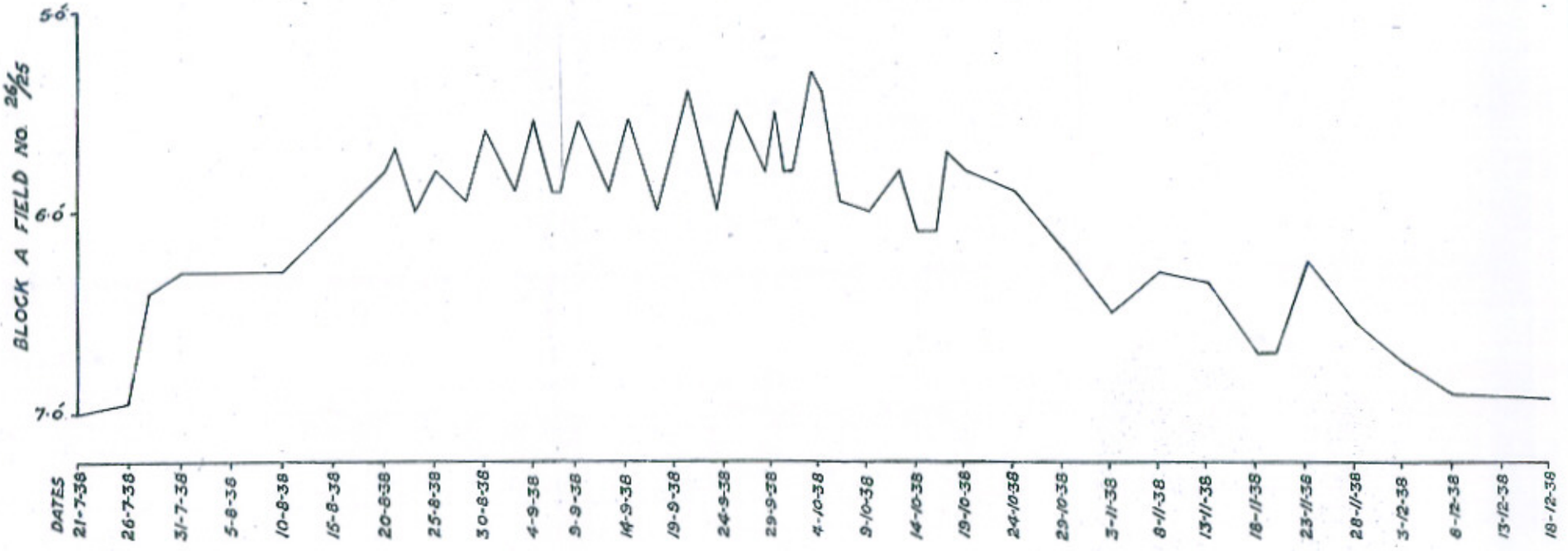


FIG. 16

Photograph showing cotton in reclaimed land seven years after reclamation. The crop shows no signs of a return to the deteriorated condition.

FIG.17

SHOWING DEPTHS OF SUB-SOIL WATER LEVELS
IN PLOTS UNDER RECLAMATION AT RENALA



DISCUSSION

Mr. Mehta in inviting discussion said that a detailed description of the investigations carried out in connection with the formation of *thur* and its reclamation had been given in the Paper. The points that needed emphasis were :—

(1) that if the water-table is situated below 10 ft. from the natural surface the salt in the water-table has no connection with the appearance of *thur* at the surface ;

Examples :—(*a*) Settlement Report of Gujranwala District; (*b*) Special Thur Girdawris in deep water-table areas ; and (*c*) The rapid spread of *thur* in deep water-table portions of the Lyallpur District.

(2) that if the soil crust is more than 10 ft. thick the rise of subsoil water stops when the water touches the soil crust. No signs of waterlogging appear at the surface under these conditions ;

(3) that under Punjab conditions the amount of water lost by evaporation decreases with the depth of water-table. When the water-table reaches a depth of 6 ft. the loss of water by evaporation from the surface appears to cease. For the sake of safety a depth of 10 ft. has been assumed;

(4) that before the commencement of irrigation over large areas, salt is distributed throughout the depth of the soil crust and in the absence of irrigation no salt-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 upon 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 move to a greater depth. If however the quantity of irrgation water used is insufficient to balance

the losses due to transpiration and evaporation and the zone of accumulation is within 10 ft. from the surface then the tendency will be for the zone of salt accumulation to move upwards. If crops requiring light irrigations, for example, cotton, wheat, toria, etc., are continuously grown and the monsoons happen to be poor the tendency for the zone of accumulation of salt is to move upwards. If wet crops like rice are grown then the salt is removed from the soil profile to the alluvial sand below;

(5) that permanency of reclamation is assured if the salts are removed below a depth of 10 ft. From Fig. 9 it is concluded that if the excess of salts is removed from the soil crust then deterioration is unlikely. There is no zone of accumulation of salts and therefore no movement of salts up and down can take place. Observations both with regard to the yields of crops and the distribution of salts in soil profiles of reclaimed land, for a period of 8 years after reclamation, indicate no decline in the yields of crops or increase in the salt content of the soil;

(6) that two rice crops can be grown in the same season on the allotted water-supply in areas served by *kharif* channels;

(7) that the reclamation of *thur* land is a paying proposition:—

(*i*) to the small cultivator who works himself on his own land;

(*ii*) to the big landlord who employs tenants to work on his land;

(*iii*) to a capitalist who wants to make reclamation a commercial undertaking;

(*iv*) to Government who are constantly losing land revenue on land going out of cultivation and who are faced with numerous applications for exchange of land from zemindars whose lands have become *thur*;

(*v*) and to the Province in general on account of the increased prosperity due to the production of crops in previously abandoned lands.

The Author then went on to say that from a study of the literature of salt and alkali lands it was understood that the question of the existence of *thur* or *kallar* in deep water-table areas both under pre-and post-irrigation conditions had always puzzled the minds of the investigators. No satisfactory explanation was available regarding the occurrence of *kallar* patches in between other areas carrying normal jungle vegetation. The investigations carried out in the Institute and described in this Paper had offered the explanation of the existence and the formation of *thur* patches in deep water-table areas. In such areas where the zone of accumulation of salts was near the surface rain or irrigation established contact with the salt bearing layer in the subsoil. On account of the subsequent upward movement of the salt band due to evaporation, salts appeared at the soil surface and caused the land to become *thur*.

It had been stated in the Paper that the study of the problem of *thur* was started in high water-table areas in the first instance. From this, the belief that *thur* occurs on account of the evaporation of water coming from the water-table to the surface arose. It was true that the Institute shared this view at one time. In spite of the fact that the Province was losing land rapidly on account of the formation of *thur* some Chief Engineers advocated that all experimental work on this subject should be discontinued as according to the ideas prevalent at the time no useful purpose would be served by further investigation. With the restricted facilities left at the disposal of the Institute some of the investigations were continued and it was discovered that it was the salt in the soil crust and not the salt in the water-table that was responsible for the formation of *thur*, at least in those areas where the water-table was at a depth of more than 6 feet. For a considerable time this view was also opposed. Fortunately, the new theory has now been generally accepted. In the light of new data and new discoveries, the Author stated, old theories are always changed and as convincing proofs of the formation of *thur* were available now there was no reason why a change should not be

made with respect to the subject of the movement of salts in soils.

