Repelling groynes are usually constructed in a group to throw off the current away from the caving bank as a single groyne is neither strong enough to deflect the current nor so effective to cause silt deposit upstream and downstream of it.

It has long been recognised that the angle which the groyne makes with the current may affect the results. A dike built normal to the stream usually is the shortest possible and thus economical. An upstream angle is better to protect the bank end of groyne against the anticipated scour. A downstream angle might be superior for protecting a concave bank, especially if the spacing and the lengths of the dikes are such to provide a continuous protection by deflecting the main currents away from the entire portion of bank.

The system of spurs or guide bank heads should cater for all possible approaches of the river, should not create any erosion problem elsewhere and should be subject to least severity of attack during its life span so that its maintenance cost is minimum.

A spur may be described as an earthen dike projecting into river bed from a high river bank, or bund provided with an impregnable armoured head for training a river and is named as mole-head, T-head, Hockey head or inverted hockey or L-head or H.T.S according to the shape of impregnable head.

The most commonly used is the T—head spur with its head usually aligned parallel to the main current as it can take attack of the main current from a wide range of angles. The front perpendicular arm (in the direction of flow) is armoured with stone (including the back side at the nose and tail) and some portion of the upstream face of shank with its junction point with T head is also armoured with stone. T-spurs like most other types of spurs are not usually used singly but in series. The T-heads in a system of T spurs must be on a straight line or on a regular mild curve and usually spaced at approximate stream width intervals since too much distance may allow the channel to meander between the spurs. The length spacing ratio, have been developed from experience.

The United Nations publication(7) states that the spacing of spurs at 2—2½ times the length of spur at convex bends and equal to the length of the spur at concave bends is general practice. It also states that the ratio used is larger for a wide river than for a narrow one if the discharge of the two are more or less the same. Dikes on the Mississippi river were originally spaced 2½ times, the length were gradually reduced 2 times the length and now are about 1½ times the length.

A number of spur shapes and alignments have been tried int he past,(8) but no systematic study has been taken to indicate the most suitable alignment or shape under various conditions of river approach.

Generalised laboratory investigation was taken up to determine the efficiency of each known type and shape of spur for possible approach flow conditions to evolve hydraulically sound geometry of spur and to determine the correlation of length and depth of stone in apron and the most effective level of the apron.

CHAPTER V

SLOPING SPUR

Sloping spur all in stone with crown sloping towards the axis of channel was constructed (after model study) on Sanghar Nullah (a flashy stream) to protect Taunsa Town. This spur worked efficaciously to push the currents sufficiently away from the town. Similarly a sloping spur constructed downstream of Trimmu Headworks worked efficiently to push the current on to the point bar of the river bend immediately downstream of the barrage. As compared to T—spur sloping spur offers, less resistance to flow, that is lesser heading is caused by spur and maximum scour is also some distance away from the river end of the spur. The prototype behaviours of sloping spur prompted I.R.I. to take up regular study (basic) to evolve different features of the sloping spur.

(A) The Model:

Series of tests were conducted on a undistorted straight channel 200 feet long for 30 cusecs discharge representing the part of long concave bank of the river. The section of the channel was deeper on one bank and the depth decreased gradually towards the other bank. Proper arrangements were made to measur discharge from supply channel by sharp crested weir, to still the flow in stilling basin and to induce the flow to follow the section of the channel. Sand feeding machine was installed to inject the sand in the full width of channel at known rates on the model. The aperture of the sand feeding machine was

BASIC STUDY ON THE DESIGN OF SLOPING SPURS
X-SECTION AND PLAN OF SPURS TESTED

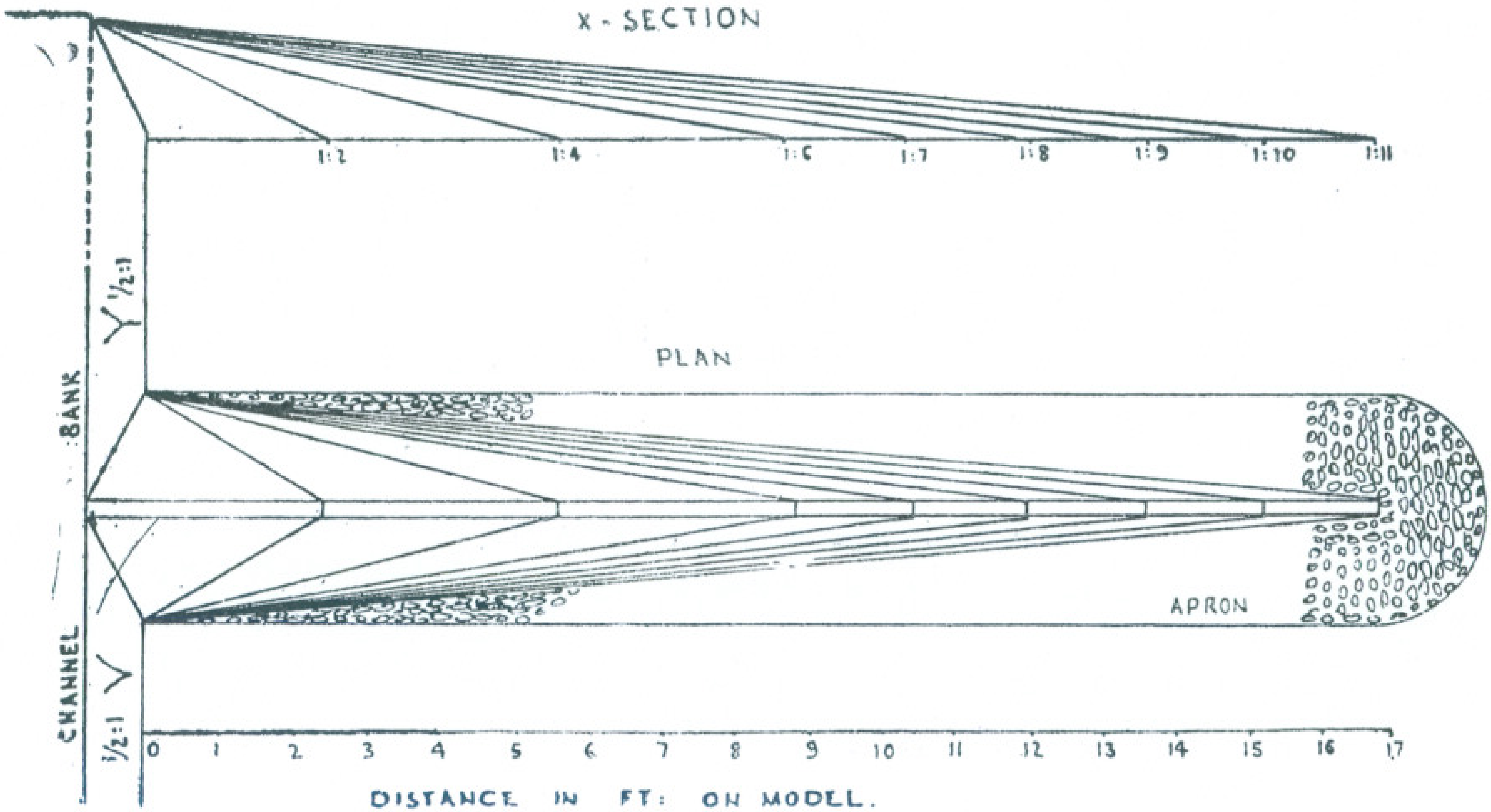


Fig. 12

Fig. 13

BASIC STUDY ON THE DESIGN OF SLOPING SPUR

Flow Conditions when :

(i) Top slope of spur = 1 : 10

(ii) Average dia of stone = 1 / 4"

(iii) Discharge = 30 cusecs.

(iv) Angle of spur with respect to flow exis. = 90°

BASIC STUDY ON DESIGN OF SLOPING SPUR

CHANGE IN THE ANGLE OF DEVIATION OF CURRENT WITH SPURS OF TOP SLOPE (1:2 TO 1:11)

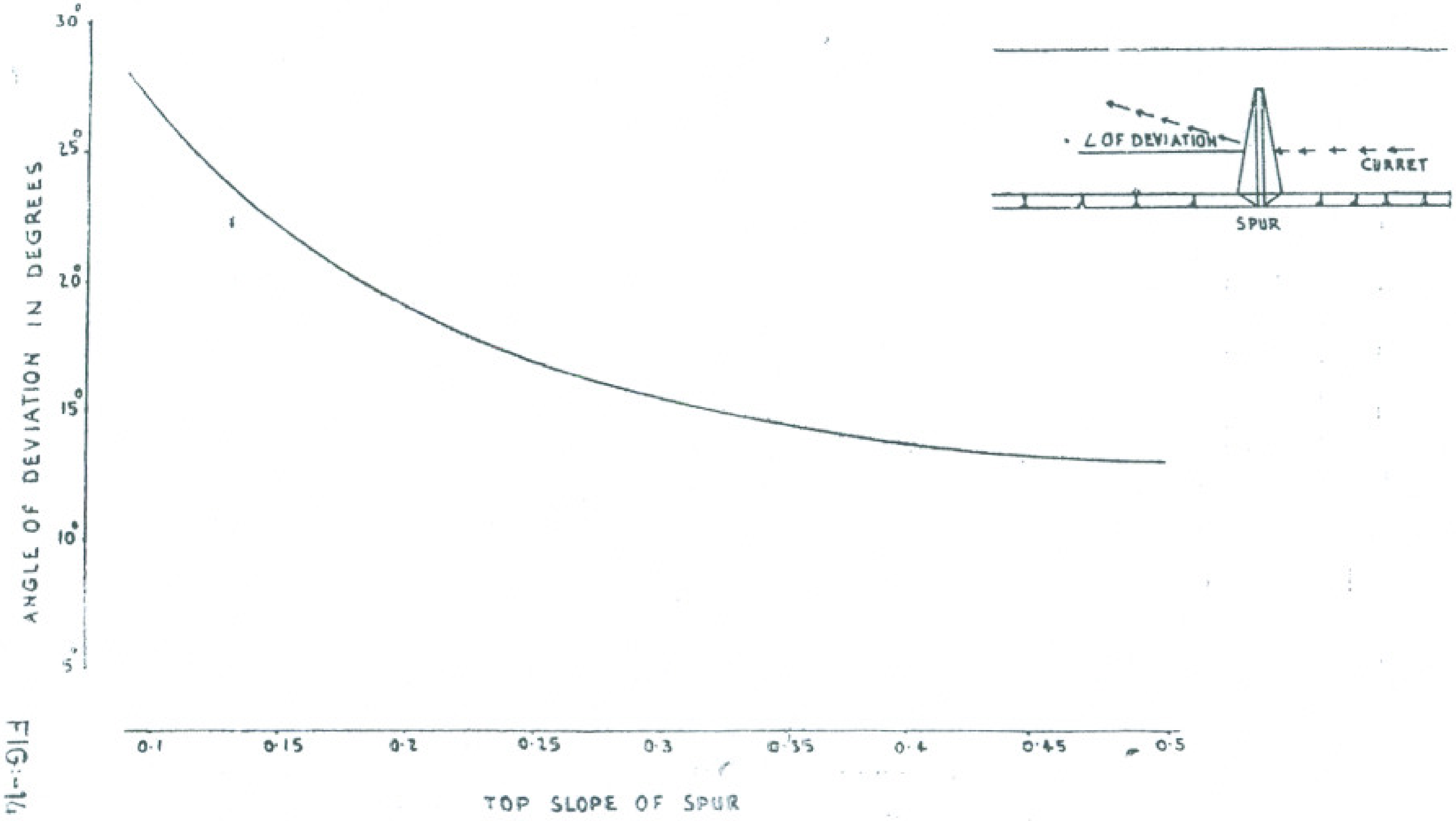


FIG:-14

BASIC STUDY ON THE DESIGN OF SLOPING SPUR
BREATH, LENGTH AND AREA OF THE RETURN EDDIES
FOR SPURS WITH TOP SLOPES(1:4 TO 1:11)

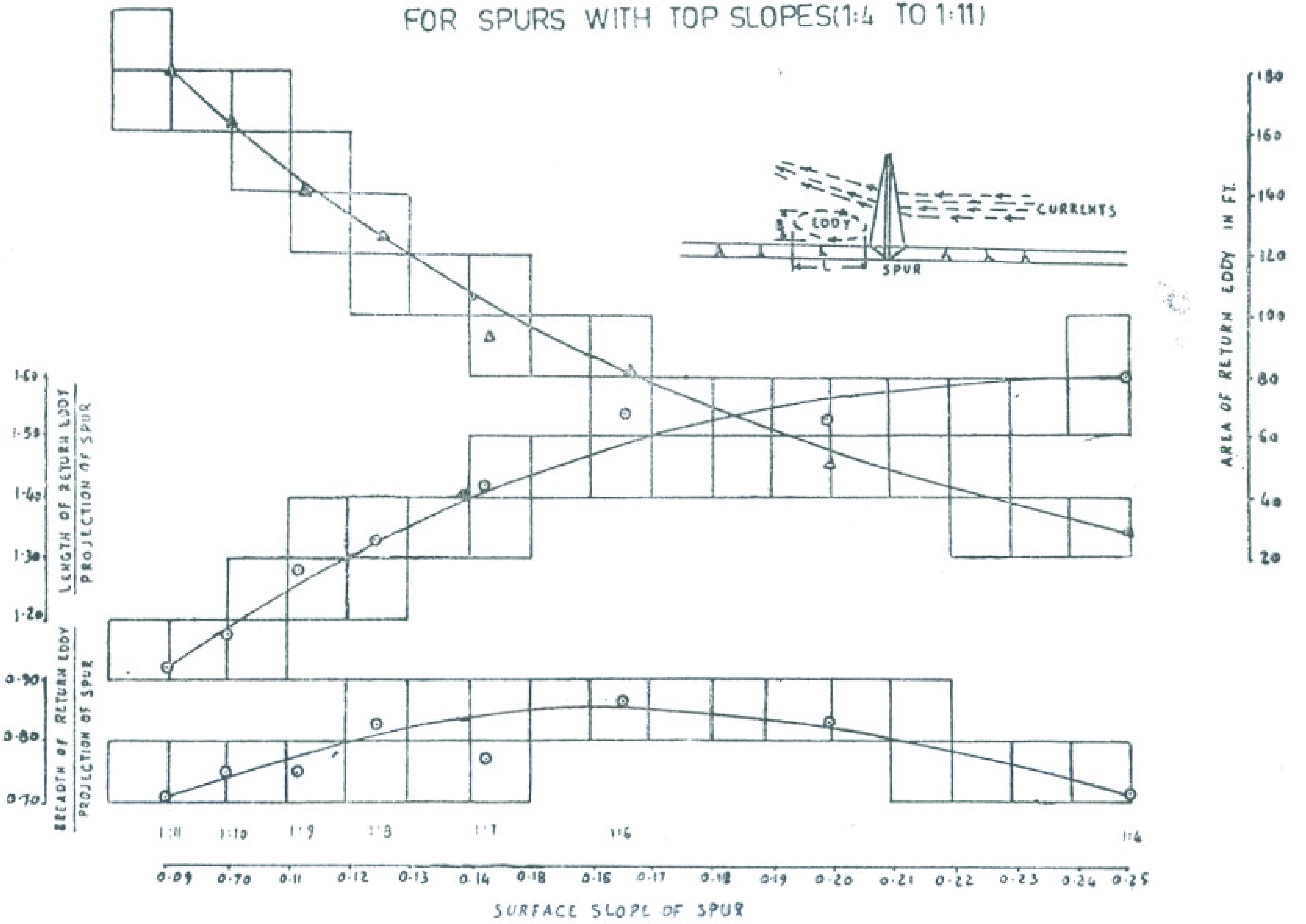


Fig. 15.

adjusted to inject sand in P.P.M. (c) proportional to discharge per foot run q at each point in section

$$\text{as } \frac{q^{2/3} \times S}{\sqrt{d}} = KC^{2/3}$$

where S is water surface slope in a thousand feet and d is fall velocity and K is a constant.

The water levels in the channel were adjusted to fix the water slope in the channel. The model with discharge of 30 cusecs and sand injected at the average rate of 100 P.P.M. was run till stabilised conditions were obtained i.e. surface slope became nearly the same as bed slope.

(B) Optimum top slope of spur :

A series of tests was run on the model with top slope of the spur varying from 1 : 2 to 1 : 11 (at 1 : 2, 1 : 4, 1 : 6, 1 : 7, 1 : 8, 1 : 9, 1 : 10 and 1 : 11). Fig No. 12. The corresponding flow area obstructed by the spur was 7%, 16%, 26%, 28.7%, 31.1%, 34.5%, 37% and 39.4% respectively. At a slope of 1 : 2, there was no eddy in the wake of the spur but boils appeared in the shadow of the spur. Whereas at a slope of 1 : 4, the localised eddy in the shadow of spur appeared and disappeared at regular intervals. With further projection of spur by flattening the top slope of the spur, the size of eddy in the wake of the spur increased in the direction of flow and in lateral direction to flow. At a slope of 1 : 8, some boiling was noticed at the interface of eddy and forward flow. At a slope of 1 : 10, the eddy was strong enough to deflect the boiling flow away from the river end of spur (Fig. No. 13). The angle of deflection of current crossing the spur against top slope of spur is plotted in Fig No. 14. The ratio of length of eddy, breadth of eddy in terms of length of spur and area of return eddy against slope of spur are plotted in Fig. No 15.

The width of eddy increases with further projection of spur pushing the forward flow towards the opposite bank. The maximum concentration of flow drifts away from the bank on which spur is located and main current is sufficently away from the toe of the spur with crown slope of 1 : 10 : Thus at a crownslope 1 : 10, of the sloping spur or even if 1 . 10 slope is built on the channel end of mole spur the turbulence and the eddy action generated by the spur move out far enough into the channel to prevent under cutting of structure.

The distance of maximum concentration of flow from toe line of the spur is plotted in Fig. No. 16. which shows that the rate of shift of maximum concentration point increases with flattening of slope of the spur. The bed contours in the vicinity of spur at the end of each test are plotted in Fig No. 17. and the ratio of maximum scour to the scour at the far end of spur is listed in table below :

Slope of spur	Max : scour below water surface	Scour at far end of spur below water surface	Ratio Max : Scour fo scour at outer end of spur.
1 : 9	2. 02	2. 02	1. 0
1 : 4	2. 25	2. 20	1. 02
1 : 6	2. 45	2. 30	1. 06
1 : 7	2. 65	2. 45	1. 08
1 : 8	2. 85	2. 55	1. 11
1 : 9	3. 02	2. 70	1. 11
1 : 10	3. 25	2. 90	1. 12
1 : 11	4. 10	3. 0	1. 36

The distance of downstream tip of shoal and upstream tip of shoal behind the spur divided by projection of spur is plotted in Fig. No. 18. It is evident that protection given to the bank on which the spur is located is about 3.5 times the horizontal projection of spur at optimum crown slope of 1 : 10.

The value of K in the formula

Scour depth ($D = Kq\ 2/3$)

at crown slope of 1 ; 10 is 2. 1 which shoots up to 2. 6 at crown slope of 1 : 11.

C. Optimum angle of spur with flow axis.

In this set of tests the spur with top slope at 1 : 10 was located at angles of 75°, $82\frac{1}{2}$°, 90°, 105°, 120° and 135° to the flow axis.

The maximum value of the head across is 0.006, for spur axis at 90° to flow axis. The head across decreases for all angles other than 90°. The velocities at various sections for different spur angles showed that maximum deflection

Basic Study on the Design of Sloping Spurs
Distance[of Max : Concentration point from far end of
Spur for Slopes 1 : 2 to 1 : 11

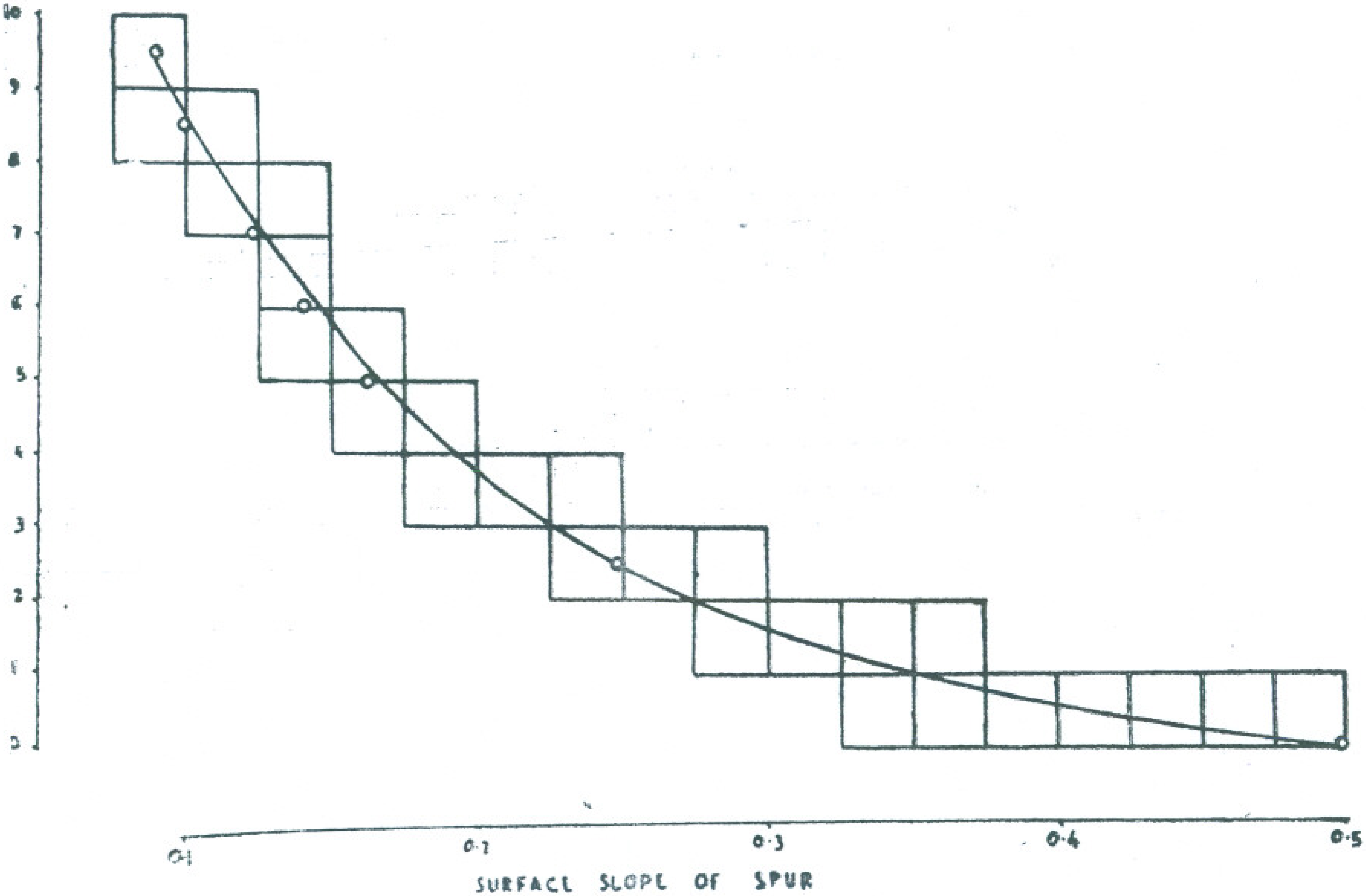


Fig. 16.

