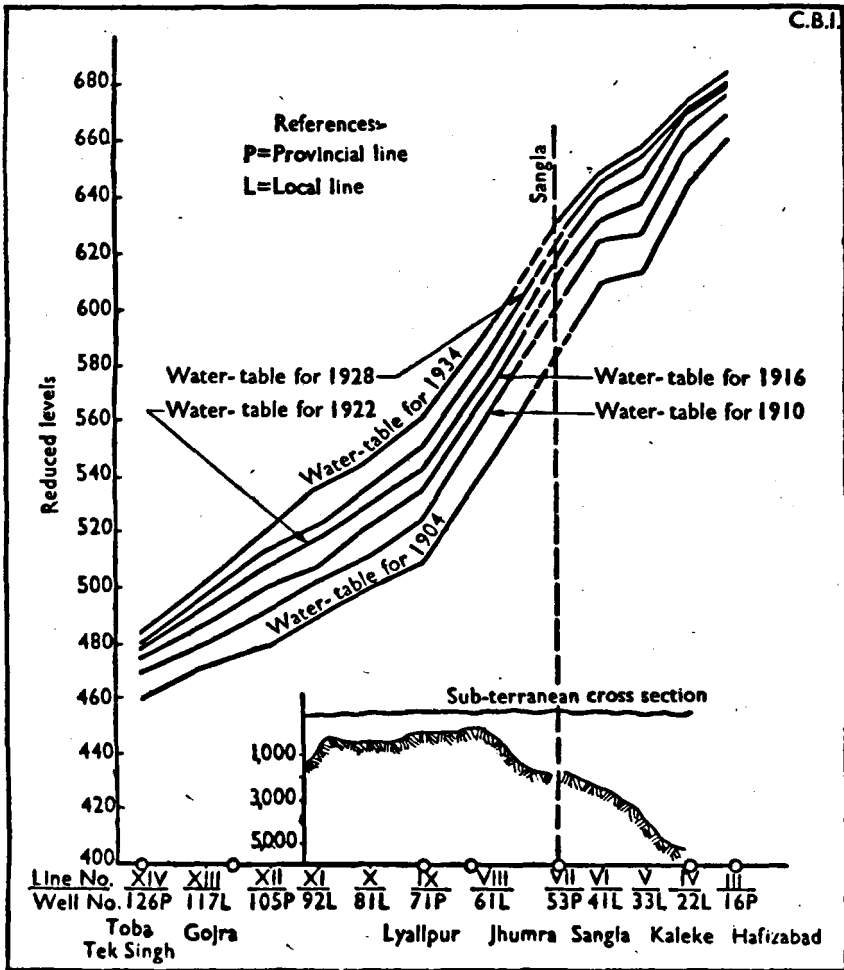


Figure 27.—Longitudinal section showing subsoil water levels at various periods in the Rechna Doab

the rise at five year intervals on a cross-section and longitudinal section of the doab. These sections are typical of the whole area. This investigation and that of Malhotra indicate that it is unlikely that lining of canals will prove an effective anti-waterlogging measure. Calculations also show that over the whole of the doab the total irrigation and rainfall load is more or less uniform. It appears,

therefore, that absorption losses from field irrigation are an important factor in the rise of water-table. This leads to the conclusion that, no matter what is done in the way of lining or opening of surface drainage, water-table rise is inevitable.

A contribution of some magnitude to the water-table of a *doab* is the flooding of the area lying on both sides of rivers. When rivers are in flood they overflow their banks and allow considerable quantities of their waters to enter the interior. For months after the flood the country remains under water.

A phenomenon which is a common occurrence in the irrigated tracts of the Punjab is worthy of notice. In making a vertical bore with the help of a sledge and a boring pipe, it has been noticed that, at times, a water-table of a very shallow depth is met more or less near the soil surface. When this is punctured the earth lower down is not saturated with water. Water-table is met further down when boring is carried to the sand layer. An example is quoted.

At the Maharawal Experimental Farm near Jaranwala District, Lyallpur, during soil sampling in berseem fields it was noticed, that a false water-table was created at a depth of about 5 feet from the natural surface. This was lying on a thick clay stratum. Below this clay layer was the real water-table lying at a depth of 14 feet from the natural surface. Fig. 28 shows that there is a heavy clay layer from the 11th to the 15th foot of the soil profile. This is what is responsible for a perched water-table. It also prevents the rising water-table to pierce through it.

That the two water-tables one above the clay sub-stratum and the other immediately below it are different and not interconnected is shown from figures for conductivity shown in Table VII.

TABLE VII

Field No.	Plot No.	Conductivity	
		False Water-table	Real Water-table
1	4	590	750
10	8	650	3,200
10	8	450	1,850
11	4	650	1,300

The conductivity (which is a measure of salt-content) of water in the false water-table is lower than that of water of the real water-table. This is due to the fact that the soil had been reclaimed and that the percolating water under berseem had not the chance to pick up any more salt from the soil profile.

Caution should, therefore, be exercised in making measurements of water-table particularly in high water-table areas when the same are observed with the help of observation pipes fitted with strainers

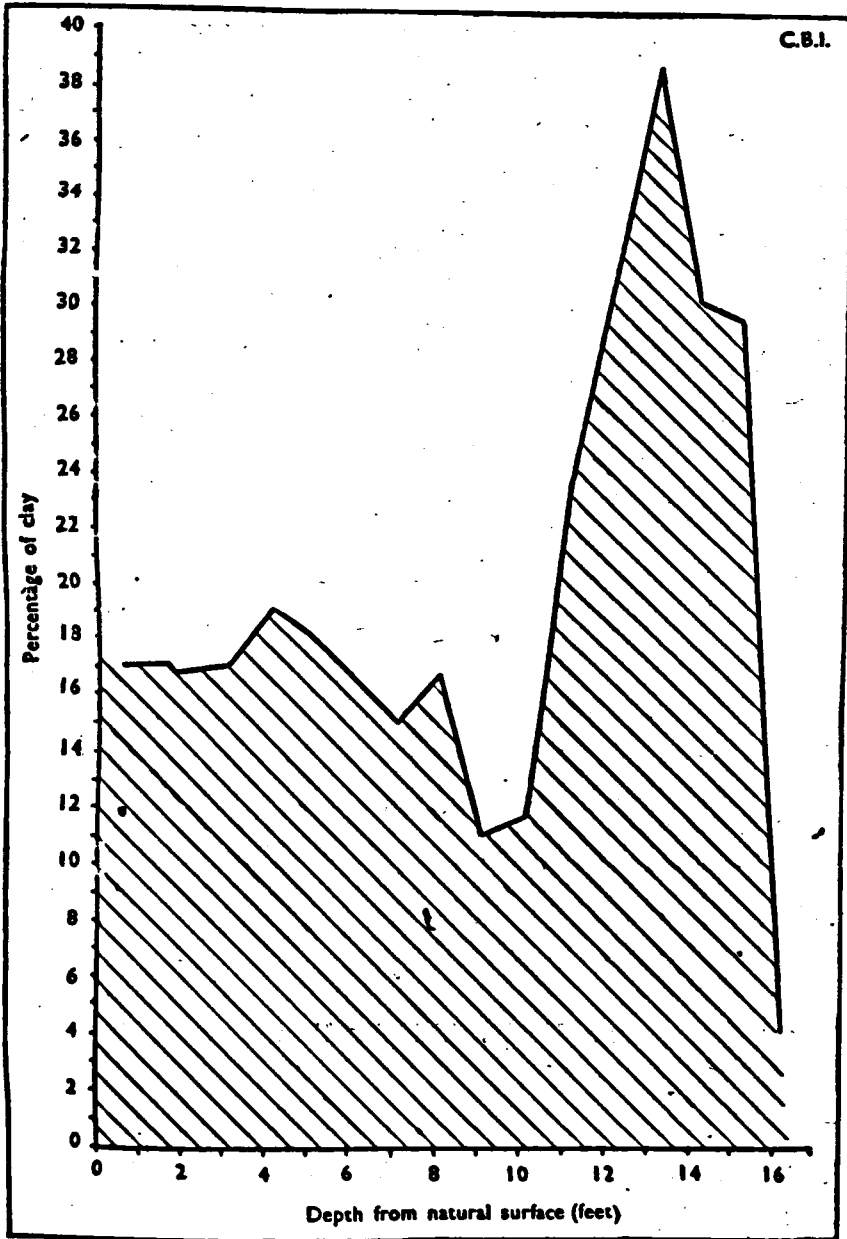


Figure 28.—Thick layer of clay in the soil profile Mahanranwala
Experimental Station Field No. 2/2.

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at their bottom ends. Care should be taken that such observation pipes are installed in the real water-table and not left at the false water-table.

Observations showed that the false water-table in berseem fields disappeared during the summer, sometime after the last cutting of berseem was taken and the field ploughed.

A second phenomenon that has a bearing on sub-soil water levels is the extraordinary sudden rise of water level in wells on account of rain. Observations made by Mehta¹⁸ showed that in an area near Sialkot, in a well 41 feet deep from the natural surface, the rain on the 15th and 16th of July had caused the water-table to rise by 3.0 feet (Figure 29). The water-table became steady at this level

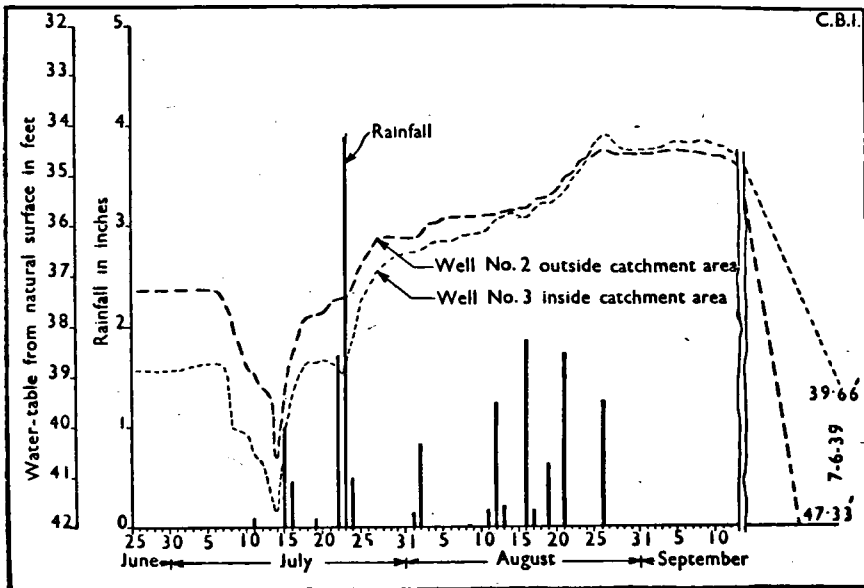


Figure 29.—Showing well observations and rainfall—Sialkot-Pasrur Area

until the 23rd when a further sudden rise took place after a heavy rain. Rainfall after this date affected the water-table to a small extent only and not suddenly. Vaidhianathan⁽¹⁹⁾ carried out a series of elaborate experiments in the laboratory. He came to the conclusion that with rain the concave menisci formed in the interstices, on account of evaporation during the previous dry period, become flattened, resulting in the release of the negative pressure. The negative pressure having been released, the water-table shows a sudden rise. The rise, however, does not represent actual additions to the water-table.

In making estimates of the rise of water-table in a given area care should be taken to reject all rises which may be the result of the release of negative pressure either due to a recent rainfall or field irrigation.

CHAPTER 8

Waterlogging

Considerable difference of opinion exists in defining waterlogging and deciding what classes of land should be considered as waterlogged. In Webster's dictionary the term 'water-log' is defined as follows :—

1. To render unmanageable by flooding or leakage of water, as a boat;
2. to deprive of buoyance by saturation with water, as floating timber;
3. to saturate with water; as, to waterlog soil by allowing stagnant water to stand on it. Waterlogged i.e. rendered soggy and untillable by water in excess of soil;
4. to cause to deteriorate or render helpless or unserviceable by or as if by saturation with excess of water; as, to waterlog vegetation, a mine, a business venture; a waterlogging of the lungs.

In 1917, when the Drainage Board was first constituted in the Punjab, the definition adopted was that land should be considered as 'waterlogged' if it has water-table within 18 inches of the natural surface. The arbitrary depth of 18 inches was probably borrowed from Clayton's book on "Land Drainage".

In 1925, the definition was again changed. It was laid down "that land should be considered to be waterlogged which, having been thrown permanently out of cultivation owing to a rise in the sub-soil water, has been entered as *banjar* in the Revenue Records and beneath which the sub-soil water is at or within 4 feet of the surface in the month of June. Areas in which salts were present, were, however, to be definitely excluded. This definition did not prove satisfactory.

In 1927-28, it was decided that regular surveys should be carried out by the civil revenue officials, both when summer and winter crops are standing, to determine the extent of waterlogged lands. The criterion laid down was: "Cultivated area will be classed as 'Sem' (water-logged) if owing to sub-soil moisture, it has become unfit for cultivation or is so badly affected that it does not produce more than a four anna crop (25 per cent of the normal yield). The damaged portion of a field should be considered by itself, irrespective of the average crop of the whole field".

NOTE 1.—Sub-soil moisture may have begun to affect a field, and it may be certain that the field will, in a short time, cease to produce more than a four anna crop. Nevertheless it will not be classed as 'Sem', unless the crop actually growing on it is less than a four anna crop. If the field is fallow and actually bears no crop it will not be classed as 'Sem', even if it has been ploughed for sowing.

NOTE 2.—Fields containing damaged patches which spoil the whole of it will be returned as wholly damaged.

According to these surveys the total water-logged area recorded for the whole of the prepartitioned Punjab amounts to 50,527 acres, the distribution of which is given below :—

	Name of District	Total area waterlogged in acres (1945)
1	Shahpur	17,498
2	Gujrat	8,497
3	Lyalpur	1,521
4	Sheikhupura	3,133
5	Karnal	3,965
6	Jhang	2,492
7	Ludhiana	995
8	Ambala	2,568
9	Gujranwala	4,783
10	Sialkot	1,265
11	Lahore	708
12	Montgomery	68
13	Hoshiarpur	158
14	Muzaffargarh	27
15	Gurdaspur	2,849
		50,527

It has already been stated that long before damage to crops on account of waterlogging is caused, salts appear at the soil surface on account of which land is classed as 'Thur'. If water-table depth alone were the consideration area damaged on account of high water-table should, therefore, be much in excess of the figure 50,527 acres. As the accumulation of salts at the soil surface is superimposed on a high water-table the germination of the seed is adversely affected and the area is recorded 'Thur'.

From the recorded depths of water-table referred to in Chapter 7 depth maps of *doabs* (area lying in between two rivers) are prepared and printed every year. In these depth maps, areas in which the water-table is situated between zero and five feet from the natural surface is considered as waterlogged. That in which the water-table is between 5 and 10 is danger area which requires drainage.

Near the river the water-table is always high. This is largely because, during summer, the supplies in the river are high. They over-spill their banks and of the volume of water spilled a large part never comes back. It remains standing in depressions and low lying areas near the rivers.

Waterlogging is apparent near the main canals and branches in reaches which are more leaky *i.e.* in which a stratum of sand exists on or near the bed of a canal and it is continuous on either side. Water-logging, therefore, extends as far as this sandy stratum exists. An illustration is given in Figure 30.

