# PROGRESS REPORT
# ON
# HYDRAULIC MODEL STUDY OF SPUR DIKES
# FOR HIGHWAY BRIDGE OPENINGS

Prepared for

U. S. Department of Commerce

Bureau of Public Roads
Division of Hydraulic Research
Washington, D. C.

by

S. Karaki

COLORADO STATE UNIVERSITY RESEARCH FOUNDATION
FORT COLLINS, COLORADO
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# FOREWORD

The hydraulic model study of spur dikes for highway bridge openings was sponsored by the State Highway Departments of Mississippi and Alabama, in cooperation with the U. S. Department of Commerce, Bureau of Public Roads, Washington, D. C. The study was undertaken in two phases and conducted in the Hydraulics Laboratory of the Colorado State University, Fort Collins, Colorado.

The first phase was a qualitative study to determine the effects of various spur dikes on development of scour at a bridge abutment. The objective of this phase of the study was to determine the importance and inter-relationship of various geometric characteristics of the spur dike and its location relative to the highway embankment. It is this phase of the study that is reported herein.

The second phase will be undertaken to establish a design criteria for spur dikes that bridge engineers may use in designing spur dikes for installation.

The writer intends that the motion-picture film taken of the study will accompany and become a part of this report. It is important that the reader makes visual comparisons of various tests, especially for flow conditions, that are not included in the photographs of this report.

The principal investigator was the writer, assisted by F. Videon and other staff members. General supervision and advice was given by Dr. A. R. Chamberlain, Chief, Civil Engineering Section. Acknowledgement is given also to C. F. Izzard, Chief, and J. N. Bradley, Research Engineer, both of the Hydraulics Research Division, Bureau of Public Roads, Washington, D. C. for technical assistance and for reproduction of the motion picture film.

## SYNOPSIS

The preliminary study of hydraulics of spur dikes for highway bridge openings was made in the Hydraulics Laboratory of Colorado State University. Various tests were made and results were recorded with motion-picture film and still photographs. Qualitative analysis of the results have indicated that spur dikes should be designed with two requirements; (1) to prevent formation of eddies, and (2) to distribute flow more uniformly through the bridge opening. The two requirements cannot be satisfied separately because of their inter-related and somewhat conflicting effects on the geometry of the spur dike. The shape of the spur dike is thus, apparently dependent upon the condition of flow on the portion of the flood plain obstructed by the highway fill. Future studies will test for various flow conditions on the flood plain and the results will be analysed to develop design criteria to be used by bridge engineers for designing spur dikes.

# CONTENTS

## FIGURES

FIGURES - - Continued

FIGURES - - CONTINUED

FIGURES - - Continued

# I INTRODUCTION

Scour at bridge abutments during floods has long been a problem to bridge engineers. Where a highway crosses a river with a wide flood plain it is necessary, for economic reasons, to project the highway fill onto the flood plain so that a minimum bridge length is constructed. During times of flood, the embankment on the flood plain is an obstruction which forces the flow along the embankment to the bridge opening. The quantity of water flowing on the flood plain, obstructed by the highway fill, and forcibly concentrated near the abutment, creates locally high velocities and eddies at the abutment. The ensuing scour undermines the abutment foundation and causes bridges to fail.

Scour at abutments can be reduced by constructing a spur dike at the abutment. A spur dike is a projection extending upstream from the highway embankment, usually near the bridge abutment. It is shaped in such a way as to obstruct the flow along the highway fill and redirect it to merge smoothly with the flow directly approaching the bridge opening. See Figures 4 and 5. Spur dikes will not in general prevent scouring, for scour will likely develop near the end of the dike. However, the scour hole is displaced from the vicinity of the abutment to some location upstream where no damage is done to the bridge abutment or piers.

Spur dikes have been used by some states for a number of years. Some have been in existance for twenty years or more, with apparently no damage to the dike, and more important, no scour developed at the bridge section. Other dikes have required annual maintenance on the dike itself. Still others have not been subjected to floods of any magnitude so that no useful information is available from them.

There is apparently no rational method for design of spur dikes in current design practice. Most dikes have been constructed at the abutment, but without knowledge as to whether another position might be more appropriate. Lengths and shapes for dikes have been estimated and the estimates have usually been based on the designers experience.

To better understand the hydraulics of spur dikes and to develop design criteria, a model study was initiated in the Hydraulics Laboratory of Colorado State University. The initial phase of the study was considered a pilot or preliminary study and this report is a progress report on that phase. The scope of the first phase included qualitative determination of the effects of shape, length and position of the spur dikes on scour at the abutment with but one condition of flow in the approach channel and through the bridge opening. Several isolated tests were made for studying the effects of different approach flow conditions on local scour, but there was not sufficient study conducted in this first phase to enable assembly of data for a design criteria. Motion-picture films and still photographs were taken of all tests.

## II EQUIPMENT

### Flume

The laboratory study was conducted in a flume 16 feet wide and 84 feet long. It consisted of two sections of flume, each 32 feet long, separated by a recessed section 20 feet in length. The bed of the flume consisted of sand to form an erodible bed. See Figure 1 for a graphical representation of the sieve analysis for the sand. In the section upstream from the recessed or test section, a sand layer of about one inch thick was placed on the bed. Sand was also placed downstream of the test section. This was done so that the same channel roughness would exist throughout the length of the flume. In the test section, the flume bottom was recessed to the floor of the laboratory, approximately four feet deep, to provide scour depth for the models.

The height of flume for the 32 foot section upstream of the test section was 4 feet. From the beginning of the test section to the downstream end of the flume the height was one foot, measured from the surface of the bed to the top of the guide rails. Guide rails were placed on the sides of the flume, with a fixed slope of 0.0003, for the screed and the instrument truss.

The head box constructed for the flume was essentially a manifold with adjustable openings so that lateral distribution of flow could be controlled.

Two screeds were constructed for the flume, one for use upstream of the test section and another for use downstream where the height of the flume walls differed. These screeds were used to smooth the bed surface prior to each test. An instrument truss was constructed for use in the test section to measure water surface elevation around the dike and embankment. Stilling wells were installed on the sides of the flume to measure the water surface in the flume.

## Models

Highway embankment models were made of plywood and sheet metal. The top width of the embankments were one foot with side slopes of 1 1/2 : 1. The height of the road bed above the channel bed was 0.6 foot. See Figures 2 and 3. The embankments projected from one side of the flume, representing only partial models of bridge crossings. The sides of the flume represented some point in the river where the stream lines were essentially unaffected by the construction of the embankment.

Figures 4 and 5 show typical spur dikes tested in the flume. Two widths of bridge openings, 8 feet and 4 feet, were used in the flume. The major portion of the study was made with the 8 foot opening, with only two tests made with the 4 foot opening.

The models of the spur dikes were made erodible with a sand-cement-bentonite mixture. The ratio of the mixture was kept constant for each test so that comparison of erosion on the different spur dikes could be made. A preliminary study was made on the sand-cement-bentonite mixture in order to obtain the most desirable proportions of the mix. The most satisfactory proportion was found to be 250 parts of sand to 1 part cement and 2 parts of bentonite by weight.

The various shapes of spur dikes were modelled by cutting a template for the top of the dike from sheet steel and forming the side slopes of the spur dikes with a template. Side slopes for all spur dikes were 1 1/2 : 1.