DRG: 26 72-29/11

BASIC STUDY ON THE DESIGN OF SLOPING SPURS
DISTANCES OF LEFT BANK SHOAL FROM C.L OF SPUR
DIVIDED BY PROJECTION OF SPUR

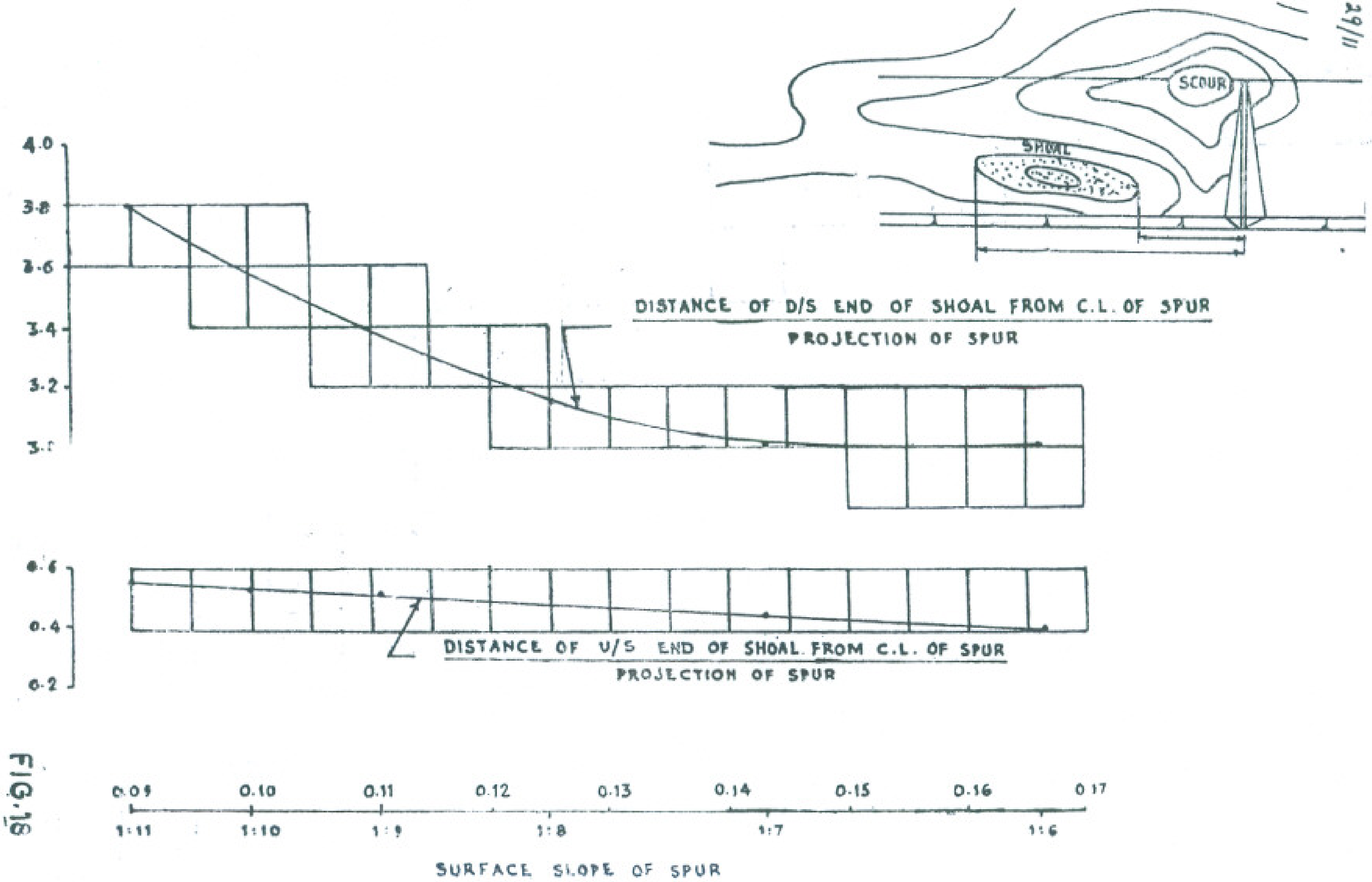


FIG.18

of line of maximum velocity from the bank to which sloping spur is abutted ocours at an angle of 90° to flow axis. The cross-push of the flow towards opposite bank was insignificant when spur was at 75° or 135° to flow axis because after a local kick-off, the flow regresses back along the spur bank of the channel. This observation is also confirmed from the channel bed configuration recorded after the end of each test. The maximum depth of scour, the secondary scour downstream of the spur, scour at the nose and scour along upstream face of the spur below bed level are recorded in the table given below :

S. No.	Angle of spur w. r. t flow axis	Disch : in cusecs	Max : scour D/S	Secondary scour D/S	Scour af the nose	Scour U/S slope in to scour hole.
1.	75	30	1. 85	0. 13	. 63	. 63
2.	82	30	1. 75	×	. 68	. 77
3.	90	30	1. 75	×	. 68	. 80
4.	105	30	1, 42	×	1. 05	. 63
5.	120	30	. 66	. 45	. 57	. 61
6.	135	30	. 60	. 47	. 20	. 55

Which shows that the sloping spur is most effective at 90° to flow axis.

The scour at the nose of the spur has been observed to be less than the maximum depth of scour. The ratio of these two is given in the following table :

S. No	Angle of spur axis w. r. t flow axis	Max : depth of scour below water surface	Scour at the nose below water surface	Ratio Max : Depth scour ot nose.
1.	75	3. 45	2. 23	1. 50
2.	82½	3. 35	2. 28	1. 50
3.	90	3. 35	2, 65	1. 30
4.	105	3. 02	2. 20	1. 30
5.	120	2. 70	2. 17	1. 20
6.	135	2. 20	1. 80	1. 20

The angle of deflection of the current while crossing the spur as a function of the spur axis location has been plotted in Fig No. (19a) which indicates that the maximum deflection is achieved if the spur axis is located perpendicular to the flow axis. Percentage of the stone launched as a function of the spur angle with flow axis has been plotted in Fig No. (19b) which shows that launching of stone is minimum at spur angle of 90°. The value of K in the fromula D=Kq 2/3 is maximum at 2. 27 for 75° and goes on decreasing gradually with increase in spur angle and is 1. 76 for spur location at 135° w. r. t the flow axis and 2. 15 for spur angle of 90°.

Conclusions :

(*i*) If the crown slope of spur is steeper than 1 : 4, the return eddy does not form in the wake of spur and spur does not act as sloping spur.

(*ii*) The optimum crown slope of sloping spur should not be less than 1 : 10 because with steeper slopes, a secondary scour pit appears in the wake of spur.

(*iii*) The bank protection given by sloping spur of the spur is about 3. 5 times the horizontal projection of the spur into the channel.

(*iv*) The value of K in the scour formula (scour depth) D=Kq 2/3 is 2 : 15.

(*v*) Optimum angle of the sloping spur with respect to flow axis is 90°.

D. Demerits of sloping spur.

If the river meander is travelling downstream and if the meander works deeper upstream of the sloping spur it is difficult to retain the key of solid stone into the bank against the onslaught of parallel river flow which undermines the structure. This was cause of failure of sloping spur D/S of Trimmu Barrage. So the location of sloping spur has to be very judicious and should be located on a firm bank or downstream of a control point. The subaqueos inspection and repair to launched apron on river end portion of sloping spur becomes difficult during floods. It is ideal spur for hilly and flashy streams where inspection and repair is not difficult job.

BASIC STUDY ON THE DESIGN OF SLOPING SPUR
ANGLE OF DEVIATION OF THE CURRENT AGAINST
ANGLE OF SPUR WITH RESPECT TO FLOW AXIS.

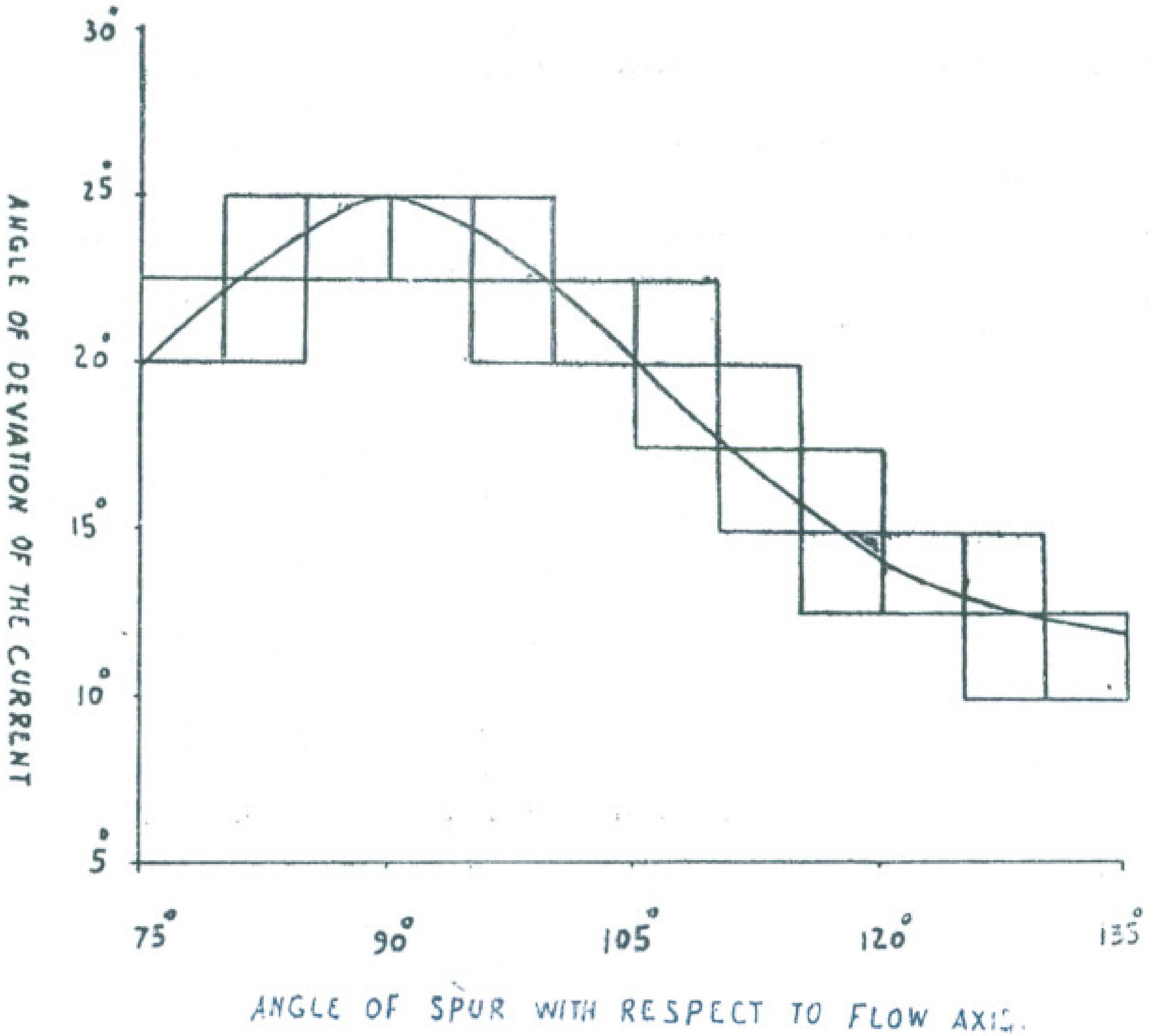


Fig. 19 (a)

Basic Study on the Design of Sloping Spur
Percentage of Stone Launched Against Angle of Spur with Respect to Flow Axis

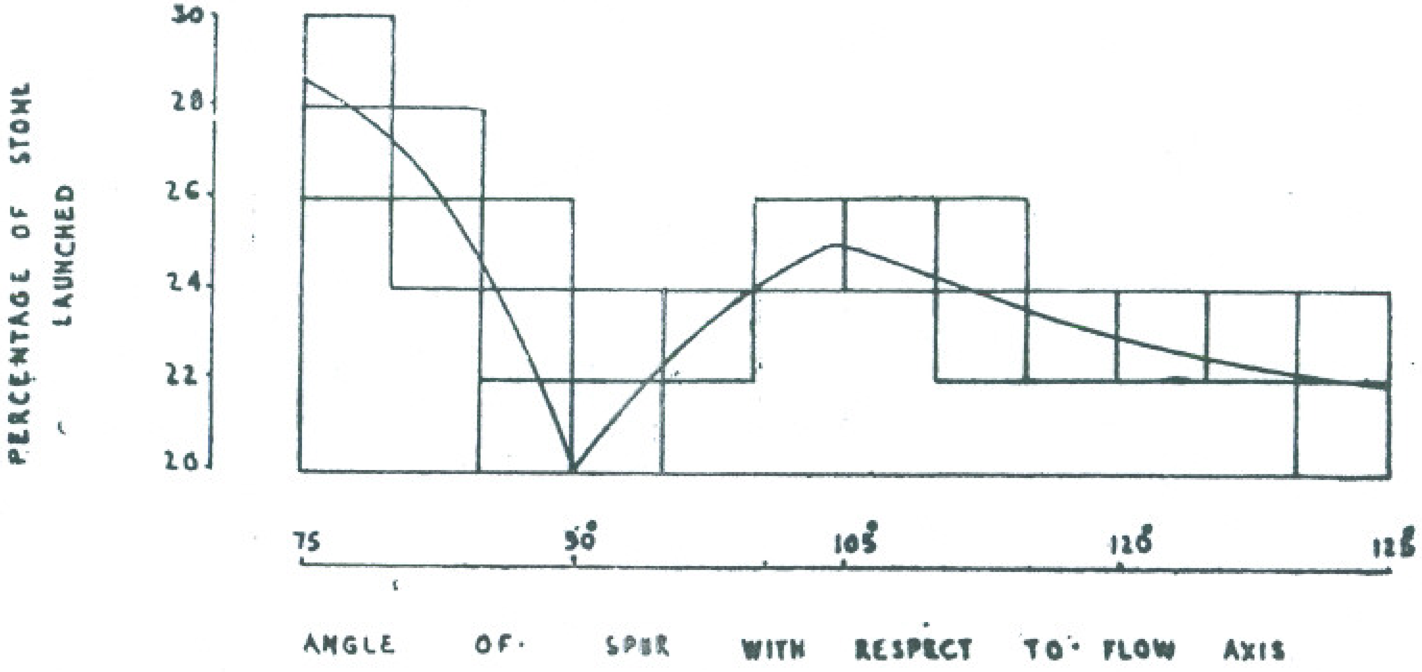


Fig. 19 (b)

CHAPTER VI
T-HEAD SPUR DIKES

Dr. Mushtaq Ahmad Concluded from his experiments that T head spur is most economical in stone.

The most commonly used shape of the spur dikes is the T-head spur with its head usually aligned parallel to the main current. The head of T-spur has a sand or clay core sloped on 1 : 2 and armoured with 3′ thick stone over a spawl or a graded filter. Enough stone is placed in the stone apron over the river bed to protect the toe of armoured slope. The apron launches into scour area and provided armour against further damage. The slope of shank of spur in the vicinity of spur head is also graded in 1 : 2 and paved with stone and duly protected with stone apron to cater for eddy. The performance of T-heed spur was studied for different river approaches to visualise the set of conditions that can be inimical to the safety of the spur itself.

The Model :—

A horse-shoe natural loope of River Sutlej was selected to represent the model river for this study. The selected loop was moulded to a natural scale of 1/40 in a fine, incoherent sand of mean dia 0.178 m.m. The model was fed by a sharp crested weir provided at the inlet of the model and water level in the river was controlled by a flap gate fixed at the tail end of the model channel.

To induce more bed movement and side cutting on the outer bank by increasing the flow concentration along the outer bank, the depth of flow along concave bank was increased at the cost of reduction of depth along the convex bank without altering the area of flow section.

Test Conditions :—

In all the tests mentioned in this report, the T-spur head was constructed, in sand graded in 1 : 2 slope which was covered with crushed stone of the size varying from 40 to 150 lb. on prototype in a thickness of 3.75 feet. The depth of apron was kept 6.0′ and the width of apron was 50.0′ on prototype. In each test, the model after being moulded accurately in accordance with modified cross section was run for 1969 river hydrograph with a superposed peak of 200,000 cusecs. Discharge less than 20,000 cusecs were omitted on the model.

Tangential river approach to spur head.

The T-head of a spur is usually aligned parallel to the main current as envisaged after construction of spur. After construction of spur, the scour at the spur head attracts the current on to it and this combined with natural tendency of river meander to travel downstream results in some embayment upstream of spur to capture the spur head. This embayment subsequently deepens out to attain a threatening posture to the spur shank. So the first test was with ambient embayment. T-spur of 500 feet head was located slightly downstream of the apex of the river bend. The spur was projecting into the river channel to occupy about 20% of the channel width. The model was run for a complete hydrograph varying from 20,000 to 200,000 cusecs. The flow currents approaching the T-head of spur showed that the main current approaches almost tangential to spur head at low and medium flows, with gently curved embayment upstream of spur with a small deflection angle. From the model it was observed that with this set of approach conditions the launching of the apron was guite smooth and regular. With the rise in river stage, increasing per foot run discharge along spur head and curving of current in plan, the channel along the spur head starts degrading with a resultant scour along the toe of apron (See Fig 20 1). This scouring undermines the stone along the far end of horizontal apron and chunk of stone slips down to position D as shown in Fig No 20.2. Due to gap in between launched stone at X and the intact apron combined with scouring in the gap, a part of stones rolls down to 'Y' (Fig No. 20.3).

The scour now occuring at Y undermines the stone at X which ultimately rolls down to Y and even beyond that to position Z (See Fig No. 20.4). The scouring action at toe of stone at X continues to undermine it till a part of residual horizontal apron falls down and again sand at X gets covered (See Fig No. 20.5). At the same time the scour occurs at Y and the stone at Ymoves down to cover the area betwen Y & Z, leaving an unprotected gap between Y and X. Thus with the rising stage, the process continues till the scour is stabilised and the slope is fully protected as shown in Fig No. 20.6.

The bed contours of river area in the vicinity of spur head and cross sections of the launched apron plotted in Fig No. 21 clearly indicate that the loose apron had launched completely at the upstream nose of the spur whereas part of apron remains intact along downstream nose. The average slope or the launched part at the point of impingement of flow at upstream nose is 1 : 2.3 which steepents out to 1 : 1.8 towards the tail end of spur head, indicatiog that slope of the launched stone is function of severity of attack. Stone losses during launching operation in this case were negligible. From the model it was however noted that at high flows when the main current curves round the upstream nose of the spur head, a turbulent eddy forms along the river face of the head just downstream of separation point of flow at the upstream nose of the spur head (See Fig No. 22). This reverse eddy moves up and down (with stage of river) the armoured slope of spur head resulting in sucking out of sand under stone protection on the slope of spur-head as shown in Fig No. 22, This phenomenon is similar to wave run up and recession on sea beaches protected with rip raps and clearly indicates the necessity of providing some coarse material under the stone pitching to protect the fine sand from being washed out by the eddy formation or instantaneous water level fluctuations and high turbulence.

