PAPER No. 230.

REMODELLING DISTRIBUTARIES AND DISTRIBUTION OF WATER TO AREAS IRRIGATED BY COLONY CANALS.

BY

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Introduction.

From November 1927 to April 1933 I held charge of the Lower Jhelum Canal Circle, and from December 1933 to May 1938 I held charge of the East Circle of the Lower Chenab Canal.

During this period of nearly 11 years, owing to the unsatisfactory distribution of water for irrigation, drastic remodelling of distributaries was carried out in both Circles.

In this paper I propose to review the remodelling of the Mithalak Distributary of the Lower Jhelum Canal, as the remodelling of this channel was more difficult than the remodelling of any other channel on that canal. I shall then review in greater detail the remodelling done in the East Circle of the Lower Chenab Canal between 1933 and 1938.

In the past, when it was found impossible to get water to the tail of a channel, the line of least resistance was generally adopted, and the outlets were adjusted, or reduced in size.

Insufficient attention was paid to the hydraulic condition of channels, and very few attempts were made to investigate the cause of a channel working unsatisfactorily, and to remedy defects.

Owing to the partition of holdings in areas irrigated by Colony Canals the question of the equitable distribution of water for irrigation is becoming more important every year, and I consider that the time has now come for Government to lay down a clear and definite policy for remodelling on each canal. In my opinion a different policy is required for each canal, and any attempt to lay down a general policy for all the canals in the Punjab is doomed to failure.

The remodelling policy of each canal should be periodically reviewed, and revised, when experience shows that it is defective.

In this paper I do not propose to advance any new theory regarding the flow of water. The paper is based on records, and facts.

Remodelling on the Lower Jhelum Canal between 1928 and 1933.

In 1928 the distribution of water for irrigation on the Lower Jhelum Canal was most unsatisfactory. On the Northern Branch it was necessary to run about 200 cusecs more than the authorized full supply discharge at the head of the Branch to meet the indents at the heads of distributaries. Even with this additional discharge it was impossible to get full authorized discharge to the tail of many channels.

Conditions on the Southern Branch were not much better.

Mr. (now Sir J. B. G.) Smith, Chief Engineer, asked me to tackle the question, and try to improve distribution.

The matter was discussed with the Deputy Commissioner, who asked me to take up the remodelling of the Mithalak Distributary first, as water was urgently required for irrigating a large area of unallotted land at the tail of this distributary.

In his Paper No. 154 Mr. K. R. Sharma has given a very detailed account of the remodelling of this distributary, so I shall confine myself to a description of the more important aspects of the remodelling.

The remodelling of other channels on the Lower Jhelum Canal was carried out on lines similar to those adopted for the remodelling of the Mithalak Distributary.

Remodelling of Mithalak Distributary.

The Mithalak Distributary takes off the left bank of the Northern Branch at R. D. 63,875, a distance of 52 canal miles from the head of the Lower Jhelum Canal. Its authorized full supply discharge is 136 cusecs.

The distributary was opened for irrigation in 1901.

1901 to 1907.

The history of this distributary shows that, between 1901 and 1907, trouble occurred chiefly due to flat slopes, and poor command. In 1907 the designed slopes were—

R. D. 0 to 67,000	1/5000
R D. 67,000 to 1,25,564	1/5714
R. D. 1,25,564 to tail	1/5000

In order to command high land 30 stop dams were sanctioned.

Bearing in mind that in 1907 the authorized full supply discharge at the head of the distributary was 160 cusecs, and that the head regulator consisted of three spans, each of 7′, with a crest at the designed bed level of the Northern Branch, and drop gates for regulation, it is not surprising that the distributary silted.

In 1907 one of the three bays was closed, and a masonry wall was constructed across the front of the regulator in the bed of the Northern Branch. The top of the wall was 3′ above the bed of the Northern Branch.

The Engineers-in-charge of the distributary apparently thought that this wall would exclude heavy bed silt.

The distributary continued to silt, and there was serious shortage at the tail.

1908 to 1917.

No remodelling appears to have been done between 1908 and 1914.

In 1914 Mr. Woods took up the question of remodelling this channel, and much argument arose regarding the best method of rectifying the unsatisfactory distribution of water.

Eventually Mr. Woods decided to remodel the channel to the data given below—

Water Slope	R. D. 0 to 67,000	1/4444
	R. D. 67,000 to 1,25,564	1/5714
	R. D. 1,25,564 to tail	1/5000

Authorized Full Supply Discharge at Head	150 cusecs
Designed Bed Width at Head	17′
Designed Full Supply Depth at Head	3·9′
Critical Velocity Ratio at Head	1·0

Mr. Woods also decided to remodel the head regulator to his rising cill type. He provided four spans, each of 7 feet, with rising gates, so that the water, entering the distributary, passed over the top of the gates.

1918 to 1928.

In 1918 the orifice outlets were replaced by Kennedy Gauge Outlets.

In the same year Mr. Woods inspected the distributary, and was horrified to find that a discharge of 168 cusecs

(the authorized full supply discharge was 150 cusecs) was required at the head to feed the tail.

The Full Supply Level at the head had also risen about 1′ about the level proposed in Mr. Woods' remodelling.

Between 1918 and 1928 the distributary continued to give trouble, but no attempt was made to remedy matters.

1928 to 1933.

When I assumed charge of the Lower Jhelum Canal Circle in December 1927 I found that, although 158 cusecs was being passed into the head of the distributary (136 cusecs should have sufficed), it was necessary to tatil outlets to get water to the tail.

An accurate and very detailed survey of the distributary was made, and this disclosed the conditions noted below—

(*a*) The head regulator, constructed in 1916, still existed, and regulation was being done over the top of the gates.

(*b*) The distributary was working with the water slopes given below—

R. D. 0 to 39,500	1/4000
R. D. 39,500 to 67,000	1/4300
R. D. 67,000 to 1,25,564	1/5200

(*c*) The bed widths were—

R. D. 0 to 39,500 Average bed width was 30′ but designed width was 17′

R. D. 39,500 to 67,000 Average bed width was 25′ but designed width was 14′

R. D. 67,000 to 1,25,564 The width at R.D. 67,000 was 25′ against designed width of 14′. At R. D. 1,25,564 the width was 12′ against designed width of 9′

The records showed that, prior to Mr. Woods' remodelling, the distributary was very wide and shallow, and that no attempt was made, during Mr. Woods' remodelling, to contract it to the designed width. Apparently Mr. Woods thought that his new regulator, with overshot regulation, would exclude coarse silt, and that the distributary would automatically contract. The reverse actually occurred.

After examining the new hydraulic survey I came to the conclusions noted below—

(*a*) The trouble was mainly due to a defective head regulator, which, although it had been designed to draw off only top water, actually drew off water containing a large quantity of coarse silt. The face of the regulator was set back about 25′ behind the toe of the inner side slope of the Northern Branch, so that a pocket was formed in front of the regulator, in which severe eddy action occurred. This action lifted the coarse silt from the bed of the Branch, and caused it to enter the distributary over the top of the gates.

(*b*) The channel was too wide and shallow especially in the head reach.

I decided to carry out the remodelling noted below—

(*a*) Mr. Woods' head regulator was scrapped, and a new regulator, similar in design to that shown in Plate No. 6, was constructed. With this design the eddy action in front of the regulator vanished, and the water entered the distributary smoothly.