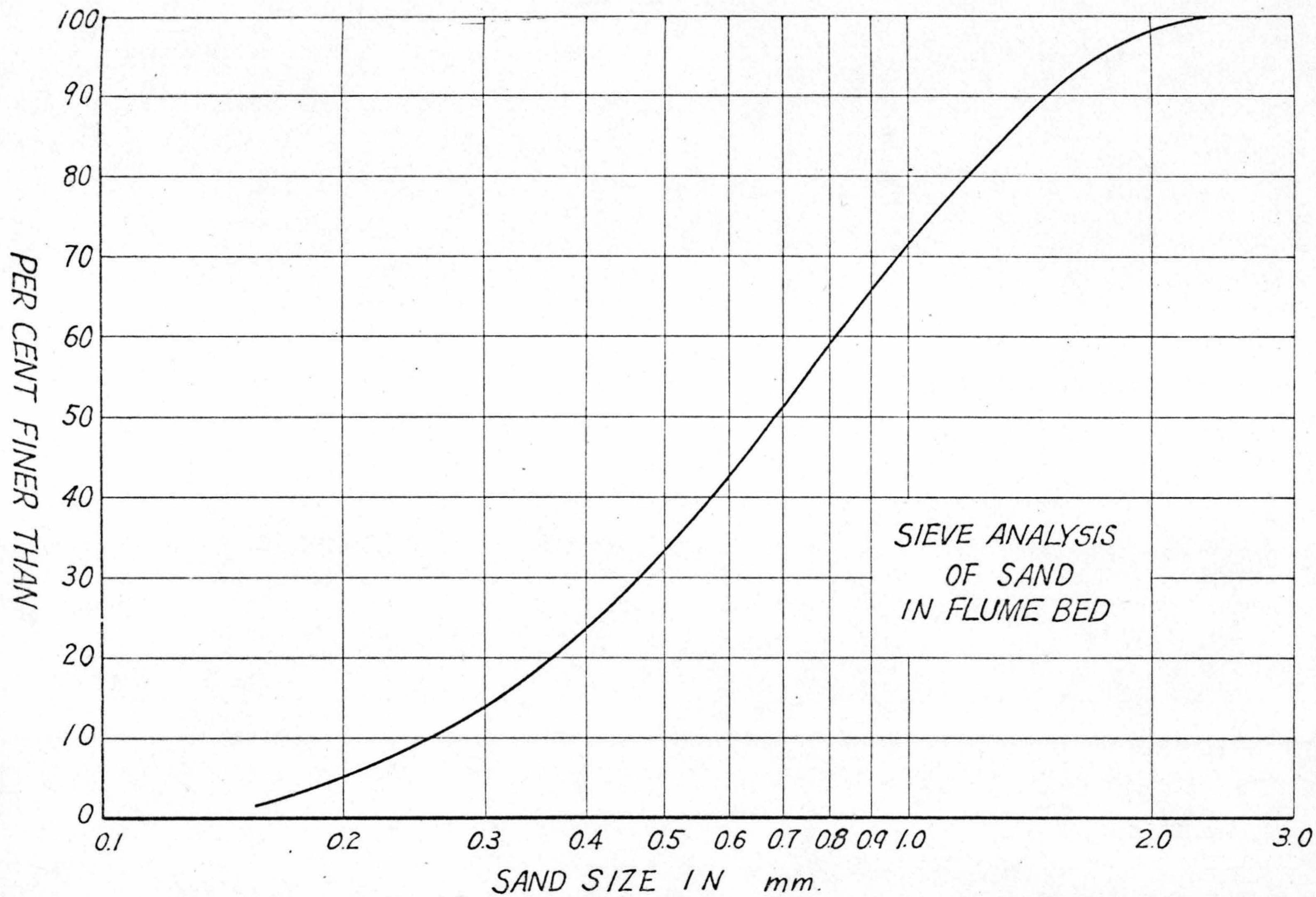
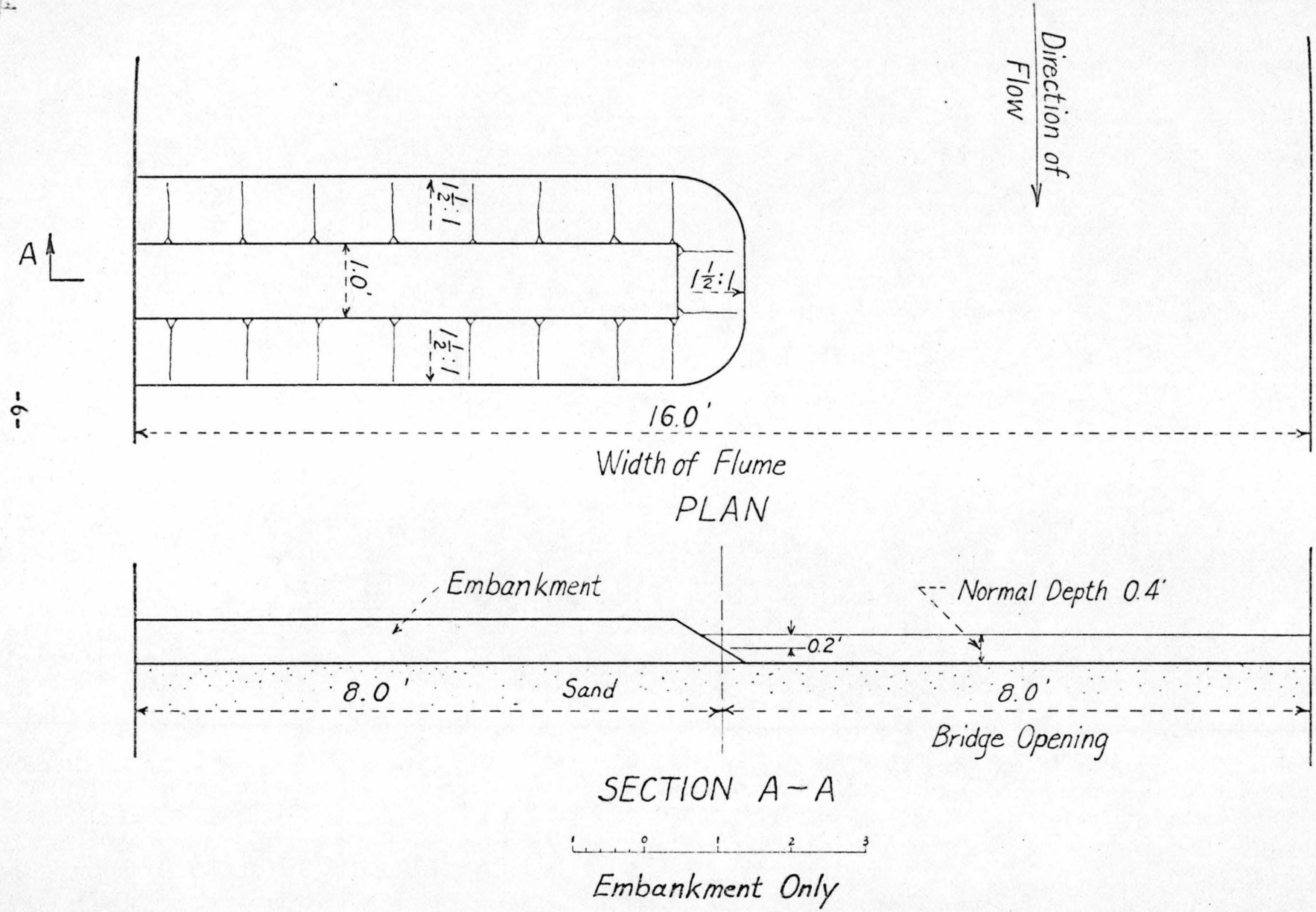
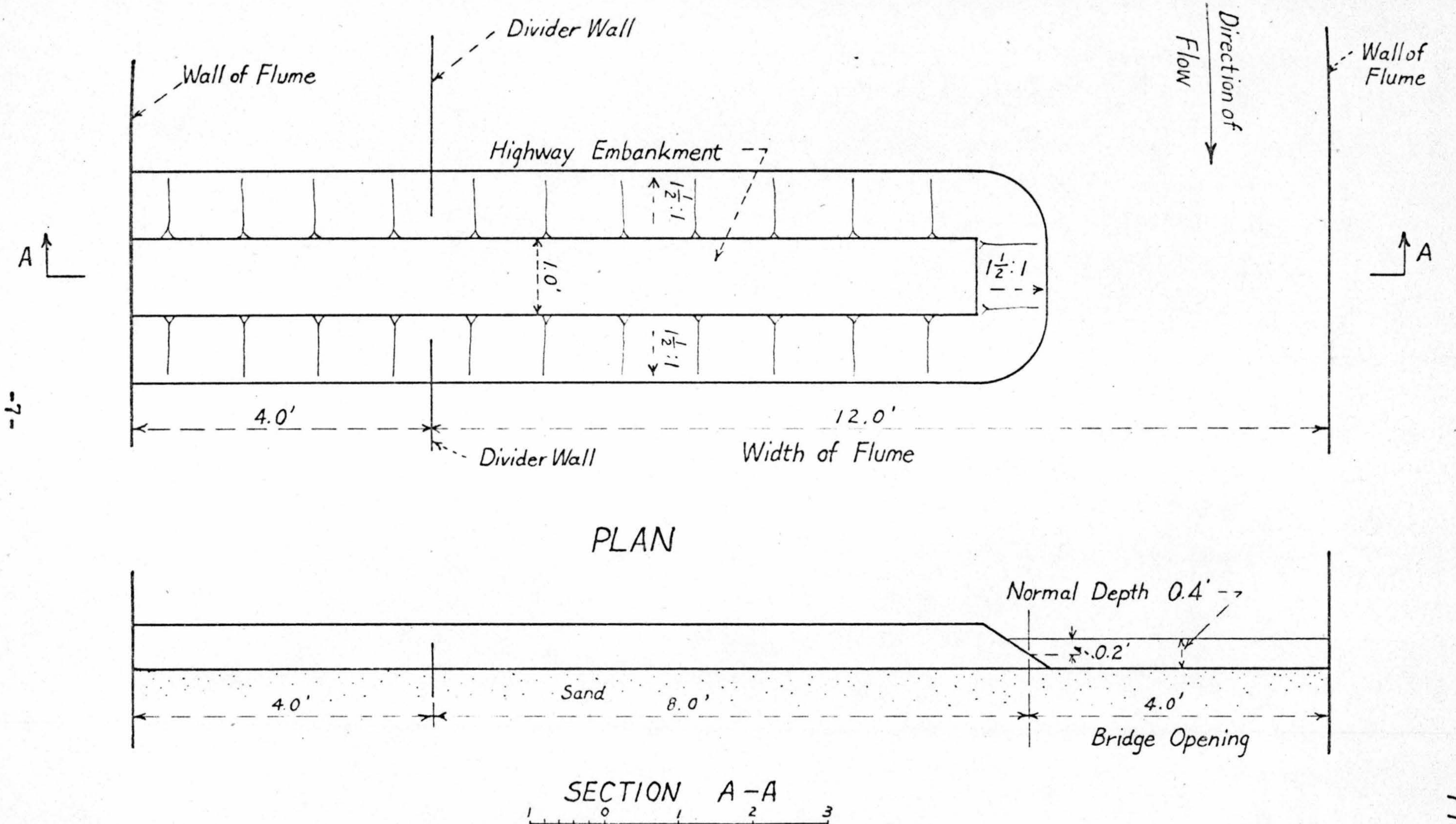