T-spur tied to R.M.B. of Qadirabad Barrage at its R.D 29 was constructed after 1973 floods to provide protection to R.M.B against secondary channel (which was developing into main channel) which had eaten away quite a chunk of R.M.B between R. D. 29-30 and 25-26. The shank of T-spur was 3500′ and T was 400′. The stone armour over the slope was 1.5′ over a spawl of 6″. The depth of apron at the toe of slope was 2.0′ which increased to about 4.75′ at the outer end of apron. The toe wall was also not provided. To stop parallel flow along the upstream face of shank of spur, and move the velocities away from the spur and to prevent scour arounds the upstream end of T-head a mole headed branch spur was tied to the shank of main T-spur. The T and mole spur came into action for the first time in 1975 floods. Due to mole headed spur the embayment above upstream nose of T was limited and mild but was instrumental in sweeping of the main current to take straight run to the barrage nearly along the axis of the barrage. A mi d eddy formed just downstream of the separation point at the upstream nose of T-spur. The crown width of T-spur was 60.0′. Due to intense rain (3.5″) on 29.8.1975 runnels behind the river side slope of the spur ripped up the stone from the slope. The flood in the river peaking at about 4 lacs followed the callapse of the slope armour, the return eddy got intensified which washed away about 200 feet of upstream portion of T by 3.9.75 excepting a portion of upstream slope of the damaged portion of T-head.

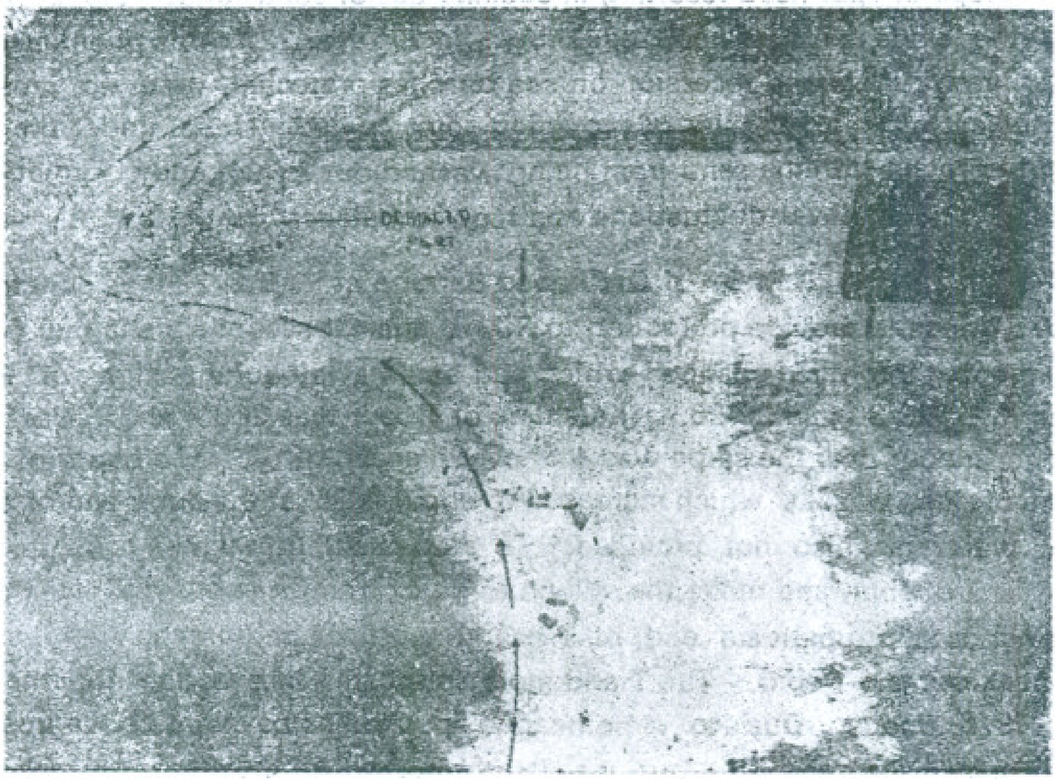
Deep embayment above spur-head.

Most of the failures of T-spurs have been attributed to deep embayment above the spur head, which results in heavy erosive action against the upstream face of shank of spur and excessive boiling and diving of currents in addition

Fig. 22

MODEL OF BASIC STUDY ON SHAPE OF T-HEAD SPURS

Close up of spur head showing damaged slope due to eddy formation along the up stream nose.



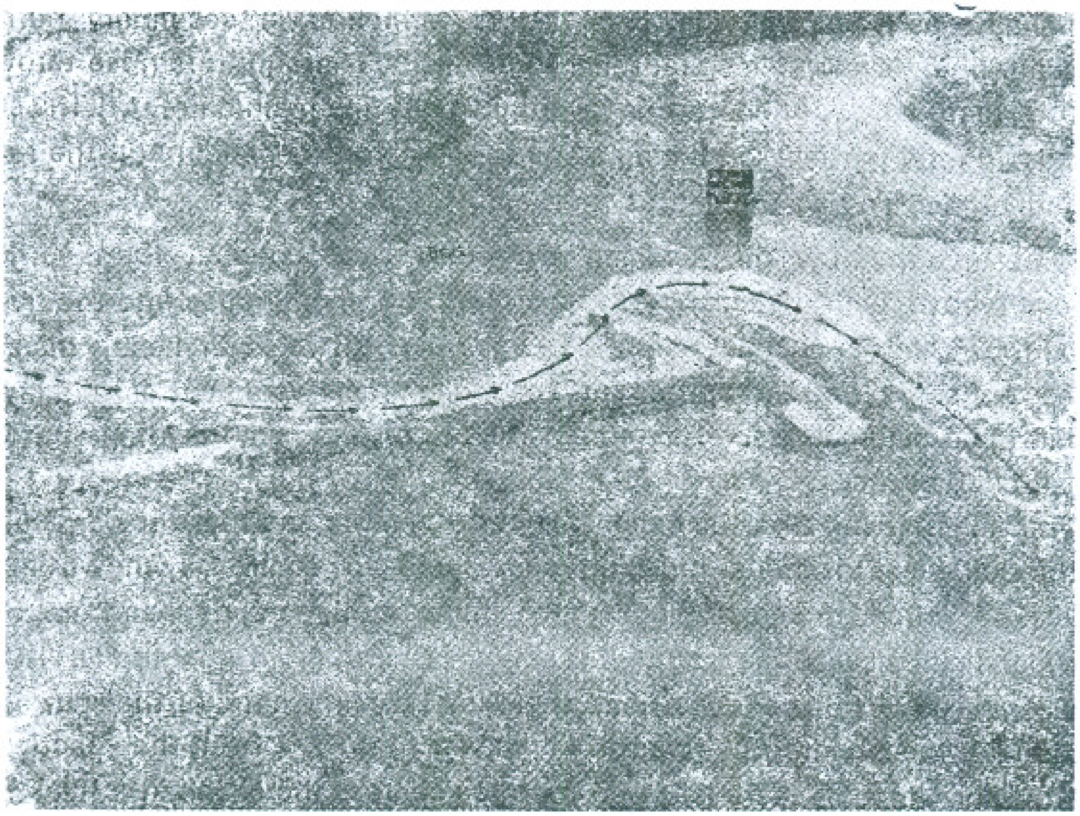
to its acute curvature in plan at the upstream nose of head of spur. As the flow straightens out by the reverse curvature in plan after by-passing and getting away from the head of spur, it acquires a rising component. The diving flow at nose causes scour and the rising flow downstream removes most of the scoured material and heaps it up, which in turn causes formation of secondary current. As the scour hole develops, a spiral roller forms inside it around the nose throwing the scoured material out of hole to be swept away by the main current. The scour hole tends to refill partially on falling stage to the extent depending on the rate of flow reduction and on bed transport conditions.

To observe the flow phenomenon when the river channel forms a deep embayment above spur head, it was projected on model deep into the river to cover about 57% of the channel width. The geometry of the spur head, thickness of rip-rap on slope and in apron and the stone grade were kept essentially the same as in the previous tests. The model was run for the same hydragraph with peak of 200,000 cusecs.

With the rise in stage the main current drifts more and more towards shank and at 150,000 cusecs it starts brushing past the spur shank as shown in Fig No. 23. The order of velocity along the shank at this stage varies from 3 to 6 ft/sec, which is inimical to the safety of the spur shank. From the model it was indicated that under these conditions there is every likelihood of the spur shank to be eroded or breached at the point of impingement of flow or at the junction of shank with the head as there is 3 to 5 feet head across the shank at a river stage of 100,000 to 200,000 cusecs. The main current after veering round the spur head concentrates at the upstream nose of the spur-head and dives down in a gullot in between spur head and heavy boiling region on the other side. The main flow after leaving the scour zone gets deflected to the opposite bank. With the rise in river stage the scouring action at the upstream nose is very brisk (heavy scour is experienced) and the resultant launching of apron is quite irregular. The stones rolling downstream the horizontal apron to cover the unprotected scoured part of the slope are picked up by high velocity diving currents and are swept away lower down resulting in slipping of the stone at junction of apron and slope of spur and subsequent launching of stone protecting the slope. The bed contours and cross-section at the nose of spur head at the end of test are recorded in Fig No. 24 which delineates the scour hole and shows that the horizontal apron as well as the slope protection have settled.

Fig. 23

Photograph showing main currents brushing the upstream face of spur shank at high flood.



150,000 Cusecs,
Looking from downstream

T-spur constructed to protect the diversion bund during diversion of river to the Taunsa Barrage in 1957-58 failed in 1962 floods due to deep embayment above T-head that resulted in excessive scour caused by eddies, turbulence and high velocity restricted flow by-passing the upstream nose of the T-spur.

Head on attack to T-spur head.

Alluvial channels are unstable and ever shifting and where no upstream training works are constructed, the river may approach head on to a spur head. To simulate head-on approach of the main river to the upstream nose of the spur, the spur was located upstream of the apex of the bend. After refixing the bed, the model was run for the usual hydrograph, peaking at 200,000 cusecs.

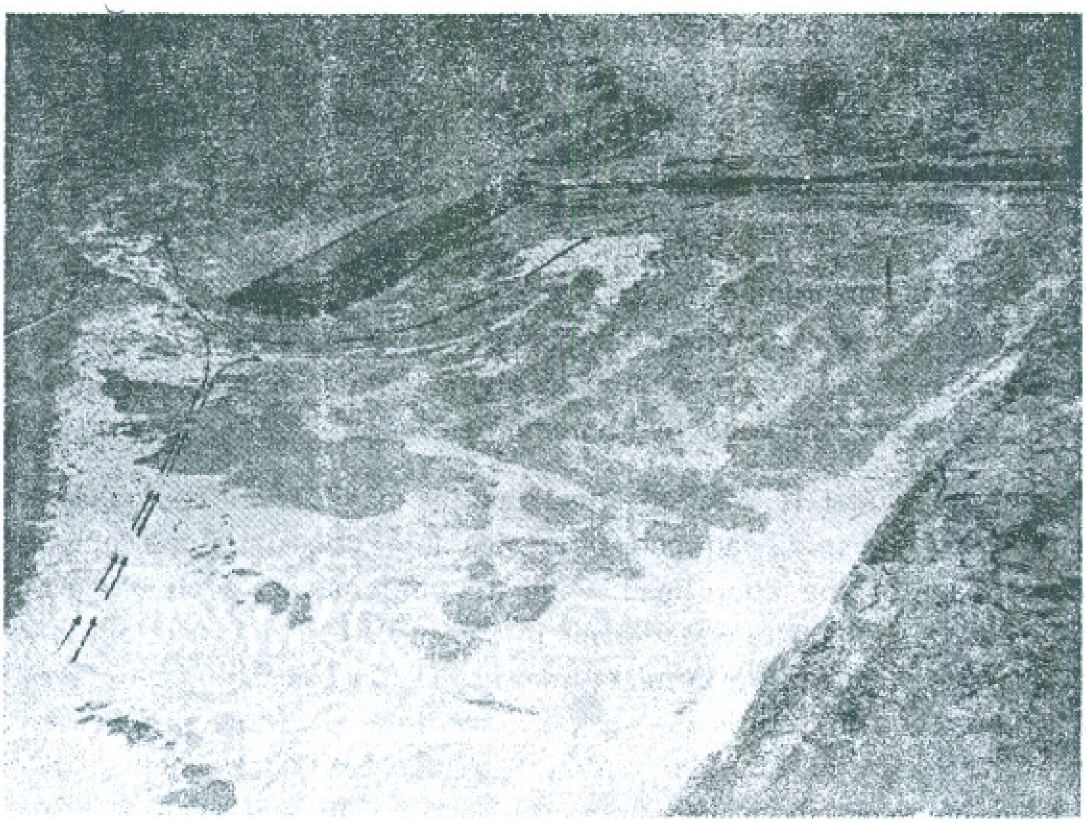
From the model it was observed that the main current impinges upon the upstream nose of the spur head and bifurcates into two parts-one entering the pocket upstream of the spur head while the other moving down along the river face of T-head of spur The water levels in the pocket rise to certain elevation and then start falling as flow entering pocket piles up and then leaves the pocket after attaining a certain level in the pocket. The flow conditions at the spur head at a river discharge of 150,000 cusecs are recorded photographically in Fig No. 25.1, which shows the flow entering the pocket upstream of the T-spur head and resulting in rise of water level in the pocket till the water level in the pocket is at or above the energy line of the aproach channel. Then it gushes out with a high velocity (Fig No. 25.2 resulting in lowering of water level in the Pocket. This phenomenon sets up a surging and heaving action in the pocket upstream of the spur. The wave height and frequency goes on increasing with the increase in river stage. The fluctuations in water level in the upstream pocket at river discharge of 150,000 cusecs and 200,000 cusecs are reproduced in Fig No. 26 which shows a level variation of 2.3 and 3.5 feet at respective discharge of 150,000 cusecs and 200 000 cusecs. When the pocket is filled to the highest elevation, the head across the spur shank is of the order of 7 feet. The waves working against the earthen shank may erode the shank of spur.

It was observed on the model that launching of stone at the upstream nose of spur-head was due to head-on impingement of flow and sudden deflection of currents resulting in high velocity pressurised swirls which lift up the stone and carry it downstream. The launching of apron is irregular and spasmodic. The

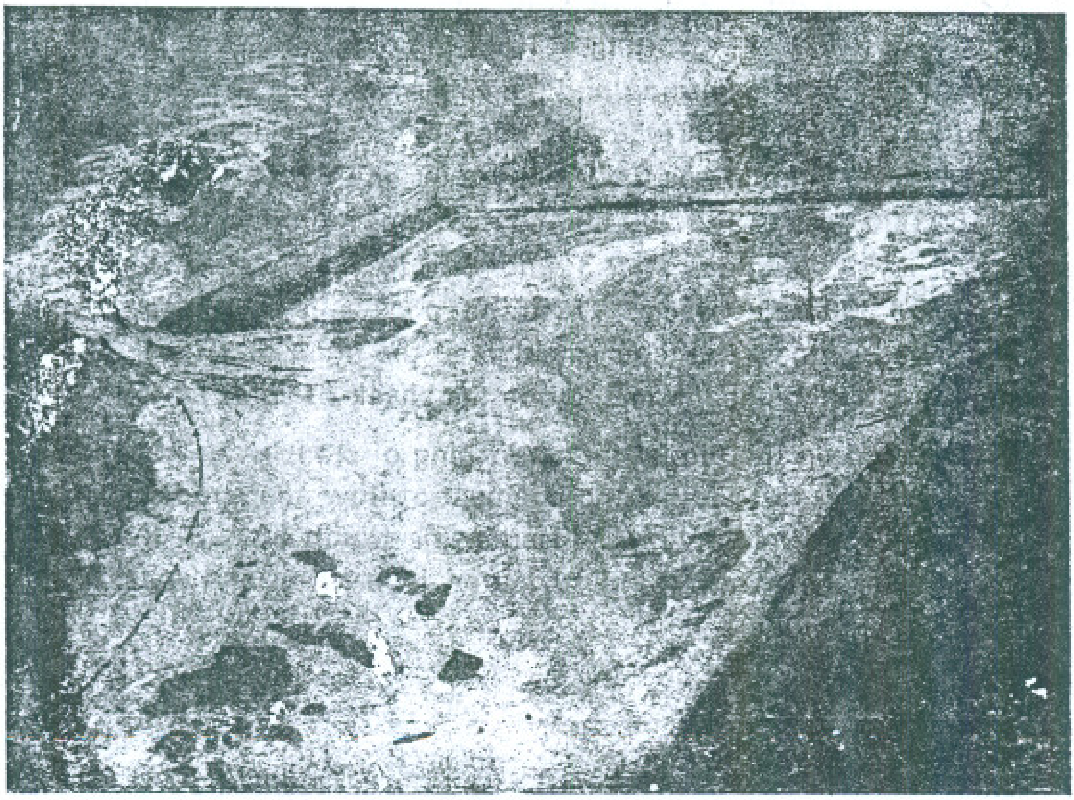
Fig. 25

Flow entering the upstream pocket of the head

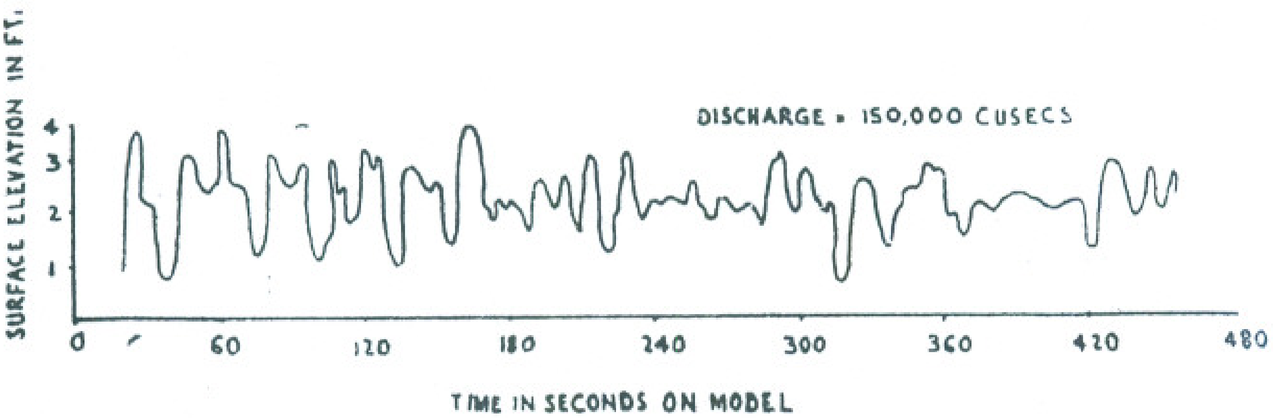
$Q_n = 150{,}000$ Cs.



Flow leaving the upstream pocket of the spur head.



MODEL OF BASIC STUDY ON SHAPE OF SPUR HEAD
SCALE - 1/40
WATER LEVEL FLUCTUATION IN POCKET U/S OF SPUR HEAD



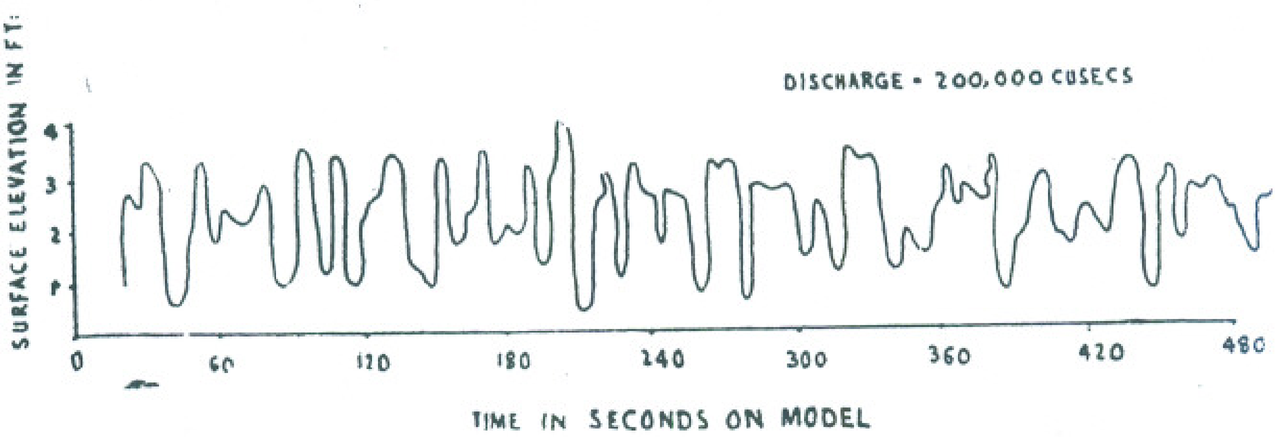


Fig. 26

continuous rise and fall in water level also sucks out the finer material under the stone pitching on slope and results in failure of the slope. The bed contours and cross sections at the end of test run are plotted in Fig No. 27. The figure shows that a part of spur-head gets washed during high flows inspite of some stone dumping from the top.

Summary and Conclusions :

(1) (a) Performance of the conventional T-head spur when the river channel approaches tangential to the spur head and forms a mild embayment above the spur, is quite satisfactory. The rip-rap in the horizontal apron launches gradually and uniformly with the rising stage of the river and covers the subaqueous slope below apron, right upto the deepest point of the scour hole.

(b) As the scour at the upstream nose of spur head is attracting the current, the mild embayment upstream of spur-head may deepen out. The mild embayment may also deepen out due to continuous one-sided swing in the current imposed by the upper river bend.

(2) With the formation of deep embayment above the spur-head, the main current gradually drifts towards the spur shank and ultimately starts hitting hard against it. It is one of the most intractable problems facing the engineer to save the failing shank. If there is time new shank in a set back position is the only answer. If the length of the T-head above pivot point is not adequate the shank of spur may fail due to development of scour hole at the upstream nose of head of spur towards the shank of the spur.