The Author illustrated his remarks by means of solid models showing the relationships of salt content and the degree of alkalisation of the soil with the yields of rice and the absence of any effect of the water-table on the movements of salts in the soil crust to the natural surface.

The Author then showed a cinema film of the methods empolyed in the examination of soils and the processes of reclamation.

Mr. Blench commented that Mr. Mehta's Paper was valuable, not only because general knowledge was desirable on reclamation methods, but also because it brought to notice a fact that was not commonly known, namely that land might go *thur* because of economy in waterings.

Although appreciating the facts of observation he was not satisfied with all the detailed deductions, not with the secondary position given to the *thur* which arises as a direct result of the capillary fringe that forms from a high water-table.

Regarding *thur* appearance when the water-table is remote he enquired whether Mr. Mehta agreed with the following general explanation.

"On a wide average, salts are distributed fairly uniformly throughout the crust when neither water from above nor below has managed to reach them. On average clay, rain and irrigation waterings do not penetrate more than a fraction of the soil crust thickness, the fraction being about $\frac{1}{3}$ to $\frac{1}{2}$ in the Rechna Doab and equivalent to something more than 5 ft. Having reached its maximum penetration the moisture is disposed of by evapotranspiration during dry periods. The water in this zone acts as a vehicle for salts and, when moving downwards, takes them to the bottom of the root-zone. When moving up the salts rise; but there are other causes of rise of salts, such as temperature gradient of soil water affecting the solubility. Whatever the detailed mechanism, the

fact remains that the salts move up and down in the zone of water penetration, and the upward movement is during drying periods. Salts below that zone are unaffected so long as the water-table is remote. Suppose then that it has been the custom to apply irrigation deltas that affect a zone of depth D. If in the course of years, or due to a sudden remodelling of an excessive outlet, delta is decreased, penetration will only occur to a depth *d*, smaller than *d*; but the amount of salt moving in the new zone *d* will be that which formerly occupied D. Therefore the concentration of salt will be greater on an average and damage to crops will be more likely. A bad monsoon, by reducing delta, will accentuate the effect."

Assuming this explanation is correct it is hard to relegate *thur* arising from an inflated water-table to a secondary place—quite apart from the facts to be referred to shortly—for, when the water-table reaches the soil crust a capillary fringe forms at some 5 feet a year and moves the salts in the zone from the bottom of the crust up into the D zone, where the actions explained by Mr. Mehta would continue as usual, but now with a greatly increased salt load. To illustrate this take Fig. 5 pit 2. In the 12 foot zone there is an average of about 0·7%, *i.e.*, 8·4 units of salt. In the 12 to 37 foot zone there is an average of about 0·2% salt giving 25 x 0·2=5·0 units of salt. An inflated water-table would be expected to concentrate the whole 13·4 units in the 12 foot zone and make matters much worse. For pit 2 the proportionate effect would not be so great; but in pit 3 it would be greater. As there is a minimum lethal dose of salt the introduction of extra salt from below due to an inflated water-table is more important than mere figures can show. In short, the average salt content of the zone D may not be harmful ; but the average salt content of the whole crust definitely is, and it is the inflated water-table that brings it to the root zone.

The facts of the relative importance of the phenomenon discussed principally by Mr. Mehta, and of the salt appearance that occurs with an inflated water-table,

seem to be given sufficiently accurately by the official Sem-Thur Girdawari started in 1927. It is to this Girdawari that Mr. Mehta refers in page 124, and states that areas have been selected. This selection was done principally because the problem was acute in those areas, but not acute in unselected ones; and additions to the selection have been made year by year as the need arose. Assessment Reports of the whole Doab make it clear that the selection was sound. So does an inspection. It is impossible to liken the state of *thur* below Lyallpur to that above Sangla. The Girdawari results are plotted yearly by Drainage Circle, as are the water-table depths, and it is clear that really bad *thur* advances with the advance of high water-table. The line referred to on page 127 shows the worst *thur* at its extremities where the water-table is high and has, in fact, ceased to rise, as Mr. Blench had verified in connection with his own work. This is shown by the *thur* maps. While agreeing completely about the occurrence of *thur* with deep water-table, and the reasons put forward for it, he was of the opinion that an extention of the same theory, personal observation, and official records, showed that the appearance was more accentuated and much more damaging where the action of the capillary fringe was made possible by high water-table.

He was in full agreement on the danger likely to arise from decreasing delta.

He thought there was a flaw in the argument in the last para of page 130. It was quite correct for the conditions hypothecated ; but the conditions that brought up *thur* were different. The capillary fringe forms very slowly, and can reach some 15 feet—the Hudiara Nullah near mile 15 of the Multan Road showed a 12 foot one clearly during winter, along with the salts it had brought up. The possible rate of formation seems to be, from American information, about 5 feet in the first year. The whole of the salts of the crust can be dissolved in a foot or so of soil-water. Therefore the salts can be moved up by the *front of the fringe,* and should only take about 2 years to get into zone D, where the action al-

ready described does the rest. The reason that a fringe can advance 5 feet a year, or thereabouts, with a supply of only some 6″ of "solid water" is that a capillary fringe is not fully saturated, so the effective porosity for its rise is small. If the effective porosity were 15% then the fringe would rise 40 inches in one year with 6″ supply, assuming the soil itself were able to transmit at that rate against its very great resistance. Facts in support of this explanation could be found from Renala or Buchiana where the appearance of bad *thur* has coincided closely with the stoppage of well rise, which is itself a result of capillary fringe formation.

In view of this explanation, Mr. Blench did not agree with the remark of the previous paragraph of Mr. Mehta about what would be expected from evaporation. He attributed the *thur* appearance with high water-table to Mr. Mehta's theory and other reasons in zone D, but with the salts from below brought into zone D by the front of the fringe.

Although agreeing with the general statements, he did not think that Fig. 7 proved them. The rise in the number of fields gone out of cultivation occurred during a period of average *steady* delta.

He further disagreed with Fig. 6 as being based on scanty data of very limited application. American references made it clear that most experiments of the type were for open soils, and stated that for close soils capillary rise was much greater and therefore evaporation, which acts on the *top of the fringe—not on the water-table*—will act at greater water-table depths in close soil such as the Punjab sub-soil. The Hudiara Nullah provides visual proof. Research Institute Publication Vol : 5 No. 3 shows measurement of 0.7 cm. of evaporation in June from 22 feet deep. At this rate, suitably averaged, evaporation could stop the rise of wells at the tail of the Rechna Doab 20 feet down ; and the figure is a flat contradiction of Fig. 6. The final fact remains that wells do stop rising at a variety of depths usually round 10 feet average which is presumably why Mr. Mehta accepts this figure on page 130 although it contradicts Fig. 6. However, the figure is not essential to his main argument.

As Mr. Mehta had mentioned evaporation and capillary fringes in the body of his work, Mr. Blench asked if he would answer the following questionnaire, which was designed to find the reason for certain Punjab opinion that the stoppage of well rise was not due to evapo-transpiration—although this cause was stated in all books he had consulted, and verified by all calculations he had done—but due to some unassigned cause.

1. Referring to the graphs of wells of the Rechna from head to tail, plotted from 1907 to 1938, and recorded in Appendix A of a Note on Water Equivalent of Well Rise in the Rechna Doab (available recently with D.I.R.) did he agree that the general type shows an average steady rise followed by an abrupt change to stability about an average?