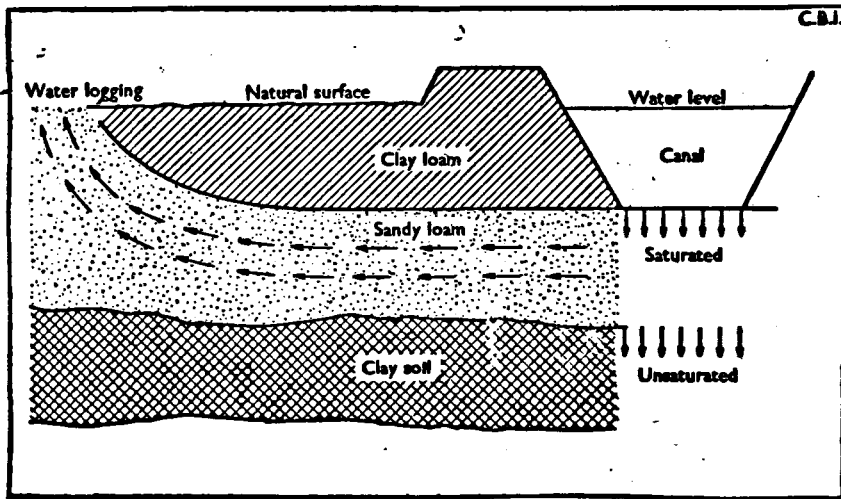


Figure 30

In Chapter 9, it has been shown that moisture movements in soil columns are all vertical. It has also been shown, Chapter 7 that the rise of the water-table is more or less uniform over the whole of the *doab*. From a reference to Figure 31 it would be seen that the land surface of the *doab* is roughly divided into a series of irregularly shaped basins, the edges or watershed lines of which are formed by the crests and the hollows of which form the catchment areas. Usually, each catchment area has, at some point, a gap or opening through which the excess of water of the area can pass into the other catchment and then ultimately into the river. But, on account of the construction of canals, railways, roads, embankments and field *bunds* for cultivation, most of these openings are not now working. The rising water-table naturally fills these depressions first. They form lakes and present difficulties in reclamation. Pumping is the only remedy. Depressions in Renala Estate, Lower Bari Doab Canal, Chaks 625 and 626 G.B., Lower Chenab Canal and the Bazida Jatan area in the Western-Jumna Canal area are notable examples.

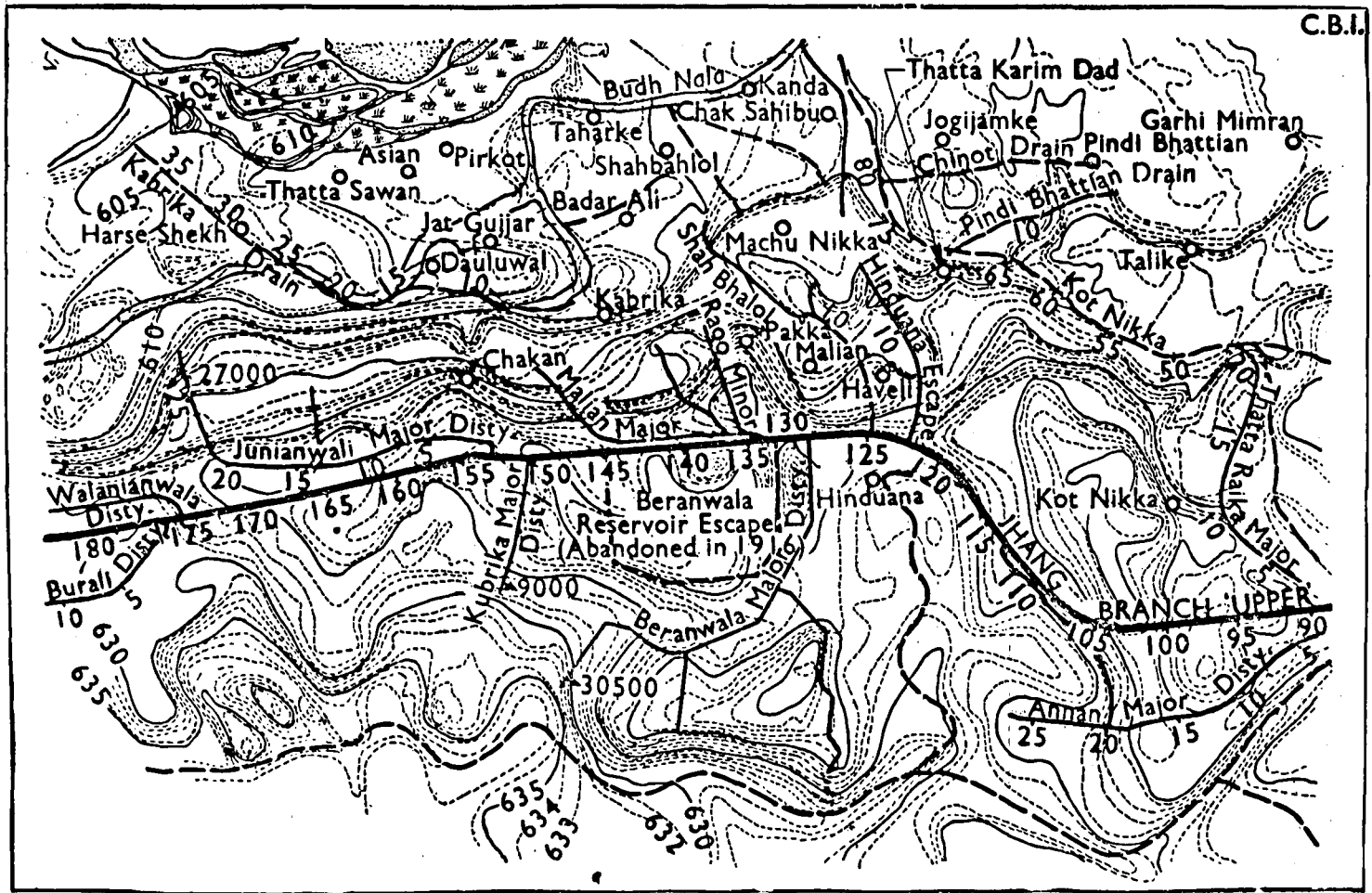


Figure 31

CHAPTER 9

Reclamation of Salt and Alkali Lands in Deep Water-table Areas

We are now convinced that land reclamation involves—

- (a) a soil survey ; taking soil samples to a depth of ten feet at least, to determine the salt content and alkalinity, as also the nature of the salts ;
- (b) reduction of salt content to the limit of 0.2 per cent. in a depth of 10 feet ;
- (c) reduction of alkalinity to the limit where it does not exceed a *pH* value of 8.5.

Reduction of Salt Content

Only those fields are included for land reclamation which in the official survey have been classed as damaged from salts. As, in the definition of damaged land, even such fields as, are affected to the extent of 20 per cent. are also included, the majority of the fields selected for reclamation are either under cultivation or are only recently abandoned. Not much levelling is therefore, required. But the lay-out is changed so that each individual plot is not more than one-fourth of an acre and it can be irrigated independently from the water-course. The arrangement of plots is shown in Fig. 32. Leaching is started as soon as the reclamation water-supply becomes available in the beginning of the summer. Leaching becomes more and more effective as the monsoon approaches. This is partly because, with the advance of season, increased water supplies become available and partly, because of excessive humidity, evaporation from the soil is considerably reduced.

Leaching is continued till the sowing of rice. During this period there is a natural growth of grasses which indicates improvement in the condition of land. At this stage rice is sown and leaching is continued under rice. Rice is the only crop which can stand a high salt content and also alkalinity and can grow while leaching is in progress.

Precautions

(i) All plots should be level so that water stands uniformly over the surface ; this makes leaching more effective.

(ii) Each individual plot should receive irrigation direct from the water-course. In no case should water be allowed to pass from one field to another.

(iii) The natural growth of grasses and other vegetation, during the preliminary period of leaching, should not be disturbed. The carbon dioxide generated by the roots of these grasses helps in breaking up soil alkalinity.

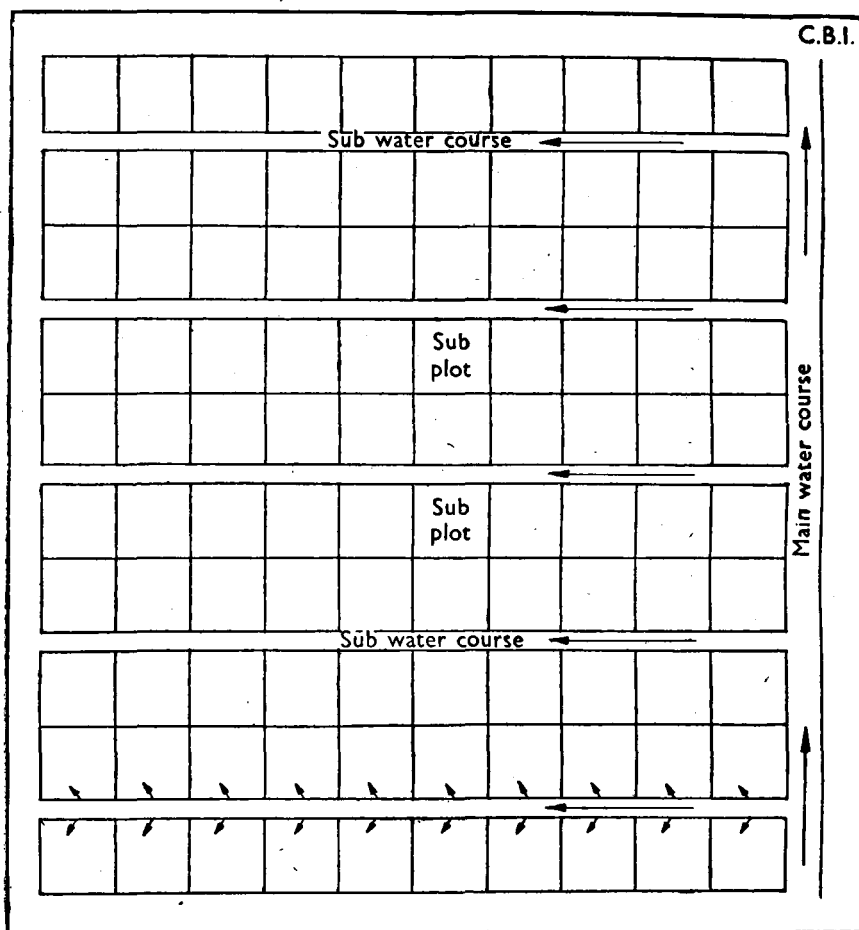


Figure 32

(iv) Before transplanting rice, irrigation should be stopped; fields ploughed and levelled if necessary and watered again. In no case should fields be ploughed under water. Puddling (ploughing under water) is a harmful practice. In the presence of salt this completes the reaction between the clay component of the soil and the sodium salts thus converting the whole of the clay into sodium clay, causing impermeability and retarding the downward movement of water and salts.

When rice is harvested soil samples are taken a second time and examined in the laboratory. The results of analysis indicate the effect of leaching and the depth to which the salts have been washed. Examples are given in Table VIII.

TABLE VIII

Data showing the effect of leaching on the movement of salts, at
Bahlewala Experimental Reclamation Station

Site	Depth	Per cent T.S. before leaching	Per cent T.S. after leaching for one season	Tons of salts present per acre before leaching	Tons per acre of salts left after one season's leaching	Increase or de- crease in tons	Cumulative increase or decrease in tons per acre
1	2	3	4	5	6	7	8
55/1	1st foot ..	1.72	0.39	30.16	6.82	-23.34	
	2nd foot ..	1.82	0.70	31.76	12.20	-19.56	
	3rd foot ..	1.82	0.71	31.76	12.40	-19.36	
	4th foot ..	1.62	1.29	28.35	22.57	-5.78	
	5th foot ..	1.63	0.60	28.53	10.50	-18.03	-86.07
	6th foot ..	1.75	0.92	30.62	16.10	-14.52	
	7th foot ..	1.42	2.20	24.85	38.50	13.65	
	8th foot ..	1.32	2.80	23.10	49.00	25.90	
	9th foot ..	1.35	2.20	23.62	38.50	14.88	+30.26
	10th foot ..	1.50	0.95	26.25	16.60	-9.65	
	Total ..			279.00	223.19	-55.81	
55/3	1st foot ..	2.00	1.08	35.00	18.50	-16.50	
	2nd foot ..	1.68	0.28	29.40	4.90	-24.50	
	3rd foot ..	1.88	2.61	32.90	45.50	12.60	
	4th foot ..	3.10	2.00	54.25	35.00	-19.25	
	5th foot ..	2.70	1.79	47.25	31.32	-15.93	-63.58
	6th foot ..	0.66	1.09	11.75	19.07	7.32	
	7th foot ..	1.20	0.70	21.00	12.25	-8.75	
	8th foot ..	2.08	0.65	36.40	11.38	-25.02	
	9th foot ..	1.70	0.70	29.75	12.25	-17.50	
	10th foot ..	2.75	1.64	48.10	28.70	-19.40	-63.35
	Total ..			345.80	218.87	-126.93	

TABLE VIII—contd.

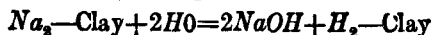
Data showing the effect of leaching on the movement of salts, at Bahlewala Experimental Reclamation Station.

Site	Depth	Percent T. S. before leaching	Per cent T. S. after leaching for one season	Tons of salts present per acre before leaching	Tons per acre of salts left after one season's leaching	Increase or decrease in tons	Cumulative increase or decrease in tons per acre
1	2	3	4	5	6	7	8
55/4	1st foot ..	1.80	0.28	31.50	4.90	-26.60	
	2nd foot ..	1.90	0.32	33.25	5.60	-27.65	
	3rd foot ..	1.80	0.55	31.50	9.62	-21.88	
	4th foot ..	1.80	1.44	31.50	25.20	-6.30	
	5th foot ..	2.90	1.22	50.75	21.35	-29.40	-111.83
	6th foot ..	1.70	1.12	29.75	19.60	-10.15	
	7th foot ..	1.60	1.05	28.00	18.37	-9.63	
	8th foot ..	1.90	1.30	33.25	22.75	-10.50	
	9th foot ..	2.10	1.90	36.75	33.25	-3.50	
	10th foot ..	2.15	1.80	37.62	31.50	-6.12	-39.90
	Total ..			343.87	192.14	-151.73	
55/5	1st foot ..	1.40	0.24	24.81	4.20	-20.61	
	2nd foot ..	2.35	0.47	41.12	7.73	-33.39	
	3rd foot ..	2.65	1.42	45.37	25.60	-19.77	
	4th foot ..	2.50	1.33	43.75	23.30	-20.45	
	5th foot ..	1.72	1.24	30.10	21.70	-8.40	-102.62
	6th foot ..	1.45	1.21	25.37	21.17	-4.20	
	7th foot ..	3.05	2.90	53.03	50.75	-2.28	
	8th foot ..	3.60	1.30	44.78	22.75	-22.03	
	9th foot ..	1.30	1.72	22.37	30.90	8.53	
	10th foot ..	1.18	3.40	20.65	59.50	38.85	+18.87
	Total ..			351.35	267.60	-83.75	

From this table it will be seen that in the same area the effect of one season's leaching is different in different fields. Whereas in field 55/1 55.81 tons of salts have been removed to depths below 10 feet, in field No. 55/5 salt removed is 83.75 tons, in field 55/3 126.93 tons and in field 55/4 the reduction is of the order of 151.73 tons. All these fields require another season's leaching and a crop of rice.

Reduction of alkalinity

The leaching of salts from the soil is only the first stage in land reclamation. During leaching, when the concentration of the sodium salt solution falls below the critical point, the sodium clay is no longer stable but begins to break down as the result of hydrolysis according to the equation :—



The result of this reaction is that the clay is now in the presence of a solution of sodium hydroxide which is alkaline. In this solution the clay becomes deflocculated and the soil is more or less impermeable to water. At this stage the soil is unsuitable for crops, with the exception of sugarcane and rice. Sugarcane cannot be sown at this stage because that is not its sowing season. Rice is the only crop left.

The excess of salts having been removed the next difficulty is to overcome the effects of hydrolysis produced by leaching. The following are the known methods to reduce the alkalinity in the soil :—

1. The conversion of the sodium clay into another type of clay by base exchange. The salts that are normally utilised are calcium sulphate (gypsum) and calcium chloride and sometimes magnesium sulphate and ferrous sulphate.

Calcium sulphate is very slightly soluble in water and its solution in the soil is never concentrated enough to produce base exchange to any appreciable degree. As soon as the quantity of calcium sulphate solution is reduced below the amount necessary for flocculation the land does not respond to cultivation and cropping until further dressings of calcium sulphate are given.

Some important points to remember, in the use of gypsum, are :—

- (1) it must be finely powdered ;
- (2) it must be properly incorporated with the soil ;
- (3) it must be thoroughly leached through the mass of soil, that is, the gypsum must be dissolved in the soil solution and this solution must come in contact with all the soil particles.

If the land has been left long enough after deterioration due to salt action, the alkalinity of the soil as indicated by pH values is so high that its reduction by the addition of sufficient quantities of calcium sulphate becomes expensive and beyond the means of the ordinary farmer.