(*b*) The grading proposed by Mr. Woods in 1916 was adopted, *viz.*

R. D. 0 to 67,000	1/4444
R. D. 67,000 to 1,25,564	1/5714
R. D. 1,25,564 to tail	1/3636

This grading is flat, but a steeper grade could not be obtained without abolishing the control points, which was not considered desirable.

The bed widths and depths were also the same as those adopted by Mr. Woods, but the channel was artificially forced to conform to the new section by forming berms with hanging bushing.

A detailed description of the method adopted for tightening this distributary will be found in Mr. Sharma's Paper No. 154.

After 10 years' experience of remodelling I have come to the conclusion that the method adopted on the Mithalak Distributary, *viz.*, hanging bushing, is not satisfactory. The only satisfactory method of forming berms to reduce the width of a channel is longitudinal bushing.

(*c*) The control points at R. D·s 39.500; 67,000 and 1,25,564 were retained, but the notches were abolished, and wide broadcrested weirs, similar in design to that shown in Plate No. 9, were constructed.

New control points of similar design were introduced at R. D.s 1,250; 16,000 and 85,707, (the offtake of a minor). The first of these new control points serves as a meter flume for controlling the discharge entering the distributary.

(*d*) The outlets were reconstructed in October 1928 to the design advocated by Mr. Crump in I. B. Paper No. 26. The crests were set at 0·6 *d* (*d*= designed depth of water in the distributary).

Most of the year 1929 was spent in getting the channel into order, as an immense amount of silt clearance, raising and strengthening banks, and tightening, had to be done. Early in 1930 the distributary was working to the new designed conditions.

During the summer of 1930 the distributary silted badly between R. D. 16,000 and the tail. This silting was attributed to the high setting of the crests of the outlets, so, during the winter of 1930-31, the outlets were again remodelled.

The design adopted was Mr. Sharma's modification of the A. P. M., as experiments, carried out at Sargodha, had shown that this outlet drew off more silt than Mr. Crump's original design.

The outlets were set with their crests at 0·8 *d* between R. D. 0 and 67,000, and at bed level below R. D. 67,000, as the command below this R. D. was good, and the working head of most of the outlets was very big.

Since 1931 the only trouble that has occurred, as far as I am aware, is silting between R. D. 67,000 and 1,25,564. In my opinion it is impossible to prevent this silting, as the slope of 1/5714 is too flat for the discharge of 60 cusecs. so, before I left the Lower Jhelum Canal in 1933, I issued definite orders that this reach should be silt cleared, whenever necessary.

The slope of 1/5714 is necessary to obtain sufficient command for the minor, which takes off at R. D. 1,25,564 to irrigate the Sargodha Civil Station, which is situated on very high ground.

I inspected this distributary in 1937, and found that it was working extremely well. There was, if anything, a

slight tendency to scour, due probably to the still pond method of regulation at Rasul, which was started in about 1932.

Conclusion.

The case of this distributary shows that remodelling must be done thoroughly, if it is to be successful. It is useless to tinker with outlets, if the head regulator is defective.

The unsatisfactory conditions on this distributary, prior to 1930, were chiefly due to a defective head regulator which sucked in enormous quantities of coarse silt, which caused the channel to widen, and steepen its slope.

It is most satisfactory to find that, in spite of the flat slopes, particularly below R. D. 67,000, the channel has worked satisfactorily since 1930, and no general remodelling of outlets has been found necessary during this period of nine years.

Remodelling in the East Circle of the Lower Chenab Canal.

When I assumed charge of the East Circle of the Lower Chenab Canal in December 1933, the distribution of water for irrigation was most unsatisfactory. I attribute this state of affairs to the fact that, after the Great War, there was a call for economy, so very little money was available for such work as remodelling between 1920 and 1930.

During 1932 and 1933 my prodecessor, Mr. Colyer, improved conditions by wholesale scrapping of old outlets, such as Kennedy Gauge Outlets, and orifices, but he did not hold charge of the Circle for a long enough period to do any serious remodelling.

In 1934 I reported at length on the condition of channels, and the distribution of water in the East Circle, and made it quite clear that, if any considerable improvement was to be expected, a large sum of money would have to be spent over a period of several years. During 1934 I was given an additional sum of Rupees two lakhs, over and above the sanctioned budget, for remodelling, and during the next three years I was given sufficient money to carry out all the remodelling that could be done during the available closures of the canal.

The results have, I maintain, justified the expenditure that was incurred, as the condition of distributaries, and the distribution of water in the East Circle is now extreme-

ly good, and probably much better than in any other Circle.

I now propose to relate the histories of three distributaries, *viz.*—

Mungi Distributary with a head discharge of 144 cusecs.

Awagat Distributary with a head discharge of 55 cusecs.

Kheowala Distributary with a head discharge of 20 cusecs.

After studying these histories I think the reader will realize how necessary it was to carry out drastic remodelling in the East Circle between 1934 and 1938.

Mungi Distributary.

This distributary takes off the left bank of the Lower Gugera Branch at R. D. 2,94,000, which is 143 miles from the head of the canal, and 18 miles from the tail of the Branch.

The distributary was opened for irrigation in about 1900.

The Full Supply and Bed Levels are shown in Plate No. 2, and the hydraulic data will be found in the statement in Appendix A.

The head regulator, as originally constructed, consisted of two spans, each of 7'5', with a crest level with the bed of the Lower Gugera Branch. This crest is shown on the "Longitudinal Section through Mungi Distributary" in Plate No. 3. Its R. L. was 550'76.

1900 to 1907.

(*a*) In 1904 the outlets were reduced in size to get water to the tail of the distributary.

(*b*) By 1907 the Full Supply Level at the head of the distributary had risen about 1', and below the fall at R. D. 52,000 by about 2'6'. The water slope between R. D. 0 and 52.000 had increased from 1/4444 to 1/4000: from R. D. 52,000 to 93.500 from 1/5000 to 1/4000 ; and from R. D. 93,500 to the tail it had flattened from 1/4444 to 1/5000.

With the flat slopes, as originally designed, and a head regulator with its crest level with the bed of the Lower Gugera Branch, and a velocity of about 9 *f/s* under the regulating gate, it is not surprising that the distributary silted.

In 1907 fairly extensive remodelling appears to have been carried out, as four bridges were raised, and the existing water slopes, *viz.*—

R. D. 0 to 95,000	1/4000
R. D. 95,000 to tail	1/5000

were adopted as the designed slopes.

The authorized full supply discharge at the head was reduced from 193 to 160 cusecs, and the outlets were reduced in size.

1907 to 1916.

Between 1907 and 1914 nothing of interest exists in the records.

By 1916 the full supply level had risen over the levels prevailing in 1907 by the amounts noted below—

R. D. 0 to 35,000	0·5′
R. D. 35,000 to 70,000	0·5′ at R. D. 35,000 increasing to 1′ at R. D. 70,000
R. D. 70,000 to 1,08,000	1′ at R. D. 70,000 increasing to 1·5′ at R. D. 1,08,000.
At the tail	0·5′

To get water to the tail it was necessary to run 40 to 60 cusecs more than authorized at the head.

The channel had become very wide and shallow.

In 1916 the distributary was remodelled, and a water slope of 1/4444 from head to tail was adopted.

Plate No. 2 shows the full supply and bed levels of 1900 and 1916.

Kennedy gauge outlets were installed throughout the channel.

1916 to 1926.

In 1919 the Kennedy gauge outlets were raised, and a control point was constructed at R. D. 1,08,300, to improve the command of the outlets taking off above this point.