2. Is it a fact that from the head to about line VII of wells (*i.e.*, a line from about Chiniot to Balloki) the stability of wells was reached several—sometimes many years ago?

3. Is this stable average depth of well level about 10 feet?

4. Is he aware that the steady rise before stability was reached was equivalent to not more than 6″ of delta annually?

5. Accepting that this 6″ figure is correct, and that evaporation from a tank of water at Lyallpur is over 120″ a year, does he agree that evaporation, aided by increased transpiration, must be able to use up the 6″ annually at some water-table depth?

6. Does he agree that the evaporation does not occur direct from the water-table: but from the top region of the soil-water that is in connection with the water-table by means of the capillary fringe?

7. If 6 is agreed to, does he agree that water-table depth alone is not a criterion of evaporation opportunity; but that the nature of the sub-soil, by its ability to lift a fringe that can expose its top to evaporation, or mix with the zone of surface water penetration—where his

Paper shows that evaporation is proceeding—must also be stated ?

8. If 7 is agreed to will he state what type of soil was dealt with in his Fig. 6? If that soil was sandy will he agree that the same evaporation would occur at a greater water-table depth with a clay soil that could lift a high fringe ?

9. Does he agree that Punjab sub-soil can easily lift a 10 feet fringe ?

10. If he does not agree, how does he reconcile his answer with what is visible in the Hudiara Nullah, and with Dr. Puri's work on capillary pulls ?

11. If tank evaporation in one district is 60″ a year, and in another 100″ a year, in which district would the stabilisation level of wells be lower ?

12. If the answers to the preceding questions still cause him to dispute that wells are stabilised in the Rechna by evapo-transpiration, what causes can he put forward except increased river regeneration and sub-soil flow down the Doab ?

13. If he accepts the former alternative how can it be reconciled with the fact that the original well-rise in the now stabilised zone was equivalent to more than 1,000 cusecs, but the increased regeneration of rivers, due partly to the Chaj Doab, is not of this order ? And with the further fact that well cross-sections over the Doab show that most of the cross seepage flow is into the Doab, not out of it ?

14. If he accepts the latter alternative why is it that the well records mentioned in 1 never show an increasing rate of rise due to flow coming from further up the Doab ?

15. Can he produce any work of reference that explains the stoppage of wells in flat arid districts by anything but evapo-transpiration ?

16. Can he produce any alternative explanation consistent with facts ?

17. Referring to Fig. 5 does he agree that salts from the 12 ft. to the 37 ft. zone must be brought up by the capillary fringe when it forms ?

18. If not, why should they behave differently than salts in the 12 ft. zone ?

19. If the capillary fringe does bring up the salts of the lower zone, can he maintain that *thur* will not become worse than previously ?

Mr. Blench's own answers would be :—

1. Yes.
2. Yes.
3. Yes. 10 feet or a bit more.
4. Yes.
5. Yes.
6. Yes.
7. Yes.
8. Sandy soil
9. Yes.
10. Does not arise.
11. The district of 100″ a year.
12. None.
13. Does not arise.
14. Does not arise
15. No.
16. No.
17. Yes.
18. Does not arise.
19. No.

Mr. Blench apologised for such a lengthy discussion but said that there seemed a dual danger that the new work might cause established facts to be forgotten, or the established facts might belittle the new and valuable work. Also, the Paper had a direct bearing on his own work.

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Dr. E. McKenzie Taylor remarked that this Paper deals with one of the most important problems now facing zemindars in the Punjab. The presence of salt in the soil crust is one of the most general soil characteristics in the area west of a line joining Jhelum—Gujrat —Lahore—Ferozepore. East of this line salt occurs locally but it does not seem to be so generally present as in the other area. The first indication of the appearance of salt is the decline in yield of cotton which has a relatively deep root system. At this stage of deterioration the wheat crop may still be giving high yields owing to its shallower root system and, therefore, the indication given by cotton is overlooked. In the final stage of deterioration, the wheat crop is suddenly affected by *thur* patches due to the last stage of the rise of salt being in progress. The examination of a large number of soil profiles well distributed over the Province indicates that over considerable areas deterioration of the soil due to the rise of salt must be feared.

The Author has set out the conditions leading to the rise of salt and the method to be adopted for its prevention. In a written contribution received by the speaker Mr. Blench has attempted to connect the rise of salt with the rise of water-table, a connection which the Author has pointed out does not necessarily exist and, in fact, cannot exist in areas of deep water-table.

Mr. Blench has raised a number of points upon which a considerable amount of information has recently been collected at the Research Institute.

Mr. Blench has instanced a capillary fringe of 15 feet in the Hudiara Nullah but gave no information regarding his investigations to prove that this is, in fact, a capillary fringe. In a normal soil subject to loss of water by evaporation at least four moisture zones are present; (1) a zone subject to loss of water by evaporation and therefore with a steep moisture gradient; (2) a zone having an almost constant moisture content, the moisture being derived from the surface and held by the soil against gravity. This zone has a moisture content

known as the field-moisture capacity ; (3) a zone in which water may be lifted from a water-table, but the soil is unsaturated and is at field-moisture capacity ; and (4) a small zone of complete saturation to which the laws of capillarity may be applied. In stating that the capillary fringe is 15 feet, Mr. Blench is combining the zone of field-moisture capacity and the zone in which water may be raised from a water-table and he has made no experiments to distinguish between them. The properties of the zone of field-moisture capacity have recently been investigated in some detail and its bearing on salt movement and the effect of evaporation upon the water-table has been examined.(1)

Mr. Blench stated that the salts in the soil crust can be *dissolved* in soil water, and proceeded to discuss their subsequent movement. The speaker has yet to find in the Punjab an irrigated soil profile in which the salts are not already in solution in the soil water even when the water-table is at a depth of 40 ft. Mr. Blench appears to imagine that the salts in the soil crust are present in the solid form and go into solution in the water composing, what he calls, "the front of the fringe." As this conception of the condition of the salt is entirely erroneous, his subsequent argument breaks down.

Mr. Blench has described data obtained in India as scanty or by some other such term. He much prefers American or South African data some of which may truly be called scanty and a large portion inapplicable to Punjab conditions. He stated that the American references regarding capillary fringe were for "open" soils and he classified the Punjab soils as "close" soils. These are both new terms in soil literature. Soils are usually referred to as light, loam or heavy. The speaker has consulted some of the American references and has found that the everage Punjab soil is lighter than those from

(1) "Some Aspects of the Physics of Water-Table Rise and Salt Movement in the Soil under Irrigated Conditions" by E. McKenzie Taylor.

"Proc. of the Indian Academy of Sciences,"
Vol. XI, 1940, pp. 451-466.

which Aermican data are available. His statement that evaporation will act at a greater depth in Punjab soils than in the American soils to which he refers is incorrect.

The speaker now deals with an important part of Mr. Blench's remarks. Mr. Blench referred to an Irrigation Research Institute Publication in which evaporation from a Punjab soil was recorded. These experiments were carried out in 1933, the conditions of the investigation not being those imposed by nature. No exception can be taken to Mr. Blench quoting the results but a protest must be recorded regarding his use of these results when he deliberately omits from his quotation a most important conclusion regarding the effect of evaporation on the water-table which was mentioned in the paragraph following that quoted by him. This conclusion is "This rate of fall (of water-table) is more than three times greater than can be accounted for by evaporation." If this had been quoted by Mr. Blench, his other conclusions regarding evaporation would have been untenable.