Calcium chloride is, no doubt, more soluble than calcium sulphate and, therefore, more efficacious but, owing to the large amount of sodium to be replaced in a soil, its cost makes its use prohibitive.

Magnesium sulphate is also expensive. At the same time the resulting magnesium clay does not permit the soil to obtain as good a texture as in the case of calcium clay.

Ferrous sulphate has been used successfully. The clay produced in this case is ferrous clay. The treatment, however, is too expensive for ordinary farming.

(2) The method that has found general application in the Punjab and which proved efficacious and successful is the growing of rice at a stage when preliminary leaching is finished and the excess of salts has been removed from the first one or two feet of the soil. The roots of the rice crop appear to generate carbon-dioxide in the soil which converts the sodium hydroxide successfully into sodium carbonate and sodium bicarbonate. The soil in the presence of sodium bicarbonate is again permeable. Leaching can, therefore, be continued, and the decomposition of sodium clay as the result of the hydrolysis also becomes a continuous process.

With continued cultivation, cropping, breaking of the sodium clay conditions arise so that calcium which went into an insoluble form during the process of salinisation and alkali formation becomes soluble again; it thus gets a chance of converting the sodium clay into calcium clay.

Farmer's Standard of Judging Soil Alkalinity

In the field, farmers judge the reduction of alkalinity in the soil from the yields of rice. From this they decide the system of cropping that should be applied to any particular field under reclamation.

With the object of confirming these standards a study of the root system of rice plants grown in fields giving varying yields of rice was made at the Chakanwali Reclamation Farm. After the rice was harvested, roots of individual plants were exposed and washed. These were later photographed. Some of these photographs are produced in Figure 13. From the data collected the following conclusions have been drawn :—

1. A yield of rice of 10 *maunds* per acre and below appears to indicate soil alkalinity represented by a *pH* of 9.5 to 10.0.
2. Above 10 *maunds* of rice per acre the alkalinity is much lower; the *pH* value of the soil usually being between 9.0 and 9.5.
3. As the alkalinity decreases *pH* 9.5, the root system increases rapidly in size.

The reader not acquainted with conditions of farming in the Punjab may feel some difficulty in realising why rapid methods of base exchange by the addition of calcium salts are expensive and not workable and why the relatively slow process of reclamation through a system of cropping is preferable. To make this clear it is necessary to realise that the most prevalent form of cultivation is through a system of tenancy. The tenants usually employed in canal colony

areas are tenants at will. Their period of tenancy is renewed from year to year. Instances are available when tenants are shifted from one block of land to another each year. According to practice a tenant has to employ his own bullocks and implements; he has to provide seed at his own expense and when the crop is ready for division at the threshing floor he has to share it with the landlord at fifty-fifty basis. Charges for canal irrigation are also borne half and half. The landlord, however, pays the whole of the Government land revenue. From this it is easy to realise that the tenant does not want to invest much money for permanent reclamation or improvement on account of the insecurity of his tenure and also the fact that half the recurring profit goes to the landlord. The landlord does not want to invest more money in land as he thinks half the profit on account of that investment will go to the tenant.

Instances are available when the meagre produce of three *maunds* of rice per acre in the first year of reclamation has been divided half and half between the landlord and the tenant.

Physico-Chemical Changes Resulting from Land Reclamation

In land reclamation carried out under Government agency it is now a standard practice to examine soil samples for salt content and pH values to a depth of ten feet after every crop of rice. More detailed examination of soil samples from reclamation areas has been made by Hoon and Dewan ⁽²⁰⁾. They have arrived at the following conclusions :—

- (i) There is a decrease in the calcium carbonate content which contributes appreciably to an increase in the calcium status of soil and decrease in the cementing effect of calcium carbonate. The increase in calcium status and decrease in the cementing effect are helpful to soil in obtaining better tilth.
- (ii) The calcium content in the exchange complex of soils increases after the first year's reclamation; but, after the second reclamation cycle, it shows a tendency towards decrease, either throughout the depth of the profile or at least in a column of soil near the surface. In the latter case, there is a corresponding increase in the lower portion of the profile. This, in the opinion of the authors, is attributable to the utilisation of calcium by crops or its removal from the surface to the lower depths of the profile.
- (iii) The tendency for the available phosphate is to increase throughout the depth of the soil profile, more especially in the top portion, after one reclamation cycle, and to decrease in the top portion with an accumulation lower down after the second cycle of reclamation operations. The increased availability of phosphates as the result of reclamation operations is a desirable feature and indicates improvement.
- (iv) There is a conspicuous decrease in the manganese content of soil. This may be attributed to the general reduction of soil alkalinity. This is again a desirable change.

(v) The monovalent bases (Na, K) in the exchange complex of soils either decrease throughout the soil profile or at least in its top portion after one reclamation cycle. After a second year's treatment monovalent bases have a tendency to increase in the top portion of the profile and decrease lower down. It might be expected that gypsum, which has been found to be present in soils, contributes its share of calcium towards soil amelioration.

Permanency of Reclamation

The question naturally arises that, if the excess of salts is removed to a depth of 10 feet and the alkalinity is also reduced to the limit, is reclamation permanent. In other words, after reclamation is completed, land will not begin to deteriorate again when reclamation

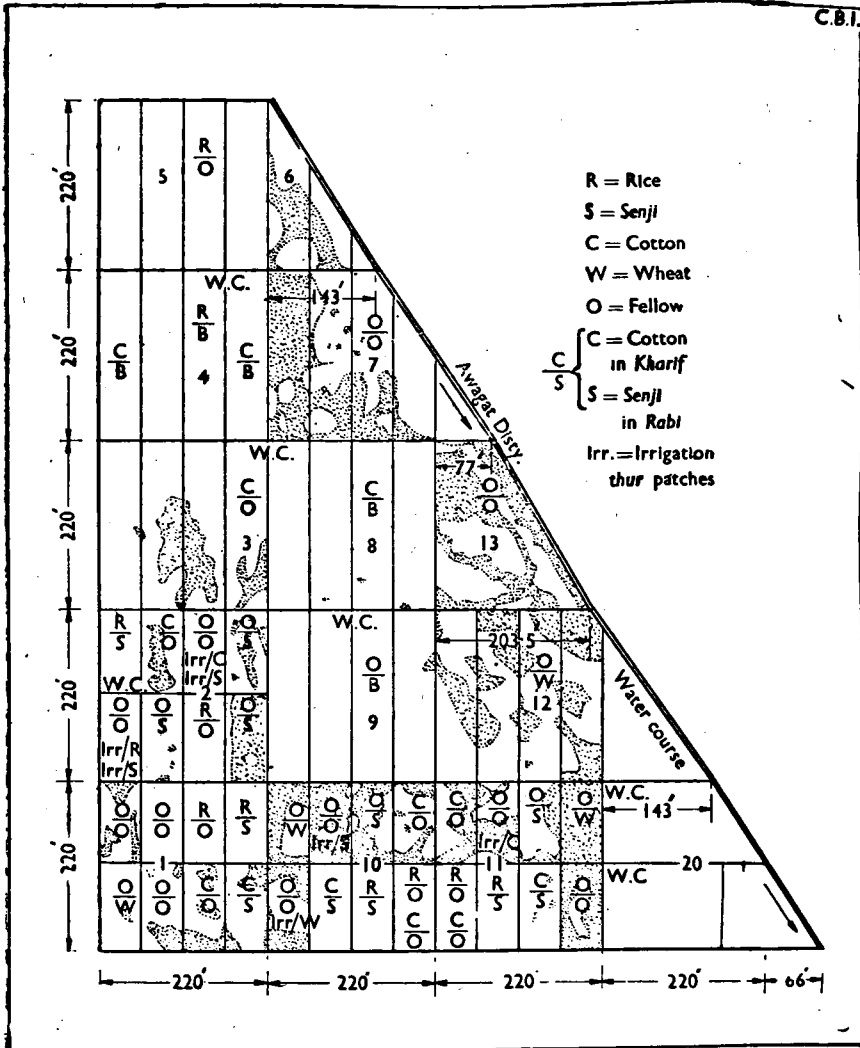


Figure 33.

Figure 34. Cotton/Fallow
yields of cotton per acre

	mds.
1937	—19.9
1938	—18.6
1939	—13.3
1940	— 6.4

The yields of cotton show a distinct decline.

In the photograph are seen patches of salt. These patches are increasing.



Figure 35. Cotton/Senji
yields.

Cotton	Senji
1937—14.2	Good
1938—13.5	Fair
1939—13.5	Fair
1940— 6.4	Poor

Cotton is a light irrigation crop; so is Senji. In spite of the fact that Kharif and rabi crops are grown in this field thur patches have started appearing. The fields of crops are declining.

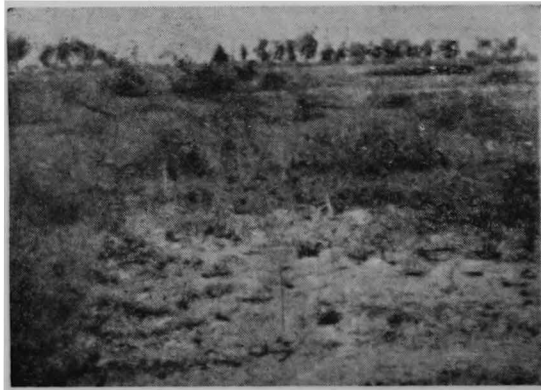


Figure 36. Fallow/wheat
yields per acre

1937	—32.6
1938	—25.6
1939	—22.0

In the photograph thur patches are very prominent when one thur starts in a wheat field subsequent deterioration is very rapid.

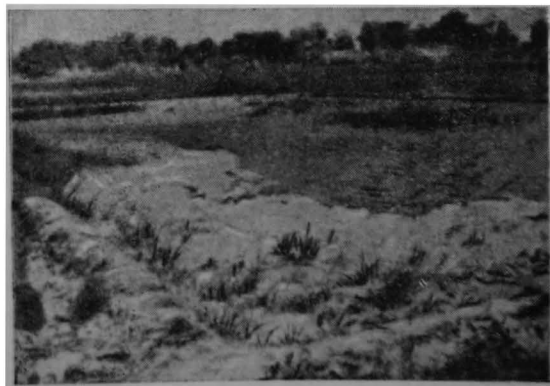


Figure 34. Fallow/Senji
 1937—Good
 1938—Good
 1939—Fair
 1940—Poor

Patches of thur are visible in the photograph.

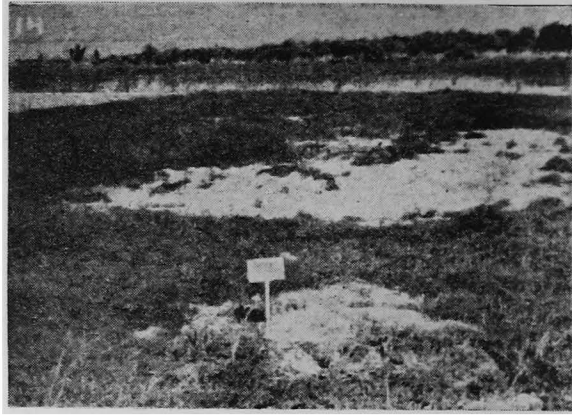
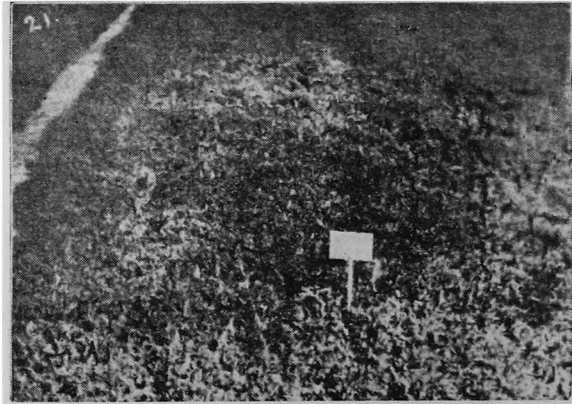


Figure 38. Rice Berseem.
 Price of berseem per acre

This land has improved considerably. The price of berseem realised is increasing. In a portion of this field cotton was sown after two rice crops. The yield of American cotton was 17 maunds per acre.



water supply is withdrawn, rice cultivation is stopped and a normal water allowance and a normal rotation of crops are restored.

In the Chapter dealing with the formation of salt lands it has been stated that, under Punjab conditions, water which reaches a depth of more than 10 feet cannot return to the surface by evaporation. If the whole of the excess of salt has also been removed to that depth then it is unlikely that any salt can come up to the surface on account of upward movement. In this connection it is necessary to refer once again to the experiments carried out at the Maharanjwala Experimental Station. After three years' cropping, the results of the various cropping systems had become apparent. A soil survey was carried out and patches of salts noticed at the soil surface were measured and marked on the map. A copy of this is reproduced in Figure 33. Photographs taken after three years' working of the farm are given in Figs. 34, 35, 36, 37 and 38.

From a study of the map (Figure 33) and the photographs, it would be realised that with the present duty of water the growth of crops like cotton, wheat and *senji* must lead to salt movement towards the surface.

WATER-TABLE AREAS

The growth of rice during the summer or berseem during the winter, with the normal amount of water now supplied for these crops, either depresses the zone of salt accumulation or checks its rise towards the surface.

Providing rice is grown in the initial stage of development to depress the zone of salt accumulation then cotton, wheat and *senji* can follow rice without causing the upward movement of salts.

With the low supplies of water in the rivers during the winter season, the growth of berseem on a large scale is not feasible. The only practical method for the control of salt movement, therefore, is leaching and the growth of rice during the summer.

Absence of salt in plots which were leached and which had carried rice situated adjacent to other small fields in which salts had appeared showed that all movements were vertical and that there was very little salt movement horizontally.

Fields 4 and 5 after reclamation were put under a normal rotation of crops on normal water supply. Observations showed that no deterioration on account of salt movement had taken place till 1947, i.e., a period of seven years.

Under the direction of Dr. McKenzie Taylor, Mr. Jesson, Superintending Engineer, Lower Jhelum Canal, started a reclamation experiment in 1931. The whole of this land was reclaimed in 1933 and the special water supply was withdrawn. The land was given to tenants on lease with its normal supply of water supply from the *zamindari* water-course. Since 1935 rice has not been sown.

From yields of crops and the analyses of soil samples it is concluded that there is no decline in yields of crops nor is there any tendency for salts to appear at the soil surface at least for a period of 12 years after reclamation. A photograph of cotton sown in reclaimed land is shown in Figure 39.

The reclaimed land is situated in an area where the water-table is consistently on the rise. In 1947, the water-table had reached a height which was 8 feet below the natural surface. The fact that no deterioration had taken place and no upward movement of salt was noticed indicates that even in a high water-table area where the salt content of the water is high there is little likelihood of salts rising to the soil surface under normal cultivation and normal irrigation.

Other illustrations of crops sown in reclaimed land are shown in Figures 40 and 41.

Nitrogen Deficiency

On account of continuous leaching and the growth of rice during the reclamation period the available nitrogen in the soil is reduced considerably. In order to set right the nitrogen balance of the soil a leguminous crop is invariably sown after rice. If winter water supply is available in sufficient quantity then the best crop to follow rice is berseem (*Trifolium Alexandrinum*). If, however, the water available during the winter is insufficient for maturing a berseem crop *senji* (*Melilotus parviflora*) can be sown. In case winter water-supply cannot be arranged, then gram is sown after rice. This matures on water stored in the soil profile, during leaching and the growth of rice, and almost always gives a good yield. The introduction of a leguminous crop after rice each reclamation season helps in keeping up the yields of crops in a normal rotation on normal water supply following reclamation.