If the shank remains, intact, the high concentration and spiral eddies at the upstream nose of spur head do not allow proper and smooth launching of the stone apron. The stone rolling down from the horizontal apron is picked up by the high velocity currents and swept away lower down resulting in collapse of the spur head. If this type of flow is anticipated short spur dikes perpendicular to the main dike provide enough roughness to push out velocities away from structure and prevent scour.

(3) When the river channel approaches head on the spur head, lot of heaving and surging is manifested in the pocket upstream of the spur

shank head. The rise in water level upstream of the spur shank increases the head across the spur. The wave action is inimical to the safety of the shank of the spur and rip rapped slope of the spur head. The spasmodic gushing out of stranded flow in pocket at the upstream nose of the spur head results in heavy concentration of flow and generation of eddies and swirle which may result in failure of the spur head. The soluiton lies in replacing the straight head of T-spur by a longer and diverging out guide head of the shape of guide bank head as it was done in case of three left bank T-spurs at Taunsa Barrage.

CHAPTER VII

HOCKEY SPUR DIKES

A spur dike aligned to follow the shape of hockey stick is another type of spur dikes. This type of spur has successfully worked above Islam Head Works on Sutlej River for some time, but later on another T-head spur had to be constructed downstream of hockey spur of create a pocket in between the two spurs as in the absence of lower spur, there was a heavy action along downstream face of hockey spur, which was checked after construction of lower T-spur. Due to curvature in the hockey spur it can cater for deeper embayment as compared with T-spur. The pocket formed upstream of the hockey spur acts as a cushion to bolster the main current advancing towards the spur head. The performance of the hockey spur was tested for the following two extreme approaches of the river.

(1) River channel forming deep embayment above the spur head.

(2) Head-on approach to the spur.

In both of these tests the spur head was aligned at a redius of 500′ with its nose and upstream face protected by stone rip rap of 2. 75′ depth over 9″ spawal with 6 feet deep and 50′ long horizontal apron along the toe of the slope The model was run for the usual river hydrograph with peak flow at 200,000 cusecs.

Deep embayment above spur head :

The flow conditions at the spur head at a river discharge of 20,000 cusecs are photographed in Fig. No. 25. The maximum concentration was noticed at the nose of spur. The per foot width concentration was maximum along the toe of spur nose and decreases towards opposite bank. An eddy appeared at the back of spur downstream of point of separation of flow from the spur nose. The velocity of eddy is as high as 13 feet per second at river discharge of 200,000 cusecs. The flow drawn in by the negative valocity zone forms a secondary current along the downstream face of spur though the main current gets deflected away from the spur. The converging and diving flow at the nose of the spur rises back to the surface in the form of a boil Fig No. 28. The surface velocity along the two faces of the hockey spur starting from zero R.D. (at the tip of hockey nose) at different river discharges is given in Table No. II which shows that the velocity increases along the two faces of the spur and extent of shank under attack increases with the increase in river stage. Due to converging and diving currents there is a heavy scour in the vicinity of spur nose and the material scooped from the scour hole is removed by boiling flow to form a bar at the back of spur. The spur nose gets damaged due to heavy scour at the toe of spur head. As is evident from the contours and cross sections of the spur head plotted in Fig. No. 29, the eddy and the secondary current erode the spur head at its back face especially at the junction of stone pitching and earthen bank. Thus an isolated hockey spur though safe on the upstream face it is not safe at the nose and the downstream face of spur head.

Head-on approach :

To attain head-on approach of the main current to the tip of hockey spur, the position of the hockey spur with respect to the channel was modified. The pocket forming upstream of the spur pushed the main current away from the spur nose and so there was no action on the upstream face of the spur and the current brushed past the nose of the spur along its downstream face. The entire flow passed through a narrow gullet along the downstream face of spur nose. The bed contours and the cross sections at the end of test run are plotted in Fig. No. 30 which show that there is no action on the upstream face of spur whereas the stone on the downstream face of the spur head gets settled due to heavy action at the back of spur. There is no secondary current in this case and the flow after impinging the downstream face of the spur gets deflected toward opposite bank.

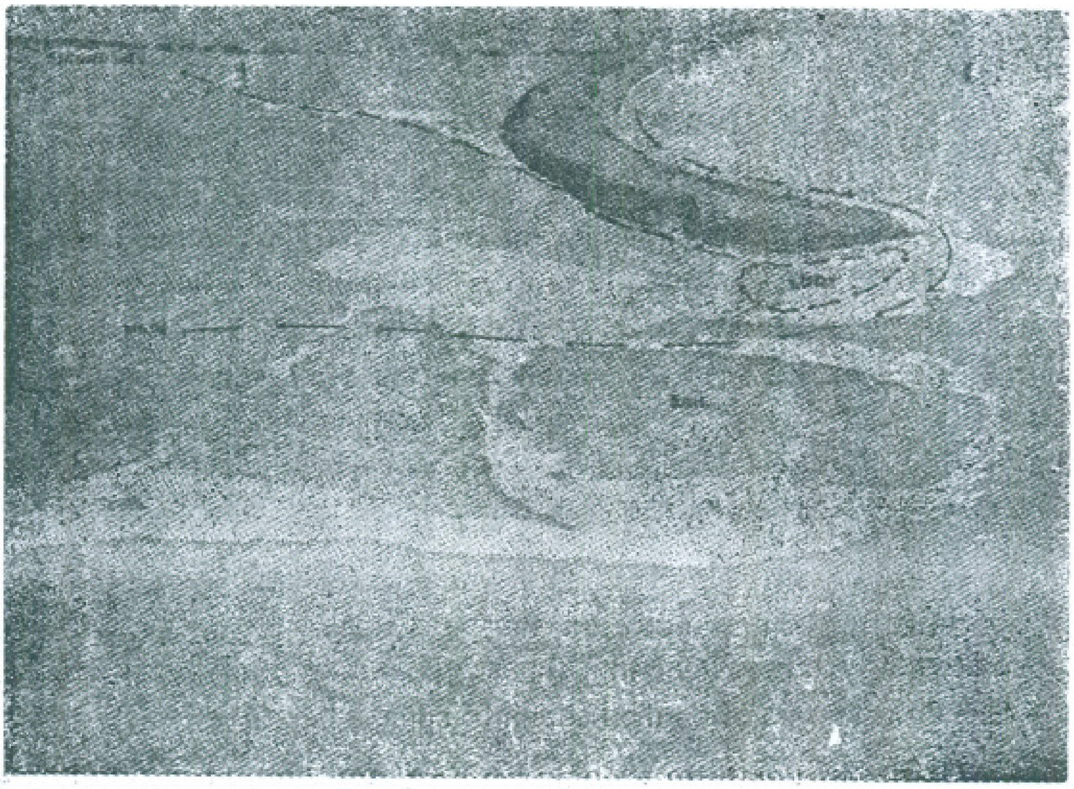
Conclusions :

From these tests it is clear that the hockey spur is subjected to severity of

Fig. 28

MODEL OF BASIC STUDY ON SHAPE OF T-HEAD SPURS

Photograph showing damaged slope due to eddy formation along the upstream of T-head spur.



flow and the damage to the spur is generally confined to the tip of spur and along downstream face of spur.

To avoid the damage at the nose and back face of the hockey spur, it is essential that another spur is constructed at an optimum position downstream of the hockey spur to form a pocket that keeps off the secondary current from the back of the spur.

CHAPTER VIII

T-CUM-HOCKEY-CUM SLOPING SPUR

To overcome with the demerits ot isolated T, hockey or sloping spurs described above and combine their merits, the three spurs were merged into a single T-cum-hockey-cum sloping spur with the quantities of stone on slope and apron almost equivalent to that involved in the construction of conventional T-head spur. This spur Fig. No. 31 combines all the good features of T, hockey and sloping spurs. The T part of this spur guides the flow to pre-specified course, the hockey component caters for deep embayment above the spur head and can take attack of the river from a wide angle.

The sloping nose at the tail end of spur with crown slope of 1 : 8 to 1 : 10 induces a week silt depositing eddy on the bank side of the spur shank which wards aff the secondary current from the shank of spur and provides adequate protection to the downstream of earthen shank of spur.

In the absence of upstream training works, the swing of the river towards the right flank away from the axis of the river immediately above Taunsa Barrage was a continued process that culminated in the formation of heavy embayment behind the right guide bank that deflected the main flow towards left guide bank resulting in formation of a heavy shoal along right guide bank. This approach was responsible for uneven flow distribution in different bays of the barrage during floods and excessive silt entry into D. G. Khan canal off-taking on the right bank. To guide the river through the barrage with a limited obliquity commensurate with silt exclusion from left bank canals and to attain nearly uniform discharge distribution in different bays of the barrage during floods, two right bank spurs were constructed at an angle of 30° with the barrage axis. (Fig 2) The fourth upper-most spur on left bank is also T-cum.hockey-cum sloping spur.

As a part of the project [to guide and control the flow for the right handed river approach], two spurs were constructed along right bank upstream of Chashma Barrage. The lower spur is hockey-cum-T-cum sloping spur. The upper spur is a T-head spur because the hill salient upstream of the T-head spur projecting into the river acts as a spur and disallows deep embayment to form above the T-head spur. The hill salient, upper T-head spur, lower hockey-cum-T-cum sloping spur and right guide bank formed a long broken guide bank on the right flank of the barrage which will stabilize the river channel for all times to come.

A single T-cum-hockey-cum sloping spur on left flank of Indus to protect Ghazi Ghat was constructed before 1975 floods. This spur behaved as expected of it. Hockey-cum-T-cum sloping spur was constructed on right bank of Kabul river opposite left bank Khesghi lift irrigation scheme. The spur is not yet captured but has already deflected the current towards the in-take of pump house of Khesghi lift scheme.

Prototype behaviour of T-cum-hockey-cum sloping spur alone proved that this type of spur can take attack from wide angle of river approach due to formation of a pocket along hockey component of the spur whereas the T component directs and guides the flow lower down. The sloping tail end of the spur provides adequate protection to the downstream face of the spur shank against parallel flow or a secondary current.

Experiments for the best geometry of Hockey, cum-T-cum sloping head.

The model study on 1 : 40 natural scale model of prototype river bend was initiated to determine :

(*i*) Optimum radius of the hockey element of hockey cum-T-cum sloping spur.

(*ii*) Allignment and length of the spur head (T-part).

(*iii*) Optimum slopes for the upstream and downstream ends of the spur head (sloping part).

Radius of the shank with its junction with spur head :

In the first set of tests the radius of the shank at its junction with the upstream end of spur head located at the apex of outer bank of river bend with a projection of 30% into channel was increased from 200 feet to 1200 feet at interval of 200 feet in each test and the curved portion (hockey component) was stone armoured on model. Zero radius was not tried as in this case the spur head will become L head design. The spur head was kept fixed at 750′ and was aligned on radius of 4000. The tail end of spur head was also kept fixed at 1 : 10.

Each test was run for one hydrograph peaking at 200,000 cusecs after fresh moulding of model river bend. The model tests indicated that with the increase of radius of the hockey component, the embayment above upstream end of the spur increased and the entire channel flow converging at the upstream end of head of spur after leaving the end would sweep to the opposite bank. The silt laden bottom and helicoidal currents would move towards the concave bank after leaving spur head. Contours after one hydrograph run with radii of the hockey as 200 and 800 feet are compared in Fig No. 32. which indicates that with increase in radius from 200 to 800.

(*a*) The secondary channel dewindles and the flow in main channel gets augmented.

(*b*) The shoal in the wake of spur warps up and increases in extent.

(*c*) The deflection of current away from the spur increases.

(*d*) The scour at the upstream nose of spur increases by about 4.5′.

The recession of convex bank opposite to the spur head for different radii of the shank is compared below :

Radius of shank in ft.	Distance of opposite bank from spur head on prototype
200	980′
400	1000′
600	1013′
800	1040′
1000	1050′
1200	1076′

The increased deflection of the main current away from the spur head resulted in shifting down of the stagnation point of secondary current with silt depositing slow eddy in the wake of spur Fig No. 33. The surface velocities recorded all along the hockey face are listed in Fig No. 34 which indicates that with increase in the radius. the maximum velocity along hockey face gets reduced, the length

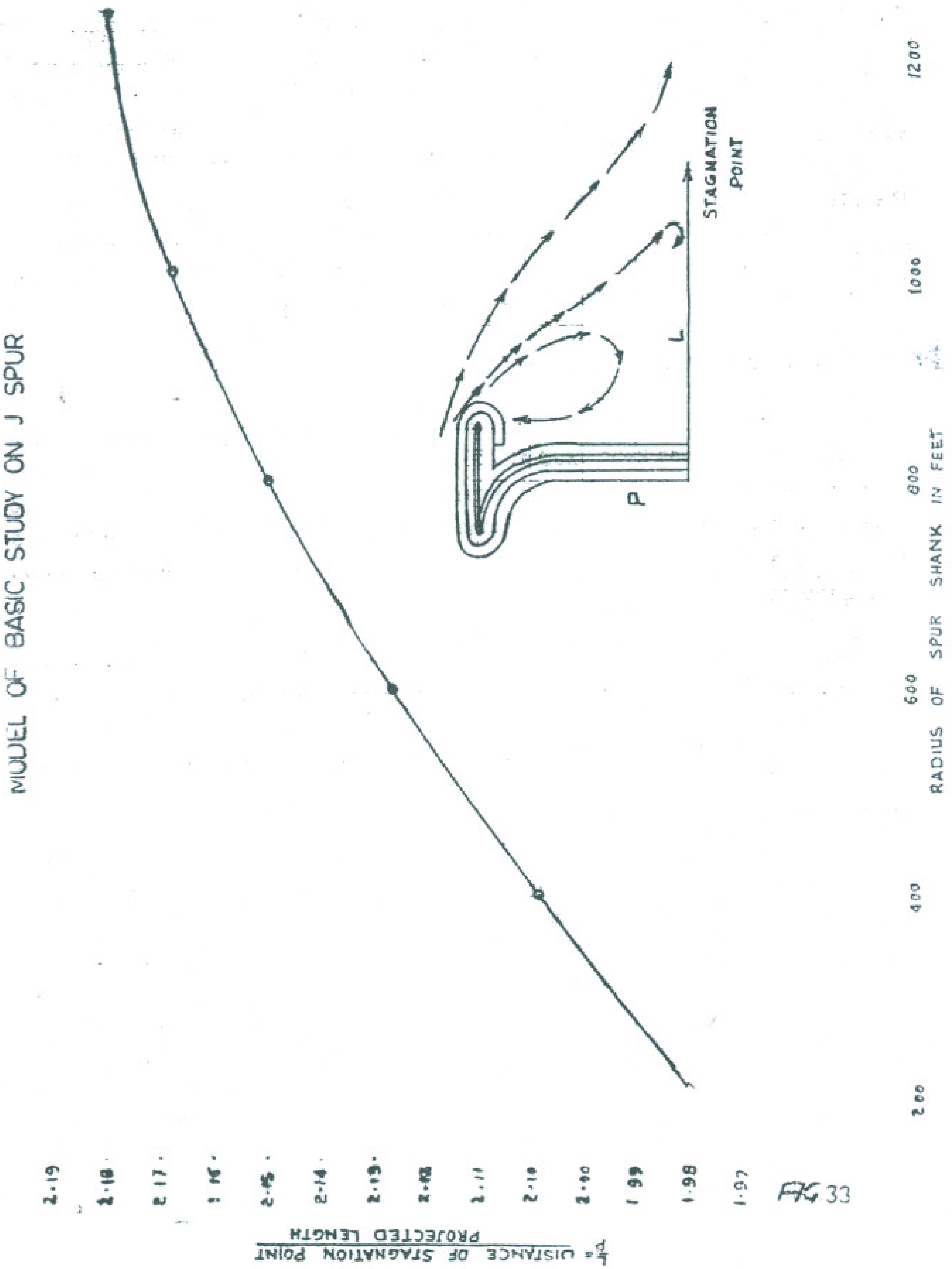

MODEL OF BASIC STUDY ON J SPUR
STAGNATION POINT
L
P
RADIUS OF SPUR SHANK IN FEET
200
400
600
800
1000
1200
2.19
2.18
2.17
2.16
2.15
2.14
2.13
2.12
2.11
2.10
2.00
1.99
1.98
1.97
$\frac{L}{P}$ = $\frac{\text{DISTANCE OF STAGNATION POINT}}{\text{PROJECTED LENGTH}}$
FIG 33

Fig. 33

of hockey exposed to velocities more that 3 0′ remains almost the same with increase in radius of hockey (or the recession of hockey), the flow in the embayment upstream of the upstream end of spur head increases, and the degree of convergence of flow at the U/S head of spur head also increases substantially. The dead pocket upstream of hockey does not permit high velocities along the hockey face of the spur. The scour co-efficient K of scour formula $D = Kq^{2/3}$ increases slightly with scour Fig. 35. The maximum value of K is 1.275. From these tests it is evident that optimum radius of hockey is 1000 feet, but the radius can be reduced to 800 feet for spurs with shorter length of heads.

Radius of the spur head :

In the set of tests to determine the optimum radius of the spur head the length of main head was kept fixed at 750, radius of the axis of spur head was varied from 1000′ to 6000 feet at interval of 1000′. In all these tests the radius of the hockey component of the spur head was kept fixed at 1000′, and the tail end had a slope of 1200. The model was run for the usual selected hydrograph.

From the model it was observed that with shorter radius the flow follows all along the spur head and so more flow is directed towards secondary channel. The bed contours of the tests run with radii of the spur head as 1000′ and 6000 are compared in Fig No. 35 which clearly indicates that with shorter radius the alignment of the scour hole contours is more favourable for secondary channel whereas in case of bigger radius the contours are inclined towards the main channel indicating that main channel has developed at cost of secondary channel. Thus the contours indicate that with larger radius of the head the percentage of the flow in the main channel increased. The protection afforded fo the right bank downstream of the spur increased with increase in radius of head of spur Fig. No. 37. With the increase in radius of the spur head, the concentration at upstream end of the spur head also gets increased as shown by scour co-efficient plotted in Fig No. 38 which in turn helps in kicking off the current more and more away from the spur head. The shifting back of the bank opposite the spur head with the increase in the radius of the head as recorded during this set of tests is as below:

Model of Basic Study on Spur

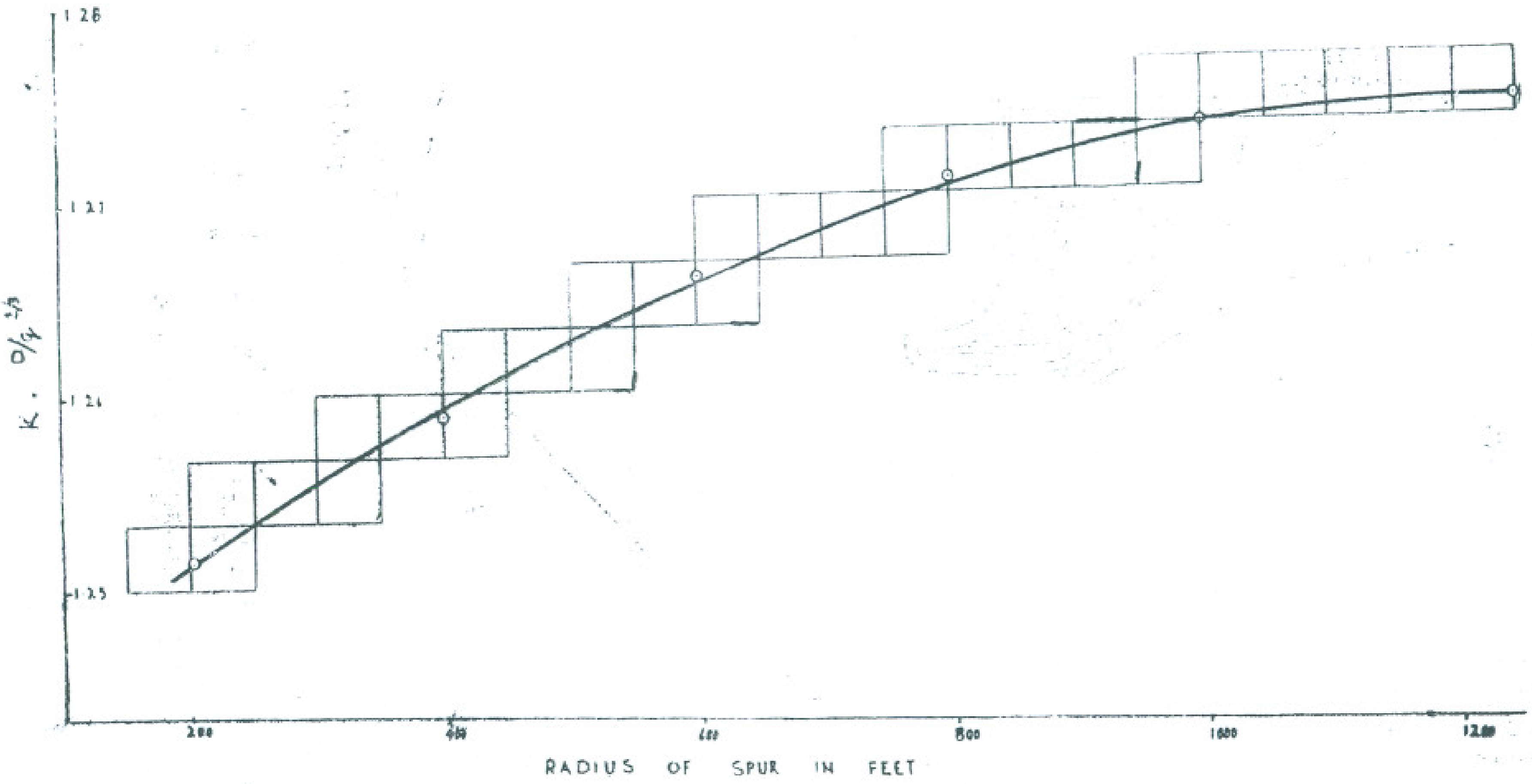


Fig. 35

MODEL OF BASIC STUDY ON H.T.S. SPUR

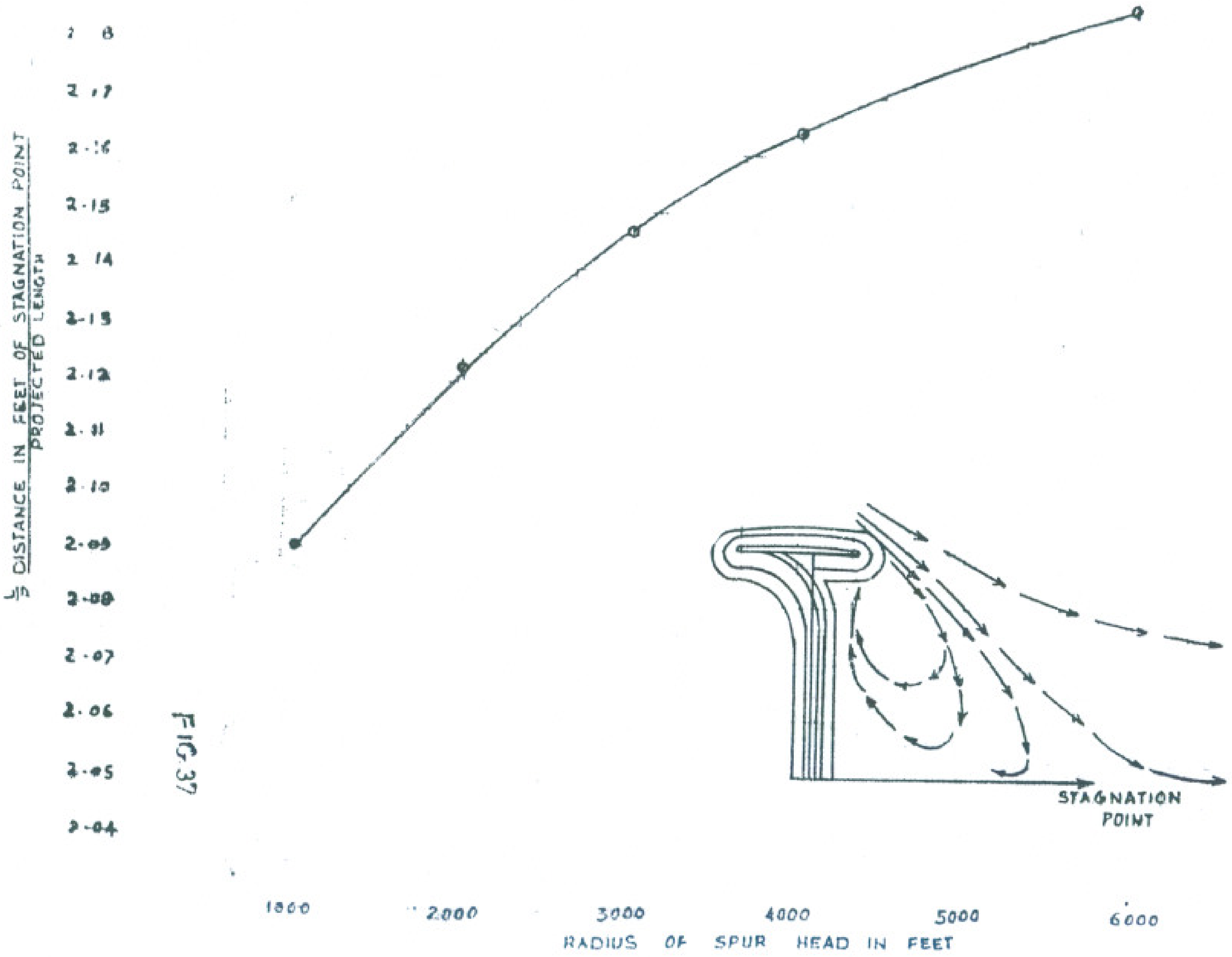


FIG.37

MODEL OF BASIC STUDY ON H.T.S. SPUR

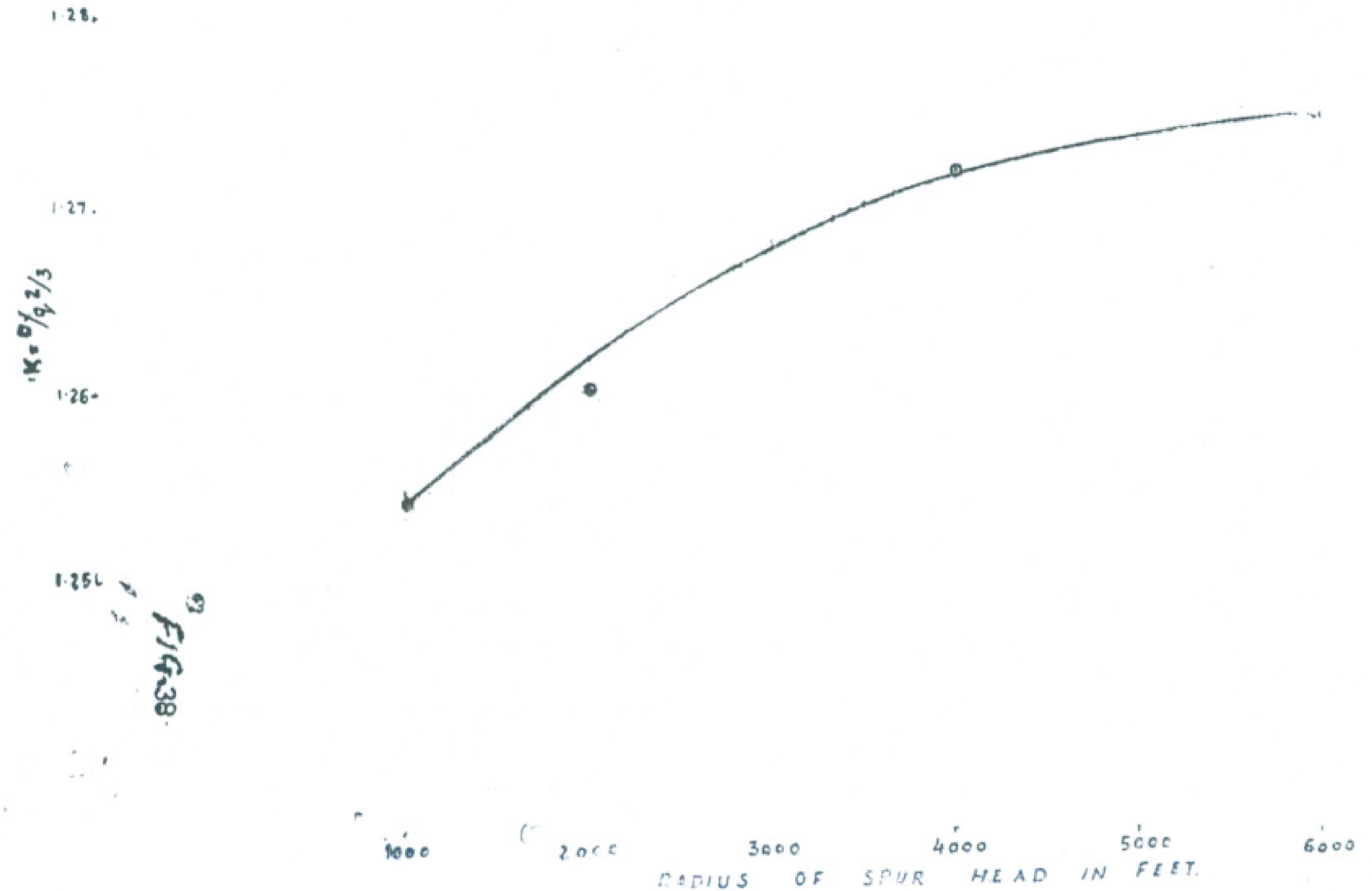
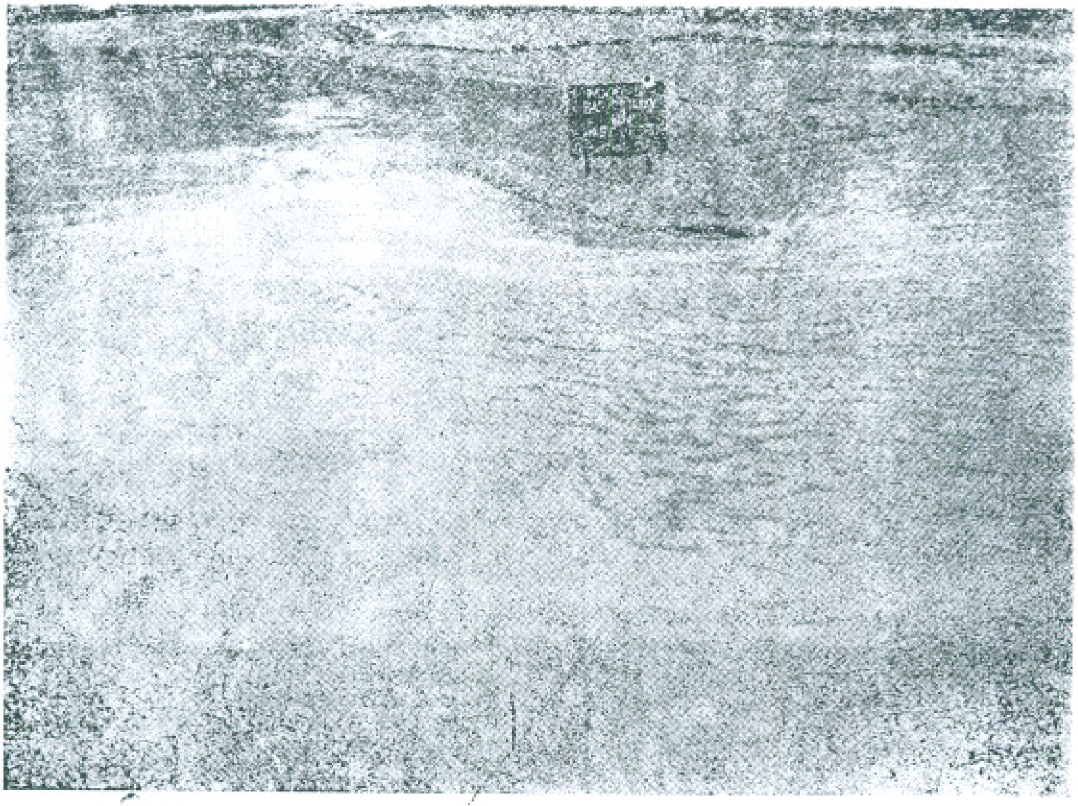


FIG.38

Fig. 39

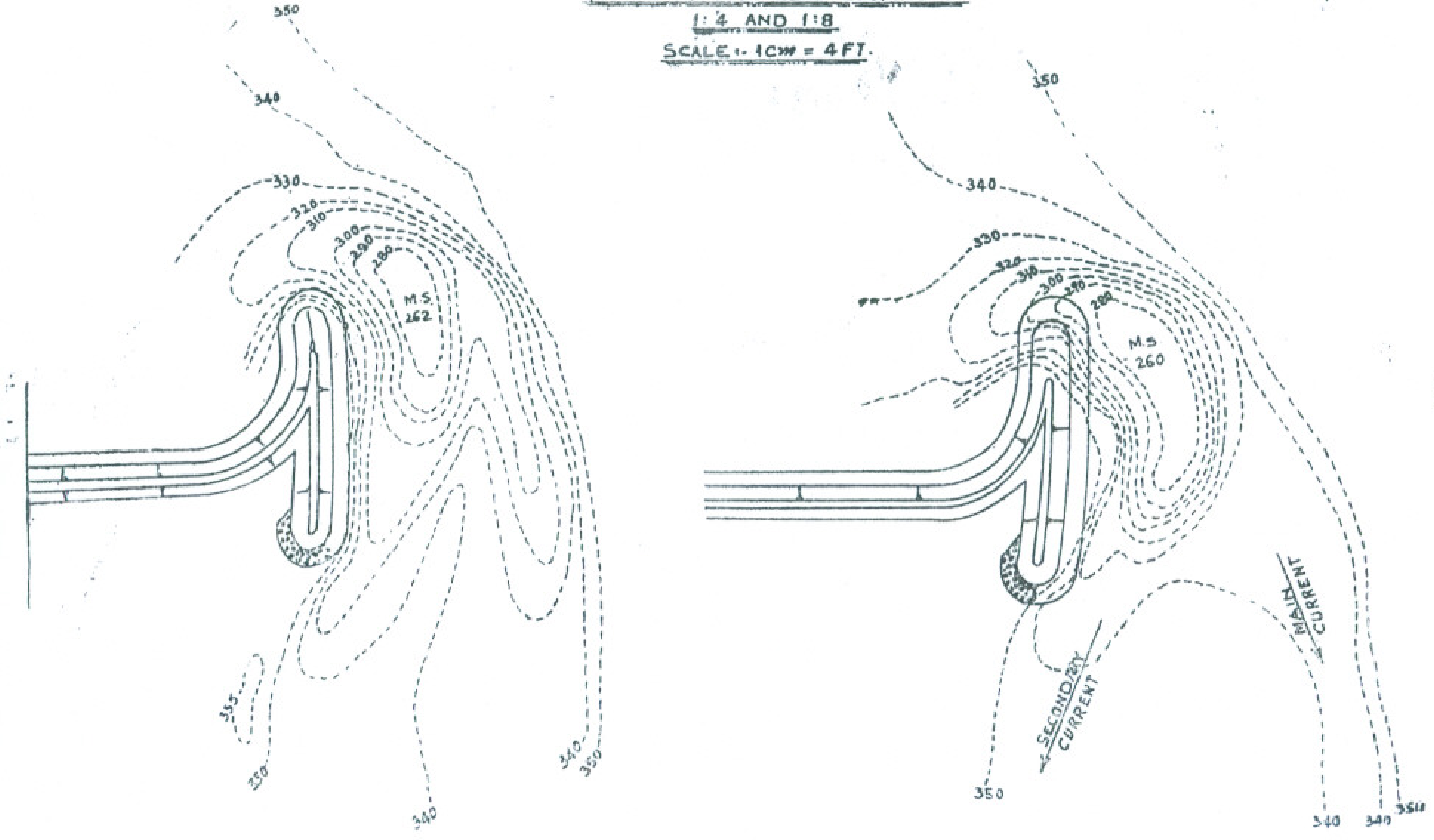
MODEL OF BASIC STUDY ON H.T.S. SPUR

Photograph shows drop across the U/S end of spur head with slope 1 : 0.



MODEL OF BASIC STUDY ON H.T.S. SPUR

BED CONTOUR AFTER THE TEST WITH
U/S END OF SPUR HEAD SLOPING AT
1:4 AND 1:8
SCALE :- 1CM = 4FT.



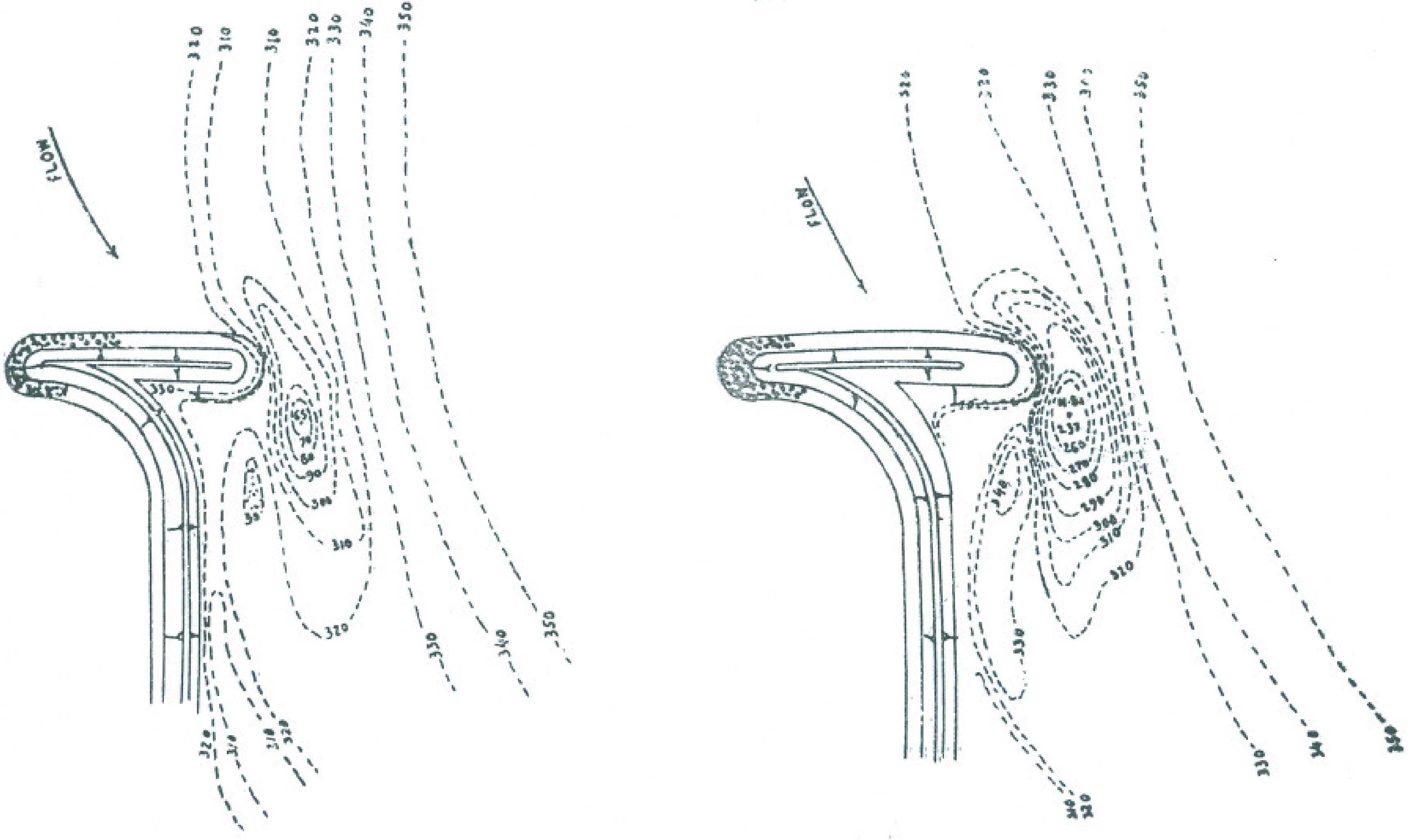
SLOPE OF U/S END - 1:4

SLOPE OF U/S END 1:8

Fig. 40.

MODEL OF BASIC STUDY ON H.T.S. SPUR

BED CONTOURS AFTER THE TEST WITH
D/S END OF SPUR HEAD SLOPING AT
1:2 AND 1:8
SCALE:- 1Cm = 4 FT.



SLOPE OF D/S END=1:2

SLOPE OF D/S END=1:8

Fig. 41

Radius of head in feet	Distance of opposite bank from spur head.
1000	990′
2000	1003′
3000	1033′
4000	1050′
6000	1096′

From these tests it is clear that with larger radius of the spur head the deflection given to the flow by the spur is more as compared to shorter radius or the spur head.

The prototype performance of the hockey-cum-T-cum sloping spur and the model tests shows that the length of the head may be roughly equal to the half of Lacey's width for the discharge which repeats after 2 years.

Optimum slope of upstream end :

With a view to reduce the severity of attack at the upstream nose of the spur it was given slopes flatter than 1 : 2. Flatter slopes tried were 1 : 4, 1 : 6, 1 : 8. It was observed that the flatter slope acts as a slant weir with low head drop (Fig. No. 39) resulting in lifting up of stone in apron which results in much earlier damage to upstream nose Fig No. 40.

Optimum slope for downstream end :

To determine optimum slope of tail end of spur that provides full protection to the downstream face of the shank against eddy flow and turbulence, the slope of the tail end was varied to 1 : 2, 1 : 3, 1 : 4, 1 : 5, 1 : 6, 1 : 7, 1 : 8, 1 : 9, 1 : 10 and 1 : 11. In this set of tests the river approach was modified to attain a head on approach to the tail end of spur head as similar conditions prevailed at the upper hockey cum T cum sloping spur on right flank of Taunsa during the first year after the construction of spur. The test indications are that with the lengthening of downstream end of the spur head to flatten the crown slope of tail end,

(*i*) The point of maximum scour shifts away from the spur head at its tail end.

(*ii*) The length of the sand bar forming along the downstream face of the shank increases directly with the flattening of the slope at tail end.

(*iii*) The extent of eddy in wake of spur increases and its velocity decreases. With flattening of tail end from 1 : 8 to 1 : 10 the velocity of back eddy is slow enough to deposit silt.