Mr. Blench admits that wells stop rising at various depths. How then can this cessation of rise be attributed to evaporation which cannot have the same effect at all depths ?

In the questionnaire which Mr. Blench put to the Author he suggested that an abrupt change of the rise in water-table occurred just before stability was reached. The curves to which Mr. Blench refers have been drawn by eye and, by eye, equally good curves could be drawn to show that the change before stability was gradual.

In two other questions which Mr. Blench asked, he refers to the evaporation of water from a tank at Lyallpur and a tank in another district in which the evaporation was 60 inches a year from a free-water surface. This question appears to be perfectly straightforward but it is put as a result of an argument developed by Mr. Blench in one of his notes on the stability of the water-table in

certain areas. The argument of Mr. Blench, unlike the tanks, will not hold water.

From the phraseology used by Mr. Blench, it is obvious that he has consulted an excellent book entitled "Moisture and Farming in South Africa" by Mr. W. R. Thompson, Senior Lecturer in Agronomy, University of Pretoria.

In the note referred to Mr. Blench states that the evaporation from a free-water surface in South Africa is 60″ per annum and that the evaporation from a free-water surface at Lyallpur is 130″ per annum. (In the question he gives this as 120″ per annum). The first point to which the speaker wishes to draw attention is that he has taken the lowest figure for South Africa. Why did he not quote 75″ from Bulawayo or 88″ for Kimberley? The speaker suggested that the reason is that the difference from the Lyallpur figure would not have been so striking and Mr. Blench's argument would not have been so strong. Why also did he not quote Mr. Thompson who states "The annual evaporation from a free-water surface varies from about 2·5 times the annual precipitation at Johannesburg to almost 5 times the annual precipitation at Kimberley and Bulawayo? These figures, in themselves, show that the evaporation from a free-water surface in a tank has no relation to water reaching the soil surface and to evaporation therefrom. The speaker suggested that Mr. Blench did not quote this as it would have refuted his argument.

The next point deals with the evaporation tanks. The tanks used in South Africa are of the standard Symons pattern, 6 ft. × 2 ft. × 2 ft. insulated, sunk into the ground to a depth of 10″ and containing a depth of 10″ of water. If meteorological observations are to be comparable, the measuring installations must be standarised. A Research Assistant was sent to Lyallpur to obtain details of the apparatus used there for determining the evaporation from a free-water surface. The apparatus consists of a *circular* tank 4 ft. in diameter,

10 in. deep, un-insulated, and placed above the surface of the ground. The measurements at Lyallpur are subject to increased evaporation due to more effective wind action, higher temperature of water due to less depth in the tank, and increased sources of heat due to the absence of insulation and the situation above ground level. Had Mr. Blench been conversant with meteorological work he would, before using the figures, have made certain that the observations were being taken under similar conditions.

Further, Mr. Blench has apparently only glanced at Mr. Thompson's work as he has omitted to state the limitations that Mr. Thompson himself places on the observations. Three quotations from Mr. Thompson to illustrate the point will be given :—

(*a*) p. 163. " However, they (the free-water surface losses) cannot be compared with losses from actual soil conditions and have accordingly little value from an agricultural point of view."

(*b*) p. 166. "No accurate relation, however, exists between evaporation from a free-water surface or from porous instrument and the soil ."

(*c*) p. 174. "No relation exists between evaporation from a free-water surface and that from a moist soil. *A detailed study of the data clearly indicates this.*"

The above quotations amply demonstrate that Mr. Blench is far from justified in applying data for evaporation from a free-water surface to evaporation from a soil.

Mr. A. W. M. Jesson remarked that he was glad to see that the Author of the Paper has collected all the information on the subject of *Thur* and has presented it before the Congress for discussion. The speaker has been very closely associated with the subject and when the experimental stage was over, he started, in consultation, with Dr. McKenzie Taylor, reclamation on a very small area in the Lower Jhelum Canal. Sir J. B. G. Smith, was the Chief Engineer in charge of the Northern Administration when this experiment was undertaken. The speaker was then of the opinion that the experiment should be tried on a much larger scale than was actually put in hand. The Chief Engineer, however, agreed to the experiment being started on only 11 acres of land. A separate outlet from the distributary was sanctioned for this area. The experiment was very successful but he was disheartened at the Government's attitude towards reclamation in 1931. From 1931 to 1938 Government simply watched the increase of *thur* without either taking steps to start reclamation or to prevent the formation of *thur*. He was pleased that the methods for the reclamation of *thur* have been found successful in zemindar's land and that calculations indicate that reclamation will be a commercial proposition. It is also gratifying to note that the methods for the prevention of the formation of *thur* have been evolved and that they can be made applicable in the beginning of Irrigation Projects when all the water was not allotted and there was no difficulty in growing rice.

To his mind reclamation must come whether Government takes the initiative or big zemindars start the work or it is done by the petty landowners. From his personal experience he was of the opinion that to make reclamation absolutely successful it was necessary that the Revenue and the Irrigation Departments must work in very close co-operation.

Mr. Nand Gopal remarked that the Paper was a lucid exposition of the problem of *thur* which has baffled Scientists and Irrigation Engineers of this Province for many years. Mr. Mehta was to be congratulated for the patient scientific research he has done on the subject. It

was a relief to note that rise of water-table was not the only or main factor that accounts for *thur* lands. Irrigation below or above a certain intensity of waterings was the main cause. So that rain-water in occasional excessive quantities, not removed from the fields must also be responsible. This seemed to suggest that field drains were a necessity where irrigation was practised. This has been found to be so in America and the speaker thought if reclamation on the lines advocated by Mr. Mehta was practised on a large scale, they would find field drains indispensible. This would necessitate a complete system of drainage, which for no other reason but vast expense will not be practicable.

On page 145 Mr. Mehta advocates reclamation without field drains as in his experiments he found the waterings applied for the purpose had no effect on the water-table. This was so because it was an experiment on a few acres in one place. If he does only that much at a time, of course, there will be no appreciable rise but to reclaim all the *thur* lands in one Doab at this rate will take a good few centuries. If he hastens the process and uses, a few hundred cusecs for reclamation rise in water-table must occur to an appreciable extent. In areas with high water-table, he himself says, drains are necessary. He was of opinion that the method of reclamation suggested in the Paper was undoubtedly sound but the rise of water-table must be reckoned with if any large scale operations were undertaken and full provision for drainage facilities made. Otherwise it may be a case of "Out of frying pan into the fire." A better solution would be to line canals and affect corresponding reduction in the usual addition to subsoil by seepage losses.

2. On page 129 Mr. Mehta has quoted Dr. Puri and says where the soil crust was more than six feet deep the water-table does not rise through the crust. This was difficult to understand. He supposed it was not meant that when thickness of crust exceeds 6 ft., it becomes impervious. If it is not impervious, water must rise into it whether more or less than 6 ft. thick.

When the water-table all round has risen, but according to Dr. Puri it has not risen when crust is more than 6 ft. thick, water must be under pressure and nothing but impervious material in the crust will prevent its rise into it. The fact was that the crust has in some places a good proportion of clay or impervious material and water rises very slowly but rises all the same. It may be decades before it penetrates through a depth of crust of more than 6 ft. It was also a fact that the rate of rise in any material falls as the water-table gets nearer to the surface and, therefore, the rise through the crust having a good proportion of clay can be very slow. It can also happen that a pit dug in such material may not show free water on the first day it is dug. That is because clay was a good retentive and transmits flow of water very slowly. Even some sands although saturated are bad yielders. They seem to have some sort of affinity for water. Dr. Puri may be able to explain these features by chemical formulæ and theories. What the speaker said was based on hard facts met with in practical experience of digging drains and sinking tube-wells.