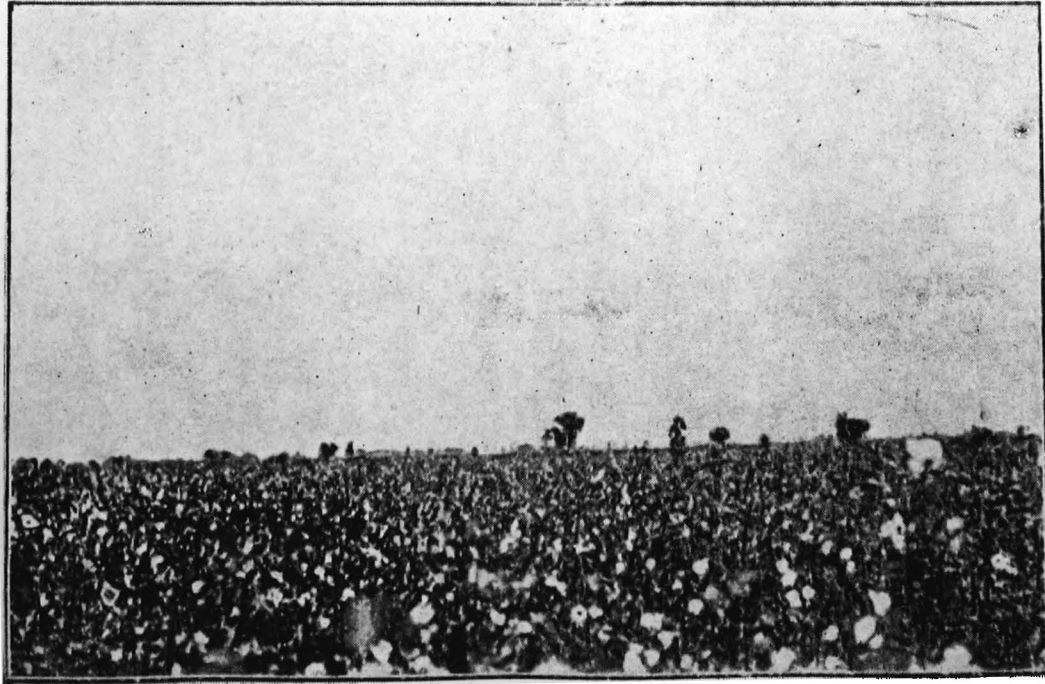


Figure 39.



Figure 40.

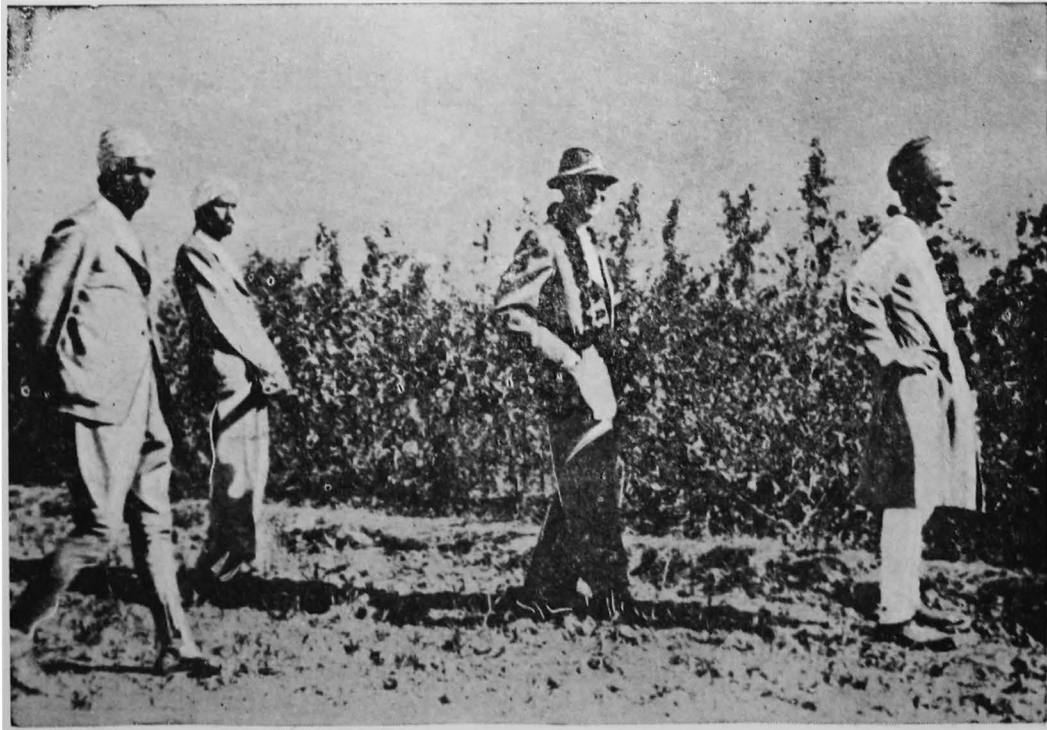


Figure 41.

CHAPTER 10

Reclamation of Salt and Alkali Land in High Water-table areas

The first requisite in dealing with a high water-table area is drainage.

The method of reclamation is essentially the same as described in Chapter 9, *viz.*, leaching, growth of rice and a leguminous crop following rice. The difference is that, in the case of a high water-table area, a smaller depth of soil is to be leached and consequently the period of leaching is reduced.

The number and the intensity of drains required for the de-watering of a high water-table area depends upon the type of soil and the monsoon rainfall. For the average Punjab alluvial soil the most suitable system is shown in Figures 42 and 43. The distance

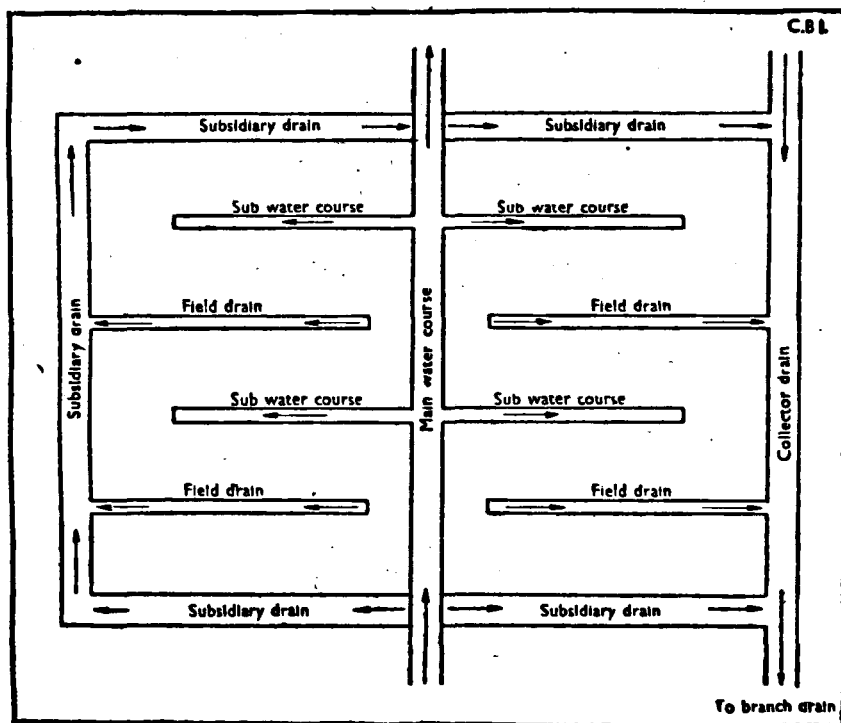


Figure 42.

between successive field drains is varied according to the soil type. If the soil is light then field drains are constructed approximately 200 feet apart (acre lines); if however, soil is relatively heavy then they should be placed at 110 to 120 feet distances.

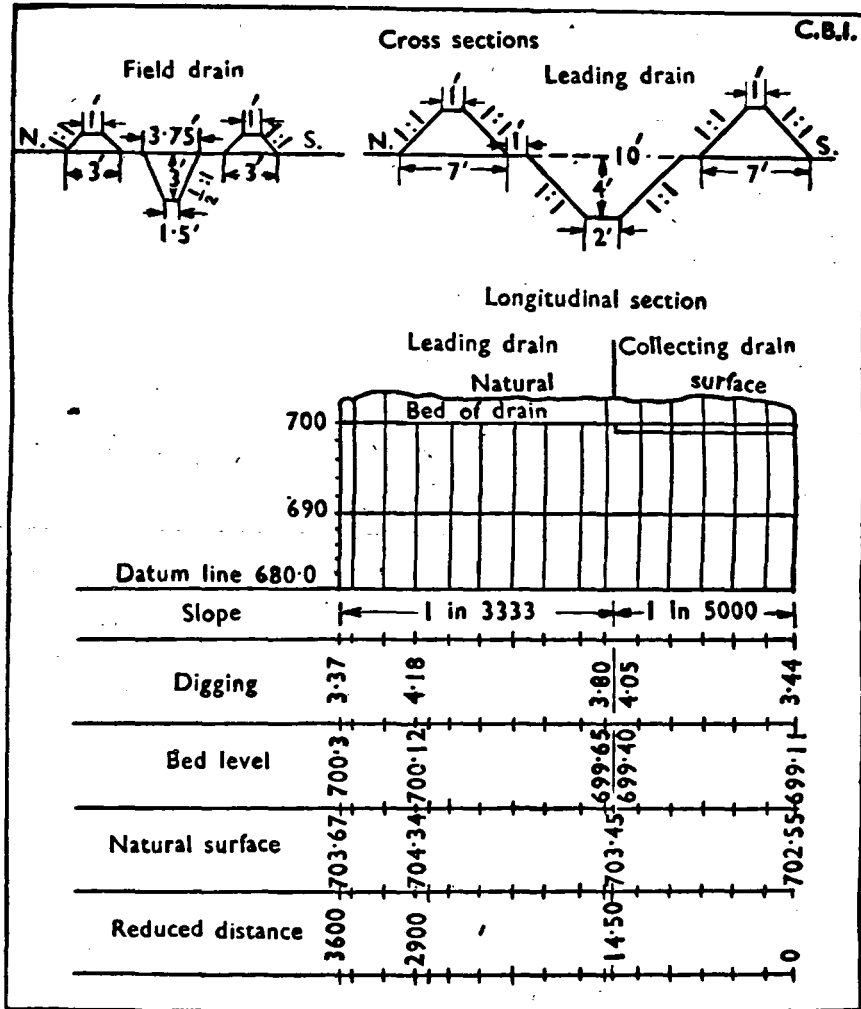


Figure 43.—Chakanwali Reclamation Farm—typical sections of drains

The main water course runs across the field in the centre. From the main water-course, small channels are taken along the length of each sub-plot so that each individual field is provided with water direct from the water-course. The field drains are located perpendicular to the main water course and run along the plots. These empty themselves into the leading or the collecting drain which ultimately joins the main drain.

The drainage system proposed does not help in lowering the water-table to any appreciable extent except when the water is right at the surface. This is not even expected, considering that the depth of

field drains does not exceed three feet. What it does is that the sub-soil water is kept in motion. That way plant roots are able to get all the oxygen they need. In a stagnant water-table, however, there is accumulation of carbon-dioxide and other gases and the plant either dies or gives reduced yield.

For reclamation of large tracts the standards laid by the Land Reclamation Board are :—

- (i) Areas in which free water exists should be drained when these lands would pass into class (ii) below ;
- (ii) Areas where the water-table is within six feet of the surface should be provided with seepage drains or tube wells, after which reclamation might proceed ;
- (iii) In areas where the water-table is between 6 and 10 feet land reclamation should proceed, but the water to be used for reclamation in such areas should be restricted ;
- (iv) No restriction should be placed regarding reclamation of *thur* areas in which the water-table is more than 10 feet from the natural surface.

The experimental work carried out at Chakanwali Reclamation Farm gave conclusive evidence that, in a high water-table area, if the drainage system is maintained then there is no difficulty in raising crops like rice, sugarcane, cotton and wheat. The yields obtained are above normal. Amongst fruit trees *guavas*, *phalsa*, grapes and mangoes are particularly successful. Vegetables were almost all successful.

The second important conclusion reached was that, if the standard of irrigation-agriculture is to be maintained then for canal colonies areas two alternatives are possible :—

- (a) On account of the consistent rise in water-table a stage would be reached when the water-table in whole *doabs* would be near the surface ; an extensive drainage system like that designed at Chakanwali would be required and the country and the farmer should be trained in the art of cultivation of high water-table areas and the maintenance of the drainage system. That this is a practical proposition is shown by the fact, that, at Chakanwali, a large area was worked through a system of tenancy ; the tenants being responsible for maintaining the field and the collector drains. The branch and the main drains are maintained by Government.

Costing accounts have been maintained. These show that if labour is employed on wages the construction of the field and collector drains costs a farmer Rs. 6 per acre and their maintenance not more than Rs. 2 at pre-war rates. When wages are high the costs are Rs. 17 and Rs. 4 respectively. It must be remembered that the Punjab farmer seldom employs labour on payment. The labour provided by the family is sufficient to do the whole of the earthwork involved in the digging of drains and also their maintenance.

- (b) That means should be adopted not only to prevent a further rise of water-table but also to lower it to a depth below the pellicular zone. A special Sub-Committee appointed by the Waterlogging Conference considered this question in detail and estimated that for a particular area of 5.7 million acres, 3,600 cusec of water should be pumped from the sub-soil if the water-table is to be stabilized. If, however, it is to be lowered to a depth below the pellicular zone, extra pumping would be required. They worked out that the pumping of such enormous quantities would cost Rs. 315 lakh capital and Rs. 75.5 lakh running expenditure; which distributed over the area amounts to Rs. 5.14, capital, and Rs. 1.23 running expenses per acre.

Fears have been expressed that, in high water-table areas, the liberal allowances of water for land reclamation would tend to further raise the water-table and thus bring about waterlogging and accelerate the formation of *thur*. It was, however, in such areas that *thur* formation was at its worst and reclamation was badly needed.

In order to obtain data on this important subject two reclamation areas were kept under observation. At Renala Estate, district Montgomery, observation pipes were installed both in high land and the depression area. A third pipe was installed at the deepest point in the trough. The results obtained showed that, both in high land and the

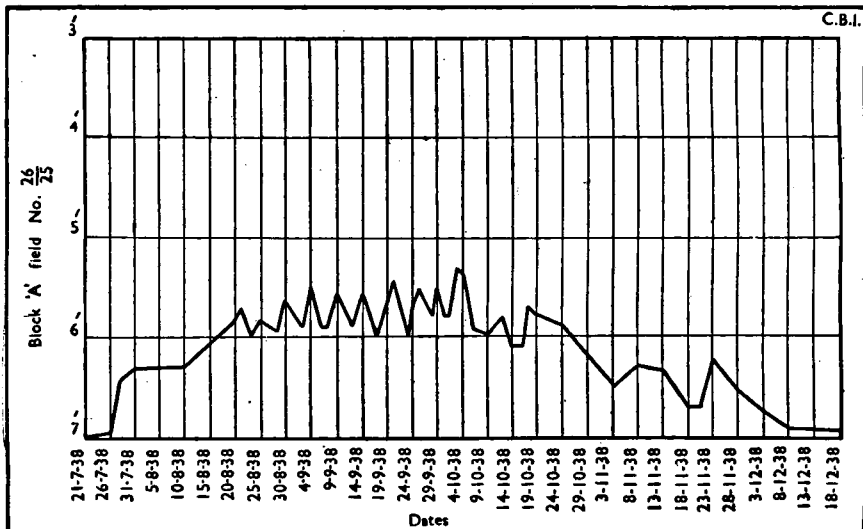


Figure 44.—Showing depths of sub-soil water levels in plots under reclamation at Renala.

depression where reclamation was in progress, a local rise in the water level took place during leaching and the growth of rice. When irrigation was stopped and the rice harvested the water level fell to its original level. The permanent rise that took place was equivalent to the annual rise in the whole of the tract. The fluctuations in the levels of the depression area are shown in Fig. 44.

Observations of the third pipe in the lowest part of the trough showed that the water-level in the pipe was not affected by leaching the neighbouring *thur* land or the land on the high level.

Sarup Singh, Superintending Engineer, Ferozepur Canal Circle, initiated careful observations of well levels in the area under reclamation, the adjoining area carrying normal crops on normal water-supply and the un-irrigated and un-cultivated area further away. He found that, after rice was harvested, the net rise in the water-table was the same in all the three areas. This was equivalent to the general rise of the water-table of the entire tract.

Haigh (notes in office files) examined this question exhaustively. He estimated the effect of a rise in level of the water-table on *thur* formation and compared it with the rate of reclamation. According to his calculations the maximum increase in *thur* formation due to the additional rise in water-table on account of land reclamation in the Rechna Doab should not exceed 5 per cent. of the area going out of cultivation at present. This is equivalent to 660 acres only. Against this, the amount of water available for land reclamation brings back to cultivation a very much larger area. The balance of advantage, therefore, lies strongly in favour of continuing reclamation in high water-table areas.