In order to get water to the tail the portion of the distributary below R. D. 1,08,300, and the Mungi minor, which takes off at R. D. 1,08,300, were run in rotation. This was necessary as the cultivators tampered with the outlets, which could be made to draw off more than their authorised supply by plastering the vents with mud.

In 1921 the distributary was regraded to the slopes given below :—

R.D. 0 to 52,000	1/4000
R. D. 52,000 to 93,000	1/4444
R. D. 93,000 to tail	1/5000

In an endeavour to exclude coarse silt a raised cill was constructed in front of the head regulator.

Trouble with the outlets still continued, and the supply at the tail was short, so in 1923 the outlets were adjusted.

In the same year a meter flume was constructed at R. D. 1,300 and the gates of the head regulator were removed, regulation being done with karries.

1927 to 1933.

Silting still continued, so in 1927 a skimmer was constructed in front of the head regulator. The piers, on which the slab of the skimmer rested, are shown by broken lines on the plan in Plate No. 3, and in the same Plate will be found a section of the skimmer. This device would have excluded coarse silt, if there had been free flow under the slab. Unfortunately a big deposit of silt formed in front of the exit of the tunnel, and it was found that clearing the deposit was useless, as it formed again. This deposit was probably caused by the King's vanes in front of Janiwala distributary head, which are also shown by broken lines in Plate No. 3.

During 1929 it was necessary to run about 12 cusecs more than the authorized discharge of 143 cusecs in order to get any water to the tail.

The distributary continued to give trouble so in 1933 the slope was increased to 1/4000 from R. D. 0 to 1,08,300, and 1/3636 from R. D. 1.08,300 to the tail.

The 1933 levels are shown in Plate No. 2.

The Kennedy gauge outlets were replaced by A.P.M.s, and in a few cases, where the command was poor, by open flume outlets.

1934 to 1939.

When I assumed charge of the East Circle in December 1933 the distributary was still giving trouble, and it was impossible to get full authorized discharge to the control point at R. D. 1,08,300, even though more than authorized discharge was being run at the head.

Violent silt movements were also taking place during the summer, which affected the supply in the tail reach.

A new and accurate hydraulic survey was prepared, and on the longitudinal section were shown not only the usual data, such as water levels, bed levels, &c., but also details of each outlet, such as crest level, working head, water level in the water-course, &c.

After examining the survey, and inspecting the distributary, when it was dry and in flow, I came to the conclusion that the defects noted below were causing the trouble :—

(*a*) The skimmer in front of the head regulator was not working properly due to the silt deposit at the exit of the tunnel. The skimmer simply formed an obstruction to flow in the Lower Gugera Branch, and caused eddies, which induced coarse silt to enter the distributary.

(*b*) Bridges were in some cases drowned, and in other cases too tight.

(*c*) There were no control points between R. D. 1,300 and 1,08,300, a distance of 21 miles.

(*d*) When constructing the A. P. M. outlets in 1933 advantage had not been taken of the big working head, available in many cases, to set the crest of the outlet at a low level to draw off coarse silt.

The remodelling noted below was carried out in 1934—

(*a*) Control points, consisting of broadcrested weirs, similar in design to that shown in Plate No. 9, were constructed at R. D.s 35,000 and 70,000.

In order to obtain 0·75′ working head for each control point the water level was raised by this amount at each point. This necessitated flattening the water slope between R. D. 0 and 70,000 to 1/4444. In 1933 the distributary was working with a slope of 1/4000, so it was doubtful if it would work with the flatter slope. I had, however, made up my mind to remodel the head

regulator, and set the outlets deeper, if the channel did not work with the flatter slope, as I considered that the control points were essential. To put in the two control points, and maintain the slope of 1/4000, would have entailed much raising and strengthening of banks, which I wished to avoid if possible.

(*b*) Five bridges were widened and raised.

(*c*) Early in 1935 I found that the distributary would not work with the flat slope of 1/4444, so the remodelling noted below was carried out—

(*i*) The head regulator was remodelled to the design shown in Plate No. 3. A similar work had been constructed at the tail of the Lower Gugera Branch in 1934, and had proved most satisfactory.

(*ii*) All the outlets were remodelled. Sharma's modified type of the A. P. M. outlet was adopted, and the crest of each outlet was set as low as the working head available permitted.

In spite of this remodelling full supply did not reach the tail, so in 1936 the outlets were adjusted, as tank experiments had shown that Sharma's formula for calculating the discharge of his modified outlet was wrong for values of "*H*" exceeding 2′ (a brief note on these experiments will be found in Appendix B).

When adjusting the outlets the formula noted below was used for all values of "*H*" exceeding 2′

$$q = 7{\cdot}5 \; by \; \sqrt{h}$$

For values of "*H*" less than 2′ Sharma's formula was used, as experiments carried out at Sargodha had shown that this formula was correct for low values of "*H*".

The distributary still continued to silt, so I came to the conclusion that the only remedy was to steepen the slope between R. D. 0 and 70,000, or exclude coarse silt by constructing King's vanes in front of the head regulator.

I preferred the former, as I am only prepared to resort to silt exclusion, when there is no other remedy available. In order to steepen the slope it was necessary to raise the control point at R. D. 35,000, and raise and strengthen the banks between R D. 0 and 70,000. This work was

carried out early in 1938, and the outlets were adjusted to give authorized discharge, with the final designed full supply level, in April 1938.

The final grading of the distributary is shown by full lines in Plate Nos. 1 and 2.

The distributary has worked extremely well since April 1938, and this is proved by the graphs in Plate No. 4.

The zero line in this plate is the designed value of "*H*" of each outlet. The amount by which the "*H*" of each outlet is greater or less than the designed value is plotted on the graph, excesses being plotted above the zero line, and deficiencies below the line.

The graphs in Plate No. 4 show that the average variation from the designed value of "*H*" since April 1938 is less than 0·1′.

Bearing in mind that the average value of "*H*" between R. D. 0 and 1,08,300 is about 3′, and that the width of most of the outlets is either 0·2′ or 0·25′, reference to Appendix C will show that the variation in discharge for a difference of 0·3′ in the value of "*H*" is only 6%, so for a difference of 0·1′ the variation in the discharge of the outlet will be very small.

Conclusion.

The case of Mungi Distributary shows how necessary it is to watch a distributary after remodelling. It was a case of "If at first you don't succeed; try, try, again." If this maxim had been followed in the past so many failures would not have occurred.

Reference to Plate No. 1 and Appendix A will show that the bed widths now proposed are less than those actually existing. As the distributary has been working satisfactorily since April 1938, I would not contract it artificially to the 1938 proposed widths, but the local officers should endeavour to prevent it becoming wider. If at a later date the channel starts to silt I would be inclined to consider tightening it, as the tightening of the Mithalak Distributary was so successful.

Later in this paper I shall deal with the reasons for the distributary giving so much trouble between 1900 and 1938.

Awagat Distributary.

The Awagat Distributary takes off the right bank of the Lower Gugera Branch at R. D. 26,737 *i.e.*, immediately

above the meter flume at R. D. 27,000, which is the indenting station for the Lower Gugera Branch.

The offtake of the distributary is 90 miles from the head of the canal.

The distributary was opened for irrigation in 1900. Its length was 32 canal miles, and its full supply discharge at the head was 200 cusecs.

1900 to 1911.