PER CENT FINER THAN
100
90
80
70
60
50
40
30
20
10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
2.0
3.0
SAND SIZE IN mm.
SIEVE ANALYSIS
OF SAND
IN FLUME BED

FIG. 1



Direction of Flow
A
A
$1\frac{1}{2}:1$
1.0'
$1\frac{1}{2}:1$
$1\frac{1}{2}:1$
16.0'
Width of Flume
PLAN
Embankment
Normal Depth 0.4'
0.2'
8.0'
Sand
8.0'
Bridge Opening
SECTION A-A
1 0 1 2 3
Embankment Only

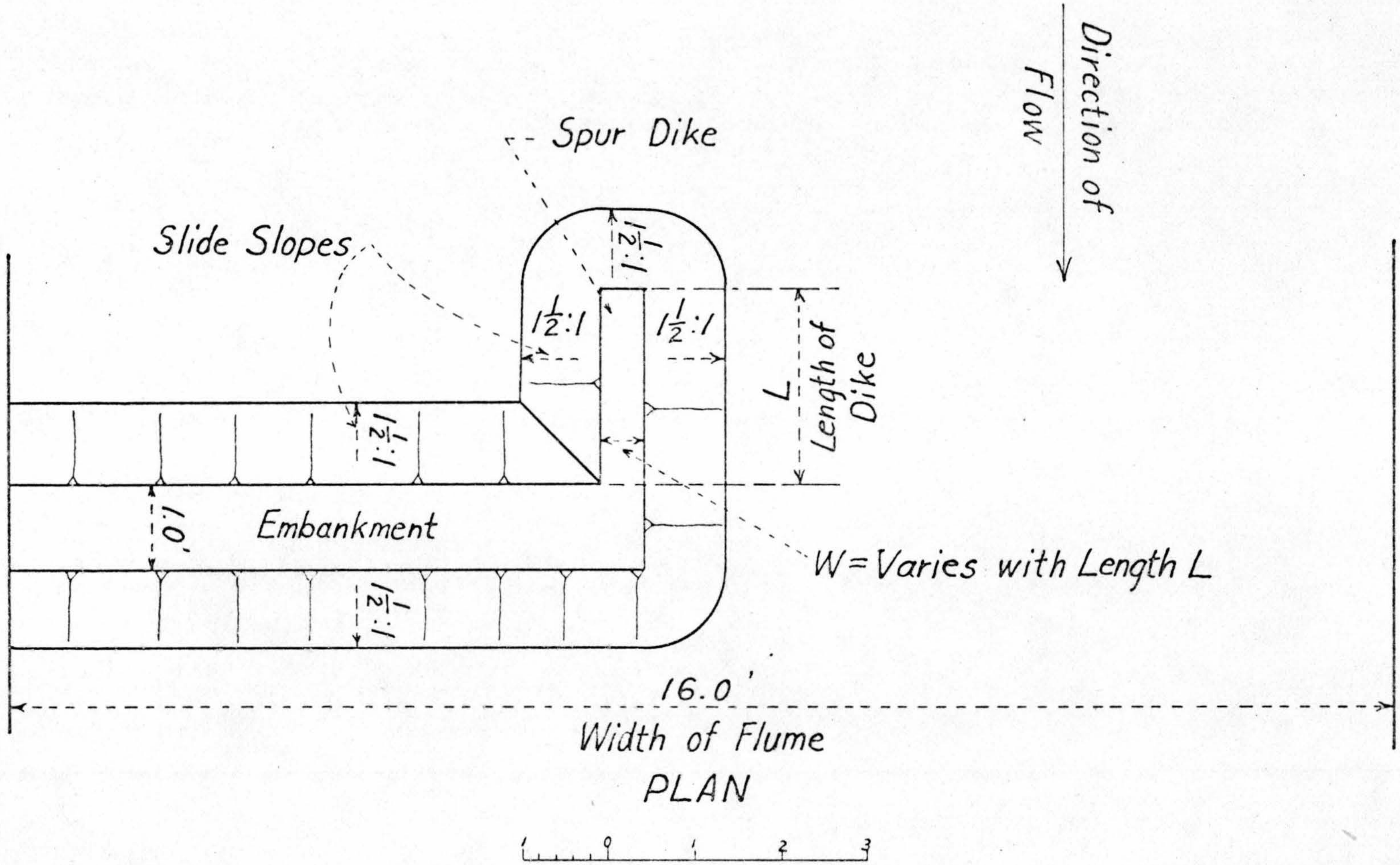

FIG. 2




SECTION A-A

Embankment Only

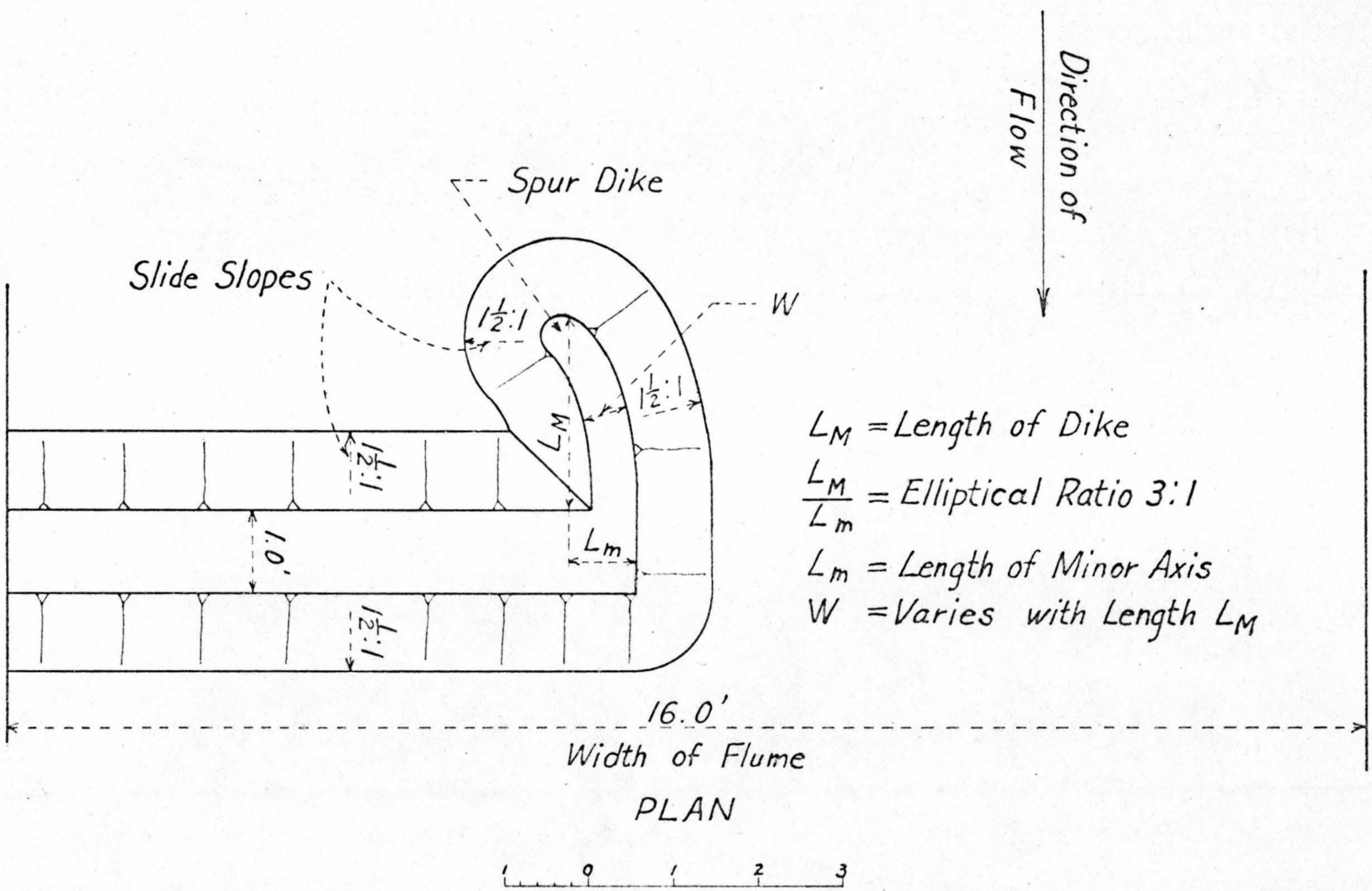
FIG. 3




Definition Sketch
Straight Spur Dike

FIG. 4

H.A




Definition Sketch
Elliptical Spur Dike

FIG. 5

## III PROCEDURE

### Development of Nonvariables

The procedure used for all of the runs was the same after certain pilot runs were made. It was desirable for this study not to set up recirculating sediment through the flume. The study was to be limited to clear water. The pilot runs involved first determining a discharge which at 0.4 foot depth would not develop ripples or dunes on the sand bed but be very near the critical tractive force of the bed material so that bed motion was incipient. This test was made with no embankment in the flume. The discharge was found to be 4.8 c.f.s. which gave an average velocity in the flume of 0.75 ft./sec. Adjustments were made in the head box so that a uniform distribution of flow across the flume was obtained with this discharge.

The length of roadway embankment, or extent of channel contraction was then determined by trial with this discharge so that a measurable depth of scour would occur within a time of about 5 hours. The proper contraction was found to be about 50 per cent, which developed a scour hole at the abutment of about 0.75 foot deep in 5 hours time. Since the sediment was not recirculated through the system, equilibrium scour conditions could not be expected to occur within a relatively short period of time; and therefore, it was considered a better procedure to standardize test time than to rely on equilibrium scour conditions because of the uncertainty of the latter and the excessive amount of time involved. Thus, conditions of 4.8 c.f.s. discharge, 0.4 foot depth, 50 per cent channel contraction, and 5 hours running time were established, and held constant throughout the major portion of the study in the first phase. Two runs were made where the contraction of the flume was changed to 67 per cent and discharge reduced to 2.4 c.f.s. and the flume width was reduced to 12 feet.

## Procedure for Each Test

Proper preparation of the channel bed was made before each run and the same slope was used for each test. This slope was set by dragging a screed across the bed of the channel guided by the preset slope of 0.0003 of the guide rails.

The spur dikes were constructed of the proper mixture of sand, cement, and bentonite and allowed to set about 18 hours before beginning the test run. This time for setting was found to be the most desirable from preliminary test runs.

Water was introduced into the flume with care during the start of each test so that scour would not occur before the proper depth was established. This was accomplished by slowly filling the flume from both ends in such a way that there was very little flow at the test section. When the proper depth was reached, the pump at the discharge end of the flume was stopped and the proper flow established through the head box. In this manner it was possible to control the test time to 5 hours and also to prevent scour before proper test conditions were established.

## Data Taken

Data obtained for the studies were largely photographic records (time lapse motion pictures) of the scouring action, motion pictures of flow pattern and motion, and still pictures of the final scour hole recording the depth and location. A complete motion-picture film was thus assembled for the entire study. In addition to the photographs, point gage readings of the water surface around the periphery of the embankment and spur dike were taken and recorded. Still photographs and some water surface profiles are included in this report.