Permanency of reclamation

The question of the permanency of reclamation from salt and alkali, rises once again. To answer this question, reference must once more be made to the experiments narrated in Chapter 6 dealing with the movement of moisture and salts in the soil profile. The particular experiment that needs to be studied in greater detail with reference to reclamation in high water-table areas is the one carried out in a glass tube filled with sand saturated with water and allowed to drain, so that the column came to field capacity. The conclusion reached is that a rapid rise of the coloured water occurred in the dry sand column but there was no tendency for the coloured water to enter the sand column at field capacity though there was a small amount of diffusion of the dye into the base of the sand column in this tube. If the tube with a column of sand at field capacity, in which some red

dye (i.e., salt) has risen at its base on account of diffusion, is raised, and a drop of water is added at the top of the tube a drop of red liquid will almost instantaneously fall from its bottom. From this the conclusion is that, if after reclamation, land on a high water-level is kept under cultivation and irrigation, then every bit of rainfall or irrigation will depress the salt zone back again to the water-table.

Summarising, if a zone of soil at field moisture capacity exists between the surface of the soil and the water-table, then there is no tendency for the water from the water-table to rise into the soil column and every time there is rainfall or irrigation any little salt water that may have entered the soil column will be depressed back almost instantaneously. These conclusions go to show that, under careful management, land reclamation on a high water-table is also permanent.

An example of permanency of reclamation is afforded by the Chakanwali Reclamation Farm (Figure 45). Plots A/1, G/1, H/1, Q

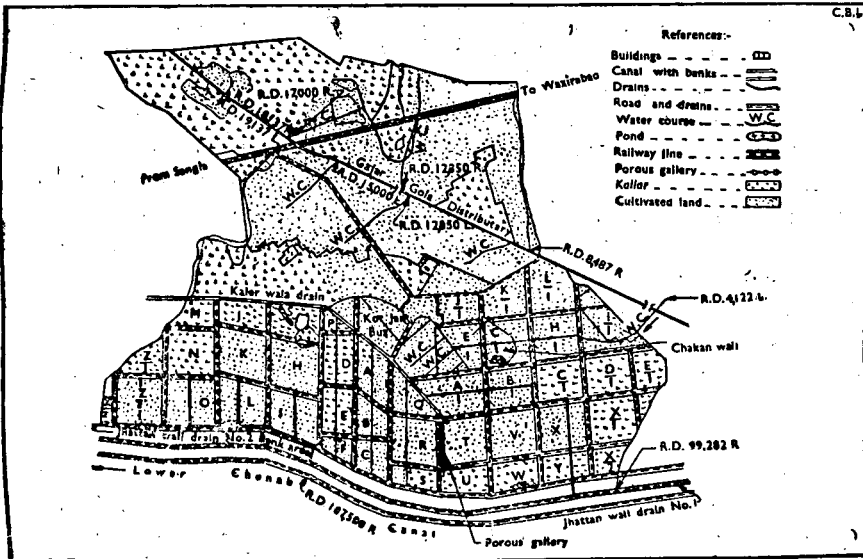


Figure 45.—Chakanwali Reclamation Farm.

and S are representative of salt and alkali land. These plots were reclaimed in 1931-32. Between 1932 and 1935 they carried crops of sugarcane, cotton, wheat, *senji*, berseem and chillies. The yields of these crops during this period indicated that the reclaimed land might be considered first class. In 1935, the farm was handed over to a lessee. At the time of handing over, the drains were maintained and, as a result, even when the canal was running full supply, the water-table was situated at a depth of $1\frac{1}{2}$ to three feet below the soil



The condition of thur land and crops growing on it after reclamation

surface. In 1938, when the farm was still with the lessee a soil survey was undertaken. The results of analyses are given in Table IX.

TABLE IX
Name of village—Chakanwali Reclamation Farm

Description of sample	Depth	Total soluble salts December, 1938	pH December 1938
A/1 Sub-plot 19, Field No. 3	0"—7"	0.10	8.20
Do	7"—14"	0.08	8.01
Do.	14"—29"	0.06	7.86
Do.	29"—36"	0.07	7.69
A/1 Sub plot 27, Field No. 1	0"—5"	0.29	8.78
Do.	5"—15"	0.11	8.49
Do.	15"—24"	0.09	7.67
Do.	24"—30"	0.04	7.38
G/1 Sub-plot 10, Field No. 1	0"—7"	0.05	7.93
Do.	7"—16"	0.04	8.18
Do.	16"—22"	0.05	8.02
Do.	22"—33½"	0.02	8.11
H/1 Su plot 19, Field No. 1	0"—5"	0.09	7.16
Do.	5"—10"	0.11	7.75
Do.	10"—21"	0.14	8.02
Do.	21"—29"	0.14	8.46
Do.	29"—35"	0.15	8.55
H/1 Sub-plot 19, Field No. 4	0"—5"	0.16	8.21
Do.	5"—9"	0.18	8.78
Do.	9"—15"	0.19	8.73
Do.	15"—31"	0.19	8.56
S. Sub-plot 1	0"—8"	0.10	7.17
Do.	8"—12"	0.10	7.05
Do.	12"—24"	0.09	7.39
Q. Sub-plot 9, Field No. 1	0"—4"	0.08	7.71

TABLE IX—contd.
Name of village—Chakanwali Reclamation Farm

Description of sample	Depth	Total soluble salts December, 1938	pH December 1938
Q. Sub-plot 9, Field No. 1	4"—8"	0.12	7.88
Do.	8"—17"	0.09	7.63
Do.	17"—25"	0.07	7.18
L. Sub-plot 10, Field No. 1	0"—4"	0.07	7.30
Do.	4"—9"	0.10	7.30
Do.	9"—17"	0.11	7.26
Do.	17"—21"	0.11	7.10

The analyses show that no deterioration had taken place and, if the drainage system were maintained, the reclaimed land was in a condition to produce excellent crops.

The waters of all drains that have been constructed for the de-watering and reclamation of high water-table areas have been continuously examined. The results of analyses show that :—

1. In the Rechna Doab the salt content of waters of the gravity drains is less than 60 parts per 100,000.
2. In the Chaj Doab all gravity drains in southern portion of the doab carry waters whose salt content is less than 60 parts per 100,000. While in the northern half of the doab of which notable examples are the 'Mona Drain', the 'Bhek Drain' and the 'Lower Raniwah Drain' the salt content is always higher than 60 parts per 100,000. In the 'Bhek' and the 'Lower Raniwah systems' the salt content has risen from 240 to 350 parts per 100,000.

In the Rechna Doab and the lower portion of the Chaj Doab there is little likelihood of salt being added to the ground surface from the water-table. Under these conditions no deterioration can be expected during or after reclamation. In the case of the northern portion of the Chaj Doab the salt contents of the sub-soil waters are very high and to keep land permanently reclaimed the management should be more careful and efficient. Reclaimed land on a high water-table should, as a rule, be given very little rest. What is required is intensive cropping, intensive irrigation, intensive manuring and a very efficient supervision.

CHAPTER 11

Execution and Financing of Land Reclamation

Before we begin to consider ways and means of executing land reclamation in the field it is necessary to realise two aspects of irrigation-farming. The first aspect is that a measured quantity of canal water supply proportional to the culturable commanded area of a *chak* is delivered at the outlet head. This water is then distributed over the area by means of a system of turns called '*Warabandi*', which is decided upon by the shareholders of water in that outlet and which is sanctioned by the Divisional Engineer. The addition of extra water for fields under reclamation necessitates the framing of new '*Warabandis*' and as *thur* areas are never in proportion to the holdings of individual shareholders difficulties are encountered in framing such *warabandis* and enforcing them in the field.

From the normal discharge of the outlet and the area of the holdings on that outlet the amount of water that each individual field receives is calculated. Similarly, with the increased discharge on account of the addition of the reclamation supply, the time required to give normal irrigation to undeteriorated fields can again be calculated. To this is added the time, required for irrigating fields under reclamation in each holding. *Wari* for each holding is thus fixed by adding the time for normal irrigation and that for fields selected for reclamation.

In most canal colonies '*Warabandi*' is of 10-15 days duration. To make leaching more effective and to facilitate growth of rice the *wari* is reduced to a seven day or preferably a 5-day period. This does involve a little more management of the '*Warabandi*' and some extra labour for each individual farmer or a tenant but, if this is not done, irrigation applied to *thur* fields is not sufficient to continue the downward movement of the salt in the soil profile nor does it enable a rice crop to be matured, thus defeating the very object of reclamation.

An easy method of calculating reclamation *warabandis* as devised by Dr. Malhotra is given below :—

Let the number of days in the <i>Wari</i> be	..	N (here 5)	
Let Culturable Commanded Area (C.C.A.) be	..	A acres with full supply factor f	
Let <i>Thur</i> Area selected for reclamation be	..	T acres with full supply factor t	
		$1,440 N$	
Then the <i>Wari</i> for C.C.A., Wt	= $\frac{1,440 N}{A (f/t) T}$ minutes per acre
		$1,440 N$	
Therefore the <i>Wari</i> for <i>thur</i> Wt	= $\frac{1,440 N}{T (t/f) A}$ minutes per acre

A sample *Warabandi* is reproduced below :—

**Reclamation Warabandi of outlet at R.D. 18154-L Munak Distributary,
Karnal Division, Western Jumna Canal.**

Culturable Commanded Area 247 acres.	Normal full supply factor 350 acres.	Normal Discharge 0.71 cusec.	Normal <i>Wari</i> 12.05 Minutes per acre.
Reclamation area 45 acres.	Reclamation full supply factor 45 acres.	Reclamation Discharge 1.0 cusec.	<i>Thur</i> 93.72 minutes per <i>Wari</i> acre.

Village Sataundi, Tehsil and District Karnal

S. No.	Name of share holder	C.C.A. in acres	Thur area in acres	Normal wari	Thur wari	Total wari
				Hrs. M.	Hrs. M.	Hrs. M.
1	Lakhi s/o Net Ram ..	36.95	7.20	7 25	11 15	18 40
2	Shanker s/o Kundan ..	18.00	3.00	3 37	4 41	8 18
3	Ganga s/o Kulu ..	2.22	1.05	0 29	1 38	2 7
4	Lakhi s/o Karta ..	5.87	1.22	1 11	1 54	3 5
5	Singh Ram s/o Nihala ..	50.40	8.87	10 7	13 51	23 58
6	Mst. Mukhtari s/o Risala	17.88	3.20	3 35	5 0	8 35
7	Sewa Singh s/o Chuharya	2.61	0.57	0 31	0 53	1 24
8	Mam Raj s/o Partapa ..	8.64	1.75	1 44	2 44	4 28
9	Sundra s/o Matu ..	42.15	7.37	8 28	11 31	19 59
10	Singh Ram s/o Sada Ram	42.00	6.98	8 26	10 54	19 20
11	Sadhu s/o Sher Singh ...	9.24	1.92	1 51	3 0	4 51
12	Asa Ram s/o Phool Singh	4.56	0.89	0 55	1 23	2 18
13	Ramji Lal s/o Phool Singh	4.40	1.02	0 53	1 36	2 29
14	Rohla s/o Makhan ..	2.31	..	0 28	..	0 28
Total for the outlet ..		247.23	45.04	49 40	70 20	120 0

Where land reclamation is first introduced and zamindars are new to this technique, there is a general tendency on behalf of zamindars and tenants to utilise the reclamation water-supply in improving the yields of their normal crops in their adjoining apparently undeteriorated fields.

To ensure success, special land reclamation staff have to be employed to select *thur* areas as far as possible in proportion to the total of holdings, frame reclamation *warabandis*, sanction such *warabandis* and record each irrigation so that the extra water allotted for land reclamation is utilised in fields selected for the purpose. Water meant for reclamation and not used for this object is classed 'Misuse' and is punishable under the Canal Act. The staff also guide and help the *zamindars* in procuring the right type of rice seed, raising rice nurseries, leaching, preparation of fields for rice and the sowing of a leguminous crop after rice. They take samples from fields under reclamation for examination in the laboratory. This helps in assessing the stage of reclamation and framing programmes for the following year.

The second aspect is that a majority of the land-owners in West Punjab employ tenants at will for the cultivation of their lands. These tenants are engaged on a yearly basis; the tenancy to be renewed each year. Instead of a cash rent the produce is divided on a share basis with the tenants; the usual terms of division of produce being $\frac{1}{2}$ landlord and $\frac{1}{2}$ tenant. Land revenue is paid by the landlord; charges for canal water are shared half and half between the tenant and the landlord. From this it is apparent the tenant would more welcome a good piece of land than an inferior type—much less salt affected.

It has been experienced that landlords, having agreed to undertake land reclamation, have been allotted reclamation water-supplies. At the time of actual working, however, the fields selected for reclamation are divided amongst a large number of tenants who naturally take to this under compulsion because they think their labour is not going to be rewarded in full. Instances are available where, on extremely deteriorated land, yield of rice in the first year has been much below normal and yet the landlord divided the produce half and half just as if it was cultivation of normal land.

In such cases, the absentee landlord leaves the land reclamation staff in the hands of a large number of tenants who are not anxious to put in their best in the work. More difficulties are thus created in accomplishing land reclamation. This is a further reason for employing adequate land reclamation staff to deal with tenants and all matters that arise during reclamation.

From several years' experience a schedule of staff required has been prepared. This schedule and the duties assigned to each member of the staff are given in Appendix I.

The best reclamation is almost always done by big landlords who obtain reclamation water supplies on a contract basis. In such cases, it is always possible to select compact blocks of *thur* land for reclamation. Thus there is no interference between reclamation water-supply and that allotted for normal cropping. Besides rates for contract water supply are much higher than those levied on crop basis. As such *zamindars* have no tendency to use more expensive water for irrigating their normal crops which are also separately assessed to water rates.

From what has been described, land reclamation involves a *thur* and *sem girdawari*, a soil survey to assess the stage of deterioration, selection of fields for land reclamation, provision of extra water for land reclamation from head to tail of the canal system, raising of banks and construction of other engineering works, remodelling of outlets, installation of extra shoots and possibly digging of new water-courses, framing of new *warabandis* and also their working in the field, recording of field irrigation, prevention of misuse of water and finally assessing the stage of reclamation by examination of soil samples in the laboratory. All this is a long process and can successfully be accomplished if it is planned well. The following time-table

has been prescribed. This time-table relates to the scheme of reclamation which has to be under operation in the year 1953 :—

January 1951

Submit to the Chief Engineer, reclamation programme for the Circle, stating supplies to be utilised each year.

August 1951

Sanction by the Government to the supplies to be used for reclamation.

September 1951

Hydraulic survey of channels.

<i>December 1951</i>	}	Checking of <i>Thur Girdawari</i> on cent. per cent. basis and analysis of soil samples of new areas.
<i>January 1952</i>		
<i>February 1952</i>		

<i>March 1952</i>	}	Preparation of a tentative remodelling cum-reclamation scheme and obtaining Superintending Engineer's approval subject to modification on the result of reclamation in <i>Kharif 1952</i> and of soil sampling.
<i>April 1952</i>		

May 1952

(a) Announce to the zamindars tentative proposals and invite applications and ask them to prepare fields before the end of *Kharif*.

(b) Prepare estimate for earthwork.

June 1952

Discuss in canal advisory committee meeting and obtain views of the Deputy Commissioners.

Note.—In the event of disagreement between Executive Engineer and Deputy Commissioner or Canal Advisory Committee the case should be dealt with by Superintending Engineer during his monsoon tour in August.

August 1952

Submit budget for reclamation.

September 1952

Get water line in the last years hydraulic survey checked.

October 1952 and November 1952

Executive Engineer and Land Reclamation Officer to get ready the final scheme and submit the same to Superintending Engineer. Sanction of the scheme by Superintending Engineer.

December 1952 and January 1953

Estimates to be got ready and sanctioned.

February and March 1953

(a) Collection of materials.

(b) Preparation and sanctioning of *warabandis*.

April 1953

(a) Outlets and masonry works to be remodelled.

(b) Pipes to be fixed.