The bed conturs of the two tests run with downstream end slope of 1 : 2 and 1 : 8 are compared in Fig No. 41 which clearly shows that with the flattening and lengthening of the slope the length of sand bar formation in wake of spur also increases. The length of sand bar (330 elevation contour) is 240 feet with 1 : 2 slope which increases to 720 feet with 1 : 8 slope. The length of this sand bar with the increase in slope length is given in Fig No. 42. With lengthening of downstream slope, the bar not only increases in length but it also shifts laterally away from the shank of the spur. The lateral shifting of this bar from reference line (axis of spur) as observed on the model is recorded in Fig. No. 43. From the figure it could be seen that the distance of the sand bar from the axis of the spur for 1 : 2 and 1 : 8 slopes is 120 and 210 feet respectively. The shifting of scour hole from axis line of the spur head with different dowstream slopes is recorded in Fig No. 44. The figure inaicates that with lengthening of down-strem slope, the scour hole shifts downstream at a safe distance from the tail end of the spur. The distance Y A is between axis of spur head & point of maximum scour for 1 : 2 and 1 : 8 slopes on the model was 100 and 240 feet respectively. The lengthening of the slope obviously is also advantageous in shifting down the stagnation point and thereby to some extent increase the efficiency of the spur. The L/P ratio for different slopes of the end of the spur head are plotted in Fig. No. 45. which shows that the protection of bank downstream of the spur is proportional to slope at the tail end of spur.

Conclusions :

(*a*) The behaviour of H.T.S type of spur on prototype has proved that this spur can take attack from wide angle of river approach due to formation of pocket along hockey component of the spur, the T component provides the desired direction to the flow lower down and the sloping tail end of the spur provides adequate protection to the downstream face of the spur shank against parallel flow or a secondary current.

(*b*) The spur head should be in a straight line or in mild curve of radius more than 5000′ as sharper the radius the stronger is the secondary current.

MODEL OF BASIC STUDY ON SPUR
LENGTH OF SAND BAR WITH DIFFERENT SLOPS OF D/S END

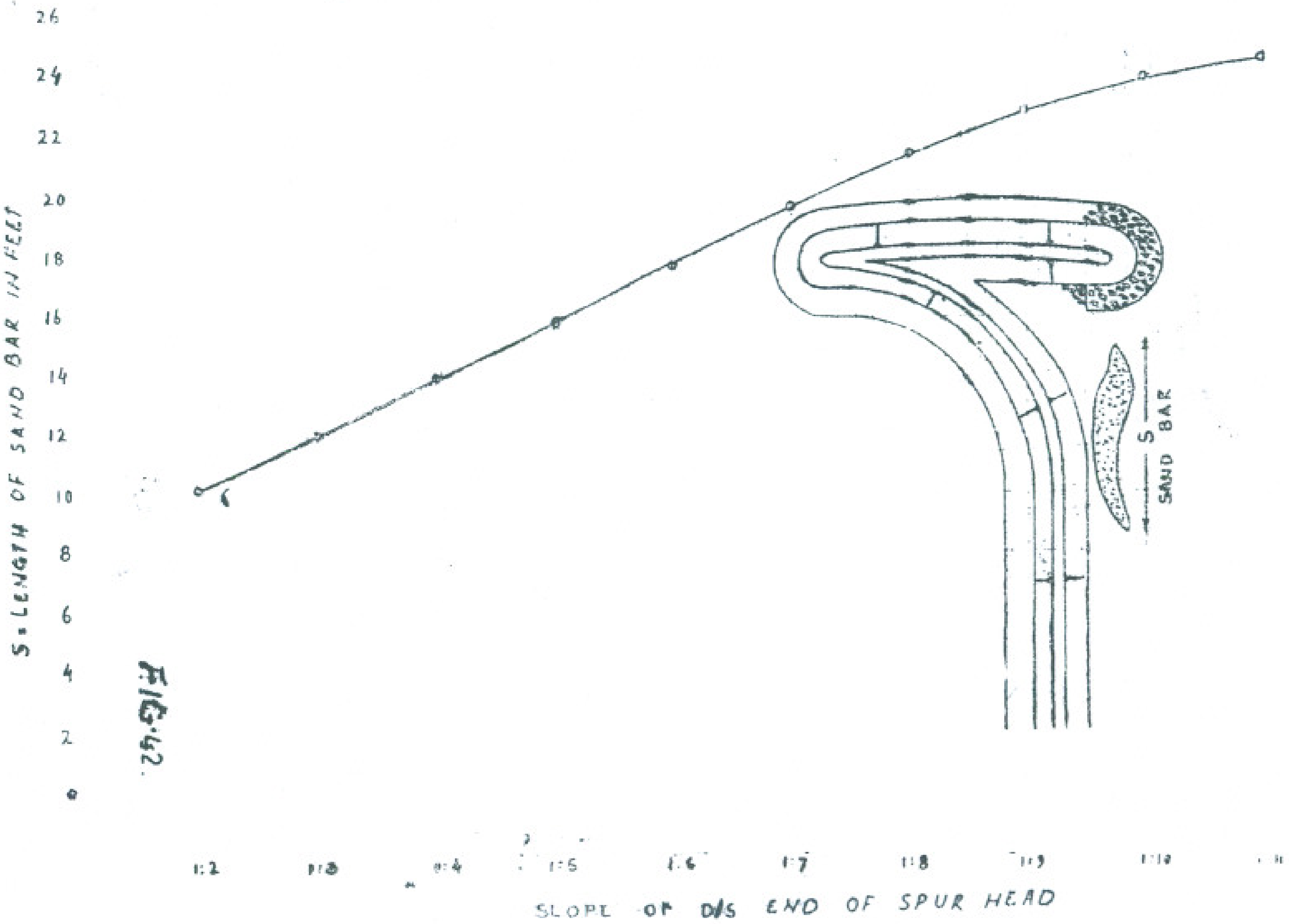


FIG.42.

MODEL OF BASIC STUDY ON H.T.S. SPUR

DISTANCE OF SAND BAR FROM C. LINE OF SPUR

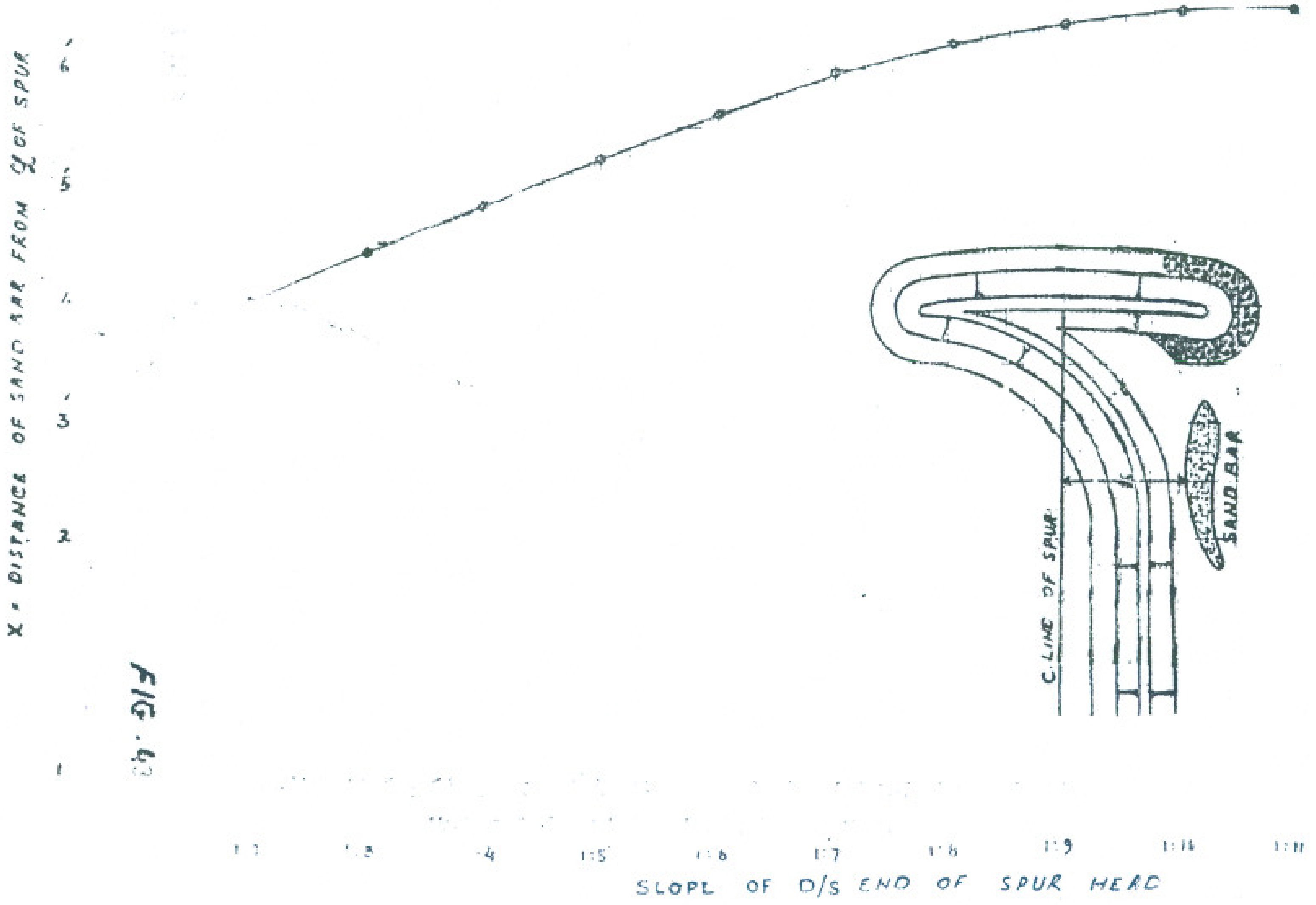
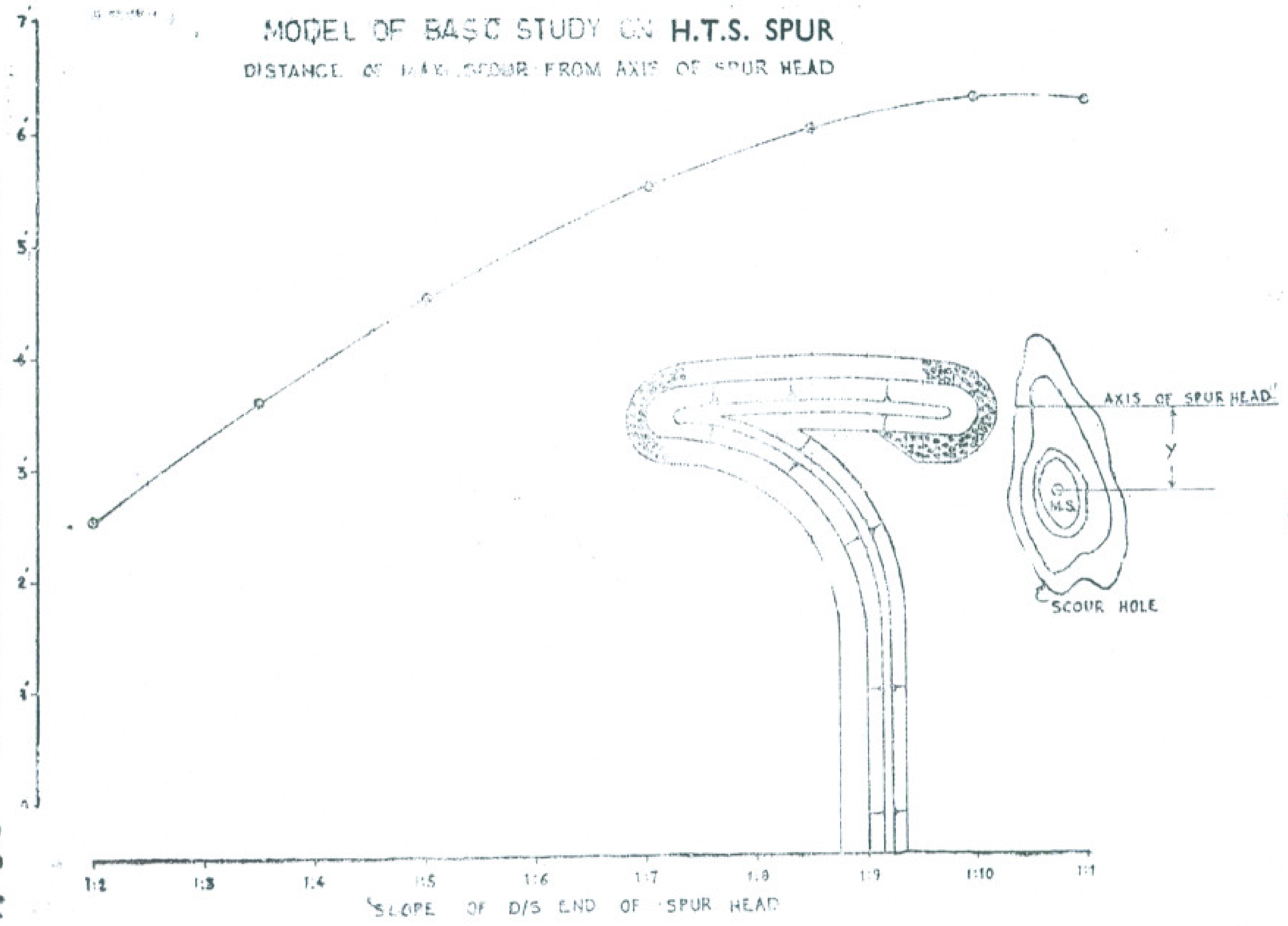


FIG. 43



MODEL OF BASIC STUDY ON H.T.S. SPUR

DISTANCE OF MAX. SCOUR FROM AXIS OF SPUR HEAD

FIG. 44

MODEL OF BASIC STUDY ON H.T.S. SPUR

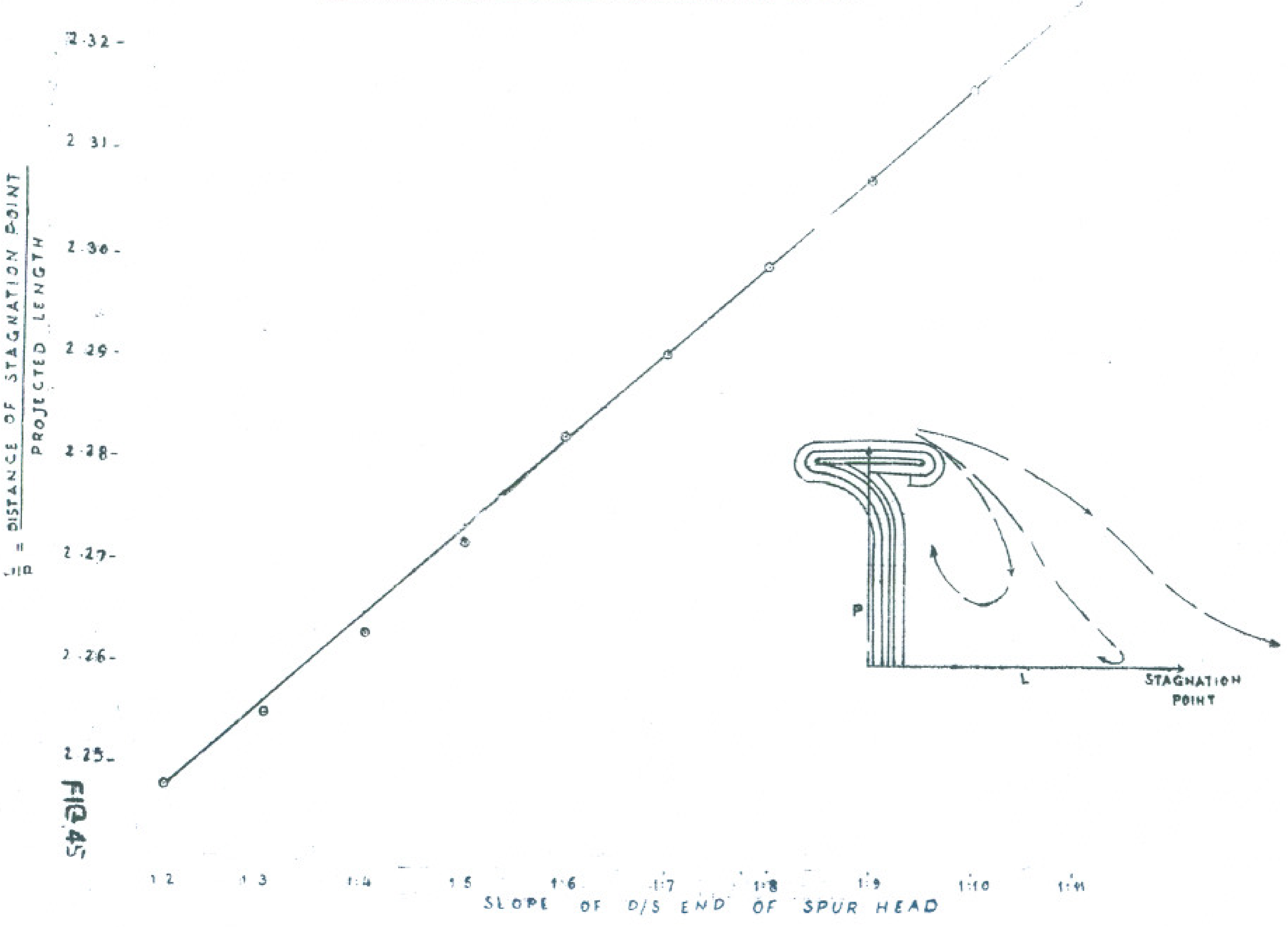


FIG.45

(*c*) That the downstream sloping nose of the spur induces a weak silt depositing eddy on the back side of the spur which wards off the secondary current and provides protection to the downstream face of earthen shank.

(*d*) The optimum radius of hockey component of spur should not be less than 1000′.

(*e*) The optimum length of the T component depends upon the individnal river and its discharge and may be kept equal to 1/2 the Lacey width of the dominant discharge that recurs after every two years.

CHAPTER IX

OPTIMUM SPUR PROJECTION INTO THE STREAM

For river bank protection purposes the length of the spur projecting into the channel and abutted to the bank or flood embankment should be just sufficient to move the eroding currents away from the bank and it must not be such as will unduly restrict the channel and cause unacceptable velocities for the safety of spur or river bank.

To determine the optimum spur projeciton into the river channel, series of tests were conducted in undistorted stabilized channel cut in sand envolope with flow section of 4.0′ ×.25′ and 100.0′ in length and moulded at a stabilized slope of 1/500 without any spur restriction. The channel approached the mole headed spur at its mole at an angle of 90°, 100°, 105°, 120°, 135° and 150° (with respect to spur shank) and the spur projection (in terms of channel width) were 5%, 10%, 20%, 30%, 40% and 50%. The bankful discharge of .78 cusecs was run for about 10 hours in each test.

The typical flow pattern with 30% projection and 20° approach channel is shown in Fig No. 46 which indicates return eddies along the upstream and downstream faces of the stone armoured spur shank in the channel. The upper eddy encroached the bank of the channel upto 40% projection and is shifted away from the bank for 40% or more spur projections.

The extent of the downstream eddy was a function of approach angle and grazed the bank for oblique angles greater than 120° and for projection less than 20%.

Fig. 46

EFFECT OF PROJECTION OF SPUR ON SCOUR
20° APPROACH CHANNEL

$Q = .78$ cs.

Flow Pattern with 30 % Projection.

The ratio of the velocity of return eddy and the average velocity in the approach channel for different projections and approach angles of 90° and 120° and 150° are plotted in Fig No. 47. The spur projection that results in return eddy velocity greater than the approach channel velocity should normally be unacceptable unless the bank and spur are adequately protected against the return eddy velocity. The velocity of upper eddy increases with obliquity substantially. The velocity of downstream eddy decreases with obliquity of approach in-significiantly.

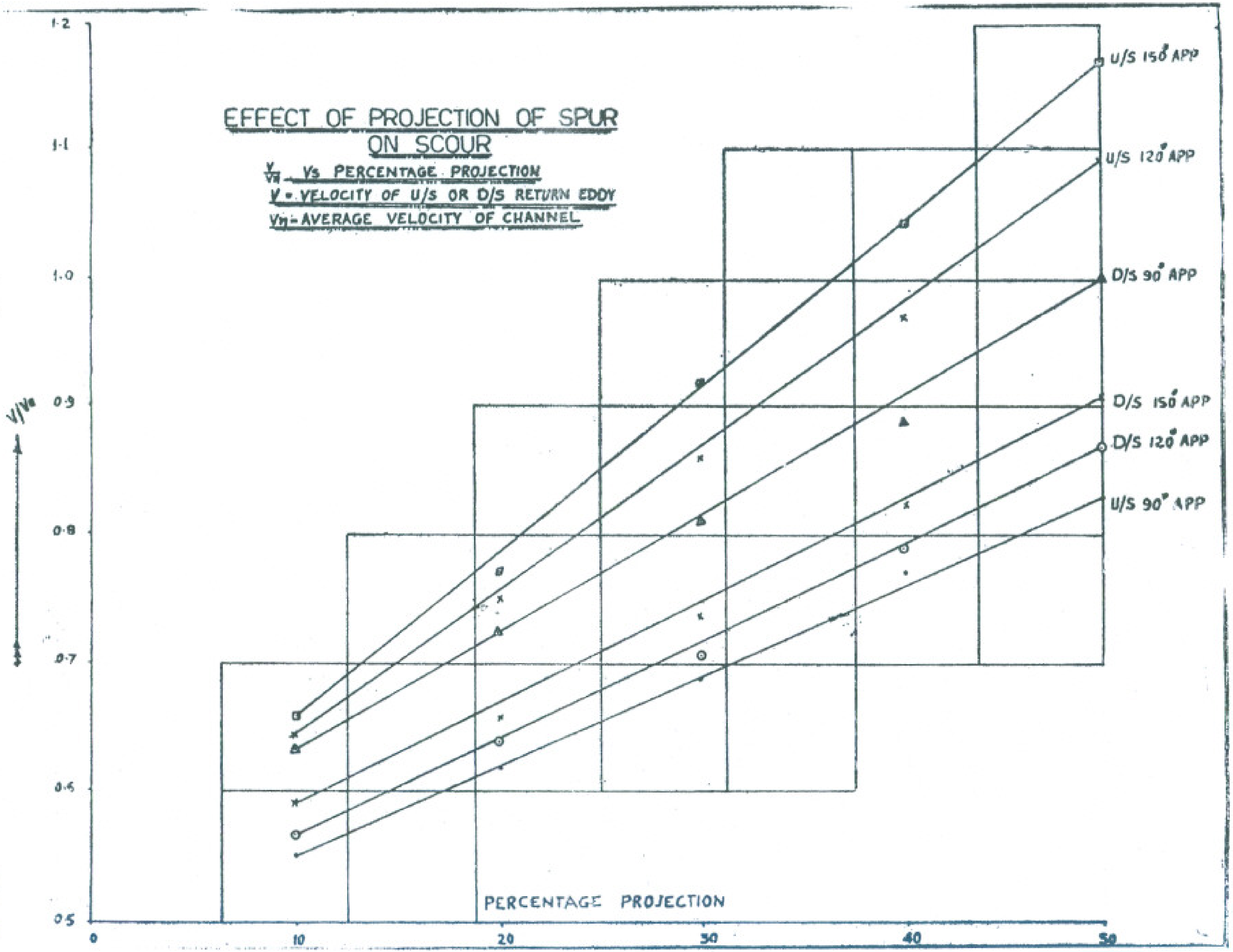
So from back eddy considerations the spur projection greater than 30% should be avoided as for as possible. The two faces of the spur shank should be adequately protected with stone of size compatable with velocity of the eddy.