Between 1900 and 1907 the distributary gave trouble, partly due to its abnormal length, but chiefly, I think, due to silting. This silting was entirely due to a defective head regulator, which was similar in design to that of Mungi Distributary, and had two spans, each of 7'5', with its crest level with the bed of the Lower Gugera Branch, with drop gates for regulation.

To get water to the tail the sizes of the outlets were reduced in 1904, and again in 1907.

Silting still continued so in 1911 the portion of the distributary below R. D. 72,700 was attached to a new distributary, having its offtake at R. D. 1,03,680 of the Lower Gugera Branch.

The discharge at the head of the distributary was reduced from 200 to 63 cusecs.

In 1911 the crest of the head regulator was raised by 2'5 and an advanced cill was constructed. The crests and advanced cill are shown by broken lines in Plate No. 6. Apparently the Engineers thought that the raising of the crest, and the construction of an advanced cill would keep out coarse silt. The reverse actually occurred.

Prior to the 1911 remodelling, when the head discharge was 200 cusecs, the slope in the first five miles averaged 1/2500. The water must have been very heavily charged with coarse silt for such a steep slope to be necessary.

Appendix A shows that, when the discharge was reduced to 63 cusecs in 1911, the slope in the first five miles was reduced to 1/4000 although, with a discharge of 200 cusecs, the channel had been running with a slope of 1/2500.

Apparently it was anticipated that the raised crest and advanced cill would keep out coarse silt, and permit the channel to run with a flatter slope.

1912 to 1921.

Between 1912 and 1916 the distributary continued to give trouble, and frequent silt clearance was necessary.

By 1916 the distributary had silted to an average slope of 1/2400 in the first five miles, and 1/3000 in the tail reach.

A slope of 1/2500 was adopted from R. D. 0 to 12,000, 1/2857 from R. D. 12,000 to 50,000; and 1/3333 from R. D. 50,000 to the tail.

The orifice and pipe outlets were replaced by Kennedy Gauge outlets.

The distributary continued to silt, so in 1921 a meter flume was constructed at R. D. 1,900, and the necessary working head for the flume was obtained by raising the full supply level between R. D. 0 and 1,900.

A control point was also introduced at R. D. 50,000.

The same grading as proposed in 1916 was adopted.

1922 to 1933.

As was to be expected silting still continued, as the head regulator was not remodelled, so the outlets were adjusted. By 1925 the head reach was so badly silted that the flume at R. D. 1,900 had become non-modular.

Between 1925 and 1930 the channel was frequently silt cleared. By 1930 the distributary was working to an average slope of 1/2200 from R. D. 0 to 31,000 and 1/2800 from R. D. 31,000 to the tail.

A further attempt was made to induce the distributary to work to the slopes proposed in 1921 without altering the head regulator.

In 1933 the distributary was again regraded to the slopes to which it was actually working, *viz.*,

R. D. 0 to 12,000	1/2222
R. D. 12,000 to 45,000	1/2273
R. D. 45,000 to tail	1/3333

The control point at R. D. 50,000 was abolished, and it was proposed to dismantle the meter flume at R. D. 1,900, but the dismantling was not carried out.

1934 to 1939.

When I assumed charge of the East Circle in December 1933 the discharge at the head of the distributary was 65 cusecs, but, even with this discharge, it was difficult to get water to the tail.

A new and accurate hydraulic survey was prepared, and this brought to light the defects noted below—

(*a*) The head regulator was similar to that of Mungi distributary, but the skimmer platform did not exist. In its place was an advanced cill. This type of head is a first class coarse silt sucker. In the case of Awagat Distributary it was undoubtedly the cause of the trouble.

(*b*) The channel was abnormally wide and shallow.

(*c*) The outlets were an assortment of Kennedy Gauge, orifices and pipes.

Due to extensive remodelling of other distributaries it was impossible to do much to this distributary during 1934, so only the head regulator, and meter flume at R. D. 1,900, were remodelled. The remodelled design for the head regulator is shown in Plate No. 6.

During 1935 the remodelling noted below was carried out—

(*a*) A distributor was constructed at R. D. 11,309, as the outlet, which took off at this point, and which was originally a minor, was not working satisfactorily, and I considered it advisable to re-open the minor.

(*b*) The distributary was graded to the slopes noted below –

R. D. 0 to 12,000	1/3000
R. D. 12,000 to tail	1/2857

These slopes were flatter than those to which the distributary was running, but I considered that the channel would work to them, as the head regulator had been remodelled. My assumption has proved to be correct.

(*c*) The outlets were replaced by Sharma's modified type of A. P. M. In many cases the crest of the outlet was placed below the designed bed level of the distributary, as there was ample working head available for modularity.

(*d*) As the channel was abnormally wide, it was tightened with longitudinal bushing.

In April 1936 the outlets were adjusted, as the experiments described in Appendix B had shown that Sharma's discharge formula, where "*H*" exceeded 2′, was wrong.

During December 1937 the bed of this distributary was staunched with sodium carbonate as an experimental measure.

Conclusion.

The Full Supply Level, as finally approved in 1938, is shown by a full line in Plate No. 5. It is the same as designed in 1935, which shows that the slope tried in 1935 is suitable, and does not require altering, as has been done in the case of Mungi Distributary.

The case of this distributary shows that in some cases when the head regulator is remodelled, it is possible to flatten the water slope. In this case the distributary was running with a slope of 1/2222, before the head regulator was remodelled. It is now working satisfactorily with a slope of 1/3000, in the head reach.

In Plate No. 5 I have shown the original bed level of the distributary. The rise in the bed during the last 40 years is remarkable. and may account for the abnormal absorption, to which reference is made below.

In Appendix E will be found the results of some observations made during the last week of August 1939 to ascertain the losses by absorption and evaporation in this distributary. During the winter a discharge of 51·5 cusecs at R. D. 1,900 gives authorized discharge at the tail, but during the summer the discharge has to be increased to 56·5 cusecs. This means that during the summer the losses amount to about 18% of the total draw off, *i.e.*, nearly double the normal allowance, which is 10%.

These observations show that the sodium carbonate treatment of the bed has not been entirely satisfactory. I think the losses are taking place through the lower portion of the berm.

Kheowala Distributary.

This distributary takes off the right bank of the Lower Gugera Branch at R. D. 64,700, 97 miles from the head of the canal. It is a ditch distributary with a head discharge of 20 cusecs.

It was opened for irrigation in 1900.

1900 to 1904.

In 1900 the slope was 1/2857, bed width at the head 5′ and F. S. Depth 3·0′, the head discharge being 28 cusecs.

The head regulator had a span of 3′ with its crest at the bed level of the Lower Gugera Branch. and a drop gate for regulation. With such an arrangement the velocity under the gate was about 10 *f/s*, as the working head was about 4′, so it is not surprising that the channel silted.

In 1903 the slope was increased to 1/2500, and the bed width at the head was made 13′ with F. S. depth 1·5′.

The distributary continued to silt, so in 1904 the bed width was again reduced to 5′ at the head. The slope was kept at 1/2500.

1905 to 1921.

No record exists to show what work was carried out between 1905 and 1921, so we can only assume that frequent silt clearance was done, as no alteration was made to the head regulator.

By 1921 the water level at the head had risen about 2′ above the 1900 level, and the slope in the first two miles had increased to 1/2000, so the distributary was remodelled with this slope from R. D. 0 to 10,000, and 1/2500 from R. D. 10,000 to the tail.

Most of the outlets were cast iron or masonry rectangular orifices, some being free fall, and some submerged. These were remodelled so that all were of the free fall rectangular orifice type.