Financing

For all land reclamation schemes which have been in operation from 1940 to 1945 careful costing accounts have been maintained for all types of estates, viz. :—

- (a) when reclamation is undertaken by land owners who are also the tillers of soil and the land has recently deteriorated.
- (b) when land as in (a) is put under reclamation with the help of tenants at will.
- (c) when land is reclaimed by a landlord in a compact block on a contract supply of water.

These accounts show that reclamation under conditions (a), (b) and (c) leaves a profit even in the first year to tenants, landlords and also to Government. The government provides the extra water which brings revenue in the form of water-rate, and land revenue; otherwise this extra water is never let into the canal. It goes into the sea.

From 1941-42 to 1947, all land reclamation budgets were prepared as self-paying propositions. All expenditure on establishments, construction of special engineering works and installation of extra shoots was balanced against income on account of water-rate and land revenue from fields under reclamation.

When, however, reclamation of the extremely deteriorated types, e.g., *Bara* lands of Lower Bari Doab Canal, '*Chitdain*' areas of Mailsi Canal and the *Rakkar* areas of Haveli and Rangpur Canals and also the extremely deteriorated type in the head reaches of the Upper Chenab and Lower Chenab Canals was undertaken, it certainly required a certain amount of capital to be invested in the first instance. Full income is not expected in the first year. On that account, for the development of this type of land in the newer canal colonies, the government introduced a system of leases. The conditions on which leases were sanctioned are given in Appendix II.

CHAPTER 12

Land Reclamation Legislation

A careful study of the Chapter dealing with the formation of salt lands indicates that, left to their own talent and resources the rural community has been unable to protect the soil against natural forces which tend to deteriorate land. In the search for higher immediate returns the *zamindars* have been cultivating larger areas on the same water supply. If this continues unabated the entire tract will be abandoned to future sterility.

Therefore, for the protection of the soil and bringing it in condition for higher forms of farming, government help is essential. To be effective, this help from government is to be carried out under a co-ordinated plan of activities.

The details of engineering works to be executed in connection with land reclamation, the number of operations that have to be carried out strictly according to time-table and the fact that some lazy and obstinate shareholders can impede reclamation measures necessitate some sort of legislation.

In 1946, the Waterlogging Conference appointed a sub-committee to consider what sort of legislation was required. The draft legislation suggested by this sub-committee is given below. It seemed to the sub-committee that a separate legislative measure dealing with control of land reclamation would appear clumsy. They recommended that the clauses of such a measure should be incorporated in the Canal Act. Land reclamation is an irrigation subject and, if a separate act were enacted, various provisions of the Canal and Drainage Act would have to be repeated in the new act. The suggested clauses of the draft legislation are :—

- A. Whenever it appears expedient to the Provincial Government that general land reclamation is necessary to be carried out in a certain area, it may, by a notification published in the official gazette declare that such area is under a land reclamation scheme.
- B. The Provincial Government shall decide the process under which land reclamation of the area is to be carried out and frame rules for carrying out the said process of land reclamation. Such rules may provide for the Provincial Government or Canal Officer, duly authorised to order :—
 - (i) improvement, alteration, extension or curtailment of any water course.
 - (ii) amalgamation or separation of any irrigation *chak*.
 - (iii) transfer of any area from one source of irrigation to another.

- (iv) temporary increase or decrease of water allowance to any area or total curtailment of water supply.
 - (v) alteration, amendment or cancellation of any order already in force regarding the distribution of water on any watercourse or the issue of a fresh order superseding any existing order or mutual arrangements.
 - (vi) prohibition of the growing of any crops or laying down any specific crop rotation.
 - (vii) application of any type and quantity of manure, whether green, artificial or farm-yard.
 - (viii) construction of any field drainage works.
- C. On the publication of such rules and the sanctioned process of land reclamation the Divisional Canal Officer/Land Reclamation Officer shall issue notice to the owners of land of the villages affected fixing a date not earlier than 15 days from the date thereof, and place, when and where, he proposes to take a land reclamation scheme agreement for that village.
- D. On the date so fixed, the Divisional Canal Officer/Land Reclamation Officer shall explain the rules and the process of land reclamation to the land owners in that village. If the majority of the land owners give their consent to the conditions as set forth and the proposal be accepted by the Provincial Government or a Canal Officer specially authorised on this behalf by the Provincial Government, the agreement shall be considered binding on all the owners of land of that village.
- E. On the acceptance of the agreement, the Divisional Canal Officer/Land Reclamation Officer shall prepare a detailed scheme for the reclamation of the area in the village and publish the scheme for general information of the land owners concerned.
- F. Within 30 days from the publication of the notice under Section E, any person interested in the land or watercourse to which the notice refers, may apply to the D.C.O./L.R.O. by petition, stating his objection to the scheme or any part thereof.
- G. The D.C.O./L.R.O. may proceed to enquire into the validity of the objection, personally or through a Canal Officer subordinate to him, giving previous notice to the applicant and the persons interested of the place and time at which such enquiry will be held. The D.C.O./L.R.O. shall record in writing all orders passed by him, under this Section and the grounds thereof.
- H. Any land owner or persons interested may appeal within thirty days, against the order passed by the D.C.O./L.R.O. under Section G above, to the Superintending Canal Officer. The Superintending Canal Officer may order a

fresh enquiry to be made or may pass any order that he deems fit. The order passed by the Superintending Canal Officer shall be deemed to be final and the scheme as approved by him shall then come into operation.

- I. (i) All land owners or persons interested will be bound to carry out, within reasonable time, the orders issued, from time to time, by D.C.O./L.R.O. which are in accordance with the details of the scheme as approved *vide* Section H above. Any irrigation carried out or crops raised in contravention of the orders as issued will be deemed to be unauthorised irrigation.
- (ii) In cases of persistent default, the Provincial Government may order the Collector to take temporary possession of the area to carry out the process of reclamation through Government agency. When reclamation is completed, the land shall revert to the original owners and the Provincial Government may levy an acreage rate to recover the cost to it of the reclamation. Such rate, if not paid on due date, shall be recoverable as arrears of land revenue.
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CHAPTER 13

Role of Jantar in Land Reclamation

Jantar (*Sesbania Aculeata*) also known as *Dhaincha* is a small soft wooded plant of rapid growth. It belongs to the leguminosae family, plants of which are known to fix nitrogen from the atmosphere into the soil. Previously the plant has been used for providing temporary hedges in newly-built houses. Its use as green manure is only recent and the important part it plays in land reclamation is worthy of notice.

Jantar is introduced in the process of reclamation at two distinct stages :—

- (a) After a successful crop of rice, to reduce the residual alkalinity which develops in the soil as a result of the action of sodium salts and the clay during leaching and growth of rice.
- (b) As a first crop in land under reclamation where rice is not likely to give successful yields.

If *Jantar* is to be sown as a first crop in deteriorated land, a preliminary leaching before sowing is always helpful. When *jantar* is sown in the second year of reclamation the seed is broad-cast at the rate of 30 seers per acre. The only preparatory tillage required is one ploughing with a country plough. *Jantar* can stand a certain amount of salt and a fairly high degree of alkalinity in the soil. The seed germinates within a week and when the plants are three to four inches high first watering should be given. Subsequent waterings can be as few as can be spared or as frequent as desired to depress the salt zone in the soil. *Jantar* can stand drought and heavy waterings. When the plants have attained the height of 4½ feet, a cutting should be taken and cut plants utilised for green manuring in an adjoining field. If reasonable care is taken of the crop it should be possible to take a second cutting of *jantar*. This can be similarly utilised for green manuring a second adjoining plot. After second cutting the crop is left to mature and form seed. *Jantar* thus gives a yield of 8 maunds per acre of grain and approximately 200 maunds of *jantar* sticks. Dried sticks are allowed to soak in water for a few days when it becomes possible to peel off fibre from the stick. This fibre is used for making ropes, sacks, carpets etc. The residual sticks are used either in making *chhappars* or as fuel. At Chakanwali Reclamation Farm it is noticed, that, after the harvesting of *jantar*, considerable quantities of cow-dung are released by tenants to be added to the manure heap.

A series of experiments have been in progress both in the field and the laboratory to investigate the changes that take place during the disintegration of *jantar* stalks and leaves when used as green manure. Observations indicate that :—

- (a) Considerable quantities of gases are evolved. Of these carbon dioxide is one. This helps in reducing soil alkalinity.

- (b) Under certain conditions evidence of generation of sulphuretted hydrogen (H_2S) is obtained. Sulphuretted hydrogen is a strong agent for developing an acid medium which again is helpful in bringing the alkaline soil to more congenial conditions for plant growth.
- (c) Water extracts of *jantar* leaves taken after varying periods of disintegration have indicated an acid solution of the strength of as much as N/50. This gives an assurance of restoring the pH values of the soil to that considered normal.

When the experiments now being conducted have progressed further it is considered it will be possible to place the process of land reclamation on a sounder footing than hitherto.

In terms of money, cultivation of *jantar* can be depicted in the following manner :—

S. No.	Portion of the crop	Value	Remarks
1	Two hundred <i>maunds</i> of green crop as a first cutting to be used as green manure.	Rs. 25	} In the Thal it finds a ready sale for goats and sheep to graze. It has been possible to sell green crop at Rs. 50 per acre per cutting.
2	Two hundred <i>maunds</i> of green crop as a second cutting to be used as green manure.	25	
3	Eight <i>maunds</i> of <i>Jantar</i> seed at Rs. 10 per <i>maund</i> .	80	<i>Jantar</i> seed is at present in great demand.
4	Fifteen <i>maunds</i> of <i>Jantar</i> fibre at say Rs. 10 per <i>maund</i> .	150	<i>Jantar</i> fibre makes very good ropes, sacks and carpets which find a ready sale in the market.
5	Two hundred <i>maunds</i> fuel at say annas four a <i>maund</i> in the village.	50	
	Total value of an acre of <i>jantar</i> crop ..	330	

The search for substitute fibres to replace jute has been intensively pursued in many countries. With the partition of India and the allotment of that part of the Ganges-Brahmaputra delta area suitable for jute production to Pakistan, the necessity for this search has increased considerably. There are large tracts of water-logged land which, after drainage is provided, would present that combination of factors which make jute cultivation successful. It is worth while trying cultivation of jute in these areas. But considering that *jantar*,

- (a) grows in all types of soil, sandy, clayey, salt and alkali lands ;
- (b) can stand drought as well as waterlogging,
- (c) grows to almost the same height as jute ;
- (d) gives fibre which, if handled the same way as jute, would be as good for making ropes, bags, sacks, carpets, linoleum, webbing etc ;
- (e) can be produced cheap ;

the possibility of its extensive cultivation and manufacturing *jantar* commodities should be investigated at an early date.

The basic source of all plant nutrients is humus, the immediately usable supply of which is concentrated in the 18-inch surface crust of the earth and in the more favoured and very limited areas of the globe. In the better soils the quantity of humus diminishes almost to vanishing point at a depth of 36 inches. In the semi-arid tracts of the Punjab even winter temperatures are high enough to burn or destroy the little humus that is formed as a result of disintegration of all vegetation, in fact, all life. It must also be remembered that the majority of the fields selected for reclamation remain out of cultivation for sometime. Thus they are devoid of even the little humus that is likely to be contained in a cultivated field. Partly, on account of the absence of initial humus and partly because of the residual alkalinity that persists after the excess of salts have been washed down, reclaimed fields stand in need of greater quantities of humus as compared with adjoining undeteriorated land.

Experiments were started in 1944-45 to investigate the effect of a modified method of green manuring. Quantities of green *jantar* were placed in reclaimed fields at a depth of about 18 inches from the natural surface. The earth removed from the field was placed back. Subsequent to the burying in of green *jantar* land was given all preparatory tillage for sowing of wheat. These experiments were repeated in different parts of the Province. The results obtained showed that the yield of wheat in plots thus treated was almost twice that obtained where green manuring was done in the normal manner and three times that where no green manure was added. This increase in yield was maintained in the second year in cotton and the following crop of wheat. Observations also showed that the majority of the green *jantar* was intact at the lower depths whereas that ploughed in and buried in the top soil had almost vanished. It was considered that the increased benefit resulting from this operation would last a number of years.

On account of the increased volume of carbon dioxide generated during the decomposition of the green manure the reduction in soil alkalinity was proceeding at a more rapid rate.

One other plant which is likely to play an equally important part in land reclamation is '*Panwar*' (*Cassia Tora*). This is a leguminous weed very common all over the area in Karnal district, by road sides and in waste ground, along watercourses and other irrigation channels. It starts growing during the rains and flowers within a period of six to eight weeks. It is an annual usually reaching a height of three to four feet. If domesticated and cultivated under care, it is likely to attain a greater height.

The leaves, seeds and roots are used medicinally; the tender leaves are boiled and used as a port-herb.

A very distinguishing feature is that the plant, through its roots, is able to fix nitrogen in soils whose pH value is as high as 10.0 and where free Sodium Carbonate is present in salt-efflorescence.

Experiments are now in progress to determine the efficacy of this plant in reducing alkalinity and increasing the humus content of the soil.

CHAPTER 14

The Problem of Tirak

'*Tirak*' is the bad opening of bolls in American cotton.

This disease appears off and on in canal colony areas and in its worst form in low rainfall years. The remedies suggested are the application of nitrogenous manures and the late sowing of cotton.

During *Kharif* 1940, there was a severe attack of *tirak* in the Lower Bari and the Nili Bar colonies and in one sub-tehsil (Chichawatni), alone Government had to sanction a remission of Rs. 45,000 in land revenue. The description given by the district officers, who made the survey, showed a state of affairs comparable to the picture of a salt zone in the soil profile. This observation harmonised with the fact that, in the Renala Estate, cotton was not attacked by *tirak* in fields which had been reclaimed whereas *tirak* was present in cotton in adjoining undeteriorated land. It was decided that the removal of the salt-zone from the soil profile for the prevention of the *tirak* attack on American cotton should be further investigated.

For the investigation proposed, Government sanctioned an anti-*tirak* centre to be established in the Montgomery district. A survey of cotton fields in the Chichawatni area was carried out by the Executive Engineers and the local Civil Officers. Approximately 2,000 acres belonging to 600 *zamindars* were selected for treatment. A soil survey was undertaken by the Land Reclamation Department, and from the results of analyses it was known that, in all fields, the salt content was high at some depth of the profile within six feet of the natural surface.

Extra water on the basis of one cusec. for 50 acres was given and added to the existing water-courses and the *warabandis* reduced to five-day *waris*. As the experiment did not relate to reclamation of deteriorated land, but only to the depression of the salt zone in the soil profile, leaching was not started till May 15, when more water was available in the river. Rice was transplanted in the month of June. Gram followed rice. In *kharif* 1942, cotton was sown which was not attacked by *tirak*. Observations were continued in the following years and it was noticed that in the fields treated in 1941 *tirak* attack was particularly absent.

In a normal soil profile, where the salt content and alkalinity are normal to a depth of 10 feet, a zone of salt accumulation was placed at a depth within six feet. American cotton grown in this patch was attacked by *tirak* whereas cotton in the adjoining patch was free from this attack.

In experimental plots in reclaimed land *tirak* to American cotton was caused by the application of salt water.

These observations confirm the conclusion that *tirak* on American cotton and salt in the soil profile are closely associated. The explanation for this phenomenon is found in the simple process of osmosis. Cotton roots when they reach the salt bearing layer of soil, instead of drawing water and nutrient solution from the soil, have to part with some cell-sap which in return considerably reduces the vitality of the plant; hence the bad opening of bolls.

CHAPTER 15

Land Reclamation and Grow more Food

Does 4,000,000,000 acres seem like a lot of land? That is the world's farming area. It is only 11 per cent. of the land on the face of the earth. On this land must depend more than 2,000,000,000 people for their food and clothing. Millions of these people have never had enough to eat.

Considering Punjab as a whole, although the proportion of land to population is not much different, the thing to be remembered is that approximately three million acres are salt affected and the rate of deterioration is on the increase. Every acre reclaimed in the Punjab, therefore, is a distinct move towards 'Grow More Food'. If, for the sake of argument, it is supposed that all the three million acres are reclaimed, it means an addition of three *crore maunds* of food to the country annually.

It has been demonstrated that the presence of a zone of salt accumulation at some depth within the first ten feet of the profile can be responsible for depressing the yields of crops. At a very conservative estimate, if this decrease in yield is assessed at 10 per cent. of the normal yield, then the removal of this zone of accumulation from an area of 120 *lakhs* of acres would mean another increase of 120 *lakhs maunds* of produce.