Sir William Roberts remarked that he found himself in the somewhat enviable position of having listened to a very able Paper by one of his old students. He has however been improved so much through contacts with first Mr. Wilsdon and then Dr. McKenzie Taylor, that he almost failed to recognise him and felt like a pupil receiving instructions in the 1st year at a college. At any rate, the Paper is the result of detailed and careful work and was well worthy of serious consideration.

In the past Irrigation Engineers have been ready to criticise the farmer for using too much water. He has been heavily backed in this by Agricultural experts such as Sir Albert Howard. The agriculturist has every interest financially in making the water go as far as possible and it was refreshing to find support for his efforts from an able officer of Dr. McKenzie Taylor's calibre.

The speaker should also like to draw attention to one other aspect in the study of this problem and that was a

closer study of the actual water transpired by the crop. It was he thought generally admitted that at least 300 lbs. of water must be traspired in producing one pound dry matter in a wheat crop. Now an average crop of wheat can contain 16 mds. of grain, 24 maunds of *bhoosa* and at least 12 maunds of stubble and roots, making altogether 52 maunds. It was also recognized that the wheat crop when fully ripe contains about 5% of water, so that to produce 2 tons of dry matter would require 600 tons of water, *i. e.*, equal to 6" delta. There are many crops which produce a very much higher quantity than this of dry matter and therefore consume a good deal more water. He would like to see this aspect of the case put forward more prominently when studying losses by evaporation and percolation.

Mr. Ishar Dass remarked that as one who was in charge of reclamation farms in Chak 188 N. B. and also in Chak 187 N. B. Faruka Distributary Lower Jhelum Canal referred to by the Author on pages 141, 142 and as one interested in reclamation of *thur* soil he would offer the following remarks :—

The Lower Jhelum Canal used to be closed for a number of days periodically as an anti-waterlogging measure in summer, during the years 1931-1935 when he was on that canal. It appeared from the knowledge, the Author has given them, that this practice must have done more harm than good. The Author has tried to prove with a graph that it was by heavy waterings and not by starving *kharif* crops that the soil reclamation would be successful. Therefore extensive watering should be our watchword during summer.

The Author has suggested rice of the *Sathra* variety best suited for reclamation purposes. He would like to know if he had analysed the word SATHI of which the Punjab Zemindar says :—

ستھی پکے ستھیں دنیں جے پانی ملے آتھیں دنیں

He would suggest also DARRA or *Safaida* variety of rice. This can also be matured during August when the supplies are available in abundance. It is a good yielder and does not compete with money crops like

toria, cotton, and wheat.

It would be noticed that for reclamation by the method of crop rotation extensive areas under rice will be necessary. For practical purposes the rice should be such as SATHI or DARRA which could be matured during July and August at the time of abundant supplies, but these are inferior varieties and are not much in demand as food-stuffs.

There is the question of excessive watering required for *kharif* crops which has been stressed by the Author. This will need more water in our distributaries and canals. There is enough water in the rivers and it is the ingenuity of the Engineer which is required to utilise it. In his opinion it is practical that we can run our channels with higher discharges during *kharif* and give more water to the zemindars. The problem no doubt will require proper designing. It is a problem of revising our distribution system of water whereby more water can be given in *kharif*.

Mr. B. L. Uppal remarked that the Author of the Paper deserved to be congratulated for giving a very clear description of the interesting problem of *thur* and of the methods adopted for reclamation.

So far the layman's idea was that *kallar* or *Thur* affected areas were the result of progressive irrigation and the rise of subsoil water. The Paper, however, showed conclusively that the water-table was not responsible for the presence of the salt in the soil crust, and that the formation of *thur* was dependant on the original salt content of the soil crust. It had been stated that the increase of *thur* was due mostly to progressive increase in Kharif Irrigation, and decrease in delta or the depth of water used per acre. So far, the Irrigation Department had been feeling proud at getting the maximum intensity of irrigation with the same amount of water, or in other words at watching the decrease of delta, but the Paper showed that the achievement of getting a low delta and securing more irrigation was attended with the evil of bringing the salt to the surface. How is this evil to be checked? For reclamation of

thur land an extra supply of water has to be given. How is this extra supply to be found ? At odd places, it may be possible to allow an extra supply during *kharif*, but the method cannot be adopted on a large scale as the capacity of each canal at its head was limited. One possible method was to advise people not to over-irrigate in *kharif* and to sow rice in fields which begin to show signs of *thur*. The Irrigation Department should definitely discourage over-irrigation. A practical method of stopping over-irrigation would be to order stoppage of *kharaba* on all outlets which are known to be doing more than the permissible limit of irrigation.

On the Upper Bari Doab Canal it was known that most of the *kallar* affected areas were outside the irrigation boundaries. In the case of well irrigation, it was stated in the Paper that as penetration of irrigation water into the soil does not moisten the layer which intervenes between the salt layer and the surface soil, therefore no rise of salts takes place. He would ask the Author to offer an explanation for the increase in *thur* areas outside the irrigation boundary.

Experiments have so far been made on canal-irrigated areas with high and low water-table, but no experiments appear to have been made in *chahi* or *barani* areas outside the irrigation boundary. It will be useful to study ways and methods to reclaim such areas.

For large areas outside the irrigation boundary, it would probably be useful to provide tube-well irrigation which will have the effect of washing the salts down to the water-table.

There are one or two points which should be clarified by the Author :—

On page 134 it is stated :—

" From Fig. 8, 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 to 7 ft." The diagram shows that the area of

accumulation is much larger than the area from which salt has moved down. What is the probable source from which this excess accumulation has been derived ?

Similarly it is stated :—

"Fig. 9 shows the distribution of salts in the profile before and after the growth of one rice crop. It will be seen that with the heavy irrigation given to rice, the salts have been almost completely removed from the soil crust and there is no zone of accumulation." There is no proof to show how far downward the salts have moved for it to be considered by the Author that deterioration in future was unlikely to take place.

Mr. G. R. Sawhney remarked that the Author was to be congratulated on writing a very useful Paper on an important and urgent matter which was one of the problems of the day.

It was very gratifying to see that the research authorities have after all these years, changed their belief, and are now agreeing that the formation of *thur* has not much connection with the rise in water-table.

It was not the progressive increase in *kharif* irrigation that matters so much as the areas cropped during *kharif* and left uncultivated during *rabi*, when the effect of extreme variations in temperature brings the *thur* to the surface.

For any area to be affected by *thur* the presence of salts in or round it, is necessary ; with humidity in the air the salt may then come up to the surface by mere deforestation, or by extreme variations in temperature, or may even collect there by being washed down from the surrounding higher *thur* affected areas. *Thur* is also specially brought out in a very striking manner by the effect of the setting sun. This phenomenon is proved by the fact that *thur* or *kallar* mostly appears on the surface of our masonry works, spoil banks, etc., facing west and also by the very poor growth of flowers, etc., on the side of mounds or even in beds which face west. Even to-day a large number of patches of land big and small on Ganji Bar Distributary, which have never been irrigated, are

seen covered with *thur*. Hence *thur* is not caused merely by an increased intensity in canal irrigation.

