PAPER No. 119.

INUNDATION CANAL PRACTICE.

By P. Claxton.

Preliminary.

In this paper the writer deals with Inundation Canal Practice in all its bearings. He takes as an example the whole of the Dera Ghazi Khan Division in which he has served for many years, from 1910, off and on, till 1927. He has been able to watch problems as they have arisen and developed. Taking all these into account, and co-ordinating the many conflicting difficulties and solutions, the paper will, he hopes, not only be of general interest, but also of practical application in placing the irrigation of the Division on a better footing.

It will first be necessary briefly to touch on the behaviour of rivers in general; then to pass on to the methods of their control; and finally, combining behaviour and control, to evolve a general policy for a canal system. While this applies to gravitation supplies, there is another problem which has of late been of growing interest, dealing with pumped supplies. In Dera Ghazi Khan both problems present themselves and are dealt with.

River Behaviour.

It is well known that alluvial rivers, bearing large loads of silt, carry them on, not in one sustained effort, but by a series of jumps, or by saltation. The loads have not travelled down continuously from the hills, but are moved along by the processes of scour and erosion. Of these two, erosion, the action at banks, in contradistinction to scour, that over the bed, is the more important. It gives the heavy excess loads at various points, and causes the river to meander. In doing so it presents the problems with which inundation canal practice has to deal.

One of the first principles lays down that silt eroded from a bank very soon deposits as a shoal on *that* side. Many engineers argue that it may be, and is, carried over to the other side. The argument is based on experiments on very narrow streams in which the whole surface slope is affected. This brings about a cross current which has the power of laterally deflecting particles. This is due to the surface slope, and in rivers is confined to the bank. The silt for the remaining width is entirely controlled by the strong forward current, across which nothing may pass. The writer does not appeal to laboratory experiments for his proofs, but has shown by a few examples in other papers that the principle is supported by large river movements, sometimes involving square miles of shoal. These shoals appear and melt away in step with erosions above them, and have the power of deflecting even the main stream. They all obey the one law which the writer has enunciated.

He therefore considers it fully established. The theory is illustrated in Fig. 1 which is believed to be drawn strictly to principle.

In this diagram there is erosion from A to B on the right side. At A the stream comes into the bank, having deposited its load of silt on that side in the shoal above. The water at A is therefore clear. From A to B erosion is active, and the load of silt is consequently increasing. At B it has grown so great that the river is no longer able to carry it forward, and a shoal begins to form, diverting the stream across to C. From C the process, as at A, is repeated, only this time on the left side. The erosion from A to B is responsible for the shoal B C D E and the erosion from C to D for the next shoal on the left.

It will now be shown how, on this theory the favourable points for inundation canal heads are determined. The favourable non-silting points are those just above A, C, and E. The canal off-takes may be placed a little higher up in the creek which forms the outfall above one of these points. Creeks are favoured, since they are usually more constant than the main stream, being subject to milder attacks. They also allow of the building of groynes, or dams and thereby the off-take may be carried higher up towards the head of the creek itself. Inundation canals invariably work upstream for better command, and such canalizing of creeks is very useful.

River Control.

In controlling rivers for inundation canals, there being no stone available, use of the still-water-pocket principle must be adopted to the greatest extent. The principle is illustrated at every Bell's bund built for protection and training at important works of the Province. It need not therefore be described here. Water to be held by earth embankments must be brought to a complete stand-still, and this is effected by the formation of the still-water-pocket. Such a pocket is formed when a creek is completely closed by a dam. This, however, is not always possible, and a compromise is got by means of a groyne. The groyne is a dam which has the canal bank or the high main land, for one flank, while the other flank is in the air. Whenever possible the nose of the floating flank is placed on an island, or is carried up to a high shoal, across the main creek, working upstream at the same time so as to create a pocket. Sometimes it cannot be carried across the stream but is finished off to form a pocket on one side of it. The nose is protected by stakes and brushwood, and spurs may be added to throw off longitudinal flow along the groyne. These groynes are not only helpful in securing the early supplies, but are strong factors in keeping the canal heads clear of silt. With experience they may often be maintained even through the floods. Whether maintained or not throughout the season, they form undoubtedly a feature of inundation canals which should be recognized. A head with some sort of groyne may nearly always be found, and by it much silt clearance, may be avoided. Another very important advantage, is the control of the river which groynes afford. Developments down

side creeks are prevented, and the main stream is kept away. These are some of the leading features of control.

Policy Combining river Behaviour and Control.

Combining river behaviour and its control, the writer some few years ago attempted to work out a policy for inundation canals which he embodied in an article in *Indian Engineering*, entitled *Flood Administration and Control*. The leading principles of this policy are illustrated by the diagram Fig. 2. After further consideration and more experience, his confidence in the policy has been much strengthened.

The usual form of river is shown by the meandering course A, B, C, D, E, G, within the normal flood embankments which of course will not be so regular, but will be more or less constant, marking the limits within which the river may wander. Beyond these limits the flood embankments and main lines of canal should be built as at *a e* and *c g*. One of the features of the policy was the combination of the canal and flood embankment by aligning the canal along the borrowpits of the embankment on the river side. Thus the cost would be that of the embankment only. The canal would have no river bank but would spill over the whole river front. It, itself, would remain clear, since it would be the deepest channel which would form naturally along the embankment, even without the help of borrowpits. On the river edge it would have a high margin of spill which would keep it from returning to the river. The cross section at the time of construction would be as shown by the diagram, Fig. 3, and in time with successive deposits of silt, this would tend to grow into that shown by dotted lines.