In 'Grow More Food Campaigns' extra irrigation supplies are given during *kharif* to increase production. In the more developed canal colony areas, where intensity of irrigation has already reached the cent. per cent. limit, such supplies do not yield maximum benefit for increased water supply can only be utilised in giving more water to the existing crops. The increased yield obtained thus is only a fraction of what can be achieved, if this extra supply is utilised in bringing the adjoining *thur* area under reclamation.

In a normal rotation of crops a cusec. of water in *kharif* is hardly able to grow more than 60 to 70 acres of maize, *bajra* (*Pennisetum typhoideum*) or *jawar* (sorghum). Under a reclamation regime it becomes possible to mature approximately 45 acres of rice and 45 acres of gram on residual moisture after rice. Both rice and gram are staple food crops.

CHAPTER 16

Land Reclamation in Rural and Urban Economy

In canal colony areas receiving perennial irrigation, there are two main harvest seasons when the majority of the crop is taken to the market for sale. Amongst the *kharif* crops, the cash crop is cotton and from amongst the *rabi*, wheat. Even on the non-perennial canals of the Sutlej valley or other newer projects these two crops afford the maximum marketable produce.

It is stated in Chapter 2 that for cotton and other *kharif* crops, much smaller quantities of water are being used now than formerly and that this is a cause of the upward movement of the salt zone in the profile. It has also been shown that the presence of the salt zone within the root-zone of crops diminishes their yields. It is an admitted fact that the *zamindars* in some of the Canal Colony areas are not getting the same yields of crops as they used to do before or as they should. The main causes of this are :—

- (a) use of less irrigation water than previously,
- (b) presence of excess of salt in the root-zone of crops,
- (c) slow deterioration on account of the action of the sodium salt on the clay portion of the soil,

Instances have been quoted in Chapter 5 where some tracts have deteriorated to an extent varying from 10 per cent. upwards. This is, an index of the decrease in the wealth of the rural people that has taken place on account of land deterioration. In other words less produce goes to the market which in turn affects the economy of the town and, therefore, the country as a whole.

In market towns there are two busy seasons—the cotton season after the harvest of the *kharif* crops and the wheat season after the harvest of the *rabi* crops. The 'Cotton' season lasts from October to February and the 'Wheat' season from end of May to end of July. Labour of all-types is busy in these two seasons. During the slack period, a portion of the population move back to rural areas where also they do not find much employment.

With the introduction of land reclamation a third harvest i.e. rice was introduced and the *rabi* harvest was supplemented by the crop of gram which follows rice.

Careful accounts were maintained of a large number of holdings in which reclamation was proceeding. These accounts showed that not only were the *zamindars'* profits restored to the pre-deterioration period but in almost all cases they exceeded that level. This is not difficult to believe when it is considered that six to eight per cent. of each holding is brought under reclamation each year and that one acre under reclamation yields a normal crop of rice plus a normal crop of gram which thrives on the residual moisture after rice. This

is all additional income, as the *zamindar* still uses his normal water supply in his undeteriorated land. It is never difficult to notice if the *zamindars* or village as a whole are getting increased income. Better houses, better bullocks, increased expenses on marriages and paying arrears of land revenue are items which easily catch the eye. But instances are not uncommon when increased income led to increased use of liquor or even litigation.

Rice starts coming in the market in the beginning of September and continues till the month of February. Rice factories start working in the month of October and continue till the end of May. As the hulling of rice requires considerable handling, in spreading it daily for drying and collecting it in the evening and also for weighing, filling and carrying it from drying floor to the factory and the factory to the godown and to the retail shops and also to railway stations for export, the whole of the market labour gets continued employment instead of breaking off for the slack period. It has been noticed that one type of labour who did the drying, the spreading and the carting of rice in the market shifted back to the adjoining rural area to do the transplanting and the harvesting of rice in the field. Their condition had improved considerably. Quite a large number of them had settled in rural areas, had bought their own milch cattle and had also built houses.

Capitalists had invested money in putting up rice factories and handling rice products. These were a new feature, as rice was not a commodity received and dealt with in these towns before reclamation.

Instances were noticed, when a portion of this extra wealth gained by the cultivators was employed in purchasing such lands as were to be sold, of which a great part was naturally uncultivated. This had a tendency to raise prices of land and the standard of living in the villages.

Looking at this aspect of land reclamation from another angle it must be mentioned that, in the absence of a reclamation programme all attempts at colonisation of government waste areas of the Mailsi and the Rangpur Canals and portions of the Sutlej Valley had failed. A large number of lessees who had taken land on temporary lease had to incur considerable loss apart from the meagre income that came to the share of the tenants. The water supplies in these canals were never fully utilised.

Land reclamation was started in these areas in 1943-44. Since then, progressive increase in cultivation and irrigation had resulted. In 1946, the Government decided that land reclamation should be of an integral character. This involved not only amelioration of land but also development of all other aspects which go to improve rural life.

CHAPTER 17

Prevention Versus Reclamation

Salt accumulation and structural deterioration of soil due to the action of the sodium salts are the two main factors to be controlled in irrigation agriculture in semi-arid zones. Preventive measures must be different for different tracts of land :—

1. TRACTS WHICH HAVE NEVER BEEN BROKEN BY THE PLOUGH

It is now an established practice in the Punjab to do a scientific soil survey of all areas for which new irrigation projects are proposed. Areas in which there is danger of deterioration, due to salt accumulation should be developed on reclamation lines from the very start when irrigation water is not all allocated and leaching and growth of rice are feasible. If this is done it would ensure the elimination of troubles due to the appearance of salts and the progressive increase in the degree of alkalisation of soil.

2. TRACTS IN WHICH CANAL IRRIGATION HAS DEVELOPED AND ALL WATER SUPPLIES HAVE ALREADY BEEN ALLOTTED AND ARE BEING FULLY UTILISED.

Damage in these tracts is of two types. Firstly salts may have accumulated at the soil surface or formed a zone of accumulation at some depth near the surface due to faulty agricultural practice or the nearness of the water-table, which may be salt. In a case like this, such water as can be spared from farming of undeteriorated land or any extra water that can be made available during the *khariif* season should be used for leaching and growing rice.

For high water-table areas drainage is an immediate necessity and, if feasible, measures for lowering the water-table must also be considered. All possible means of preventing the rise of water-table above the 10 feet depth must be explored and put into practice.

In areas already under existing canal irrigation, long before the land goes out of cultivation or any significant decrease in crop yields occurs, a very gradual un-noticeable decline in yields is taking place because of the action of the sodium salts on the calcium-clay resulting in progressive increase in the degree of alkalisation. In fact, such is this unnoticeable gradual process that even in matters of standardisation, or crop assessments the soil fertility is stabilized at a comparatively lower level. This is evident from the fact that, even for standardising, the whole range 7.0 to 8.5 *pH* values has been given the status of a good normal soil. The word 'stabilized' of course does not mean that no improvement in soil fertility is possible. What it actually means is that the Punjab farmer is contented, if he gets yields in accordance with this fertility. There is no gain saying the fact that a soil with a *pH* value 8.5 or even 8.0 is an alkaline soil and is, therefore, capable of being amended further.

It must be remembered that an acre of land in the Punjab or even in India is the same amount of land as an acre in any other country and yet the yields of crops in this country are proverbially low. The reason is not far to seek. Poor soil structure has developed from handling an alkaline soil over a period of centuries and also from failure to use any correctives.

It is unfortunate that injuries of the above nature are not manifested until the soils reach the stage when costly reclamation is needed. Careful checks on soil properties and crop production have shown that crop losses develop gradually. That is, there is no critical point at which crop losses drop off sharply. The loss is gradual and increases with increase in alkalinity or severity of structural deterioration. Another reason why this gradual decline in fertility remains unnoticed is that no regular records of yields of crops are kept and during the process of deterioration, the land passes through so many hands from generation to generation.

Until the farming community rises to the occasion and they take to scientific examination of soils as a regular part of good agriculture, it remains the duty of the State to initiate scientific soil surveys of all tracts, to be repeated at regular intervals. A survey along with settlement operations in each district would be at a most appropriate period.

If signs of declining fertility are noticed from detailed soil analyses then it would be relatively easy to suggest or adopt soil corrective measures at an earlier stage of deterioration than when the damage has exceeded the limit. These correctives can be in the form of the use of gypsum or sulphur or even a change in agricultural practice or rotation of crops. Light annual applications of chemicals or slight change in cropping systems will contribute much to maintaining the soil in a good productive state and avoid the cost and loss of crops involved in reclamation.

It is now recognised that, under arid conditions with moderate rainfall, calcium sulphate gets leached to sub-soil layers and calcium carbonate that is leached or formed during the process of leaching gets deposited in large aggregates either immediately below the soil surface or a little lower down. Methods for reversing these processes to bring gypsum to the soil surface are under investigation. When this is accomplished reduction of alkalinity of the surface soil would become relatively easy and cheap.

A matter of importance in connection with this subject is the quality of canal and well water. In domestic and industrial fields it is the common practice to divide waters into two classes, namely soft waters and hard waters. In irrigation there has not been a great deal of practice in water classification as attention in this field has been largely confined to interest in the total amount of salt in a water. We have become so accustomed to the value of soft water for industrial and domestic use that hard water has been looked upon as the black sheep in the family of waters. This is, however, not true for irrigated-agriculture. In other words, hard water is best for irrigation and the harder it is the better, for "hard water makes soft land and soft water makes hard land".

The reason for this is simple. All irrigation waters contain salts in solution. Salts react chemically with the soil minerals and the clay. If sodium salts predominate in the water it is known agriculturally as a soft water. If calcium salts predominate it is known as a hard water. Sodium salts produce tight soils that are sticky when wet and hard when dry. Calcium salts form soils that are soft and friable when either wet or dry.

A second responsibility of the State, therefore, is to carry out a regular sub-soil water survey of all areas and wherever hard waters are available every endeavour should be made to use them to supplement canal irrigation. This will not only help in saving of canal water but will also accomplish reclamation without the use of gypsum or other correctives which may be inconvenient or expensive.

In Karnal district, for example, quite a large number of open wells and even tube wells contain a fairly large percentage of calcium salts.

“An ounce of prevention is truly worth a pound of cure”.

APPENDIX I

Organisation for Land Reclamation Staff

1. Land Reclamation Officer	1 for each canal system where reclamation water-supply exceeds 300 cusec.
2. Deputy Collector Reclamation	1 with each Land Reclamation Officer
3. Asstt. Land Recl. Officers	1 for every 200 cusec of recl. water-supply
4. Zilladars Reclamation	1 for every 50 cusec of reclamation water-supply
5. Reclamation Supervisors	1 for every 100 cusec. 1 extra for recording results and preparation of schemes in L.R.O.'s office.
6. Reclamation <i>patwaris</i>	1 for every 8 cusec on perennial canals, on non-perennial canals where recl. water-supply is available late, 1 for every 10 cusec.
7. Research Assistants for analytical work	1 for every 200 cusec. of recl. water-supply
8. Laboratory Attendants	1 for every 200 cusec of recl. water-supply
9. Asstt. Lab. attendants	2 for every 200 cusec of recl. supply
10. Peons	1 for each Gazetted Officer. 2 L.R.Os. Office
11. Khalasis	1 for L.R.O 1 for AL.R.O.'s office 1 for each Gazetted Officer
12. Sweepers	1 for L.R.O.'s office
13. <i>Chowkidars</i>	1 for L.R.O.'s office
14. Sweeper-cum- <i>Chowkidar</i>	1 for each AL.R.O.'s office
15. Office Establishment	1 Head Clerk 1 Accountant 2 Accounts Clerks 5 Assistant Clerks
	<i>Detail</i>
	1 Record Keeper 1 Despatcher 1 Camp Clerk 2 Assistants in accounts branch
16. Asstt. Land Recl. Officer	1 Sub Divisional Clerk in each Sub-division
17. Guard Establishment	1 Daffadar and 3 Barkandazes for the whole of the division

Duties of Land Reclamation Staff

After approval of the Land Reclamation Board, in the month of August each year, orders are issued by the Chief Engineer regarding the total water supplies that are to be utilised for reclamation of *thur* land in the following *kharif* on each canal system. Instructions regarding land reclamation technique and the distribution of water-supplies are also issued by the Chief Engineer from time to time.

Out of the total water-supply allotted for reclamation by the Chief Engineer, the Superintending Engineer will allot to each canal division the water-supply that can be utilised in that division. The allotment made by the Superintending Engineer will be made known to the Land Reclamation Officer for the circle and also the Executive Engineers concerned.

In no case will the Superintending Engineer allow any change in the land reclamation technique or the method of distribution of water laid down by the Chief Engineer without the Chief Engineer's consent.

From the results of the *Thur Girdawari* that would be available with the Executive Engineer and the results of land reclamation operations carried out previously and, also on the basis of the local conditions, the Executive Engineer and the Land Reclamation Officer will prepare schemes for the distribution of the supplies allotted to the division to the distributaries selected for reclamation by them. They will also indicate reaches of distributaries where they want to utilise the entire water supplies for the year and also submit programmes of land reclamation of the whole of the *thur* area on each distributary. Programmes thus prepared will be sent to the Superintending Engineer by the Executive Engineer for approval. Copies of approved programmes will be sent to the Land Reclamation Officer by the Superintending Engineer. The Land Reclamation Officer will then proceed to work in close collaboration with the Executive Engineer and work out the water supplies that are to be utilised for land reclamation on each outlet. Knowing the supply in each outlet, he will proceed to select with the help of his own staff fields for land reclamation. In this he will be guided by the orders issued by the Chief Engineer and the Superintending Engineer. When lists of areas are all ready, detailed proposals for areas selected for reclamation and the extra water supplies that are to be given to the outlets selected on each distributary will be submitted to the Superintending Engineer under the joint signatures of the Land Reclamation Officer and the Executive Engineer. The Superintending Engineer will then sanction the proposals and ask :—

- (i) the Executive Engineer to prepare estimates for remodelling and installation of additional shoots.
- (ii) the Land Reclamation Officer to make preparations for the commencement of reclamation during the following *kharif*.

Any alterations in the water courses and the *chakbandis* and proposals for new water courses which are considered necessary by the Land Reclamation Officer for purposes of reclamation will be carried out with the previous approval of the Executive Engineer.

At the end of each *kharif* season, the Land Reclamation Officer will supply the Executive Engineer lists of fields that he considers have been completely reclaimed.

The Land Reclamation staff, *viz.* the Deputy Collector Reclamation, the Assistant Land Reclamation Officer, the Reclamation Zilladars, the Research Assistants and the Reclamation *Patwaris* will, both for administration and technical supervision, be under the complete control of the

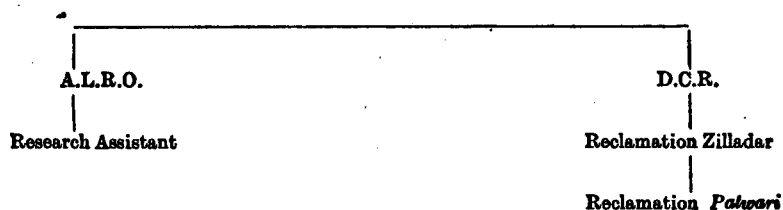
Land Reclamation Officer. They will work under his orders. The Land Reclamation Officer will write their qualification reports.

The Land Reclamation Officer under the Superintending Engineer will also have the general control of land reclamation in the circle. He will be responsible for supplying the Superintending Engineer all information regarding progress of land reclamation, prepare annual reports of reclamation operations and also proforma accounts for the circle. He will obtain from the Executive Engineers the works expenditure on remodelling and provision of extra shoots for land reclamation.

The Land Reclamation Officer will be invested with the powers of a Divisional Canal Officer under the Canal Act for the areas under reclamation and those of an Executive Engineer regarding matters of establishment, sanctioning of contingent expenditure etc. He will check at least 5 per cent. of the area under reclamation in the circle.

The organisation of the staff working under the Land Reclamation Officer will be as follows :—

L.R.O.