Salts are not active on the surface in summer, firstly because they get absorbed into the soil by the intensive heat and secondly because of the effects of the rains during the monsoon.

The Author's belief that the best yield being obtained from land just before it becomes seriously affected by *thur* was, he thought, based on some exaggeration. Zemindars invariably seem to get the maximum benefit out of everything just before they start working it at a loss. It was just the big drop in the out-turn that makes them believe in this myth.

In the case of profile under rice, the Author has not mentioned the most beneficial effect of a heavy deposit of silt on such areas under rice cultivation. In his opinion this extra heavy deposit of silt which naturally must accrue in these rice fields also helps considerably both in neutralising the salts and giving an encrustation which was neither easily affected by variations in temperature nor permits salts to permeate through it quickly. Cropping has no doubt in such areas proved very beneficial but only as an indirect agent. Give me vegetable or any other manure and enough extra heavily silted water and good tenants and I can assure you that I would reclaim any average *thur* area.

The conclusions arrived at by the Author from comparison of the areas irrigated by wells and canals are not very convincing, as a matter of fact well water itself is more likely to bring the salt from the salt layer to the surface and many fields in areas under tube-well irrigation have become *thur* on this account. Well-irrigated areas generally do not show *thur* because they are worked by a much better class of tenants and are constantly manured before each crop is sown, while holding, for holding the intensity of irrigation is more in the case of well-irrigated than in the case of canal-irrigated areas.

The limits at which yields of crops begin to drop should be further thoroughly investigated and some simple method devised by which the zemindars could see a danger signal sometime ahead of the final crash so that they could take timely action.

The comparison of yield per acre given by the Author on page 141 would tempt any zemindar to pray to God Almighty that he had all his land affected by *thur* and under reclamation instead of possessing good land ; surely there must be some other reasons for this difference in out-turn !

Dr. A. N. Puri said that one speaker has referred to the theory of the soil crust and I should like to say a few words to clear some points about which doubt has been expressed. The soil crust theory enunciates a broad generalization based on the examination of soil profiles from more than a hundred sites. It was observed that the water-table is invariably situated in the sand stratum and that water-logging has occurred only in areas which have a soil crust less than ten feet in thickness. By soil crust is meant the average Punjab soil containing about 15 per cent. clay. This is a fact which can be observed by any one who cares to dig a pit in a water-logged area. Even in areas where the land is generally affected by water-logging, portions having a soil crust thicker than 10 feet stand out like dry islands in the water-logged area. If a hole is bored through the soil crust in these dry areas, no water enters the bore-hole, until the sand is reached when it immediately starts to rise and finally attains a steady level. This shows that the water in the sand stratum is under pressure and would have risen nearer the surface had the soil crust been of a sufficiently permeable nature. A striking example of this phenomenon can be seen at R. D. 120,000 L. C. C. Main Line. In a pit dug at this place there is a pressure-pipe showing the water-table actually standing about 3 feet above the bed of the pit. The water-table in the pressure-pipe responds to the variations in the canal level and yet the bed of the pit is firm and only just moist. As a matter of fact, the moisture content of the soil is just about the

optimum for plant growth. From the practical point, therefore, this area cannot show any of the adverse symptoms associated with water-logging even if the water-table as indicated by a pressure-pipe stood above the ground level.

The importance of the soil crust theory lies in the fact that it places in our hand a useful generalization to enable us to predict what areas are likely to suffer from a rising water-table. Any one wishing to cast doubt on this theory must do so on the basis of facts. It is no use asserting that water will rise into the soil crust if left long enough. The canals have been in existence long enough to have caused this rise, if it had been possible, but it has not done so. The theory is based on facts and it can only be refuted on the bases of facts. We can go on arguing trying to prove whether the water-table is or is not in the soil crust. We may even employ sensitive instruments to show certain phenomena associated with the presence or absence of the real or supposed water-table, but it will lead us no nearer the practical problem. Those who disbelieve in this theory must find a place which is definitely water-logged by the rising water-table, and not by the storm water, in spite of having a soil crust more than 10 ft. in thickness. Having found even one such place they will have made a case for argument.

Mr. H. L. Sally said that Mr. Mehta deserves the thanks of the profession for presenting the case of *thur* areas in a concise form. He has taken pains in the compilation of tables and graphs attached with the Paper. The speaker does not generally agree with the conclusions drawn by him. But full credit must be given to him for the honest reproduction of the experimental observations. The speaker will rebut the Author's theories and base his argument on the facts supplied by the Author in his Paper.

In para. 1 of his summary the *thur* area of 5 lakhs acres and a progressive annual increase by 25000 acres appear to refer to the whole of the canal-irrigated area

in the Province. These figures should not have been given in the summary as they give an erroneous idea because the actual damage by *thur* is very much more. According to Mr. Mehta himself these figures pertain only to a few districts and there also the surveys were limited to tracts of high water-table only.

The speaker then referred to the theory of *thur* formation. Water-table alone is certainly not responsible for the presence of salts in the soil crust. They exist in all soils and at all depths and at all periods. It is only its accumulation and concentration in the zone of the crop roots that the salts make their presence felt. This disturbance in their even distribution is directly the result of canal irrigation. It is argued that when a layer of dry sand falls between the crust and the water-table, there can be no connection between the water-table and the *thur*. This may be true. But as the water-table is rising, a day will surely come when this dry layer of sand will get wet and the water-table will touch the soil crust. It will make still worse the condition of *thur* that had been caused by canal irrigation. When this condition is reached the Author takes shelter behind Puri's theory that rise of water-table stops when it is met by a 10 ft. depth of soil crust. Evidently this can be due to the crust being accepted as impermeable to moisture from below. This very crust is shown as permeable to moisture of canal water when applied from above. It is not understood how the same soil becomes porous for upper water and non-porous for lower water. There are surely no valves fixed at bottom of the crust to permit only a downward flow. During excavation of seepage drains I have met subsoil water in clay zones at innumerable places without reaching the sand strata.

The speaker accepted the theory that evaporation takes place only in the first 4 ft. from ground level. But as soon as the moisture content of 4th foot falls due to evaporation, the moisture of the 5th and subsequent feet is drawn up by capillary action. The moisture which is transferred from 5th to 4th feet is now subjected to evaporation. This process of transmission goes on right

down to the water-table. Thus though evaporation may not take place from areas below four feet yet the evaporation of the first four feet does effect the moisture content of lower levels. If the Author's theory were accepted, we should meet a clear line of wet soil at 4 ft. Yet we know when we dig a pit the moisture content increases gradually and there is no plane separating the wet and the dry soil. He has however accepted this process for crusts 6 ft. in thickness. There is no reason why the same process must not apply to thicker crusts. Fig. 8 definitely shows an increase in the total quantity of salt in the crust after a cotton crop. This increase has come through the sand layer from the subsoil water. There can be no clearer demonstration of the false notion about the 10-ft.-crust theory. The addition to salts could be made through no other source except from the water-table through the sand. Thus it cannot be denied that the crust does not resist upward movement of moisture from the water-table. The salts may become troublesome from other causes when the water-table is low, but as soon as the water-table rises and a continuity of moisture is established from ground level to the water-table, the salt trouble is both accelerated and aggravated.