This trunk canal would run the whole length of the district, more or less constant in capacity. It would feed other branches off-taking at the points *a, e, c, g*, etc. The trunk canal itself would be fed by links, run in from each of the favourable points *a, c, e*, as described above. They would be at an angle, so as to form pockets with the trunk canal, at the junction with which regulators and escapes would be built. These points would also be the heads of the branches. Each link would be under entire control at the junctions A, E, C and G, a regulator into the next compartment, and a head of a branch canal, being built at each point. By means of any of these regulators the flow in the compartment above a link would be brought under entire control, even to the extent of causing the link to work back to the river by heading up. This control would regulate silt deposits in the upper compartment to some extent. These compartments by arresting silt, would grow valuable for *rabi* irrigation, while behind the embankment, *kharif* crops would be sown. The system would be unique in making all the heads on the river available for service. The trunk canal also would be impregnable, *i.e.*, it would be impossible for river erosion to sever it. Such action frequently ruins an inundation canal. Here, however, should erosion threaten to eat into the canal it would also threaten the embankment; and as this must at all times be maintained for the preservation of the district, it would have to

be built further back as a loop, and the canal would automatically follow it. Not only would existing favourable points of the river be made available, but short cuts to others, might at any time be made along with other links. The canal, as a trunk canal, could make up shortage at one off-take with excess at another, thus making the supply more even. The large compartments would also act as dampers and would neutralize temporary shortages. Thus this plan provides for every difficulty with which an inundation canal is faced. It aims at affording a steady, even and assured summer supply.

It may be noted that one of the objects of a trunk canal, such as that described above, is to obtain, if possible not only a summer supply, but also a small winter one. This is often possible even with the present system of canals which are not in a position to tap all the available heads. By having a continuous trunk canal, all the available heads will be brought within reach, and the probabilities of a winter supply will be greatly enhanced.

Peculiar conditions at Dera Ghazi Khan.

While the ideal policy of combining is as described above, the canals in the Dera Ghazi Khan division have already been dug independently, not only of each other, but also of the flood embankments. Another obstacle in the realization of the ideal is the present system of revenue assessment on the river side of the embankment. The area on that side is classed under *kacha* and as it is neither directly irrigated nor protected, the revenue, as *malia*, is credited to the Civil Department. Thus if the flood embankments were thrown back to a line of safety, the area between them and the river would be lost to the Irrigation Department. For this reason it is necessary to push the embankments as close up to the river as possible. If it be necessary to retire from river attack at any point, and later the river moves away, an attempt is made to restore the advanced works. A see-saw along the river front, thus proceeds leading in time to a net-work of embankments, many of which are useless. The expense of such a policy is necessarily heavy. Over the past 10 years it has been Rs. 90,000 per annum in this division.

Assessment.

The first problem is how to change the assessment to provide that the revenue on the river side of the flood embankments may be credited as canal revenue. The arguments in favour of the change are many. The flood embankments are as much district works as irrigation works, vital to the existence of the district. Some compensation has been given by crediting canal revenues with the fixed assessment of wells protected by the flood embankments, but this is quite inadequate. Moreover the capital cost of the embankments is an increasing quantity, while the compensation is fixed. Again, on the river side, although the lands are not directly protected, yet they indirectly owe their existence to the presence of groynes and bunds in the creek. These groynes and bunds not only throw up large areas of silt, useful for cultivation, but

keep out the river to some extent, and also preserve them. The main flood embankments in particular afford a strip of fertile land immediately in their proximity. Thus the revenue collected from the riverain belongs rather to the Irrigation Department than to the Civil, In the Dera Ghazi Khan riverain it is comparatively small, being about Rs. 38,000 annually. While this is a figure much below the compensation payable to the Irrigation Department, yet by obtaining it, expenses may be reduced very considerably in other directions. For instance, it would be possible permanently to retire to a safer line, and thereby save at least half the cost of constructing and maintaining the network of embankments close along the river front. Under the new policy of assessment, if retirements were necessary, the revenue from irrigation along the foreshore thus formed would not be reduced. It has been calculated that the foreshore under *rabi* would be about twice the present area within the network of bunds under *kharif*, and as the *malia* rate is half that of the *kharif* assessment, the revenue would balance. The change would in no way affect the cultivator, but would merely be a paper adjustment between the two departments. The foreshore would be improved by heavy deposits of silt, while these in turn would strengthen the defence works in rear. On the whole therefore the change of policy on assessment is both simple and advisable, and there appear to be no obstacles in the way of its realization. The future policy should be straightforward, dealing mainly with the alignment of embankments and canals, so as gradually to bring them nearer the ideal.

Particular Reaches illustrating the Ideal Policy.

It is not possible to represent the division as a whole, but separate diagrams show where realignments of embankment are proposed or have been carried out.

Fig. 4 gives the river front along the head of the Dhundi Kutab in the southern half of the division. Here, it will be noticed, which has shortened the head of the canal and has created a series of compartments formed by embankments which have been built from time to time against it. The rearmost line of embankments has now been adopted for the canal which is fed through the compartments as a temporary measure. The latest proposal is to extend the canal by carrying it to a point B B higher up still. When this has been done the ideal flowing canal and river embankment aligned together will have been reached, the embankment being the further from the river. It will be noticed that these compartments are all very low. It is probable that at one time they were one of the few points where hill torrents from the west broke through the high river margin. The compartments are admirable inlets, which form reservoirs damping down fluctuations in the river. Not only do they give a constant supply but they have helped the canal since the river has failed. All silt is effectually trapped by the inlets so that the canal need fear no trouble on this score in future.

The Nur Dhundi Canal has now been linked with the Dhundi Kutab Canal at the Kutab-Nur Distributor, 12 miles below the lakes. Fig. 5 shows how this has been done. The point is interesting, since by combining the two canals the lower reaches are safeguarded. The chances of failure are halved, since two heads in place of one may be relied upon, and by careful distribution crops at the tail may be matured. Such a distributor combines three or four masonry regulators into one. Regulation, by being centralized, is more nearly perfect and distribution may be controlled to a nicety. Another interesting feature is the inlet or escape. For ten miles upstream and downstream, hill torrents form a lake on the west known as the Hamuwala Lake. The canals themselves contribute to the supply. This lake may be utilized when the river falls to feed the canals. It has been found necessary to build two more inlets down-stream of the distributor on the Nur Dhundi Canal in order effectually to drain this lake. Its bed is capable of raising a rabi crop.

The association of these two canals does not end here. After the new extension of the Dhundi Kutab Canal has been carried out, the two will together have a river front of some 40 miles which will be capable of being easily tapped. On such a long front the chances are that a winter supply will nearly always be found. The Nur Dhundi Canal has a feeding creek 25 miles long running close along the river front and off-takes from this would be short and easily excavated. The Dhundi Kutab Canal would tap another 15 miles of front, and the new head would be linked with the Nur Dhundi Canal as shown at B in Fig. 4, and again linked as shown in Fig. 5.