1922 to 1933.

In 1924 an attempt was made to make the channel work more efficiently by tightening it with brush wood spurs, but this failed.

By 1931 the distributary had silted to such an extent that it was necessary to run 31 cusecs at the head to get any water to the tail, although the authorized discharge was only 22 cusecs.

As the Full Supply Level had risen above the 1921 designed level the distributary was again regraded, and a slope of 1/2000 was adopted from the head to R. D. 13,000, and 1/2500 from R. D. 13,000 to the tail.

The distributary still continued to silt, and by 1933 the water level had risen so high that it was impossible to get full authorised discharge into the distributary, so the slope was flattened to 1/2222 by lowering the full supply level at the head. After doing this the working head through the head regulator was only 0·7′.

1933 to 1939.

When I assumed charge of the East Circle in December 1933 the distributary was still giving trouble This trouble was entirely due to a defective head regulator. As the regulator had never been remodelled, since it was constructed in 1898, it appears that the Engineers in charge had not attributed the trouble to a defective head.

The old head regulator was scrapped, and a new work was constructed, the design of which will be found in Plate No. 8.

A meter flume was constructed at R. D. 340, and a control point at R. D. 13,600.

With the remodelled head regulator I anticipated that the distributary would work satisfactorily with a flatter slope, so I adopted a slope of 1/2500 from head to tail.

The free fall orifice outlets were scrapped, and Sharma's modified A. P. M. was substituted.

On the whole the channel worked quite well, and less silt deposited than in previous years, but there was a slight tendency to silt, so, in 1938, I decided to regrade the channel to a slope of 1/2250.

The outlets were adjusted in April 1938 to give authorized discharge with the new full supply level. Since April 1938 the distributary has given no trouble.

Plate No. 7 shows the longitudinal section of the distributary.

Conclusion.

As in the case of Mungi Distributary I made a mistake, when I assumed that a grade of 1/2500 would be suitable with the remodelled head regulator.

I am now inclined to think that the control point at R. D. 13,600 was not necessary, as the length of the distributary is only five miles. It might be abolished, if the channel is ever again remodelled.

Reasons for the failure of Remodelling carried out prior to 1934.

I have been asked to record why, in my opinion, remodelling carried out prior to 1934, failed.

I think that most Irrigation Engineers will, after reading the histories of Mungi, Awagat, and Kheowala distributaries, agree that in all three cases. the failure was primarily due to a defective head regulator.

In the case of Mungi distributary the skimmer, built in front of the regulator, probably intensified the trouble of silting, as the exit of the tunnel under the skimmer slab was blocked.

In the case of Awagat Distributary the advanced cill undoubtedly intensified the trouble, as it formed an obstruction, and caused eddies in front of the regulator. In the case of Khèowala Distributary the head regulator was too narrow, and the cill was too low.

Another cause of failure were the Kennedy Gauge Outlets. The cultivators tampered with them, and this caused short supply at the tail.

Dealing with only one aspect of the trouble at a time also tended to failure. If the history of the channel had been studied, and drastic remodelling carried out, success would, I think, have been obtained in many cases.

Finally I am inclined to think that many of the Engineers, who from time to time held charge of the divisions on the Lower Chenab Canal, were afraid to put up proposals for drastic remodelling on account of the cost.

Hints for Engineers undertaking remodelling of Distributaries.

(1) First fix reliable bench marks along the channels to be remodelled. Perhaps Chief Engineer will supply any Engineer, who is interested in levelling and fixing bench marks, a copy of the instructions that were prepared in the West Circle for doing this work.

Supervision of this work must be centralized, *i.e.*, if the work is being done over the whole of a Circle, put the whole job under one Executive Engineer.

(2) Having fixed reliable bench marks carry out a detailed hydraulic survey, and plot a longitudinal section of the channel. Cross sections should also be plotted.

(3) With the hydraulic survey, and record plans of all masonry works (the record plans should be checked at site to see that they are correct) try to reason out why the channel will not work. Also read the history of the channel, if it is available. If it is not available read the files.

The longitudinal section, if prepared correctly, shows most of the information required for remodelling. A glance at it reveals the working head of each outlet, which indicates the nature of the command of the channel. The setting, *i. e.* the position of the crests of the outlets is also clearly shown.

With a little experience the Engineer will, after studying the records mentioned above, be able to decide why the channel will not work satisfactorily, but, if he is in any doubt, he should consult someone, who has extensive experience of remodelling.

(4) Having decided why the channel is giving trouble, take the case to the Superintending Engineer, and discuss it with him, and put before him your proposals for remodelling. If he agrees with your proposals get out detailed designs and estimates for discussion with the Chief Engineer.

(5) When preparing designs for remodelling masonry works do not show your proposals on a blue print of the record plan of the work, as nothing is more annoying than trying to decipher a jumble of vermilion lines on a blue print.

Draw your proposals in full pencil lines on a piece of white paper, on which the existing work is shown in full black ink lines.

Generally a scale of 1/50 is the most suitable for masonry works on distributaries.

(6) Before remodelling or adjusting the outlets on a channel get the channel itself into order, and complete the remodelling of the masonry works, especially the head regulator.

(7) If possible, after completing the remodelling of the masonry works, and getting the channel into order, allow the channel to work for a full crop before touching the outlets, even if it is necessary to run more than the authorized discharge at the head (get permission to do this).

(8) Always set the crests of outlets as low as possible. Experience shows that if, in any reach of a channel, a line is drawn through the crests of the outlets, the bed will rise at least to this line. It may rise higher.

The lower the setting the greater the draw off of coarse silt.

The setting will depend on the working head available. In order to ascertain this head have a longitudinal section

of the first mile of the watercourse prepared, when high (not uncommanded or *jhalari* land) is being irrigated. As an alternative take, as the available working head, the minimum working head shown in the "*H*" register during the last six *rabi* months.

Remember that, when an outlet has a big working head, its watercourse will have a steep slope, and can carry coarse silt on to the fields, so in such cases the crest of the outlet can be set at or below bed level without causing any abnormal silt deposit in the watercourse.

(9) Before taking up the question of remodelling outlets inspect the site of each outlet, and arrange to have a representative body of the cultivators present during the inspection Ascertain their troubles, if any, and try to remedy them during the remodelling They may want a change in the *chakbandi*, or in the site of the outlet due to high silt banks in the head reach of the watercourse, &c., &c.

(10) Do not be afraid to submit a remodelling scheme because it is expensive. It is a mistake to tinker with a channel with a view to cheapen the cost of remodelling. Remember the saying "what is worth doing is worth doing well". This does not mean that the remodelling proposals should be extravagant, but the scheme should include proposals for carrying out all works that are necessary to make the channel work efficiently.

(11) When raising and strengthening banks do not allow borrow pit measurements. Adopt bank measurements You will get much better value for your money. In both Circles of the Lower Chenab Canal borrow pit measurements are only allowed in exceptional cases.

(12) Below are given suggestions for calculating bank widths, &c.—

Bank width $= d + \sqrt{\frac{b}{d}}$ (take the result to the nearest foot) where

d = designed full supply depth
b = designed bed width

Height of bank above full supply level

up to 10 cusecs discharge	1·0′
11 to 25 cusecs discharge	1·25′
26 to 100 cusecs discharge	1·5′

101 to 250 cusecs discharge	1·75′
above 250 cusecs discharge	2·0′

Berm width at full supply level

up to 10 cusecs discharge	$1' + \frac{d}{2}$
11 to 25 cusecs discharge	$1{\cdot}5' + \frac{d}{2}$
26 to 50 cusecs discharge	$2{\cdot}0' + \frac{d}{2}$
51 to 100 cusecs discharge	$2{\cdot}5' + \frac{d}{2}$
101 to 250 cusecs discharge	$3{\cdot}0' + \frac{d}{2}$
above 250 cusecs discharge	$3{\cdot}5' + \frac{d}{2}$

The formulæ given above provide strong banks and liberal berms. If funds are scarce a lighter section may be adopted.