## IV INVESTIGATION AND DISCUSSION OF RESULTS .

The motion-picture film is a part of the report and will be referred to in this discussion. Still photographs are included and pertinent water surface profiles are appended to this report.

The first test was made without any channel contraction. This test was made to determine the maximum quantity of flow in the flume at a depth of 0.4 foot which would not cause ripples or dunes to form on the channel bed. The existence of either ripples or dunes would bring about additional variables which were not to be included in this phase of the study. A discharge of 4.8 c.f.s. was found to be the maximum discharge permissible. This discharge was checked by a continuous run of 25 hours. No ripples or dunes formed in any portion of the flume.

All tests were comparative. Initially a test was made to determine the scour pattern and depth with the highway embankment only, that is, with no spur dike. Figure 6 shows the scour hole at the abutment. Contour intervals are 0.2 foot. The direction of flow is from top to bottom of of the photograph. The embankment was 8 feet long and the opening 8 feet wide. Unit discharge of the approach flow was 0.3 c.f.s. per foot with an average velocity of 0.75 foot per second. Unit discharge through the opening was 0.6 c.f.s. per foot. Note the deepest point of the scour hole is at the upstream corner of the abutment. Note also the alluvial fan downstream. Figure 7 shows the extent of the scour at the abutment as identified by the grid lines. The grid lines on this figure are one foot squares and are used solely for comparative purposes with other tests.

The flow pattern can best be seen in the motion-picture film by observing the dye traces. The flow began to bend towards the opening about 15 feet upstream of the opening and the velocity accelerated as the flow approached the opening. There was some flow along the highway embankment. Although dye traces in the motion-picture film are distorted due to the camera angle and true flow lines are not seen. Nevertheless, the concentration of flow near the abutment can be seen by the convergence of dye traces. Also the flow lines beyond a short distance from the abutment into the opening are not greatly affected by the highway embankment.

Figure 8 shows the location and depth of the scour hole with a 2.28 ft. long straight spur dike at the abutment. Refer to the definition sketch, Figure 4, for the explanation of length of the spur dike. The contour interval in Figure 8 is 0.1 foot. Figure 9 shows the lateral extent of scour influence at the bridge. Note that although little scour was evidenced at the abutment, some scour occurred farther out into the bridge opening. The scour hole at the end of the spur dike is less in depth than in Figures 1 and 2, but wider in lateral extent. A maximum depth of about 0.15 foot is seen at the bridge opening. Some benefit has been derived from this spur dike in so far as abutment protection is concerned, but the flow lines, as seen in the motion-picture film indicates separation of flow at the nose of the dike. This causes eddies to form which are considered undesirable as they may assist in the development of scour holes.

Figures 10 and 11 show the scour pattern for a straight spur dike offset from the abutment a distance of 0.4 L, where L, the spur dike length is 2.28 ft. The scour hole is slightly deeper and the lateral extent of scour is less than with the dike at the abutment. Considerably more scour is evident at the abutment. To test the effect of offsetting the dike still further from the abutment an offset of distance L was tested. Figures 12, 13, and 14 show the results. By offsetting the spur dike this distance, essentially all benefit of the dike was lost and extensive scour occurred at the abutment with depth of scour reaching 0.4 ft.

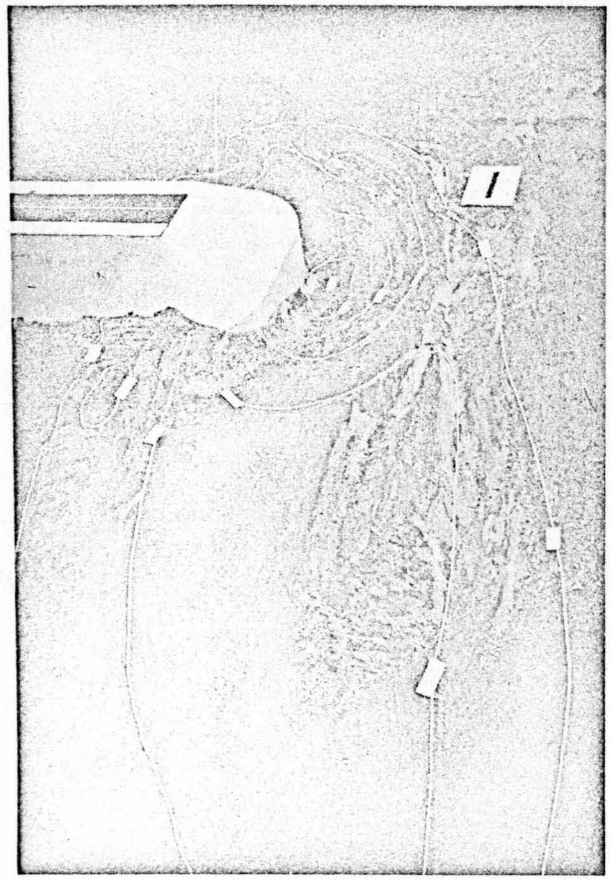


Figure 6 Scour hole at a bridge abutment without a spur dike. Contour interval is 0.2 ft.