Thus, the ideal conditions of a trunk canal capable of being fed by short links from the river, parts of these being combined with flood embankments is approached. So long as the canal sticks to the embankments it can never be severed at any point as explained above and may therefore be considered permanent.

Fig. 6 shows another reach which lies in the area once occupied by old Dera Ghazi Khan. The river left the site for years but has recently returned and made another bite which has forced us to retire to a line which once protected the cantonment of the old city against torrents from the west. The alignment of the embankment for this reason is far from straight. It will be noticed that the Dhingana Canal has here suffered from river attack. It has been severed many times, but has now been carried along the Draman Embankment as it should have been from the beginning. This embankment is doomed, but when it is breached the canal will be cut into the line of borrowpits along the Cantonment bund and will be fed from a point P on the feeding creek. As it has no left bank the water will spill and form a huge lake. This might with advantage have been done for the old city years ago. Ever since the disaster the area has been a mass of foul-smelling pits of *soma* which need to be silted up. Here then work is being done towards the ideal and by combining canal and embankment permanency is aimed at.

By an extension higher up, as shown by broken lines a trunk canal may be formed and a better alignment for the Shoria Canal found. The Shoria and Dhingana Canals would then be linked at O, where a new regulator for the Shoria Canal would have to be built. The proposal is under consideration.

Pumped supply.

The above will show what is possible and what is under contemplation in the case of gravity canals. There remains the problem of a pumped supply. This presents itself on the Manka Canal on which the new city of Dera Ghazi Khan has been built. This canal is at the head of the division, and may by linking help other canals lower down, but cannot be helped in turn by them. It is one of the most important canals and has unfortunately to depend on itself. To add to its troubles the river has worked into the high land on the west, beginning from the point of its highest offtake and extending indefinitely north. For this reason flood embankments are not required above this point. The canal is unable to reach higher points, on account of very heavy digging and having no extensive riverain which forms a foreshore of feeding creeks such as exist above the Nur Dhundi Canal and others, to assist it. Against all these disadvantages pumping is the only remedy. It is also peculiarly applicable.

The canal has been aligned as far west as possible, and by conserving command with a flat gradient of 1 in 8,000, it runs into a series of falls just below the new city of Dera Ghazi Khan. These may be combined to give one fall of 15 feet.

With such a fall it is possible to develop power, which, when transmitted back, will be capable of pumping its own supply. The maximum winter lift is found to be 5 feet, so that the balance of power after taking into account transmission losses, will be enough to keep the canal going perennially. The arrangement might be called an electric bridge or syphon.

Assume the following efficiencies :—

	Per cent.
Turbine	82
Generator	90
Transformers	98
Transmission	95
Motor	88
Pump	70

The overall efficiency from turbine to pump will be 42·3 per cent. or say 40 per cent. Seepage loss from river to fall at 10 per cent. would reduce this to 36 per cent. The canal is all in clay and 10 per cent. seepage loss is liberal.

Let x=the possible lift.

Then $x = 15 \times 0{\cdot}36 = 5{\cdot}4$ feet.

Actually x is 5 feet, but one foot more must be added for friction losses in the suction and delivery pipes.

The balance is negative but may easily be made positive by heading up at the fall, at which 5 feet extra is available, making $x=7{\cdot}2$ feet.

The above presupposes that all the water will go over the fall during the winter months when the river is low. Irrigation can then be done only below the fall. When however the river is high, during the summer months, the balance of power will be well on the positive side. Abstractions above the fall may therefore be made, and the excess power it is proposed to utilize for high-level pumping.

Now such a device would ordinarily be started by a gravity supply during the summer and once started would continue working after the gravity supply had failed. It is, however, possible that it may have to start during the winter. A stand-by oil engine and generator are therefore needed. This stand-by need not be large, since the arrangement may be primed up gradually. The first supply on reaching the fall would enhance the power which would in turn enhance supply and so on, till the full amount was built up.

This subsidiary plant will be very useful in giving added power during the low winter water levels, and it is proposed to use it for the city for commercial purposes, the summer demand being met entirely by the gravity power.

A scheme to harness the Manka Canal promises to be very remunerative. There is, however, the river to consider. The fear of its vagaries defeated the scheme as long ago as 1914, but safeguards have since been found which have again made it feasible. Electric pumping is flexible and to shift the pumps from place to place offers no particular difficulty, but the river, it has been feared, might swing away, and leave a dry foreshore across which it would not at short notice be possible to renew the supply to the pumps. This problem has now been solved by making ten miles of the river front available for pumping. Fig. 7 shows how the canals spread out delta fashion to tap these 10 miles at four different heads A, C, D, E. During the past 20 years, at least two of these heads have been available throughout every winter. The plan is to use one for a gravity supply, and to keep the other three in reserve, each as a bye-pass, for pumping which will be needed, not only in the winter, but also for some time during summer when the river is low. The heads will be dug down to the winter level, and closed at the offtake, and water being pumped over the bund as necessity arises. By pumping it is hoped to scour the bed even lower than the winter level, and with its help it might be possible to dig down to the lower bed in the first instance.

This solves the question of supply, but there are difficulties in placing the pumps. Each is a unit capable of discharging 50 cusecs*, and the

* Cusec=cubic foot per second.

combined weight of pump and pipes, (36″ in diameter) is by no means easy to handle. The problem was attempted from the land side, but proposals to run trollies on rails, or to have caterpillar tractors without rails, were found to be unsatisfactory. It has now been approached from the river side, and promises to be rearer solution. The writer is not in a position to pronounce on the feasibility of pumping from barges, but he has been assured by Messrs. Leggett and Wheatley that this may be done. Accepting their assurances he sees the last objections removed, though there are constructional difficulties which have not yet been fully solved.