The Author then goes on to blame the higher intensity of irrigation for the appearance of *thur*. This increase of irrigation is not due to new areas being brought under cultivation with the same supply of water, but by gathering a greater number of crops from the same fields. So the delta which is the depth of water on the area irrigated, may decrease but the actual depth of water applied to that particular area for two or more crops may actually increase. The Author has only to realise the correct definition of delta to change his entire theory. On the bottom of page 131 he lays down that during *kharif* salts are either stationary or else there is a downward movement. This conclusion cannot be drawn from Fig. 8 because cotton is a *kharif* crop. It is true that the cause of the increase of *thur* is that the balance of salt movement is in the upward direction. This is caused by the water-table rising and not by the reduction in the water

supplied per acre. There is no reduction in the discharges of the canals of the Punjab and the quantity of water applied to the fields is the same, though the delta has decreased. If the reduction in quantity of canal water is the only cause of development of *thur* then all areas under *barani* or well irrigation should have gone *thur* long ago. If well-water penetrates to only 20 inches depth in case of cotton, then the speaker does not see the logic of giving more water from canals so that it penetrates to say 4 ft. depth to establish a connection with the salt zone. In this the speaker found a strong reason for reducing canal supplies to the standard of irrigation supplies available from wells. Crops on canal water would then flourish as well as they do on wells. Not only the *thur* problem will vanish but sufficient supply will be made available for extending canal irrigation to another 15 million acres in the Province.

On page 144, the Author has again referred to the soil-crust theory and says that when the rising water-table touches the soil, the rise stops. Dr. Puri has seen water gushing up bores through the crust. From this he concludes that open wells do not give a correct indication of the water-table. He however forgets that when water rushes up in a bore hole it only rises to its own level which it must have attained in an adjoining softer soil. Unless the water-table is actually higher than the bottom of the crust there is nothing to create an upward pressure at the bottom of an impermeable pocket through which Dr. Puri's bore-hole happens to pass.

PERMANENCY OF RECLAMATION

Mr. Mehta claims a field as permanently reclaimed if the salts have been washed down into the water-table through the sand stratum below the crust. A typical example of this process is shown in Fig. 9. If the next *kharif* crop on this field is cotton then the speaker fails to understand why the phenomenon explained by him in Fig. 8 is not repeated. This phenomenon will pull up the salts from the water-table through the sand. The permanency of reclamation cannot be established from

theory. Reclamation of Chakanwali farm is claimed to be permanent. Yet the only plot to which canal water was not applied showed a rise of salt content of ·04% at 30″ depth to 0·29% in the first 5″, within two years. Blame is laid on the lessee. He neglected the farm not because the terms of the lease were too mild but because he did not get much profit in spite of the mild terms.

The Author pointed out that almost all the points raised by Mr. Blench had been covered by the contribution made by Dr. Mckenzie Taylor. To Mr. Blench's reference to temperature gradient of soil water affecting the solubility of salts the Author stated that the salt in *thur* lands mostly consists of sodium sulphate. The temperatures in the soils in the Punjab are always high enough to dissolve sodium sulphate. It is not until a temperature of —3°C is reached that the sodium sulphate crystallises out.

Mr. Blench had gone in considerable detail into the question of *thur* girdawris to prove that *thur* arises from an inflated water-table. In this connection it must be remembered that *thur* girdawris were not started until 1926 whereas the existence of *thur* in the girdawri areas could be traced to as far back as 1916. No records of *thur* for the period 1916 to 1926 were available. Recent checks made in areas with deep water-tables in the Lyallpur district have shown that in certain portions as much as 23 per cent. of the cultivated area has become *thur* and yet neither the local Deputy Commissioner nor the Waterlogging Assistant have asked for the girdawris to be started. Considerable areas have gone *thur* in the Lower Bari Doab Colony where girdawris are not being made. It must also be mentioned that in *thur* girdawri no record of deterioration due to *thur* can be made unless the crop is reduced below 4 annas. Figures for girdawris and the *thur* maps are, therefore, misleading in advancing the theory that the water-table is an essential factor in the appearance of *thur* at the soil surface.

In criticising Fig. 5 Mr. Blench had not defined the minimum lethal dose of salt. In pit No. 2 the soil crust ends at about 11 feet from the natural surface

below which is all sand. The salt content in the sand layers has no connection with the movement of salt in the soil crust and hence should not enter into calculations.

Mr. Blench has quoted Renala and Buchiana areas in support of the explanation that the appearance of *thur* coincided closely with the rise in water-table and the formation of the capillary fringe. No data to support this explanation has been given.

Fig. 7 is an illustration of the type of deterioration now in progress. It does not represent a summary of the results of any survey. If Mr. Blench had given the congress the data, upon which his statement "the rise in number of fields gone out of cultivation occurred during the period of average steady delta" was based, it would have certainly carried considerable weight.

The Author then answered seriately the 19 questions asked by Mr. Blench. The answers are given below :—

Q 1. This is covered by the remarks made by Dr. McKenzie Taylor. The curves to which Mr. Blench refers have been drawn by eye and therefore do not conclusively prove that the change before stability was abrupt and not gradual.

Q 2. No.

Q 3. No.

Q 4. It is not a question of 6 inches delta. It is a question of residual delta in June which means the addition of considerable more water in October to May.

Q 5. This has been dealt with in detail in Dr. McKenzie Taylor's remarks. In view of the answer to Q 4 no answer seems necessary.

Q 6. Water evaporates from the soil surface. If this were not the case then, in soils containing salt, deposits of solid salt will be found in the soil profile as a result of evaporation. Out of some thousands of profiles examined no instance of salt

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deposit in the profile below the surface has been met with. A further point that if the water evaporated were derived from the water-table at a rate equal to evaporation then no drying of the soil could occur. Surely Mr. Blench has met some dry soils in the Punjab.

Q 7. Since 6 is not agreed to, 7 needs no reply.

Q 8. Since no reply is necessary for 7, no reply is necessary for 8.

Q 9. No.

Q 10. The Hudiara Nullah area has been discussed by Dr. McKenzie Taylor. Dr. Puri's work deals either with water which is outside the sphere of evaporation or with water in a sand which has not yet come under the influence of evaporation.

Q 11. This has been fully dealt with in Dr. McKenzie Taylor's remarks.

Q 12. The possible causes can be either the pressure effect down the doab or it may be actual water flow down the doab. In this connection it may be mentioned that a rise of 2.74 feet took place in the U.C.C. area preceding canal-irrigation. Quoting from the memoir on "An Investigation of the Rise of Water-table in the Upper Chenab Canal Area":—

"The records of the pre-irrigation period are insufficient for statistical examination but they serve to indicate that factors were present which were operating in favour of a rise of water-table before the Upper Chenab Canal carried any water. It will be seen that, although magnitudes may vary, there are indications of a close association between variations in the water-table and variations in the annual rainfall. From these results, the indication is that rainfall was a dominant factor in water-table rise during the pre-irrigation period."

Q 13. Cross-sections that are available do not show that most of the cross seepage is into the doab. Most of them show that it is out of the doab.

Q 14. This has been dealt with in D.I.R's remarks.

Q 15. Do. Do. Do. Do.

Q 16. Yes.

Q 17 No. Because salts are not present as a general rule in the 12th foot or the 37th foot which is usually a grey alluvial sand.

Q 18. This question is not clear. The 12th foot is also a sand layer and would behave the same way as the 37th foot.