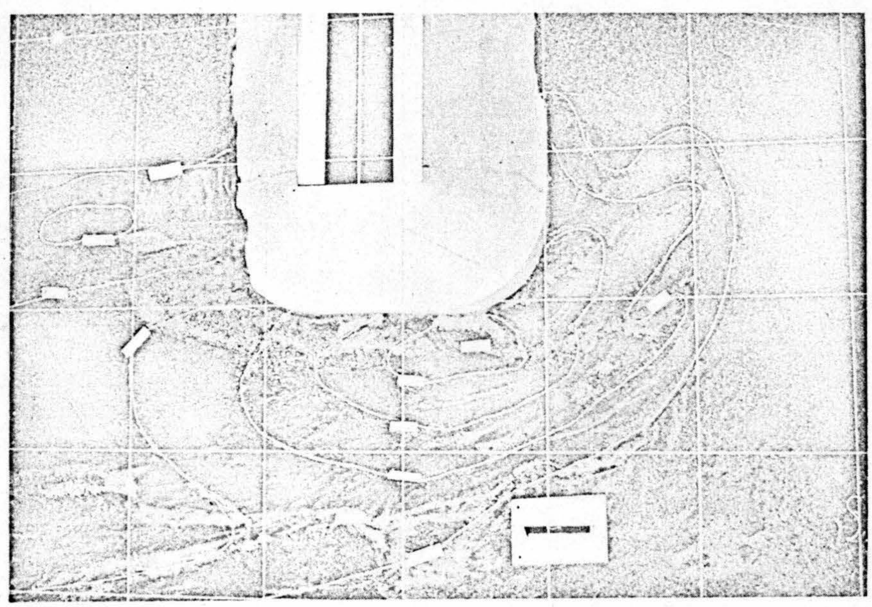


Figure 7 Scour hole at a bridge abutment without a spur dike as viewed from above. Contour interval is 0.2 ft. Grid marks are one foot squares.

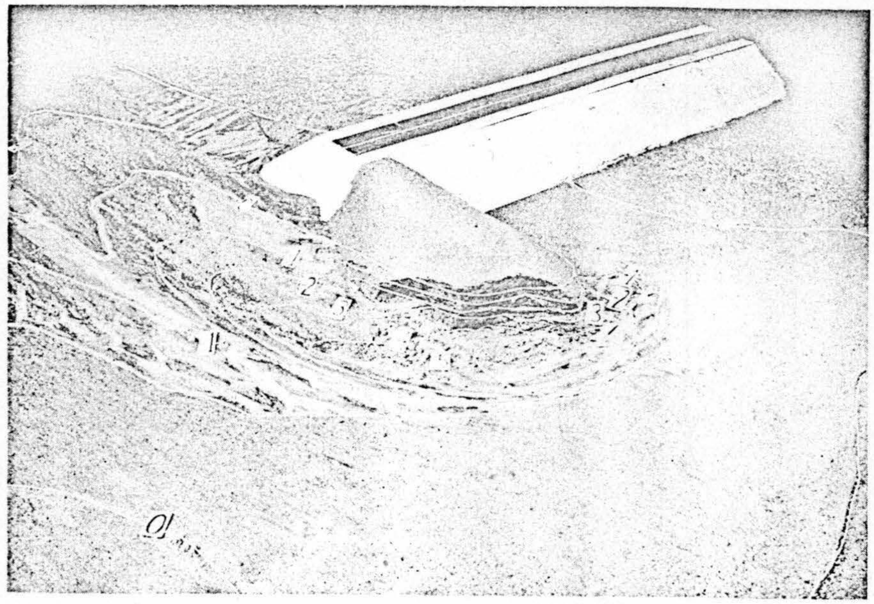


Figure 8 Straight spur dike at the abutment. Length = 2.28 ft. Contour interval is 0.1 ft.

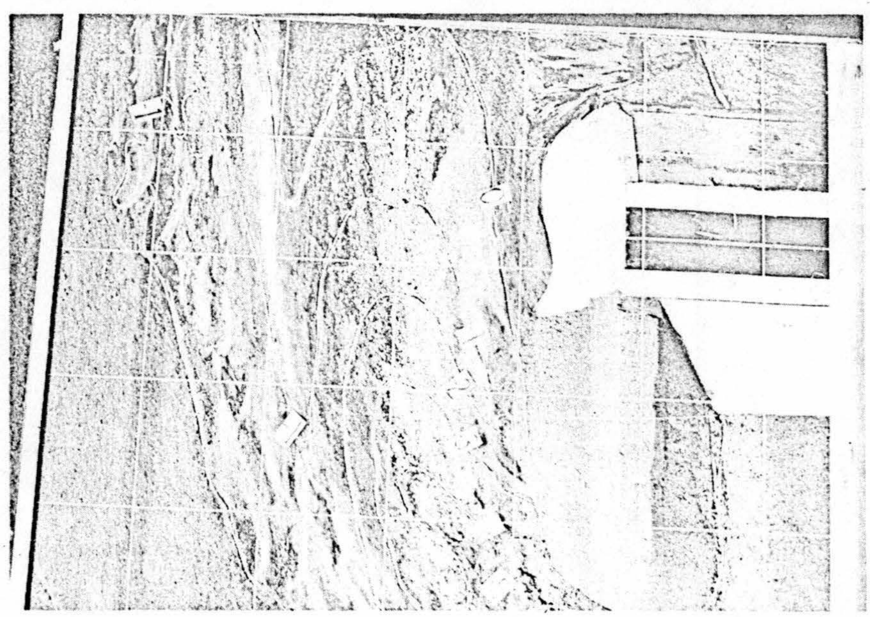


Figure 9 Vertical view of scour at the bridge abutment. Straight spur dike at the abutment. Length = 2.28 ft. Contour interval is 0.1 ft. Grid lines are 1 foot squares.

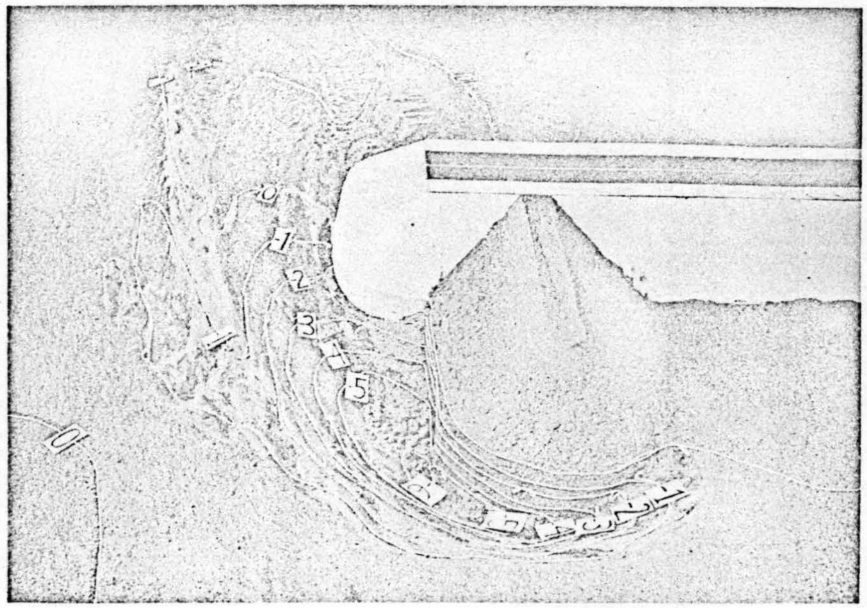


Figure 10 Straight spur dike offset 0.4L from the abutment. L = 2.28 ft. Contour interval is 0.1 ft.