The difficulties of pumping from barges have led to the reconsideration of this part of the scheme, with the result that a better solution offers itself. After examining river plans again it has been found that the fear of a shifting river has so obsessed the mind, that it has led to extreme anticipations. As a matter of fact the river is not so fickle as to abandon a head annually. It usually serves it for three, five or even ten years before doing so. A semi-permanent pumping station is therefore justified. This will most conveniently be constructed of piles. Figs. 8 and 9 show part of a design. The piles provide foundations which are stable, and they themselves are capable of being withdrawn and used elsewhere.

The design, it has been found, further simplifies the problem. It is not necessary to enter into details, it will be enough to touch on its outstanding features. The cross rows of piles have been arranged as piers to take the water pressures, with one longitudinal line between them to divide the river inlet from the canal. On the upstream side each compartment will hold a pump, which with the motor, will be carried on a column of 5 piles assembled in the form of a segment of a circle. Since the pumps will always be submerged no foot-valves for priming will be needed. What is more important losses by friction will be greatly reduced, since the suction and delivery pipes will be very short and straight. So long as the river level is lower than the canal the pumps will be active, but when that level rises above the canal they may be shut down, and water, if required, allowed to pass through them under gravity. On the down-stream side piles form the side walls and act as wings. These will take all the surging action of water at the sides, that over the bed being provided for by loose stones or brick bats. The piers of pices will carry an over-bridge on steel beams and trough-plates for the accommodation of workmen and the control of the pumps.

Such a work will ordinarily be built close to the river, say, 1,000 feet from the edge. The inlet will doubtless be subject to silting, but while the pumps are working it will remain fairly clear, and when they are closed a light earthen bund at the head will keep out water. Should the inlet however silt, there will be no great difficulty in clearing it again, since the pumps may effectually drain it, while workmen do the job.

At a pinch this work may be erected on the river itself, at the edge of a shoal. The piles may be driven rapidly and the work completed at

short notice. The down-stream piles would take all the surging action, and for the rest, bunds would answer. Thus the design offers a complete solution of one of the last difficulties.

The leading features of the scheme having been described there is no space to enter into details; many of which are interesting, but in the appendix some calculations have been added to make the paper more complete.

The recurring expenditure on fuel having been cut out the scheme has been shown to be highly remunerative. This is due to the fact that the canal already exists and does not burden the capital cost. The water rates on the other hand are extremely low, and might be enhanced. Even as they stand they give an estimated return of 25 per cent. on the capital outlay.

Since writing the above the author has received a copy of *Technical Memorandum No.* 11, *Hydro-Electric Branch* kindly written by Col. Battye in which he gives the following efficiencies :—

	Maximum efficiency.	Actual efficiency after several years.
	Per cent.	Per cent.
Pump	72	68
Motor	93	92
Transformer	98½	98
Transmission Line	95	95
Transformer	98½	98
Generator	94	93
Turbine	85	83
Overall ..	49·3	44·0

Allowing for 10 per cent. seepage loss we get an overall working efficiency of approximately 40·0 per cent. as against 36·0 per cent. assumed above. This will give a greater balance of power on the positive side in winter. We also find that a 20-foot fall is obtainable at Gadai during winter without heading up above the hot weather fool-supply levels. A substantial balance of power will therefore be available for outside uses without the help of an independent stand-by plant.

This balance of power might be computed as follows :—

Fall at Gadai	20 feet.
Maximum lift at river	5 ,,
Ditto with friction losses at newly designed pumping station	5·25 ,,
Over-all efficiency	40 per cent.

i. e., the power available at the river would lift $20 \times 0{\cdot}4 = 8{\cdot}0$ feet giving a balance of power equivalent to 2·75 feet which would be equivalent to $\frac{2{\cdot}75}{0{\cdot}4} = 7$ feet at Gadai.

With the efficiency of the generator 0·93 and of the turbine 0·83, or the combined efficiency 0·77 the balance horse-power at Gadai becomes $\frac{500 \times 62{\cdot}5 \times 7 \times 0{\cdot}77}{550} = 367$ h.p.

Col. Battye calculates that the stand-by plant for starting up should not be less than 325 kilowatts and should be located at the power station. With the very good balance of power, however, the question arises whether we should not omit the stand-by plant altogether. The generator would not come into operation before the canals ceased to flow by gravity and no stand-by plant would ordinarily be required to start it. Against a break down of one generator, the other would carry on and would be able to prime it up again. It therefore seems advisable to omit the stand-by plant.

So far heading-up above hot-weather fool-supply levels has not been favoured, but there seems no real objection. Were it permitted the balance of power for outside demand would be larger.

APPENDIX A.

Manka Canal Hydro-Electric Scheme, Calculations.

1. Maximum nett lift from river to canal—5 feet.
2. Actual lift, allowing 2 feet for pipe friction—7 feet.
3. Efficiency of pumps—70 per cent.
4. Efficiency of transformers—98 per cent.
5. Efficiency of pump motors and gearing—88 per cent.
6. Efficiency of transmission line—95 per cent.
7. Efficiency of main transformers—98 per cent.
8. Efficiency of alternators—90 per cent.
9. Efficiency of water turbines—82 per cent.
10. Fall at Power station—20 feet.
11. Discharge at power station—600 cusecs.
12. Supply to be pumped from the river—560 cusecs.
13. Capacity of each pump—45 cusecs.
14. Capacity of 4 groups, each consisting of four 45-cusec pumps 720 cusecs (allowing a little extra).

(a) Power required from eash electric motor :—

$$\frac{45 \times 62{\cdot}5 \times 7}{550 \times 0{\cdot}70} = 51 \text{ h. p.}$$

Power of each group of four pumps :—

$$\frac{51 \times 4 \times 0{\cdot}146}{0{\cdot}88 \times 0{\cdot}98} = 175 \text{ kilowatts.}$$

Power to be drawn from the far end of the transmission line :—

$$175 \times 4 = 700 \text{ kilowatts.}$$

(b) Power developed by two turbines.

$$\frac{600 \times 62{\cdot}5 \times 20 \times 0{\cdot}82}{550} = 1{,}120 \text{ h. p.}$$

Power produced by two 380-kilowatt alternators :—

$$1120 \times 0{\cdot}746 \times 0{\cdot}90 = 760 \text{ kilowatts.}$$

Power available at the far end of the transmission line :—

$$760 \times 0{\cdot}98 \times 0{\cdot}95 = 700 \text{ kilowatts (as required).}$$

(c) Oil engine 190 b. h. p.