(13) Artificial contraction of a channel should only be resorted to when it is abnormally wide. If a channel with a designed bed width of 20′ is only 4′ wider, then leave it as it is. Similarly if a channel with a designed bed width of 8′ is only 2′ wider, it should be left alone.

It is difficult to add less than, say, 2′ of berm artificially to the existing berm of a channel.

If artificial contraction has to be done, do it with longitudinal bushing, as spurs, although cheaper, are unsatisfactory.

(14) When silt clearing a channel clear it to the full existing bed width. Remember that, if a channel is wider than designed, it must not be silt cleared to designed bed level. Allowance must be made for the extra width. If it is silt cleared to designed bed level the full supply level will be lower than designed, and the outlets will not draw off their authorized discharge.

(15) During the summer the tail reach of almost every channel contracts due to growth of the berms. The supply at the tail falls, and the Engineer sometimes thinks that his remodelling has failed. This is not the case, as the tail supply will again rise to normal, when the tail reach is cleared. Generally this clearance should be done in the first week of October.

(16) Never accept the discharge of a watercourse unless it is observed with a portable tin flume. One of these flumes will be available for inspection during the Congress. In Appendix D will be found discharge tables for these flumes, and instructions for using them.

In practice I have found that most discharges can be observed with the 1·5′ flume. The small flume should only be used for discharges less than one cusec.

A detailed design of the flumes can be obtained from the Executive Engineer, Hafizabad Division, Lyallpur.

(17) If the remodelling is carried out in accordance with my policy of fixing the full supply level, it will be found that frequently some of the outlets, during the first few months after remodelling, do not draw off their authorized discharge due to the water level being lower than the designed level. In such cases *imdadi* (auxiliary) pipes should be given to these outlets, until the water level rises to the designed level.

Suggested policy for remodelling on the Lower Chenab Canal.

In the East Circle most of the distributaries have been drastically remodelled, and are now working extremely well. Their longitudinal sections have been revised, and on these has been marked the full supply level to which, in the opinion of the designer, the channel should work satisfactorily. This full supply level is shown by a full line in Plate Nos. 1, 5, and 7. The outlets have been remodelled, or adjusted to give their authorized discharge with this full supply level.

In most cases, if the distributary is allowed to silt, and the full supply level to rise, it will be necessary to raise the full supply level in the Branch Canal, from which the distributary takes off. In my opinion such raising of the full supply level in the Branch Canal would be most undesirable, as in most reaches of the Lower Chenab Canal the full supply level is already very high.

I, therefore, firmly believe, and strongly advise that the full supply level of as many channels as possible should be fixed at a definite level, and maintained at this level by silt clearance.

My reasons for advocating this policy are given below :—

(*a*) Command from most channels is now very good, and I consider that no further raising of the

full supply level, in an endeavour to command high land, should be allowed.

Land that is now uncommanded by flow should remain uncommanded, and Irrigation Engineers should resist any attempts by Revenue Officers to persuade them to raise the full supply level, or put in stop dams, to command such high land.

(*b*) If the full supply level is maintained at a fixed level no further remodelling, or perhaps I should say reduction in the discharge of outlets, will be necessary. The cultivators will welcome this.

If we can abolish the remodelling of outlets, I am convinced that the number of petitions will be reduced, which will mean less work for everyone. The abolition of remodelling of outlets will make Government, and the Irrigation Branch in particular, more popular.

(*c*) It has been suggested that the adoption of this policy will entail additional expenditure on maintenance, owing to the additional silt clearance that will be necessary. I do not agree with this suggestion, as the cost of raising and strengthening of the banks will be reduced. Time alone will show which is correct.

Even if a small additional cost is entailed surely the advantage obtained by abolishing the remodelling of outlets justifies this extra cost. I feel that the present Popular Government will agree with me on this point

For the present I would apply this policy only to the East Circle of the Lower Chenab Canal, and watch the result, an accurate account being kept of the cost of maintaining each channel.

If this policy is accepted I would suggest that, once the full supply level has been fixed for any channel, it should not be altered without the Chief Engineer's consent. There is one point to which I have not referred. It is the possibility that the channel may scour. If this does occur, and in my opinion it will not occur in many cases, additional control points can be constructed, or the outlets can be adjusted. I would prefer the construction of control points, so as not to lose command.

It should be clearly understood that for the present I advise that my policy should be adopted only in the East Circle of the Lower Chenab Canal. I think, however, that the same policy might be adopted on the Lower Jhelum and Lower Bari Doab

Canals, but before applying the policy to any other Canal a very careful examination of local conditions must be made.

Exclusion of coarse silt from Distributaries.

As a general principle every distributary should be made to draw off as much coarse silt as it can take without interfering with its regime. Drastic silt exclusion with skimmer head regulators should only be permitted in very exceptional cases. An example of such a case is the Lagar Distributary, which takes off the Upper Gugera Branch near Chuharkahna. Its discharge is only 35 cusecs, and its slope is 1/5000, and this cannot be increased. In such cases, which fortunately are rare, all coarse silt must be excluded.

In the West Circle of the Lower Chenab Canal most of the distributaries, which take off the Jhang Branch Upper, have skimmer heads, which were constructed in about 1933 and 1934. The tail distributaries of the Branch are silting badly, and the distributaries, from which silt has been excluded, are still scouring.

When I introduce this paper I will, if time permits, describe what has happened on the Nasrana Distributary. In the East Circle most of the head regulators are of the open flume type, shown in plate Nos. 6 and 8. This type has generally proved most satisfactory, as most of the channels, that have been remodelled, are now in fairly stable regime.

If skimmer heads had been constructed in the East Circle the distributaries in the lower reaches of the Lower Gugera and Burala Branches would, in my opinion, have silted solid.

Type Designs for Head Regulators, Distributors, Etc.

Head Regulators.—The designs, which I adopted in the East Circle, are shown in Plate Nos. 3 ; 6 : and 8.

In the cases of Awagat and Kheowala Distributaries the open heads were designed so that, with full supply level in the Branch Canal, the mean velocity in the flume of the regulator would be approximately equal to or slightly less than the mean velocity in the side segment of the Branch.

The gate (old type drop gates can be used) is placed on the distributary side of the bridge. Plate No. 8 shows that eight grooves were constructed in the masonry.

These grooves were constructed for experimental purposes, in order to ascertain the best position for the gate, the idea being that the high velocity under the gate should have no effect on the velocity at the mouth of the flume.

With this design there is no visible eddy action in front of the regulator.

The design adopted for Mungi Distributary is more elaborate, and expensive, and is only suitable where a big distributary takes off. Plate No. 3 shows the design.

The portion upstream of the crest is designed on lines similar to those adopted in the design of a meter flume, which will be explained later.

The longitudinal section through the Branch shows that the glacis has two slopes, the upper portion being 1 in 1·5, and the lower portion 1 in 5. This double slope brings the standing wave very close to the crest, and reduces wave action downstream.