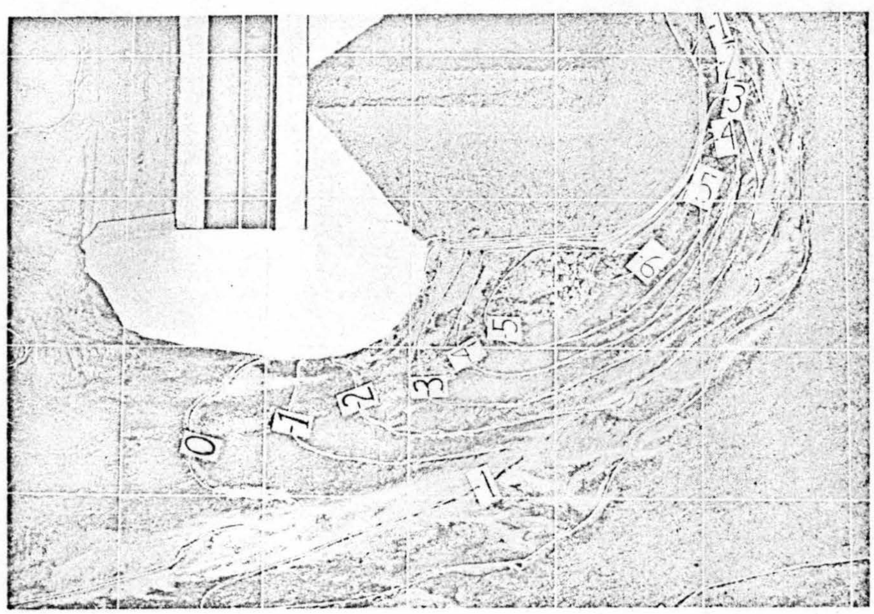


Figure 11 Straight spur dike offset 0.4L from the abutment. Vertical view. L = 2.28 ft. Contour interval is 0.1 ft. Grid lines are 1 foot square.

In order to test for different shapes of spur dikes, an elliptical dike with a 3:1 ratio of the lengths of major to minor axes was tried. Refer to Figure 5 for a definition sketch of an elliptical spur dike. The length of elliptical dike is the length of the major axis measured from the shoulder of the roadway embankment at the level of the top of the spur dike. The length of elliptical spur dike was 2.28 ft., same as the length used for the straight dikes. Figures 15, 16 and 17 show the results of the test. Considerable scour occurred at the bridge abutment with a maximum depth of 0.5 ft. for the scour hole. This can be explained by the fact that because the elliptical spur dike merges the flow more smoothly, it concentrates the flow along the dike and abutment creating greater velocity in this vicinity and thus causing more scour. Note that there is very little erosion of the spur dike as compared to the erosion of the straight spur dike located at the abutment. This elliptical dike did not effect a completely smooth flow pattern, as separation was noted near the nose of the spur dike. This can be seen more readily in the motion-picture film.

An elliptical spur dike with a ratio of 2 1/2 : 1 was then tested to determine the effects on flow pattern and scour hole. Figures 18 and 19 show the results. There is no essential difference in scour pattern and depth of scour hole from the previous test. The scour is confined to a depth of about 1 foot from the spur dike and abutment. The flow pattern was observed to be smoother than for the 3:1 spur dike. This does not, however, seem to have any apparent effect on the scour.

Figures 20 and 21 show the result of a test for a 2:1 elliptical dike. As the ellipse approaches closer to a quarter circle, there is evidenced a greater concentration of flow along the spur dike. This is indicated by comparing the scour pattern of Figures 17, 19, and 21. Although no great difference exists in the scour patterns for the three tests, comparison of Figures 17 and 21 does indicate some difference. Scour is more narrowly confined for the 2:1 spur dike than for the 3:1 spur dike, which of course is reasonable. No real significant difference in flow pattern was evident, and the motion-picture film shows none that is discernable excepting perhaps immediately adjacent to the side slope of the spur dike.

Tests with longer spur dikes were made to determine if length had significant effect on the scour pattern. Figures 22 and 23 show the result for a test with a straight spur dike at the abutment. The length of dike was 3.41 ft. It will be noted that the lateral extent of scour at the bridge opening is not different from that of the shorter spur dike of Figure 9. There is some difference at the nose of the spur dike but this could have been affected by the fact that the spur dike of Figure 9 eroded at the end, whereas the spur dike of Figure 12 did not. Some erosion of the spur dike can be seen along the downstream face of the dike. This was in part due to the locally high velocities and waves developed over the alluvial fan that was formed as the material that was scoured out moved downstream. This phenomenon can be readily seen in the motion-picture film.

Elliptical dikes were tested with a length of 3.41 ft. and the adequacy of length for protection to the abutment under the prevailing flow conditions can be seen photographically in Figures 24 through 31. Figures 24 and 25 show the results for a 3:1 elliptical dike; Figures 26 and 27 for a 2 1/2 : 1 elliptical dike; Figures 28 and 29 for a 2:1 elliptical dike, and Figures 30 and 31 for a 1 1/2 : 1 elliptical dike. It will be noted in comparing the figures above, that the length has some effect on the extent of scour at the bridge abutment and bridge section. The benefit of added length is offset however as the dike is formed closer to a circle. The streamlining of the dike is successful only in developing greater concentration of flow at the abutment and subsequently achieving greater local velocities which then causes scour. Note that for Figures 30 and 31 the lateral extent of scour is very small and some scour is evidenced at the abutment, whereas in Figures 26 and 27 there is very little scour at the abutment.

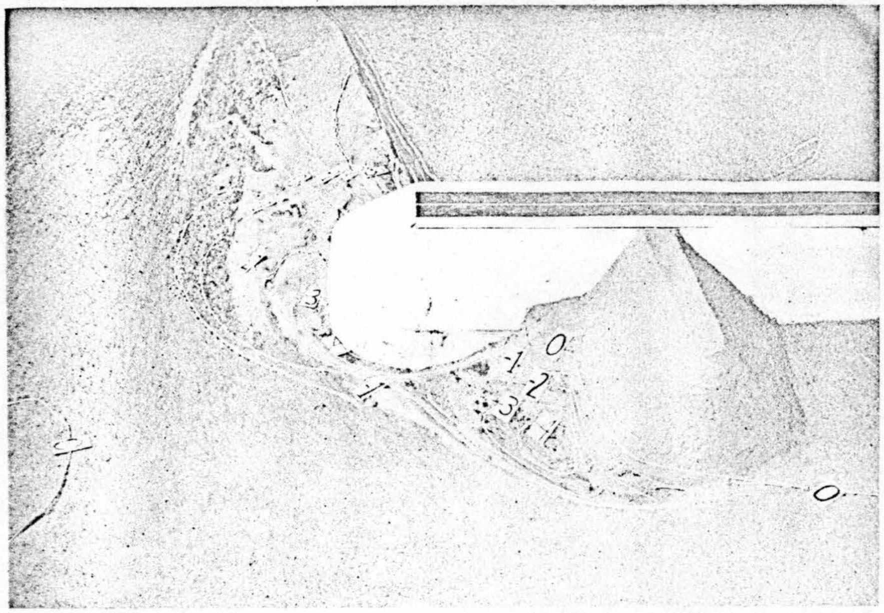


**Figure 12** Scour hole for straight spur dike offset distance L from abutment. L = 2.28 ft. Note two scour holes. Contour interval is 0.1 ft.

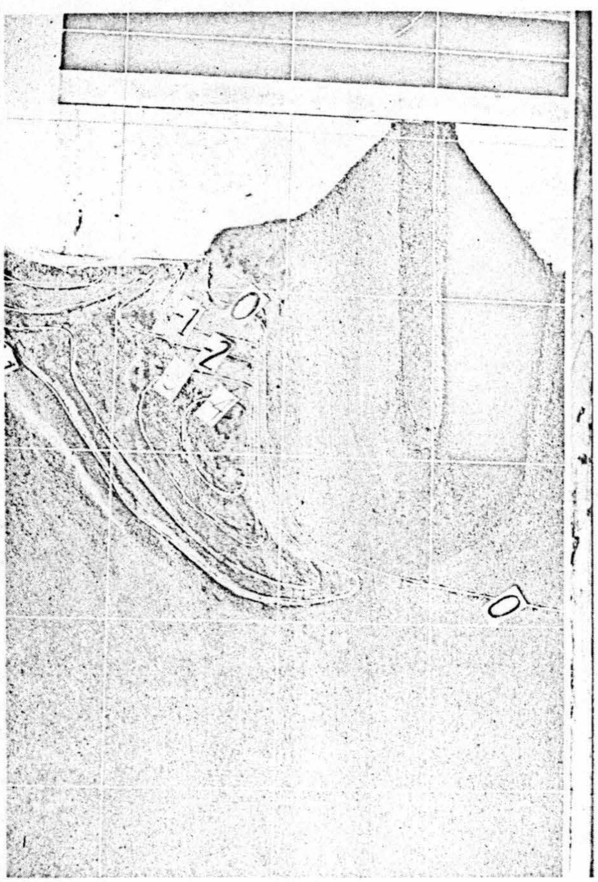


Figure 13 Scour for straight spur dike offset distance L from abutment. L = 2.28 ft. Grid lines are 1 ft. square.