Power available at end of transmission line :—

$$190 \times 0{\cdot}746 \times 0{\cdot}83 = 117 \text{ kilowatts}$$

$$\text{Capacity of plant} = \frac{190 \times 550 \times 0{\cdot}50}{62{\cdot}5 \times 7} = 120 \text{ cusecs.}$$

APPENDIX B.

Summary of Capital Cost.

Items.		Rs.
1.	Water turbines	88,000
2.	Alternators	56,000
3.	Oil engine	32,000
4.	Alternator	11,000
5.	Transformers	18,000
6.	Transformers	850
7.	Tube well for cooling generator and oil engine ..	8,800
8.	Switch gear	17,500
9.	Crane	4,500
10.	Sluice gates	14,000
11.	Lighting	3,800
	Power Station machinery ..	2,54,450
12.	Pumping sets	2,40,000
	Pumping station built on piles	30,000
13.	Transformers	19,500
14.	Switch fuses	4,000
15.	Low tension switches	6,000
16.	Lighting	3,000
	River pumping machinery ..	3,02,500
17.	High level canal pumping machinery for hot weather	98,000
18.	Transmission lines	2,02,000
19.	Power station building	1,30,000
	Total capital cost of machinery and buildings	9,86,950
	Say ..	10,00,000

APPENDIX C.

Annual Recurring Charges.

Depreciation.

	Rs.
Power station machinery Rs. 2,54,450 at 5 per cent.	12,720
River pumping machinery Rs. 3,02,500 at 5 per cent.	15,125
Canal pumping machinery Rs. 98,000 at 5 per cent.	4,900
Transmission lines Rs. 2,02,000 at 2 per cent. ..	4,040
Power station building Rs. 1,30,000 at 1½ per cent.	1,950
Total Depreciation ..	38,735

Maintenance.

Power station machinery Rs. 2,54,450 at 2 per cent...	5,088
River pumping machinery Rs. 2,72,500 at 2 per cent.	5,450
Canal pumping machinery Rs. 98,000 at 2 per cent..	1,960
Transmission lines Rs. 2,02,000 at 1 per cent. ..	2,020
Power station building	1,950
Total Maintenance ..	16,468

Oil and Stores.

Fuel oil for engine for 3 months	7,000
Lubricating oils	1,600
Various small stores	600
Total Stores ..	9,200

Salaries and Wages.

Electrical and mechanical engineer in charge at Rs. 750 per mensem	9,000
Assistant electrical and mechanical engineer at Rs. 350 per mensem	4,200
Chargemen electrical and mechanical, 4 at Rs. 150 per mensem each	7,200
Switchboard attendants, 3 at Rs. 50 per mensem each	1,800
Pump attendants, 6 at Rs. 50 per mensem each ..	3,600
Transmission line inspector, 1 at Rs. 60 per mensem	720
Oil engine drivers, 2 at Rs. 50 per mensem each	1,200
Unskilled labourers for raising sluices, watching pumps, and general purposes, 12 at Rs. 15 per mensem each	2,160
Fitter, 1 at Rs. 60 per mensem	720
Total Establishment ..	30,100

Replacement and Removal of Light Railway and Transmission Line in Wet Area.

		Rs.
Renewals and repairs to pumping station at 20 per cent. of Rs. 30,000	.. ..	6,000
Rebuilding pumping station once every 3 years	..	10,000
Total Replacements	..	16,000

Summary of Recurring Charges.

		Rs.
Depreciation	.. .. ..	38,735
Maintenance and repairs	.. ..	16,468
Oils and stores	.. .. ..	9,200
Salaries and wages	.. .. ..	30,100
Replacement and removal of pumps	..	16,000
Total Annual cost	..	1,10,503
Say	..	1,10,500

APPENDIX D.

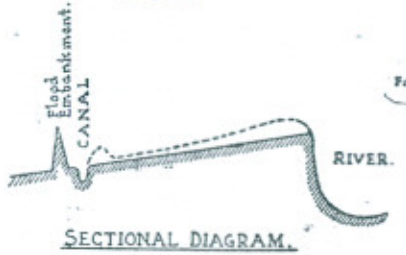
Revenue and Profit.

	Rs.
600 cusecs for rabi irrigation at 100 acres, duty at Rs. 4 per acre	2,40,000
157 cusecs pumped for high level irrigation during kharif at 60 acres duty at Rs. 3 per acre ..	28,300
200 kilowatts sold to city at 12 working hours per day for 300 days at Rs. 0-2-0 per kilowatt-hour	90,000
	3,58,300
Deduct working expenses ..	1,10,500
Net Revenue ..	2,47,800

Profit on Capital of Rs. 10,00,000 = 24·8%

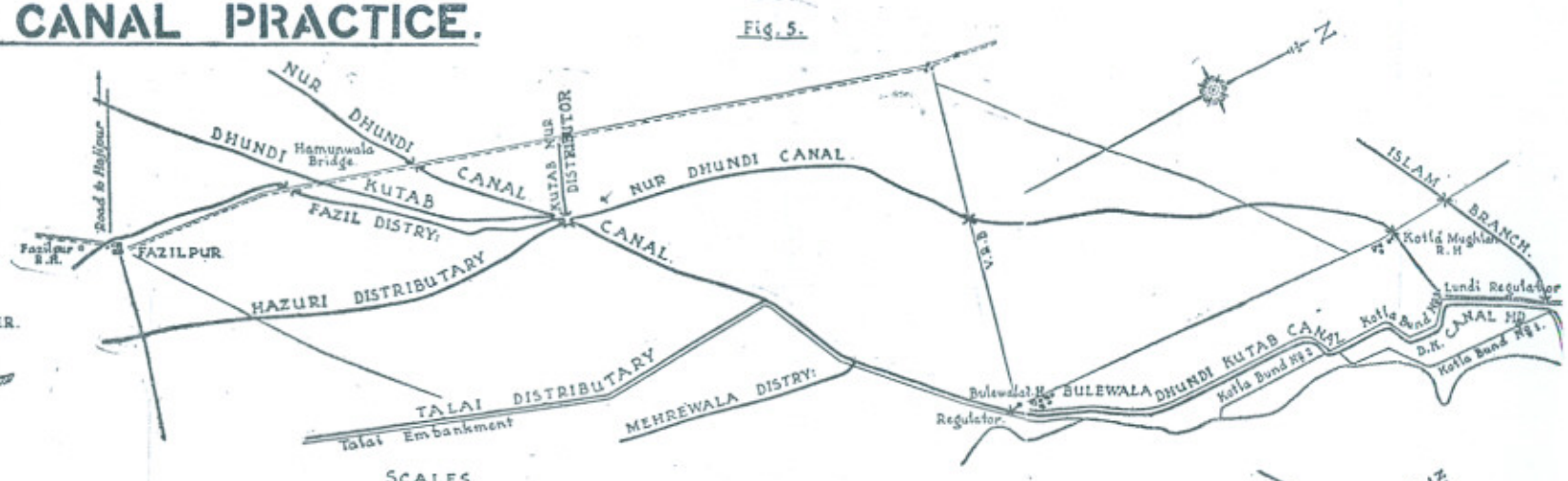
INUNDATION CANAL PRACTICE.