The broken lines on the plan in front of the head regulator of Mungi Distributary show the position of the skimmer that was constructed in 1927. A section of the skimmer is also shown.

The broken lines on the plan in front of Janiwala Distributary head regulator show the position of the King's vanes, which were constructed to exclude coarse silt from that distributary.

During the winter of 1936-37 experiments were carried out to ascertain the distribution of silt in the bays of the regulator. Silt samples were taken simultaneously in each bay at a point 6 h (h being the depth of water on the crest measured at a point 6 h upstream of the downstream edge of the crest) from the downstream edge of the crest, and at a depth of 0·6 d (d being the depth of water on the floor upstream of the crest).

The average of fifty samples is given below.

Silt in grammes per litre

	Medium	Coarse
Janiwala Bay	0·300	0·042
Right Bay of Lower Gugera Branch	0·324	0·073
Central Bay do do	0 356	0·107
Left Bay do do	0·357	0·111
Mungi Bay	0·304	0·067

It is interesting to note that there is very little difference in the distribution of the medium silt. The coarse silt is, however, less near the side than the centre, and this is what one would expect.

I should like to suggest that the Research Department should carry out model experiments on various types of head regulators, in order to obtain some information about the capacity of each type to draw coarse silt into the offtake. The experiments should be carried out with glass models, so that the movement of silt in the parent channel in front of the regulator can be observed.

At present we have no information on the subject, so such information would be most useful to Engineers about to undertake remodelling, and would in the long run save unnecessary expenditure.

Meter Flumes.

Every distributary, taking off a Main or Branch Canal, should, if possible, have a meter flume at about R. D. 1,000, so that the discharge can be obtained without having to carry out a discharge observation.

The most suitable type of flume is shown in Plate Nos. 9 and 10. The only difference between these two types is the slope of the glacis.

The minimum working head required to ensure modularity in the case of the flume with a 1 in 5 glacis is about 10% of the depth of water on the crest, so this type is suitable, where the working head is small, or silting occurs below the flume. With very few exceptions this type has been adopted in the East Circle.

The type shown in Plate No. 10 requires a greater working head to ensure modularity. Its main advantage is that the standing wave occurs near the crest, and wave action downstream is reduced to a minimum.

Where the working head is considerable the glacis can be omitted, and a free overfall adopted.

Below I give the main features of the design :—

(*a*) Very careful and detailed experiments have shown that the co-efficients, noted below, should be used in calculating the discharge, using the formula

$$q = cb(h + ha)^{\frac{3}{2}}$$

Where "h" is equal to or less than 1·0 $c = 2·95$
Where "h" exceeds 1′ and is less than 1·26′ $c = 3·02$
Where "h" exceeds 1·25′ $c = 3·05$

(*b*) Length of crest = 3 h.

(*c*) Length from downstream edge of crest to upstream face of wing wall = 10 h.

(*d*) Length from downstream edge of crest to centre of hole in gauge well = 6 h.

(*e*) Make "h" a multiple of 3″ *i. e.*, 1·0′, 1·25′. &c. keeping the width of the flume as nearly as possible equal to the bed width downstream.

(*f*) The level of the floor upstream of the crest must be such that the mean velocity on it will just exceed the critical velocity, in order to prevent silt depositing on it.

(*g*) A pipe about $\frac{3}{4}$″ diameter is suitable for the hole into the gauge well. The centre of the pipe should be 3″ below the level of the crest.

(*h*) The radius of curvature of the upstream wing walls should be 2h.

All meter flumes in a Circle should be of the same type. I prefer the type described above. as it requires less working head for modularity than a narrow flume with a big "h".

Many distributaries do not have enough working head to permit the construction of a meter flume. In such cases raise the full supply level in the Branch Canal if possible. I did this in many cases in the East Circle.

Control Points.

All control points should be similar in design to meter flumes described above.

Distributors at the offtake of minors

After the water has passed through the head regulator into the distributary its distribution to the minors and outlets should be effected without human intervention.

In the past regulation of minors was done with gates. The key of the gate was kept by the gauge reader. In the East Circle I can think of only one case, where gate regulation still exists.

At the offtake of a minor, where a fall exists, a distributor, similar in design to that shown in Plate No. 11, should be constructed.

Where no fall exists, or can be created, the head of the minor should be converted into an A. P. M., or an Open Flume without a gate.

Referring to the design shown in Plate No. 11 it will be seen that the design of the crest, and the portion of the work upstream of the crest, is similar to that of a meter flume, already described.

Special attention is invited to the A. P. M. outlet. To feed this outlet the water first passes through a Hume pipe, laid under the divide wall, which discharges into a masonry well. From the well the water passes through an A. P. M. or open flume outlet.

These outlets are very popular with the cultivators, as the command is generally good, and the discharge is steady.

On no account should any permanent means of regulation, such as karrie grooves, be allowed in the design of these distributors.

Outlets.

I, myself, prefer Sharma's modification of the A. P. M., if sufficient head is available to set the crests of the majority of the outlets at or below bed level of the channel, as experiments have shown that this outlet draws off more silt than Crump's original design. The figures in Appendix C show that, when the outlet is set low, it is fairly rigid. For a rise in the water level in the distributary of 0·3′ the variation in discharge is only about 8%, when designed "*H*" is 2·5′ and 6%, when designed "*H*" is 3·0′.

We also know definitely the correct discharge co-efficient for this outlet.

If there is insufficient working head available for an A. P. M. outlet, the open flume type should be adopted. The crest of both types of outlets should be set as low as possible, not only because low setting means that more silt is drawn off, but because the outlet becomes more rigid the lower the crest.

I suggest that Irrigation Engineers should make greater endeavours than they are making at present, to evolve a rigid module, which cannot be tampered with. I suggest

The graphs of the distributaries in the East Circle, will, I hope, be available for inspection by Members during the discussion of this paper.

So that the preparation of the graphs may not be delayed Overseers in charge of sections submit direct to the Circle Office each month the data required for the preparation of the graphs.

The amount by which the observed "*H*" of each outlet exceeds the designed value is plotted above the zero line, and similarly the amount by which it is less than the designed value is plotted below the zero line.

The graphs for each of the six months are plotted in different colours.

The only defect in these graphs is that they do not show when an outlet is not modular. I think this information might be shown by a dot, say 1/16" diameter, on the graph.

(*c*) Executive Engineers should maintain special registers, in which the value of "*H*," and the working head of each outlet is shown every month. Sample registers will be available during the discussion on this paper.

(*d*) In the Burala Division of the East Circle the Executive Engineer requires his Sub-divisional Officers, Zilladars, and Overseers, to report tail gauges direct to him, whenever they inspect a tail. He keeps a record of these in a special register. This register ensures the following :—

(*i*) If the tail gauge reported by the gauge reader frequently varies from that reported by Officers and Subordinates it is an indication that the gauge reader is either too lazy to go to the tail, or is reporting incorrect gauges.

(*ii*) If the register shows that the tail gauge is as designed, complaints regarding tail supplies can be filed. This reduces correspondence.

(*iii*) It ensures that Sub-divisional Officers, and Subordinates inspect tails at frequent intervals.

Hydraulics of Channels.

In this paper I have not attempted to discuss the hydraulics of channels, as such a discussion would make the paper very long.

Results in the East Circle indicate that a Lacey's "*f*" of about 1·1 is suitable.