Assistant Land Reclamation Officer.—He will have the same status as that of a Sub-Divisional Officer in an irrigation Sub-division. He will be incharge of land reclamation of the area allotted to him. He will supervise the work of the Research Assistants, Reclamation Zilladars and Reclamation *Patwaris*. In the supervision of the work of the Reclamation Zilladars and Reclamation *Patwaris* he will work in close co-operation with the Deputy Collector Reclamation as regards revenue matters. He will check at least 30 per cent. of the area under reclamation in his charge and all fields for which remission is recommended by the zilladars.

Deputy Collector Reclamation.—He will supervise and check the work of the Reclamation Zilladars and *Patwaris* in respect of revenue matters. He will see that the instructions issued for the guidance of the reclamation staff are properly carried out by them.

He will get special *warabandis* prepared through the reclamation staff and verify them at site before submission.

He will get indents of *khasras* and other relevant forms prepared in time.

He will go round reclamation areas and also check working of reclamation *warabandis*.

He will be responsible for compilation of remission statements.

He will check at least 10 per cent. of the area under reclamation in the circle.

Reclamation Zilladar.—He will prepare a map showing the *chakbandi* of outlets and the area to be reclaimed in each square.

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He will supervise the registration of irrigation for reclamation done on each outlet which will be recorded by the Reclamation *Patwari* in the *shudkar khasra*.

He will verify the names of the cultivators and crops.

He will maintain records of weekly and monthly progress of land reclamation by each outlet and submit the same to the Assistant Land Reclamation Officer who will submit to the Land Reclamation Officer.

He will prepare *warabandi* of each outlet according to instructions and submit them for sanction to the Land Reclamation Officer through the Deputy Collector Reclamation.

He will report to the Assistant Land Reclamation Officer names of zamindars who are found using reclamation water in the area not selected for reclamation.

He will induce the share-holders to make their water-courses straight and line them to reduce seepage losses.

He will report to the Assistant Land Reclamation Officer on the condition of crops and any calamities that may occur.

He will go round the reclamation area as often as possible and see that, during the period of leaching and the growth of rice, each field receives irrigation on dates mentioned in the modified *warabandi*.

He will see that the zamindars on each outlet have laid their fields in quarter acre plots with a water course in the middle and report to the Assistant Land Reclamation Officer the names of those who are defaulters in this respect.

He will work out the quantity of rice seed required by each cultivator and distribute the same to them from the pure seed supplied to him by the Land Reclamation Officer and maintain the *taccavi* forms. He will also be responsible for the realisation of the *taccavi* amounts so advanced. All *taccavi* accounts will be maintained by him.

He will record observations of areas reclaimed, crops grown in reclaimed fields and the yields obtained.

Any wilful negligence on the part of zamindars in the matter of land reclamation operations in the field and the weeding or manuring of crops (when manures are sanctioned against *taccavi*) will be reported by the Reclamation Zilladar to the Assistant Land Reclamation Officer who will report the same to the Land Reclamation Officer. The Land Reclamation Officer will take steps to warn the cultivators that, if they do not work according to their instructions, they are not likely to be given *kharaba* or extra water for land reclamation during the following year.

It will also be his duty to see that all land reclamation operations, viz. laying of fields and water courses, leaching, sowing of rice nurseries, transplanting and harvesting of rice during *kharif* and sowing of leguminous crops during the *rabi* are carried out on dates specified by the Land Reclamation Officer.

He will check all fields under reclamation and record his appraisal in the *khasra* against each field.

Reclamation Patwari.—He will prepare a sketch on the first page of the *khasra* and show the area selected for reclamation on each outlet.

He will book all irrigation done in the reclamation area.

He will be responsible for keeping entries in *Khasra Shudkar* up-to-date and total entries of each day of his round in the reclamation area.

He will keep the *jinswar* of the crop on each page.

He will make correct entries in the *khasra* in respect of name of owner, cultivator, crop, area sown etc.

He will help the Zilladar reclamation in the preparation of *warabandi* lists.

He will have to go round his area once every 5 days.

He will see that water is rightly distributed according to the sanctioned *warabandi*.

He will report any wastage of water or unauthorised irrigation.

He will report any wide-spread calamity or any disease on crops in the locality.

He will supervise all reclamation operations under the guidance of his officers.

Research Assistants.

1. From January 1st to March 31st, the Research Assistant will be fully busy with the soil sampling of fields selected for reclamation during the following *kharif*. Soil sampling will be done with the help of a boring tool supplied by the department but in areas representative of typical soils, he will have soil profiles dug, examine them, take detailed profile notes and also take soil samples. In examining the soil profile he should note :—

(a) The thickness of the soil crust.

(b) The structure of the soil crust.

(c) The zone of accumulation of salt.

(d) The *kanker* bed and the thickness of the *kanker* nodules, their shape and their probable composition; also if they are small size pea-*kanker* or big nodules of calcium carbonate or calcium sulphate. The mechanical texture of the soils below and above the *kanker* zone must be carefully observed and recorded. The depth of the sub-soil water should be noted. This is always helpful in interpreting the formation and growth of the *kanker* bed.

The degree of the wetness of the soil above the *kanker* bed; the *kanker* bed itself and the soil below the *kanker* bed and also the degree of plasticity of all these layers must be carefully determined. With the help of a pH testing set the Research Assistant should determine, as far possible, the pH values of the soils of the three zones, viz. above the *kanker* bed, the *kanker* bed and below the *kanker* bed.

(e) From the point of view of moisture gradients, viz. the 'pellicular zone' the 'Field Moisture capacity zone' and the 'Capillary zone' the Research Assistant can make extremely useful observations which will be helpful in the practice of land reclamation. He should record the relative depths of these zones and indicate the depth of the soil crust which is affected by evaporation and which therefore, should be included in the 'Pellicular zone'. If this differs in different areas, he should bring this to the notice of the Land Reclamation Officer who will modify the land reclamation technique for that area.

(f) In fields, where deterioration has recently started and where some crops had been grown before land reclamation was proposed, it will be useful if he, during the course of his observations records the depths to which the roots of crops have penetrated. In fields which have been abandoned for years flora typical of deteriorated lands must have grown, the depths to which their roots penetrate should also be recorded. It will be necessary to record the names of plants that grow on such lands.

(g) The colour of the horizons in the freshly exposed profile, if recorded, always leads to useful indications in the proper handling of soils and the study of other soil problems.

2. From April 1st to September 30th, the Research Assistant will begin to get results of analysis from the laboratory. He has been supplied printed ledgers together with binders for recording results of analysis of fields proposed for reclamation and under reclamation. He should record these results and study the behaviour of these fields during leaching and the growth of rice. This work he should do in the Headquarters office of the Land Reclamation Officer.

3. An important observation which he can make during leaching and reclamation is the time taken for the water in the fields to disappear. If during the course of observations he finds that in a certain field water stands at the soil surface for a considerable period and does not percolate through, he should bring this to the notice of the Land Reclamation Officer and himself make a detailed study of the field to devise ways and means by which percolation can be improved. In no case should the zamindars be allowed to do puddling before transplanting rice. This process of puddling brings about impermeability which prevents the movement of the salts from the soil surface to the lower layers.

The Research Assistant should tour the area throughout the reclamation period and should bring to the notice of the Reclamation Zilladar instances of ploughing under water.

4. From the type of vegetation and the intensity of its growth during leaching, the Research Assistant should be able to form an idea of the amount of carbon dioxide generated by such vegetation and the degree to which the alkalinity will be reduced during the leaching period. If careful notes are taken by the Research Assistant, he will find them useful in interpreting his results of analysis after rice and the yields of rice with respect to the stage of reclamation reached.

5. At the time of the harvesting of rice, the Research Assistant should bring to the notice of the Land Reclamation Officer, factors which have made reclamation successful.

6. From October 1st to the end of December, the Research Assistant will be busy again in soil sampling and in taking notes on soil profiles. He should repeat all observations on soil profiles which he made before starting land reclamation to study the changes that have taken place as a result of leaching and the growth of rice.

7. Instances where small patches of unreclaimed land in whole fields are left after reclamation will come to the notice of the Research Assistant. If the patches are insignificant then they can be left and reclamation shifted to other areas. But certainly it is the duty of the Research Assistant to make a thorough study of the un-reclaimed patches and submit reports to the Land Reclamation Officer or the Assistant Land Reclamation Officer who will give the required advice to the zamindars.

8. It is a matter of common observation that in fields having a high clay content the residual alkalinity after leaching is high. If it is due to buffer action it may not affect the yields of normal crops on zamindari supply; otherwise the yields are bound to be low. During his tours the Research Assistant should keep an eye on fields declared reclaimed and take soil samples for examination whenever he finds he is likely to get useful results.

9. If reclamation has been undertaken in high water-table areas with the help of field and subsidiary drains, the Research Assistant should take, as frequently as he can, samples of water from the drains to determine conductivity, salt content and pH values.

APPENDIX II

Conditions of leases for Reclamation of Govt. waste Land

- (1) The tenancy shall be for a period of 12 harvests.
- (2) The area given on lease will be allotted the normal water allowance both for *kharif* and *rabi*. In addition extra water for reclamation will be given only in *kharif* on the basis of one cusec for every 45 acres, either in a separate water-course or by an additional pipe in the existing water-course and an increased *wari*.
- (3) For the first four *kharif* seasons the reclamation water-supply will be charged at half the divisional rates, thereafter full divisional rates will be levied. In *rabi* water-rate will be charged at normal rates. Land that is declared reclaimed by the Land Reclamation Officer will be cultivated on the normal water-supply.
- (4) No land revenue or malikana will be charged for the first four harvests. Thereafter Rs. 1/8/- land revenue and Re. -/12/- malikana will be levied. If after the termination of the lease, the tenant elects to purchase half the area the land revenue on that area will be determined under Section 59 of the Land Revenue Act.
- (5) At the expiry of the period of lease, if the tenant has worked according to the satisfaction of the Land Reclamation Officer, the area of the block will be divided at the discretion of Government into two equal halves, one of which will be resumed by the Government and for the other the tenant will be given the option to obtain proprietary rights at the rate of Rs. 150 per acre. The total price of the land thus fixed will be recovered from the tenant, in twenty equal half yearly instalments, in ten years.
For non-perennial areas in the Sutlej Valley and also on the Rangpur Canal the rate will be Rs. 75 per acre.
- (6) The lessee is required to have the land cultivated by employing labour. In no case will he be permitted to employ tenants on *batai* till the land is completely reclaimed. Portions of land which are declared reclaimed by the department can be given on *batai* to tenants.
- (7) The lessee shall have to reside permanently in the estate in which the said land is situated within one month of the date on which the Collector passes an allotment order and within three months of the same date he shall construct temporary buildings residential and non-residential to the satisfaction of the Land Reclamation Officer on a site allotted and according to the plan approved by the Land Reclamation Officer.
- (8) The lessee will be required to arrange for accommodation for a Reclamation *Patwari* paid and appointed by Government for the supervision of reclamation.
- (9) The lessee shall have to carry out all operations regarding cultivation, layout of fields, construction of *bunds*, excavation of water-courses, leaching, and sowing of crops strictly in accordance with the instructions of the Land Reclamation Officer, both in land under reclamation and that declared reclaimed.
- (10) The lessee shall have to reclaim land according to instructions issued from time to time by the Director, Land Reclamation, and to comply with all such instructions and carry out all such orders without any objection or compensation.

APPENDIX III

References

- (1) Scofield, C.S. Annual Report of the Board of Regents of the Smithsonian Institution, 1935, page 275.
- (2) Keen, B.A. 'Nature' dated 26th March 1932. Vol. 129, No. 3256, page 463.
- (3) Ram Dass, L.A. and Malik, A.K. 'Current Science', Vol. 8, No. 6, pages 264-266.
- (4) Noble, M.K. 'Report on Irrigation and Allied Research' Poona, May 1950.
- (5) Jenney, H. and Overstreet, R. 'Cation Exchange Between Plant Roots and Soil Colloids', Soil Science 47-257-272 1939.
- (6) McKenzie Taylor, E. Puri, A.N. Asghar, A.G. 'Soil Deterioration in the Canal Irrigated areas of the Punjab Part I Punjab Irrigation Research Institute Research Publication, Vol. IV, No. 7.
- (7) Kelley, W.P. 'Cation Exchange in Soils' 1948 Reinhold Pub. Corp No. 4 U.S.A.
- (8) Hoon, R.C., Mehta, M.L. 'A study of the Soil Profiles of the Punjab Plains with Reference to Their Natural Flora' Punjab Irrigation Research Institute Publication Vol. III, No. 3.
- (9) Hoon, R.C., Dhawan, C.L. 'A Study of Soil Profiles from Un-irrigated Tracts of the Punjab Plains with reference to Their Natural Vegetation' Punjab Irrigation Research Institute. Annual Report 1937.
- (10) Wilsdon, B.H., Mehta, M.L. 'An Analysis of the Utilization of Irrigation Water in Typical Punjab Canals' Punjab Irrigation Research Institute Research Publication Vol. VI, No. 1.
- (11) Wilsdon, B. H. Percolation and Absorption of Water in the Soil", Punjab Engineering Congress, Vol. XI, 1923.
- (12) Wilsdon, B.H. and Bose, N.K. 'A Gravitational Survey of the Sub-Alluvium of the Jhelum-Chenab-Ravi Doabs and Its Application to Problems of Waterlogging'. Punjab Irrigation Research Institute Research Publication, Vol. III, No. 1.

- (13) Wilsdon, B.H. and Sarathy, R.P. "A Statistical Examination of the Sensitivity of a Water-table to Rainfall and Irrigation" Punjab Irrigation Research Institute Research Publication, Vol. I, Nos. 1 and 2.
- (14) McKenzie Taylor, E. Malhotra, J.K. and Mehta M.L. 'An Investigation of the Rise of Water-table in the Upper Chenab Canal Area, Punjab.' Punjab Irrigation Research Institute Research Publication, Vol. I, No. 4.
- (15) Malhotra, J.K. 'Rise of Water-Table in the Rechna Doab (Lower Half)' Punjab Irrigation Research Institute Annual Report 1939, pages 59-61.
- (16) Malhotra, J.K. 'Rise of Water-Table in the Area Commanded by the Basira Distributary of the Lined Haveli Canal' Punjab Irrigation Research Institute Annual Report 1945, pages 64-66.
- (17) Mehta, M.L. 'The Rise of Water-Table in the Rechna Doab', Punjab Irrigation Research Institute Annual Report 1937, page 205, Punjab Irrigation Research Institute Annual Report 1938 pages 116-117.
- (18) Mehta, M.L. 'The Effect of Negative Pressure On Well Measurements', Punjab Irrigation Research Institute Annual Report 1939, pages 122-123.
- (19) Vaidhianathan, V.I. 'Investigations on Negative Pressures in Soils', Punjab Irrigation Research Institute Annual Report 1939, pages 25-26.
- (20) Hoon, R.C. and Dewan, R.L. 'Physico-Chemical Changes in Deteriorated Soils as the Result of Soil Reclamation Operations', Jour. Central Board Irrigation Vol. 6, No. 3, pages 265-272.

APPENDIX IV

Glossary of Vernacular terms

<i>Banjar</i>	Area not cultivated
<i>Bar</i>	uncultivated tract carrying wild tree growth
<i>Bara</i>	hard intractable piece of land
<i>Batai</i>	division
<i>Chak</i>	area within irrigation boundary
<i>Chhappar</i>	thatch
<i>Chit Dain</i>	infertile land devoid of vegetation
<i>Crore</i>	ten million
<i>Doab</i>	tract situated in between two rivers
<i>Girdawari</i>	survey including measurement of irrigation and crops
<i>Kankar</i>	stone nodules
<i>Kharif</i>	summer (April to September) crop harvested in Autumn
<i>Lakh</i>	one hundred thousand
<i>Malikāna</i>	cess
<i>Maund</i>	a weight measure equal to 82 lbs.
<i>Nallah</i>	a small rivulet
<i>Papri</i>	thin cake
<i>Patwari</i>	village revenue official
<i>Rabi</i>	winter (October to March) crops harvested in Spring
<i>Rakkar</i>	land highly alkaline
<i>Sem</i>	Water-logged land or water-logging
<i>Shor, Reh</i>	salts
<i>Tehsil</i>	a part of district
<i>Thur</i>	salt affected land
<i>Warabandi</i>	schedule of turns or time shares in water-supply from a water-course
<i>Wari</i>	a turn or time share of water-supply from a water-course

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