Fig. 3.



SECTIONAL DIAGRAM.
SHOWING
EFFECT OF CONTROL

Fig. 5.



SCALES

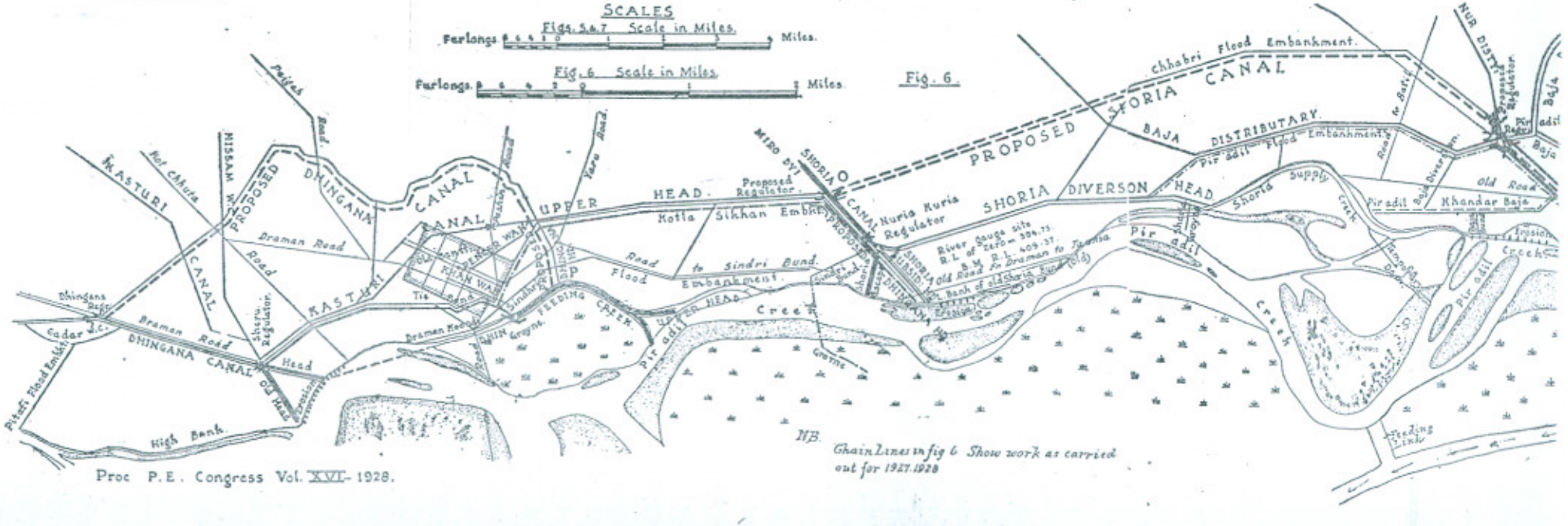
Figs. 5 & 7 Scale in Miles.

Furlongs 0 4 2 0 1 Miles.

Fig. 6 Scale in Miles.

Furlongs 0 4 2 0 1 Miles.

Fig. 6



NB. Chain Lines in fig 6 Show work as carried out for 1927.1928

CTICE.

PLATE 2.

Fig. 5.

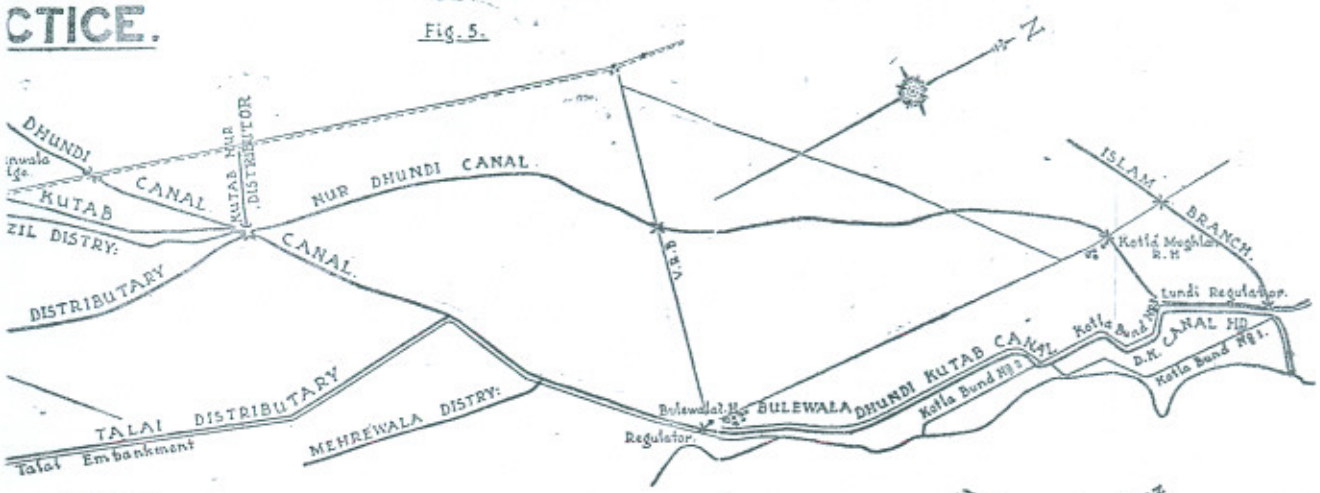
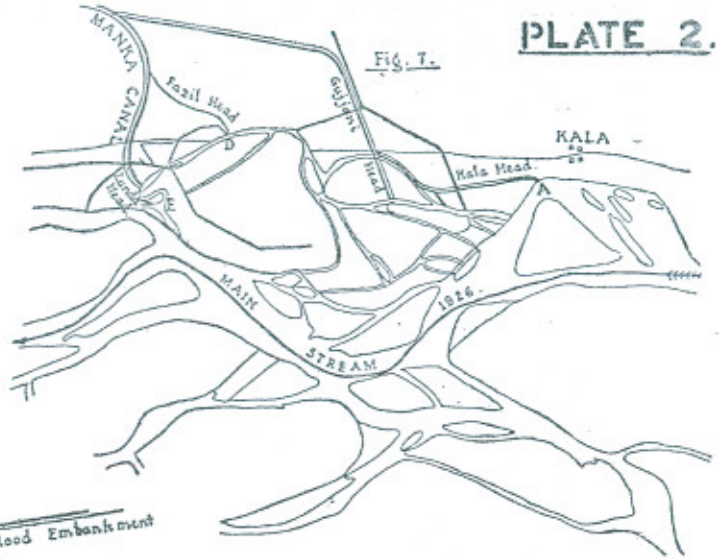