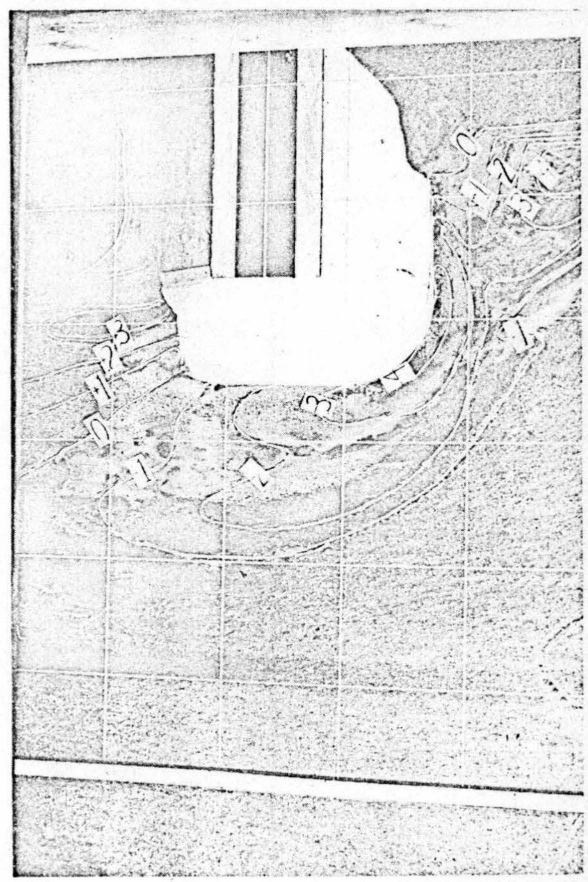


Figure 14 Straight spur dike at the abutment. Length = 2.28 ft. Contour interval is 0.1 ft.

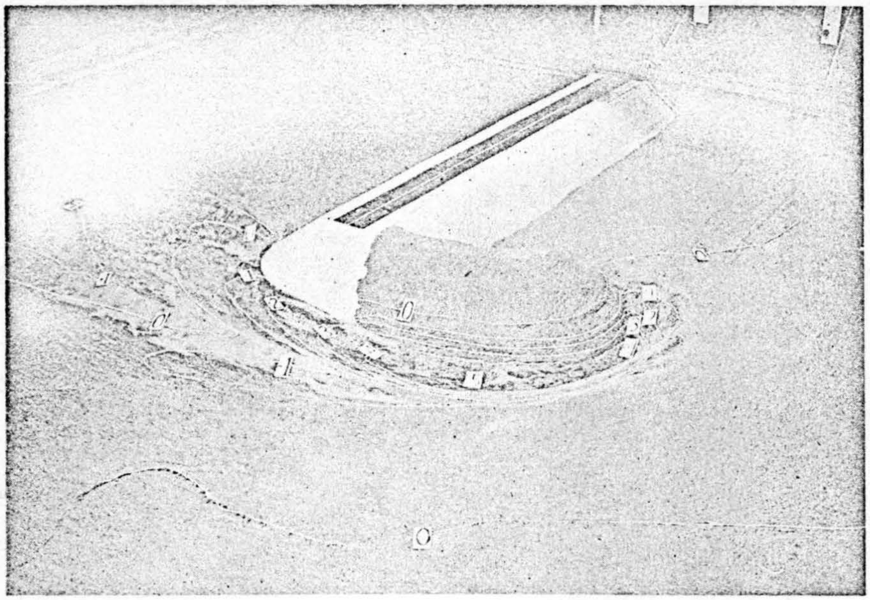


**Figure** 15  Scour for 3:1 elliptical spur dike. **L** = 2.28 ft. Contour interval is 0.1 ft.

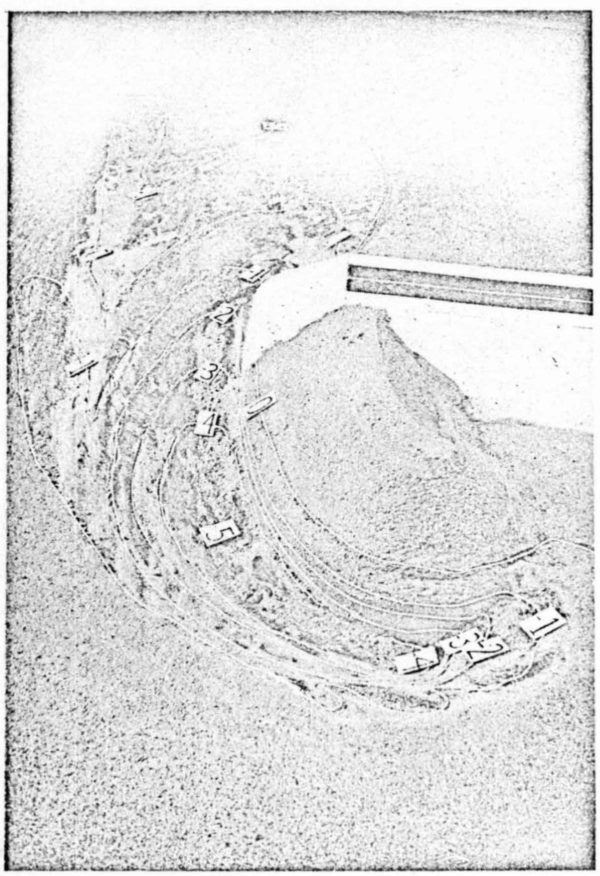


Figure 16  Scour for 3:1 elliptical spur dike. L = 2.28 ft. Contour interval is 0.1 ft.

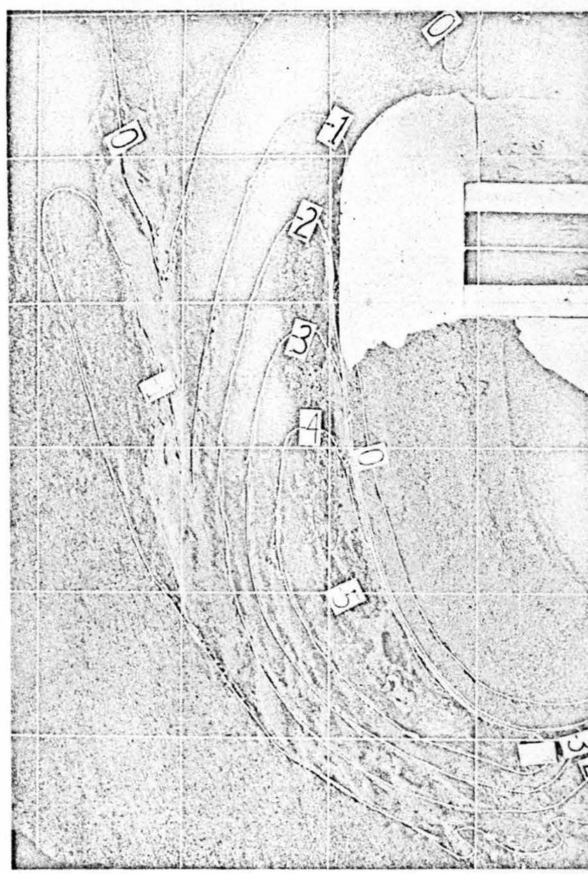


Figure 17  Scour for 3:1 elliptical spur dike. L = 2.28 ft. Note the scour is confined approximately within one foot of the dike and abutment.