In most cases in practice it is impossible to obtain the ideal slope for any given discharge. In such cases adopt the steepest slope possible, but do not abolish control points in order to obtain a slightly steeper slope. Experience shows that in the Punjab control points are absolutely necessary on a long channel, if it is to work satisfactorily. The ideal distance apart of control points is five miles.

Conclusion.

I have come to the conclusion that the time has now come to try, as an experiment, a limited amount of Central Control of remodelling. We must not, however, kill initiative, so local officers should be encouraged to continue to submit proposals for remodelling.

These proposals should be carefully scrutinized by an Officer on special duty in the Secretariat, who would not only discuss them with the Local Officers, but also inspect the channel, if necessary.

Needless to say the Officer on special duty must have extensive experience in the remodelling line, so our young Engineers should be encouraged to take an interest in this important subject.

So long as I remain in India I shall be delighted to help anyone, who cares to consult me, as remodelling is a subject, in which I am still interested.

APPENDIX A

Statement showing hydraulic data from 1900 to 1938

Year.	R. D.		Slope.	AT BEGINNING OF REACH				AT END OF REACH			
	From	To		Discharge.	Bed width.	F. S. depth.	C. V.	R. Discharge.	Bed width.	F. S. depth.	C. V. R.
	MUNGI DISTRIBUTARY										
1900	0	52,000	1 3922	193	21·0	4·2	0·95	129	19·5	3·6	0·88
	0	93,500	1/5000	124	19·0	3·5	0·91	76	16·5	3·1	0·79
	52,000	tail	1/4000	69	16·0	3·0	0·77	10	5·5	1·7	0·79
1907	93,500	95,000	1/4000	160	26·0	3·1	1·08	69	15·0	2·7	0·98
	95,000	tail	1/5000	62	14·0	2·6	1·07	8	5·0	1·7	0·68
1916	0	tail	1/4444	142	17·0	3·7	1·05	5	4·0	·3	0·84
1921	0	52,000	1/4000	143	22·0	3·2	1·07	100	19·0	2·8	1·07
	52,000	93,000	1/4444	100	19·0	2·8	1·07	53	14·0	2·5	0·92
	93,000	tail	1/5000	44	12·0	2·5	0·88	7	4·0	1·8	0·65
1933	0	108,300	1/4000	143	25·5	2·9	1·10	44	13·0	2·2	1·02
	108,300	tail	1 3636	16	6·5	1·7	1·09	9	4·0	1·6	1·08
1934	0	70,0000	1/4444	138	25·5	2·9	1·06	87	22·0	2·5	0·99
	70,000	108,30	1/4000	77	16·5	2·7	1·01	38	12·0	2·2	0·95
	108,300	tail	1/3333	14	6·0	1·8	0·93	7	4·0	1·6	0·81
1938	0	35,000	1/4200	144	19·0	3·5	1·05	113	16·5	3·3	1·04
	35,000	70,000	1/4100	108	16·0	3·25	1·05	78	13·25	3·05	1·01
	70,000	108,300	1/4000	76	12·75	3·05	1·01	36	9·0	2·45	0·96

	AWAGAT DISTRIBUTARY.										
1911	0	12,000	1/4000	63	15·0	2·6	0·96	52	13·0	2·40	1·04
	1 .00	25,000	1/4000	40	12·0	2·3	0·92	40	12·0	2·30	0·93
	25 ,00	tail	1/3636	33	8·0	2·5	0·58	4	2·0	1·60	0·79
1916		12,000	1/2500	60	13·0	2·3	1·29	52	12·0	2·20	1·29
	12,000	50,000	1 2857	39	12·0	2·0	1·15	29	10·0	1·80	1·21
	50,000	tail	1/3333	20	7·0	1·9	1·05	2	2·0	1·00	0·95
1921	0	1,900	1 2500	58	13·0	2·2	1·34	58	13·0	2·20	1·34
	1,900	12,000	1/2500	58	13·0	2·2	1·34	51	12·0	2·20	1·27
	12,000	50,000	1/2857	38	11·0	2·0	1·21	25	9·0	1·80	1·14
	50,000	tail	1/3333	20	7·5	1·8	1·08	7	9·0	1·50	0·90
1933	0	12,000	1/2222	58	15·5	2·0	1·35	51	14·5	1·90	1·38
	12,000	45,000	1/2273	38	12·5	1·8	1·29	25	9·5	1·70	1·20
	45,000	tail	1/3333	23	9·0	1·7	1·14	6	3·0	1·50	1·00
1935	0	1,900	1/3000	54	12·0	2·5	1·08	54	12·0	2·50	1·08
&	1,900	11,309	1/3000	50	11·0	2·5	1·08	47	11·0	2·40	1·09
1938	11,309	12,000	1/3000	47	11·0	2·4	1·09	47	11·0	2·40	1·09
	12,000	tail	1/2857	34	9·5	2·2	1·05	5	4·5	1·20	0·87
	KHEOWALA DISTRIBUTARY										
1900	0	tail	1/2857								
1903	0	tail	1/2500	25	13·0	1·5	0·90	11	3·0	1·5	1·00
1904	0	tail	1/2500	25	5·0	2·7	1·09	11	3·0	2·2	1·14
1921	0	10,000	1/2000	22	8·0	1·6	0·72	18	7·0	1·6	0·78
	10,000	tail	1/2500	13	5·5	1·6	0·09	8	4·0	1·6	1·09
1931	0	13,000	1/2000	21	8·0	1·55	0·72	11·5	7·0	1·2	0·75
	13,000	tail	1/2500	9·5	6·5	1·2	0·83	7	5·0	1·2	0·91
1933	0	tail	1/2222	21	8·5	1·55	0·76	7	4·25	1·25	0·83
1934	0	tail	1/2500	20	7·5	1·8	1·08	7	4·5	1·4	0·91
1938	0	tai	1/2250	20	5·0	2·1	1·16	5	3·0	1·3	1·86

APPENDIX B.

Note on experiments carried out in the East Circle of the Lower Chenab Canal to determine the discharge co-efficient of Sharma's modification of the A. P. M. outlet.

In 1929 experiments were carried out by Mr. K. R. Sharma to ascertain the discharge co-efficient of Crump's A. P. M. outlet. A detailed description of these experiments will be found in Paper No. 176.

In his report on the experiments Mr. Sharma suggested that the design of the A. P. M. should be modified, and proposed a new formula for calculating the discharge of the outlet.

I adopted Sharma's modified design for the remodelled outlets in the East Circle during 1935 and 1936, and calculated the discharge from his formula.

During 1935 I found that the outlets with "*H*" greater than 2′ were drawing off more than their authorized discharge, so I had elaborate tank experiments carried out to ascertain whether there was any error in Sharma's formula.

The experimental station consisted of a *pacca* masonry tank, 22′5′ × 20′ × 4′, with vertical sides, connected to the experimental outlet, which was constructed in the Awagat distributary, by a masonry flume about 50′ long, which had an escape on one side. In this flume a G. I. tin flume for measuring discharges of outlets, was fitted. This tin flume had been carefully calibrated independently.

Arrangements were made for varying the working head of the outlet.

The experiments were divided into two parts—

(*a*) To ascertain the discharge co-efficient of the outlet.

(*b*) To ascertain the minimum modular head.

Observations were carried out with four sizes of the A. P. M. outlet, and discharges were observed for five values of "*y*" for each of five values of "*H*".

The results are given in the statement at the end of this appendix.

Each value of the co-efficient noted in the statement is the mean of about six observations.

As a rough check on each observation the discharge passing through the tin flume was noted.