Q 19. As already stated there are no salts in the lower zone and therefore the question of the capillary fringe bringing up salts from this zone does not arise.

The Author was very grateful to Mr. Jesson for the help given by him in testing the methods of reclamation on field scale in the Lower Jhelum Colony. As already indicated in the Paper the experiment first started by Mr. Jesson, in the Lower Jhelum Colony has given very valuable results. This experiment was started in the year 1931 and the land, when reclaimed, was put on the normal supply of water. Since then it has continued to give high yields of crops. Soil analyses have been given in the paper. These show that land once reclaimed does not develop salt at any depth of the soil profile at least for 8 years after reclamation.

The Author was in perfect agreement with Mr. Jesson in :—

(*i*) That reclamation sooner or later will have to be taken up in the Punjab. The problem is really serious and cannot be ignored. The subject is absolutely new and cannot be pursued single-handed by the Zemindars without active help from Government.

(*ii*) To make reclamation most successful, closest co-operation between the Irrigation Branch and the Revenue staff is very essential.

The Author agreed with Mr. Nand Gopal's suggestion that excessive rain water if not removed from the field would make a contact with the salt bearing layer and might subsequently help in the transport of salt to the surface. Such heavy rainfall is, however very, rare in the arid districts where *thur* is present or is appearing.

With regard to his contention that if all *thur* land in any one doab were taken up for reclamation at once there was bound to be a permanent rise in water-table the Author stated that, firstly the total *thur* area in any one doab at present was not more than 10% of the culturable commanded area. Secondly, it was impossible to undertake reclamation of the whole of this area in a single year. Thirdly, the Renala experiments referred to in the Paper were carried out on a fairly big scale and still there was no rise in the water-table in fields adjoining the *thur* areas under reclamation.

On the question of the rise of water through soil crusts more than 10 feet in thickness and the low permeability of certain sands, the Author pointed out that the general alkalinity of the Punjab alluvium was also a factor to be taken into consideration. The greater the alkalinity the less the permeability.

Sir William Roberts had rightly pointed out that a change was necessary in the outlook of the irrigation engineer in the matter of the use of available canal water by the zemindar. The Author was in agreement with Sir William Roberts that, in all investigations connected with the movement of salts in soils, the effect of losses of water due to transpiration should also be taken into consideration. Transpiration in itself cannot be responsible for salt movement since it is now generally accepted that roots search for water and that water does not, to any extent, move towards the roots. The importance of transpiration lies in the fact that it may assist in the establishment of an upward moisture gradient in the soil and so possibly increase indirectly the effect of evaporation and low deltas.

The Author agreed with L. Ishar Das that canal closures during *kharif* as an anti-waterlogging measure

had not done the good that had been anticipated. On recommendations from Dr. McKenzie Taylor, *kharif* closures had been abandoned almost everywhere. With reference to his remarks regarding over-production of rice this seemed to be a matter for the recently abolished Department of Rural Reconstruction rather than for the Department of Land Reclamation since rice production was not the main object of reclamation work.

The Author referred Mr. Uppal to his introductory remarks wherein he had given an explanation of the appearance of salt at the soil surface in areas outside the irrigation boundary. Although no statistics were available, observations showed that the increase in *thur*, in *barani* and *chahi* areas was much less than in the case of canal-irrigated tracts.

With reference to Mr. Uppal's remarks regarding the quantities of salt originally present in the soil and those responsible for the zone of accumulation in lower layers, the Author pointed out that the differences were due to the variable nature of the soil within the same field.

With regard to the enquiry regarding the removal of salts from the soil crust in Fig. 9 the Author stated that as the salts has been removed to the alluvial sand below a depth of 10 feet of soil crust there was no likelihood of their coming back to the soil surface and, therefore, there was no further necessity of tracing the course of the salts below 10 feet depth.

The Author agreed with Mr. Sawhney that surface washing from *thur* land in elevated portions do spoil areas in depressions. As Mr. Sawhney puts *thur* land does occur in the higher portions but fortunately the law of gravity has prevented any one from suggesting that this has been formed by the washing of salts from the depression on to the higher areas. The explanation of Mr. Sawhney is not, therefore, of general application. On account of extensive *watbandis* very little run-off enters cultivated fields.

The Author's recommendations that rice should be the first crop in new irrigation projects was based on

the results of extensive soil surveys carried out by the Institute and Mr. Sawhney's advice that this should not be taken until *thur* actually appears at the soil surface under normal irrigation would bring the same fate to new areas as has been the case in the Upper Chenab, Lower Chenab, Lower Jhelum and the Lower Bari Doab Canal Colonies.

Mr. Sawhney advocating the use of canal silt for reclamation had stated that if he were given vegetable or any other manure, enough extra heavily silted water and good tenants, he was sure he could reclaim any average *thur* area. The term "Average *Thur* Area" needs defining before the suggestion can be seriously considered. If silt were responsible for the reclamation of *thur*, then Mr. Sawhney's requirements should be

> "vegetable or any other manure, plenty of canal silt (to be carted at Government and not at the zemindar's expense), normal irrigation and good tenants."

If there is plenty of silt, there must be plenty of water. If there is also plenty of vegetable and other manure and good tenants, then soil deterioration is unlikely to occur and Mr. Sawhney's requirements would be unnecessary. The Author knew of an instance where a big landlord has spent thousands of rupees to cart silt to his alkaline (not *thur*) lands with no benefit whatsoever. He had now started reclamation with rice under the guidance of the Irrigation Research Institute.

Tke Authur thanked Mr. Sawhney for his suggestion that the effect of the setting sun should be compared with that of the rising sun on the causation of the accumulation of salt in the soil. The suggestion that the setting sun causes more *thur* formation than the rising sun may be the origin of the term black alkali since it may be formed in the dark.

Dr. Puri had stated that the theory that the water-table ceased to rise when the soil crust was more than 10 feet thick was based on the examination of more than a hundred sites. The number of bores examined during the course of land reclamation must have run to several

thousands now and the conclusion has been amply verified.

In reply to the written contribution of Mr. Sally the Author pointed out that *thur* was on the increase even though the water-table had not risen through the sand layer to touch the soil crust. So water-table was not an essential factor in the production of *thur*.

Mr. Sally had made certain statements regarding the presence of free-water in clay layers, the withdrawal of moisture from deep depths in the soil profile to the surface, the gradual increase in moisture content of the soil with depth and the travel of salts through sand layers but had produced no experimental data in support of his arguments. As statements made by him were contrary to all observed facts and experimental results his arguments fell.

For the information of Mr. Sally the Author summarised his results on the effect of irrigation on the movement of salt in the soil profile. If the irrigation is from wells, *i.e.*, is very light, contact is not established with the salt-bearing layer below and no movement of salt takes place.

If the irrigation is heavier than well-irrigation but is not so heavy as to cause leaching then contact is established between the moisture at the surface and the salt layer and as a result of evaporation and transpiration an upward movement takes place causing the salt to travel towards the surface.

In criticising the soil crust theory, Mr. Sally had himself answered his own question by stating that wherever the soil crust was thin the water-table was at a higher level than where it was deep.

With reference to his remarks on the permanency of reclamation Mr. Sally's calculations were incorrect. He also had not examined the accounts of the lessee of the farm whereas the Author had. If land is water-logged it is impossible to do any cultivation without drainage. Mr. Sally did not state what was the depth of the water-table in his sub-division.