The mole headed spur with unsufficiently protected shank was constructed on right bank of secondary channel of river Chenab to protect Rangpur Canal from R. D 318 - 322 in the year 1964. In 1975 floods, the secondary channel became the main channel and the mole spur was fully captured and it failed on 6.8. 1975 as the armoured mole was outflenked due to rapid erosion of unprotected shank by the high velocity return eddies along the two faces of the shank.

The channel flow converges towards the scour at the head of spur resulting in heavy concentration of flow. The ratio of discharge per foot run at the spur head to the normal per foot width discharge in the approach channel for all approaches and projections of spur is plotted in Fig No. 48 which shows that this ratio increases with the spur proection into the channel. The greater the per foot run discharge q the greater the scour at the toe of slope of spur head and greater the sucking velocity along the pitched slope.

The excessive scour at the toe of upstream nose of T—spur due to very high value of q at R.D. 4 of L.M.B of Marala Barrage on 28/8/75 had resulted in settlement of upstream nose of the spur. The nose was saved by timely action in the form of rebuilding of the slope of upstream nose of spur in a solid stone (100-250 lb. stone) in a thickness of 5—7′ starting from the level of launched apron.

The stone on the slope of nose of branch spur of spur at R.D. 29 of R.M.B above Qadirabad Barrage which was 1-5′ on a spawl of 6″ thick had settled into scour due to excessive scour at the toe and settlement of apron which was only 2′ at its junction with the slope.



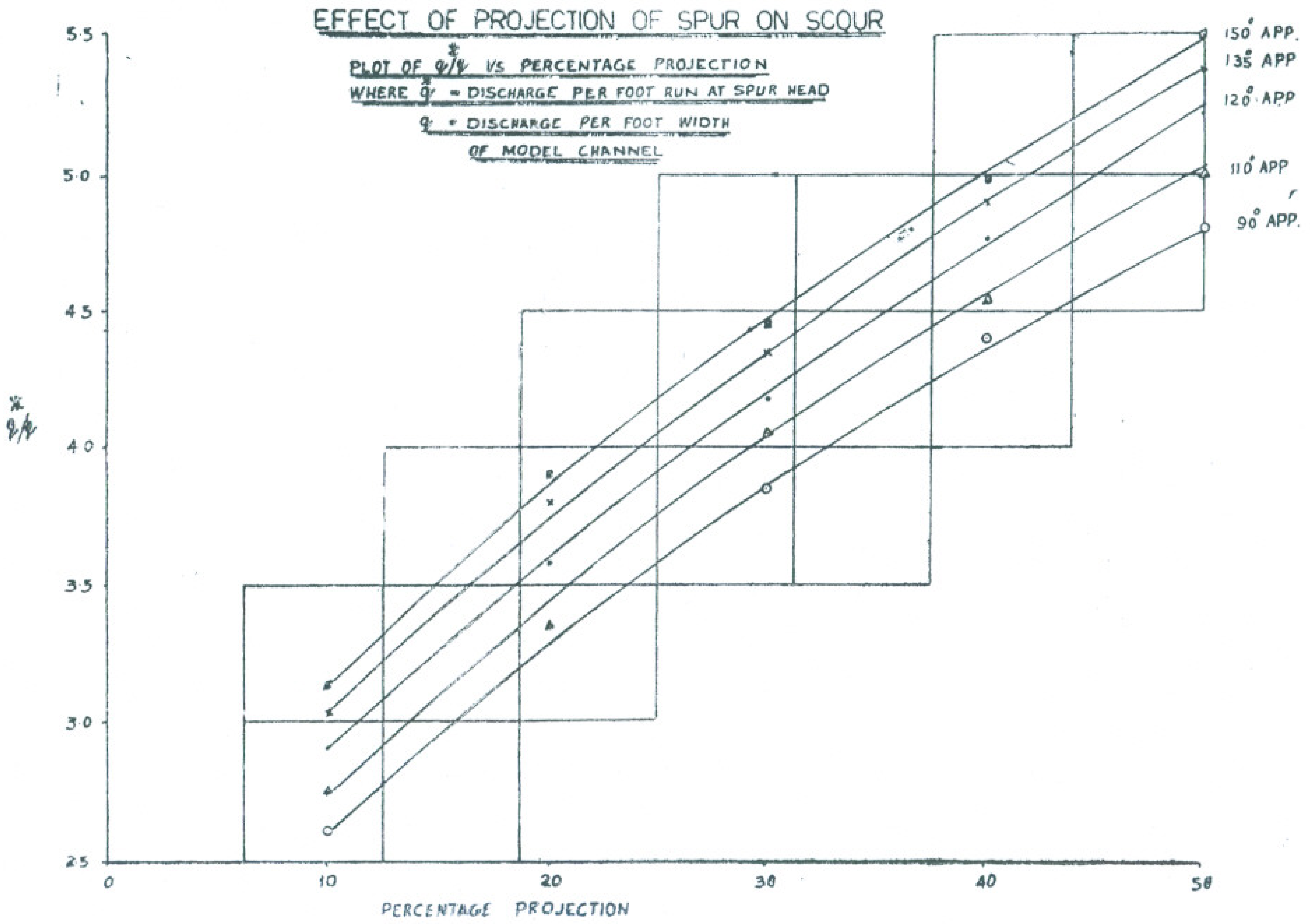

EFFECT OF PROJECTION OF SPUR ON SCOUR
PLOT OF q^*/q VS PERCENTAGE PROJECTION
WHERE q^* = DISCHARGE PER FOOT RUN AT SPUR HEAD
q = DISCHARGE PER FOOT WIDTH
OF MODEL CHANNEL
150° APP.
135° APP
120° APP
110° APP
90° APP.
5.5
5.0
4.5
4.0
3.5
3.0
2.5
q^*/q
0
10
20
30
40
50
PERCENTAGE PROJECTION

Fig. 48

Effect of Projection of Spur on Scour
Head Across Vs Percentage Projection

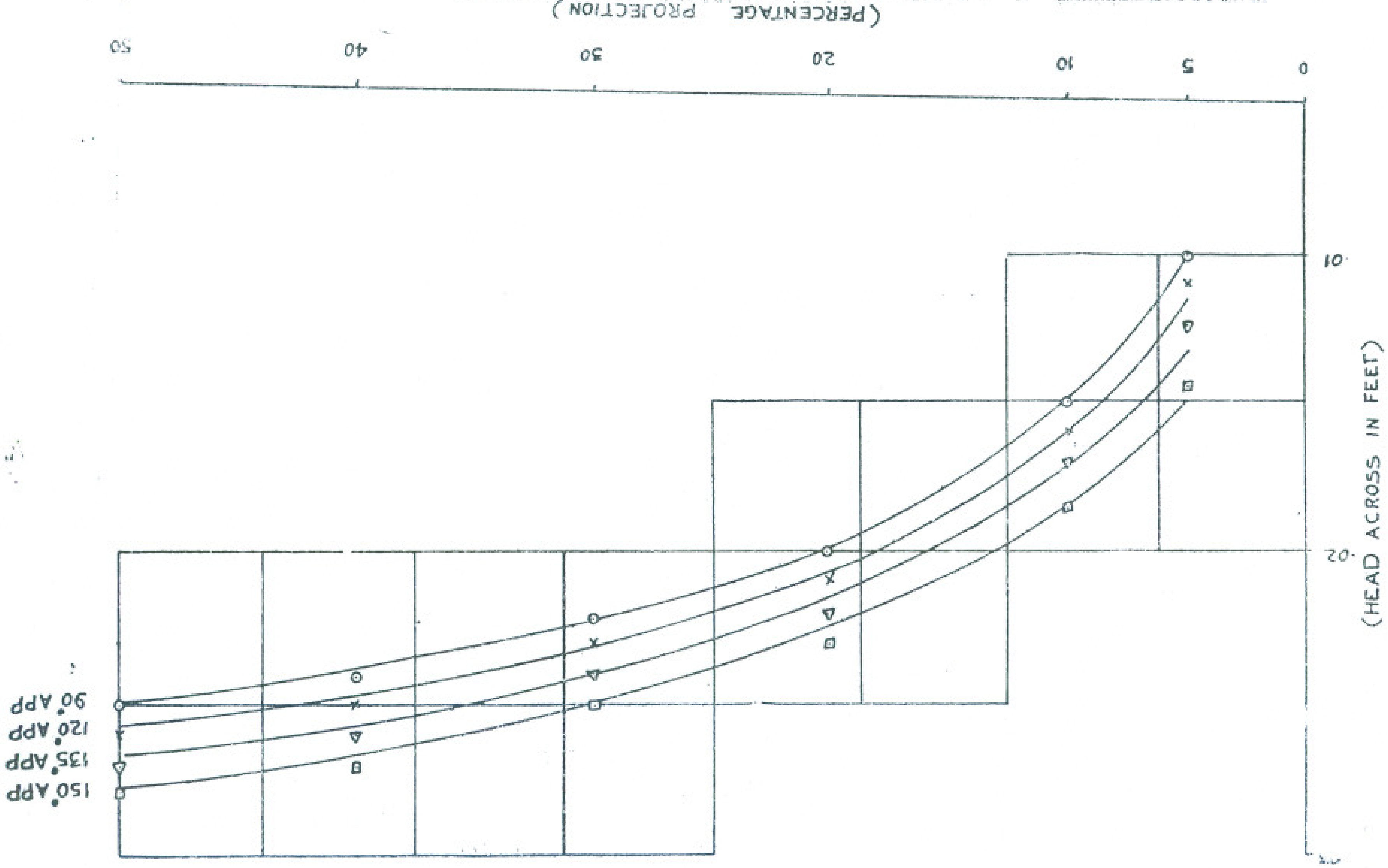


Fig. 49. (a)

Effect of Projection of Spur on Scour

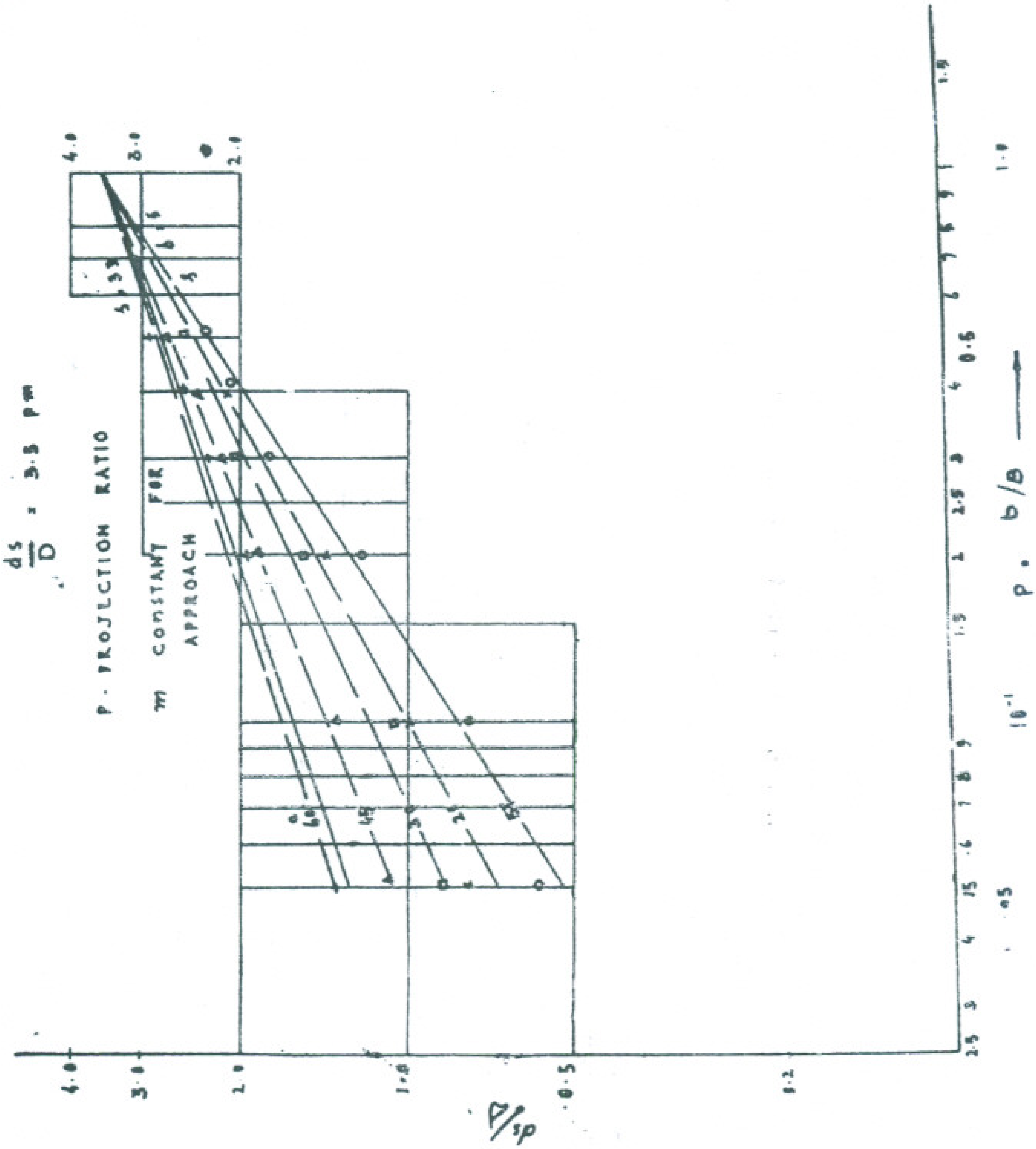


Fig. 49 (b)

Effect of Projection of Spur on Scour

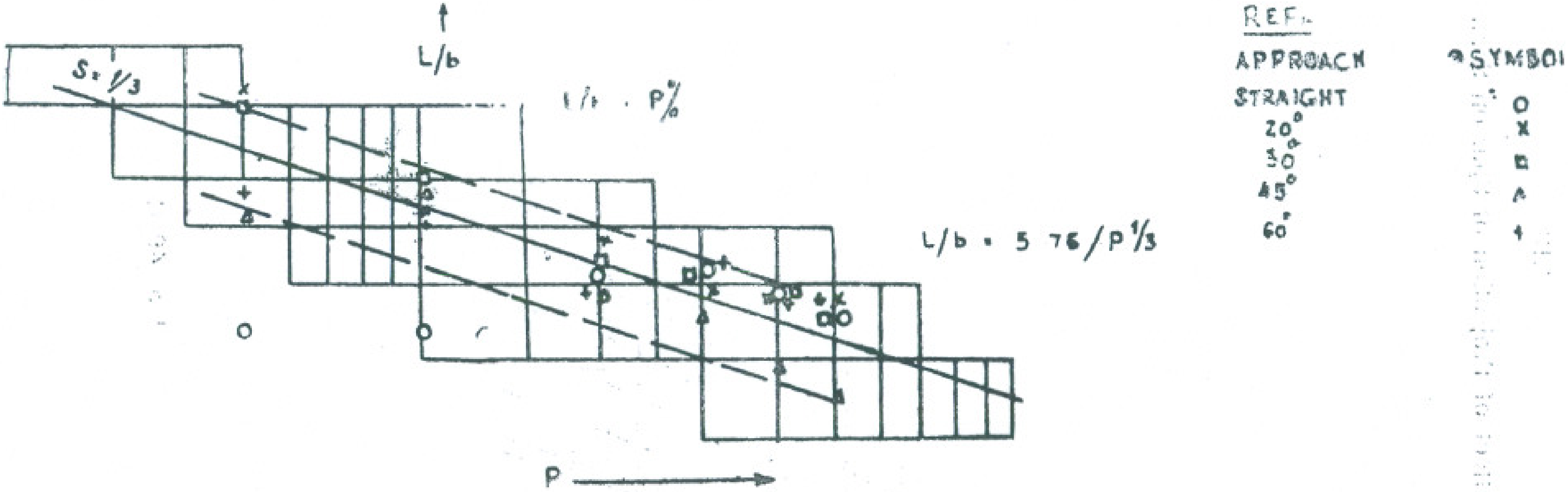


Fig. 50

The spur projection that may ultimately result in enhancement of ratio of q at the spur head to the average q in the approach channel for worst approach beyond a certain value say 4.5 to 5 should be avoided as for as possible.

The head across the spur nose against projection is plotted in Fig No. (49a). The scour depth below moulded bed level of channel ds divided by the normal depth or flow in the approach charnel for different approach engles against spur projection ratio is plotted in Fig No. (49b). The length of bank protected by spur downstream of the spur divided by channel width as plotted against spur projection ration (P) in Fig No. 50.

The scour d_s is plotted against polar area of scour pit in Fig. No. 51. The cardinal points of Fig. No. 49-51 are :

EFFECT OF PROJECTION OF SPUR ON SCOUR
POLAR AREA Vs SCOUR

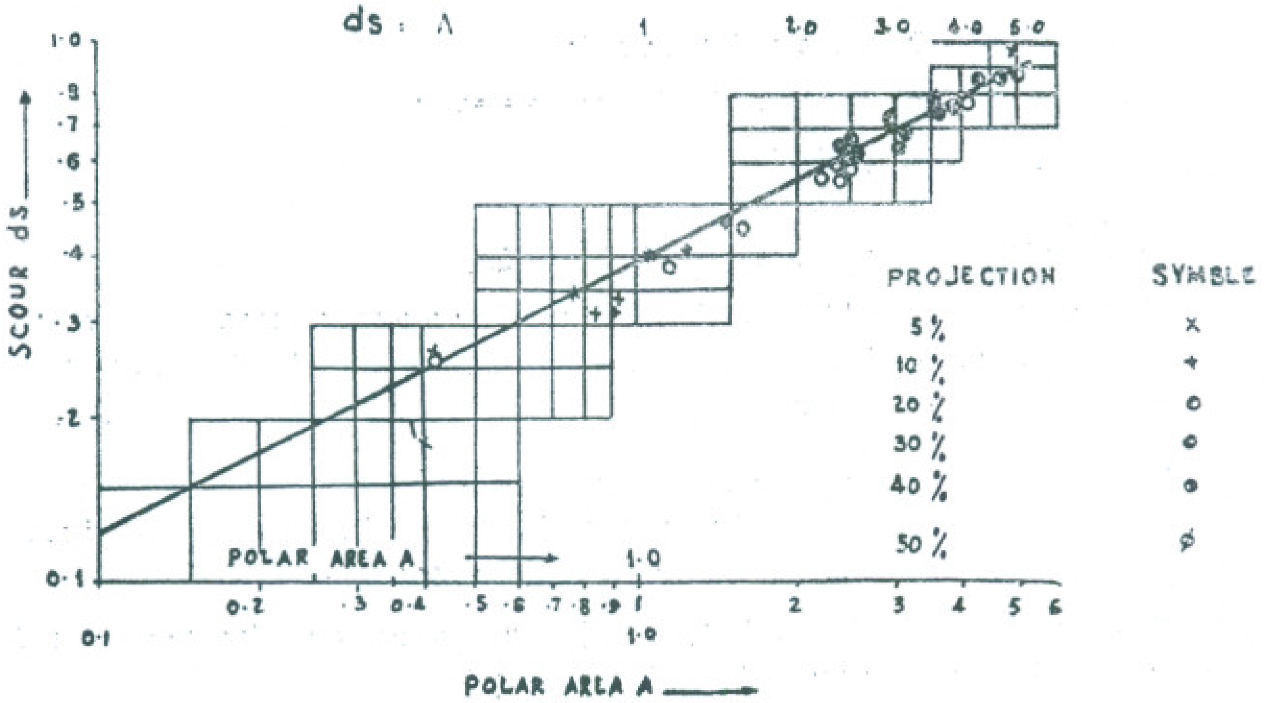


Fig. 51

(1) The scour depth $'d'_s$ for 5 to 50% projection, head across 'h' and % projection 'P' are related as ;—

$$ds/h = 15.3\ P^{1/6}$$

(2) Maximum value of scour constants

$K = ds/D$

and $K1 = ds/R$ (Lacey)

is 2.32 and 1.69 respectively for straight approach, however, there is an increase in their values by 30% due to approach from 20° to 60°.