Fig. 7.



SCALES

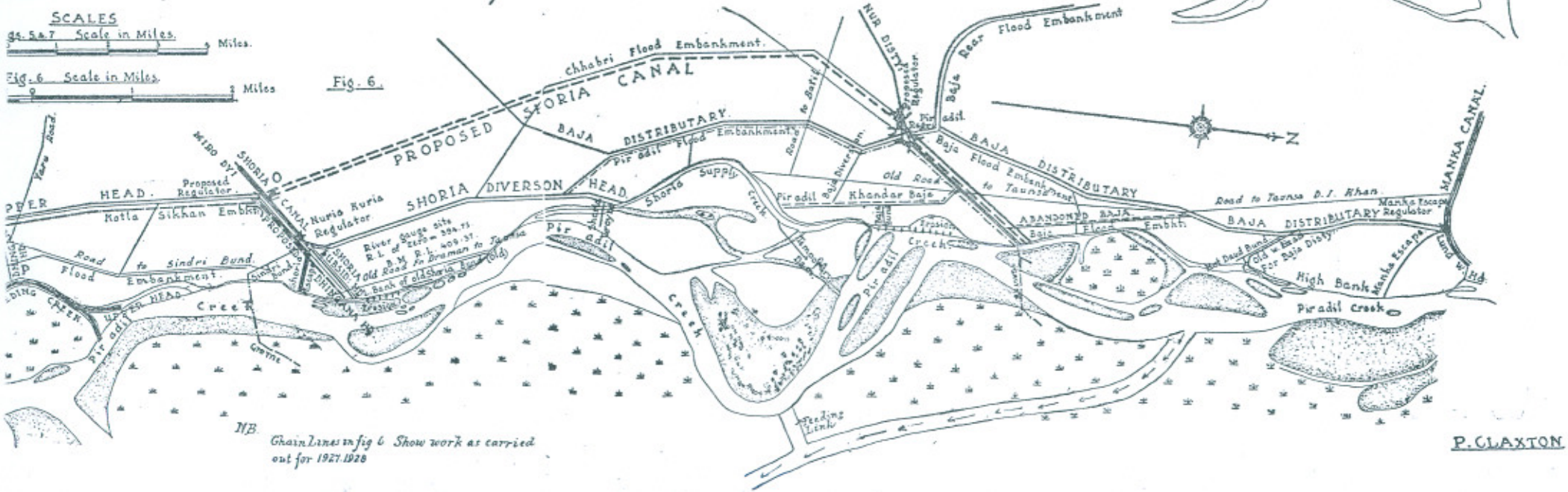
Fig. 5 & 7 Scale in Miles.

Miles.

Fig. 6 Scale in Miles.

Miles

Fig. 6.



NB. Chain Lines in fig 6 Show work as carried out for 1927-1928

P. CLAXTON

DISCUSSIONS.

MR. CLAXTON.

In introducing this paper I wish to call attention to wrong lettering on page 59. In the fourth line of the bottom para. the italics a. c. e. g. should be the corresponding capitals A. C. E. G., and in the eighth line the capitals should be italics.

In diagram Fig. 2, link Aa is shown taking off from a clear point of the main stream, and Ee from the creek above the clear point. The offtake may be from either, but E gives us the opportunity of putting in a groyne which is of the first importance to inundation canal heads. I should like to draw particular attention to the scoured low beds at the heads of canals which these groynes give us. On one canal, the Manka, a groyne scoured out 40 lakhs of silt in the head reach in one season; and at another, a groyne lowered the head reach of the Manka Canal by 4 feet, and we are to-day running a winter supply in it.

These low beds mean efficiency, and tend to make the canal semi-perennial as the combined D. K. C. and N. D. C. are now becoming. They also make the problem of pumping simpler since the pumps have to work against smaller lifts at offtakes.

The question of assessment is one which must be settled in Lahore and not at D. G. K. I, therefore, hope that the higher authorities will give far-off Dera Ghazi Khan assistance. I may mention that in Mr. Dick's Settlement it was laid down that the assessment of lands which owed their existence to the presence of bunds should be credited to us, but as no one could distinguish such, the rule was eliminated in this last Settlement. I have been going in to the matter, and it appears that actually some 8,000 acres are affected, giving an assessment which would be over Rs. 8,000. If the policy of building groynes be continued we shall soon double this area; so that out of Rs. 38,000 revenue from the river we might under the old rule have received something approaching half. It is not therefore too much to ask for the whole. It will, I think, be readily admitted that we are not being adequately compensated for work we do for the district. Our annual expenditure on renewals of flood embankments is Rs. 90,000 for which we get credit in the shape of fixed assessment of wells which is very meagre. It is not, however, the money we so much want, (though that would be gratefully received) but it is a free hand for the ideal policy along the river front. We ought to retire to a safer line, and we ought to construct our flood embankments without canal. By doing so we might very soon have one trunk canal which would be in a position to tap all the available sources of the river on one side, and redistribute the supply on the other. Both these are essential features of successful inundation canals, but both are unattainable because our losses would be considerable. Combined with flood embankments, no part of this trunk canal could, as explained, ever be severed.