(3) The analysis reveals that there exists a relation between scour constant, projection ratio and approach angle. The scour constant is given by the equation as below :

$K = ds/D = a.p^m$

where $m = .615 - .0047\ \varnothing$

$\varnothing$ = being the approach angle ;

a = a constant = 3.5

$p = b/B$, the projection ratio.

(4) Scour, polar area and projection are related as :

$ds/A^{\frac{1}{2}} = 0.3\ P^{1/10}$

where P is % projection, roughly $ds/A^{\frac{1}{2}} = 0.4$

(5) Length protected L/b is influenced more by projection than the approach angle and relation of length protected and projection is given as below :

$L/b = 5.75/P^{1/3}$

The results show that scour depth, head across, polar area as well as downstream length of the bank protected spur are all functions of the percentage of projection and to some extent influenced by the approach angle.

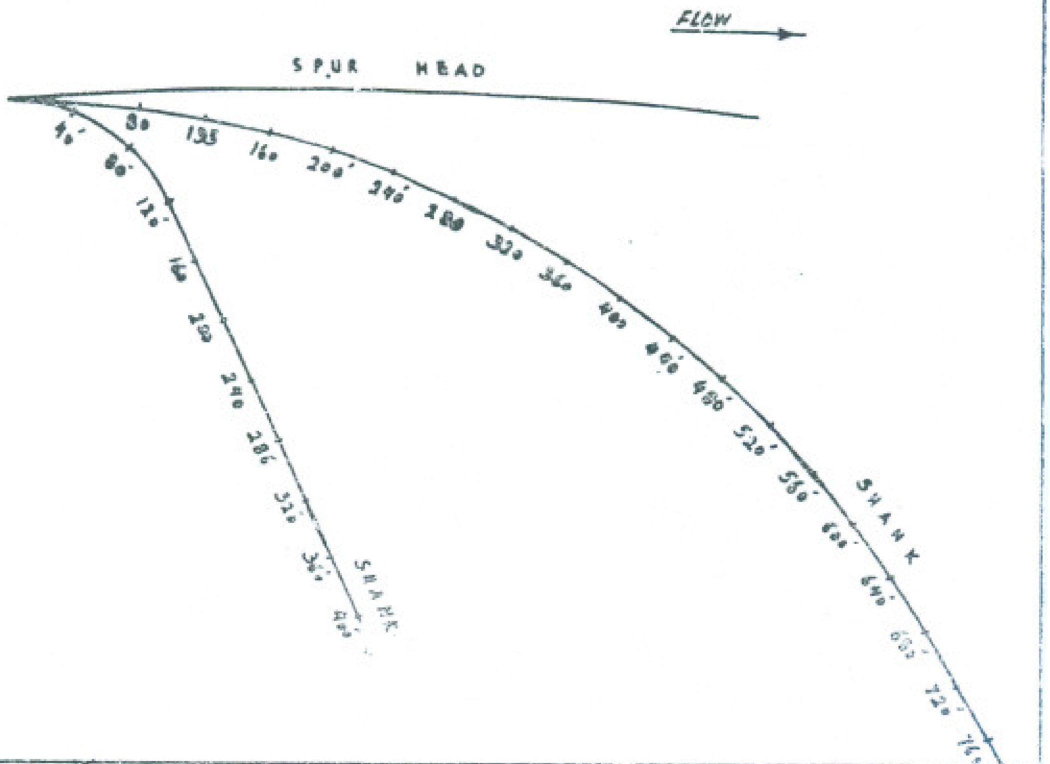
The optimum projection is 20% —30% and the optimum length protected down stream of the spur is twice the projection length.

To be on the safer side the u/s nose of spur should be designed for a maximum scour constant of ds/D = 3.5 as irrespective of the initial spur projection the river may ultimately form a deep embayment subsequent to construction of spur due to migration of meanders in the down stream direction and thus the spur may be fully captured.

FIG.34

MODEL OF BASIC STUDY ON H.T.S SPUR

SURFACE VELOCITIES ALONG U/S FACE OF SHANK FOR DIFFIRENT RADII

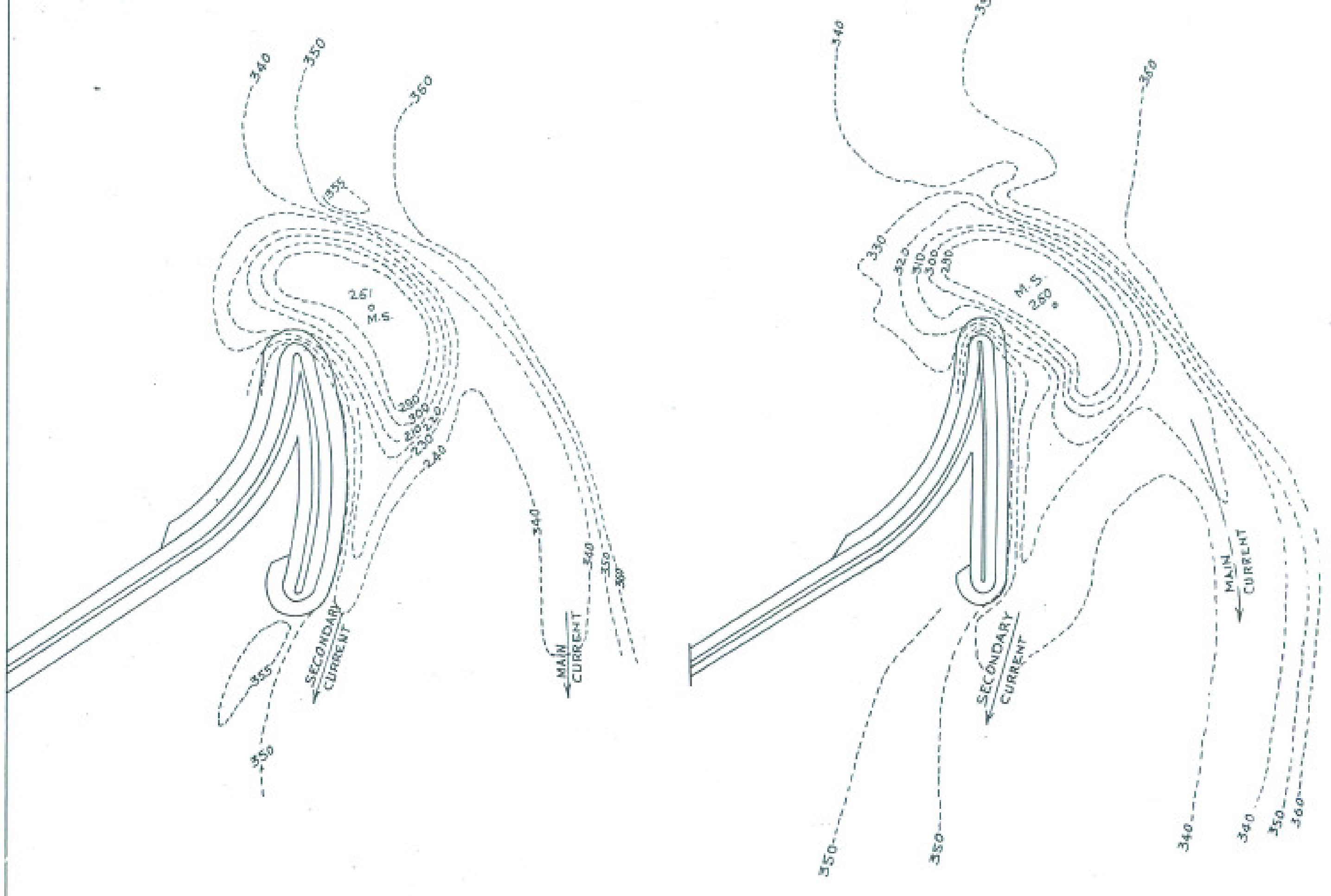


RADIUS OF SHANK IN FT.	DISTANCE IN FT. FROM U/S END OF THE SPUR HEAD										
	80	160	240	390	400	480	560	640	720	800	
200	9.5	9.5	8.6	8.0	6.75	4.7	3.9				
400	9.5	9.0	8.3	7.9	6.0	4.3	3.2	2.9			
600	9.0	8.7	8.0	7.0	5.6	3.8	3.2	2.5	2.25		
800	8.5	8.5	7.7	7.5	5.5	3.7	3.0	2.5	2.25	2.0	
1000	8.5	9.0	7.2	6.0	4.7	3.7	3.0	2.5	2.2	2.0	
1250	8.5	8.0	7.0	5.7	4.7	3.5	3.0	2.5	2.0		

MODEL OF BASIC STUDY ON J SPUR

SCALE:-1Cm=4FT

BED CONTOURS AFTER THE TEST
WITH RADIUS OF SPUR HEAD AS 1000
AND 6000FT.



RADIUS OF HEAD 1000FT.

RADIUS OF HEAD 6000FT.

FIG.36

LOWER SPUR AND GUIDE BANK PROTECTION OF MOHANJO DARO

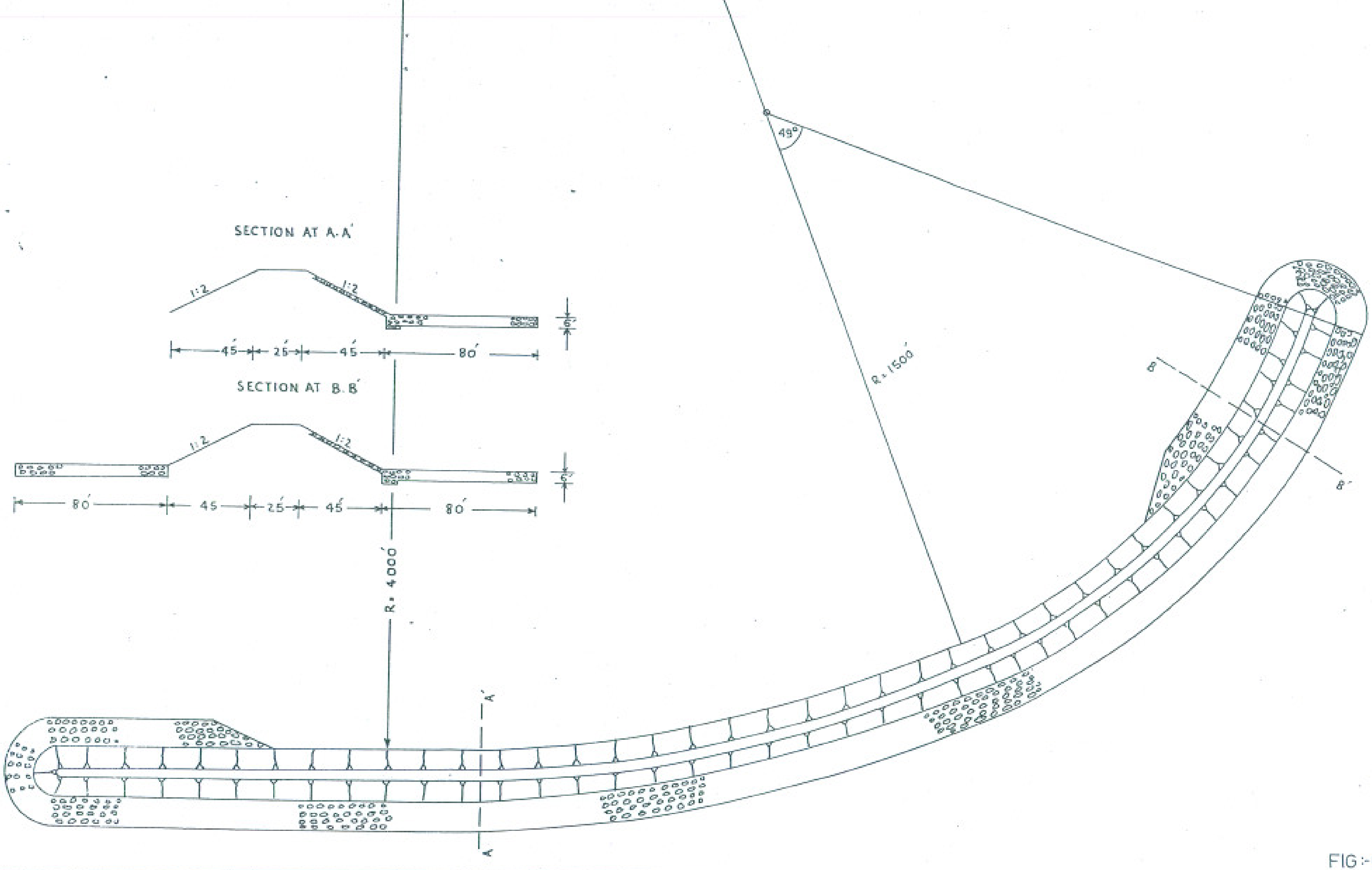
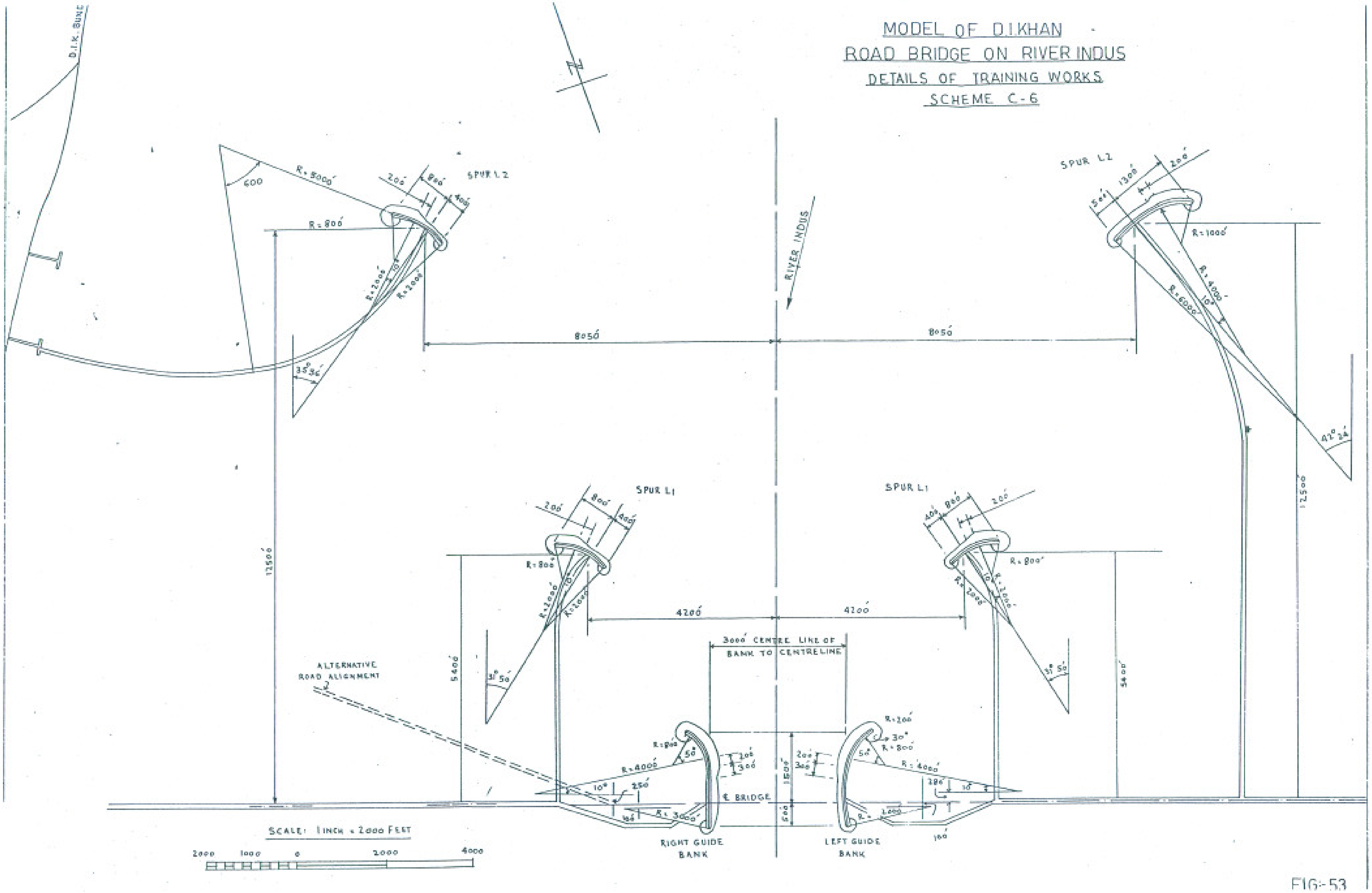


FIG:-52



MODEL OF D.I.KHAN
ROAD BRIDGE ON RIVER INDUS
DETAILS OF TRAINING WORKS
SCHEME C-6

FIG:-53

So knowing the dominant discharge from the hydrograph data the normal depth of flow D will be worked out from normal depth formula or Lacey formula the scour depth will be 3.5 x D and the quantity of stone in per foot width of apron will be 7 x3.5 xD.

CHAPTER X

CORRELATION OF LENGTH AND DEPTH OF STONE IN APRON AND MOST EFFECTIVE LEVEL OF APRON.

Guide banks on the two flanks of a bridge or a barrage were introduced by Mr. Bells to effect some saving on the length of the bridge or a barrage and to protect the flanks of a bridge or a barrage. Bells guide bank is used for training the river through a bridge or a barrage and it can be successfully used for protecting long distances of an eroding edge of a river. A single guide bank in the outside of a river bend was successfully used at River Sutlej at crossing point of Sui Gas Pipe Line and at River Indus for protection of Hala Town.

The Bells guide bank is a guide wall (in direction of flow) constructed in river bed and is an earthen embankment usually on 1:2 side slopes river face adequately armoured with stone with its toe adequately protected with stone apron with crown 15—20 feet and top level with a reasonable freeboard against highest anticipated flood level and curved at its upstream end which forms impregnable nose (Fig. No.52).

The shape of the guide bank and the dimensions of the stone apron have been controversial issues. Detailed tests were conducted at Hydraulics Field Research Station Nandipur to determine the optimum radius of nose of the guide bank, apron level, depth of stone in apron, size and gradation of stone in apron on 1:36 natural scale model of river Indus reach opposite D.I. Khan.

The conclusions of this study are:—

(*a*) The upstream nose should be curved on a radius of 1200-1500 feet to lead the flow along smooth lines without causing separation of flow from the guide bank.

(*b*) The apron level should be as low as possible from practical and cost considenations but in no case it should be higher than the minimum winter level otherwise the launching of stone will be irregular.

(*c*) The depth of stone in the apron should not be less than 5.0 feet as with 4.0 feet thickness of stone in apron the depth of stone over the slope formed by launching of apron is not adequate to stop sucking out of sand under the stone by high velocity flows.

(*d*) The stone in apron should be well graded with a good percentage of stones weighing near about 150 lbs. as the percentage losses of stone from the apron at the point of impingement of flow decreases with increase in size of stone.

(*e*) The scour is maximum in the vicinity of impingement point of currents where the flow is diving down. The order of scour is a function of localized per root run discharge at the point of maximum scour and degree of convergence of currents and is roughly equal to 1·3 × Q 1/3 where Q is maximum estimated discharge for extreme angular approach.

(*f*) It is advantageous to provide longer apron as to start with the scour is away from toe of slope and launching of stone is gradual. However the stone losses increase significantly if the stone depth in apron is 4′ and so the thickness of stone should not be less than 4.O′ and may be kept 5.O′. The length of apron if small and depth of stone is more the apron launches in the form of big lumps. The total quantities of stone in apron are determined by the scour formula as ate above. As the per root run stone is fixed, depth of stone is fixed the length of apron also gets fixed. The stone in the Outer Fringe of apron may be kept in wire netting or 'trangars' in layers of 2-3 trangars.

The length of guide bank should be sufficient to prevent formation of a bend of the river above and behind the guide bank circuitous enough to encroach the approach embankment in case of a bridge or approach the bank line beyond which further recession of bank is not desirable. The length of guide bank is dependent to some extent on the breadth of un-narrowed river. In wide Khadirs of the river the possibility of the river going round a guide bank into the still water area at its back and eroding the approach embankment, or proposed bank line may involve the use of very long and expensive guide bank. However too long guide banks are avoided by the addition of groynes higher up so spaced and aligned that the shorter guide bank (to protect to flanks of bridge or barrage) and the heads of the groynes act as one long but broken guide bank (Fig. No. 53). The training system detailed in Fig. No. 4 was evolved as a result of detailed model study for D.I. Khan bridge on river Indus.

TABLE No. II

VELOCITIES IN Ft/Sec ALONG U/S AND D/S FACE OF HOCKEY SPUR

Discharge in Cusecs	U/s Face								Tip of spur	D/S Face							
	640′	560′	480′	400′	320′	240′	160′	80′		40′	80′	120′	160′	200′	240′	280′	320′
50,000					4.0	4.8	6.0	6.8	8.7	−3.2	0	+4	3.8				
100,000			4.0	5.0	6.0	7.0	7.4	8.0	10.1	−4.8	−2.6	+5.0	4.9	4.6	4.2		
200,000	3.9	4.6	5.0	6.6	7.6	8.3	8.7	9.6	12.3	−6	−4	0.	+5.6	5.0	4.8	4.6	4.2

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