Pumping on the Manka is needed for two reasons. Firstly, the canal, as has been noted, is at the head of all the canals, and is unable to be helped by any other. Secondly, this part of the district, with the city of Dera Ghazi Khan thrown in, stands greatly in need of such assistance. The cultivators here are fairly well advanced, but are miserably poor, and the city is appallingly deficient in the amenities which one would expect to find at the headquarters of a district. A scheme of this sort appears to be the only means of meeting all these needs.

For the mechanical details I leave others better versed in these than myself to answer, but I may say that the scheme does not propound perpetual motion. It is a simple mechanical device which has already been applied in other countries.

The difficulties are not mechanical, but are all on the river front. I should be very glad if any one here will offer criticism affecting these. It is for the purpose of inviting criticism that pumping has been mentioned.

Lastly, the scheme is not, as sometimes stated, similar to the Jalalpur Pumping Scheme below Rasul. There the question of bringing the water to the pumps has not, I believe, been considered, and the lift is great, requiring three tiers of pumping stations. Here the question of feeding the pumps has been given very careful thought and provision. The pumped supply is not entirely dependent, but is largely supplementary. Inundation canals, in fact, are still the basis, but where they just fail, pumps step in to help. It is this help which makes all the difference and presents us with such good returns.

L. Radha Krishna Khanna on Mr. Claxton's Paper.

MR. CLAXTON'S paper falls far short of dealing with the inundation canals practice in all its bearing as it claims to do. More than half of the paper deals with a pumping scheme from the Indus river, which is not relevant to the subject proper of the inundation canals. Several of the remaining pages of the paper are devoted by the author to the question of advancing the line of flood protection bunds towards the river, in order that the revenue for the crops at present grown outside the flood bunds, will, in future, be creditable to the irrigation department, by virtue of those areas becoming included within the line of protection. The author has stated in his paper that for the last ten years they have been spending on an average Rs. 90,000 per year on advancing these lines of flood bunds, so that, Rs. 8,000 or so of the revenue from the riverain tract, which now goes to the civil department, may become creditable to the irrigation department.

Thus the subject proper of river control and other problems connected with the working of the inundation canals has been dealt with in the space of three or four pages; and as everyone knows that the problems of the inundation canals are far too many and complicated to be exhaustively dealt with, within the limit of a few pages, the author's claim of having treated these problems in all their bearings is not tenable.

The main problem of the inundation canals is to secure adequate supplies for these canals in the middle of April or very early in May so that the zamindars can sow valuable crops such as indigo, sugarcane and cotton, instead of cheap rice and fodder crops. The other difficulty experienced in the working of the inundation canals is the disposal of the vast volumes of surplus water which come into these canals in flood days. And last, though not the least important consideration is to arrange things in such a way that, after the depredations caused on these canals by the floods, the canals should continue to flow, at least, to the end of September, for *rabi* sowings.

None of these three principal problems have even been touched upon by Mr. Claxton. We can effectively solve the difficulty about early supplies by having long feeder channels or creeks, dug deep to winter spring levels at their heads near the rivers. The question of disposal of surplus water can be dealt with by providing capacious escapes for these canals ; but the escapes must be so located that there will be flow from the escape to the river in flood days. A few leading cuts from the river to the feeding channel dug to proper bed levels, will generally secure late running of the canals for the *rabi* sowings, after the ravages of the floods. The groynes mentioned by Mr. Claxton are very good indeed for early supplies for the canals ; but it is not always the case that a canal offtakes from a small arm of the river in which a groyne can be built in winter. Also these groynes are liable to be washed away in floods ; so that long feeder channels running through firm ground are the only effective means for securing early supplies in the inundation canals.

Mr. Hadow on Mr. Claxton's Paper.

MR. HADOW admitted his complete ignorance of inundation canals, but said that he was very interested in the paper in connection with the problem of improving the inundation canals in Muzaffargarh district which papers he had recently seen. From these papers, he had gathered that the difficulty lay almost as much in keeping flood water out as in getting canal water on to the land. It seemed to Mr. Hadow that the system advocated by Mr. Claxton, namely, that of a combined trunk canal and embankment was what was required and he enquired whether such a system had actually been tried on the canals in Mr. Claxton's charge and whether it had been a success. If so, the application of the system to Muzaffargarh district might result in a beneficial improvement.

Mr. Claxton's Replies to Criticisms on his Paper.

MR. RADHA KISHAN KHANNA by his remarks has rather knocked the soul out of my idea. I thought I had made it plain enough. Answering his questions, I would say that assessment has to be dealt with so as to give us a free hand on the river front by which we may develop a very economical policy.

The question of early supplies has been answered by groynes. In Muzaffargarh because they do not have groynes they are up against difficulties.

The number of points tapped by a trunk canal system would be unlimited because the canal runs close along the river and connecting links might be made at small cost. The trunk canal would have an enormous capacity ; having no left bank it would in fact be more or less a lake.

Dealing with the question of heads going higher up, this system takes into account all the heads of the district. Our endeavour is to work upstream constantly.

The matter of escapes is difficult because river water levels are high when water needs to be escaped, but by regulators at the links water may be controlled, excess being choked back.

Answering Mr. Hadow's questions, I have to say that this system, the Trunk Canal System, where the canal follows the flood embankment without having a left bank is actually working on two canals. This year we are extending it to the Shoria Canal shown in Fig. 6, the work actually done for 1927-28 being shown in chain lines. I may also say that this system may be applied to the Muzaffargarh System of Canals as easily or even more easily than to Dera Ghazi Khan.