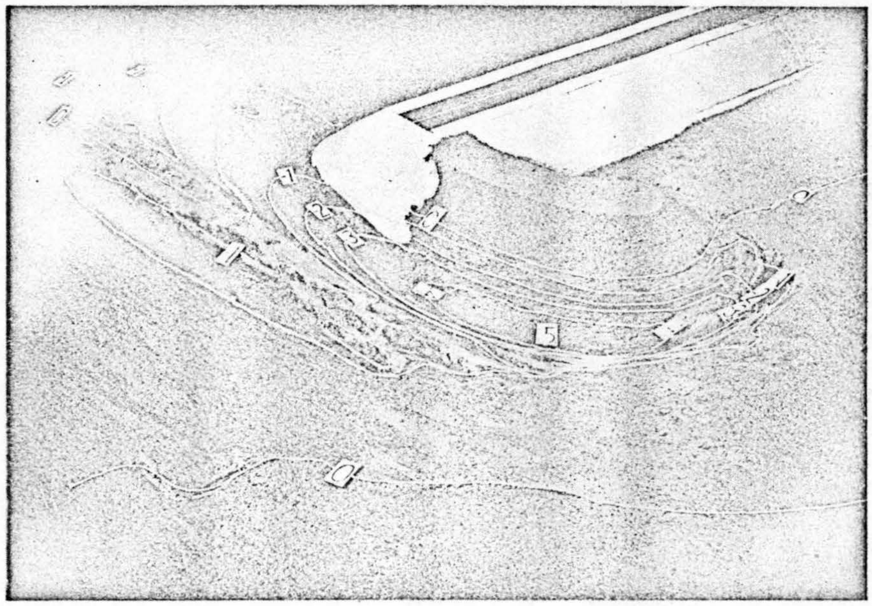


**Figure** 18 Scour for 2 1/2 : 1 elliptical spur dike. **L** = 2.28 ft. Contour interval is 0.1 ft.

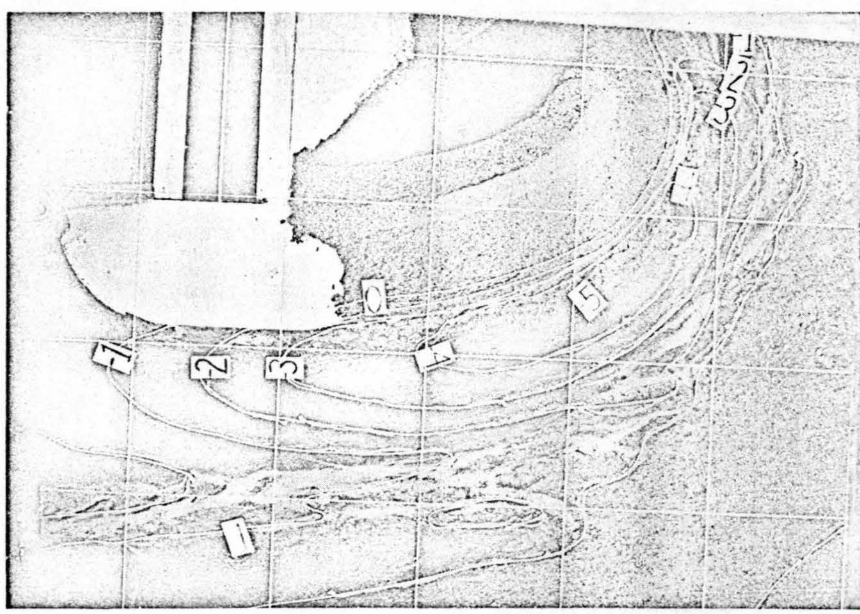


**Figure** 19 Scour at abutment for 2 1/2 : 1 elliptical **spur** dike. L = 2.28 ft. Contour interval is 0.1 ft.

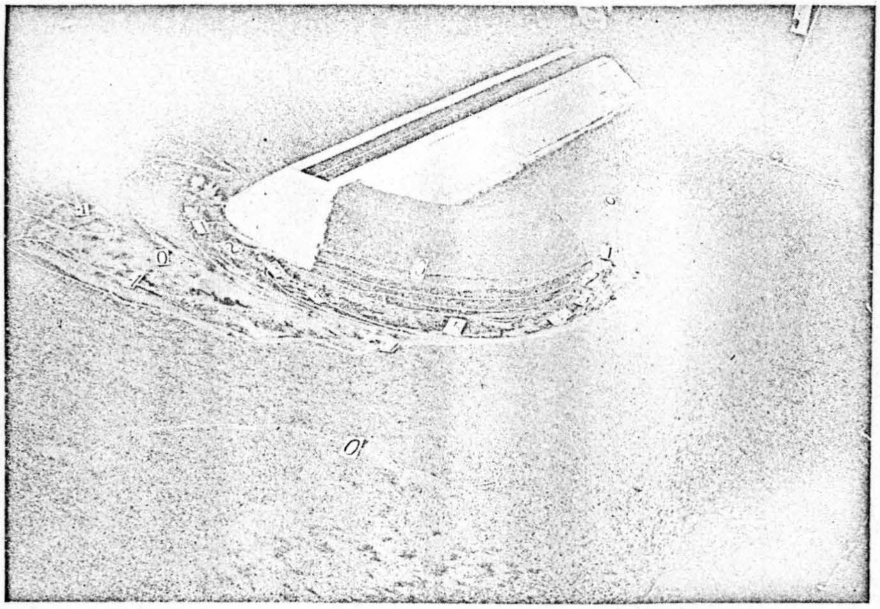


Figure 20   Scour for 2:1 elliptical spur dike.
L = 2.28 ft. Contour interval is 0.1 ft.

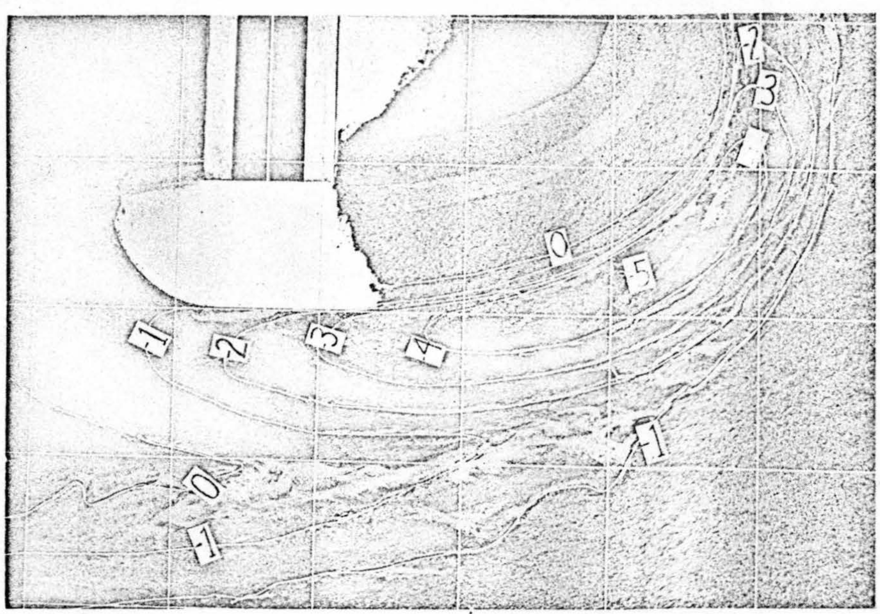


Figure 21   Scour for 2:1 elliptical spur dike.
L = 2.28 ft. Contour interval is 0.1 ft.

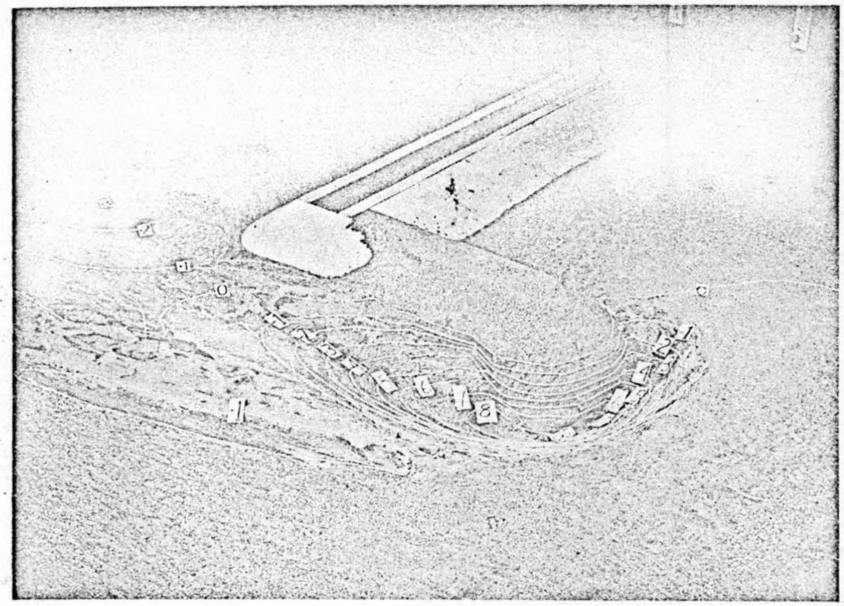


Figure 22 Scour for straight spur dike at the abutment. L = 3.41 ft. Contour interval is 0.1 ft.

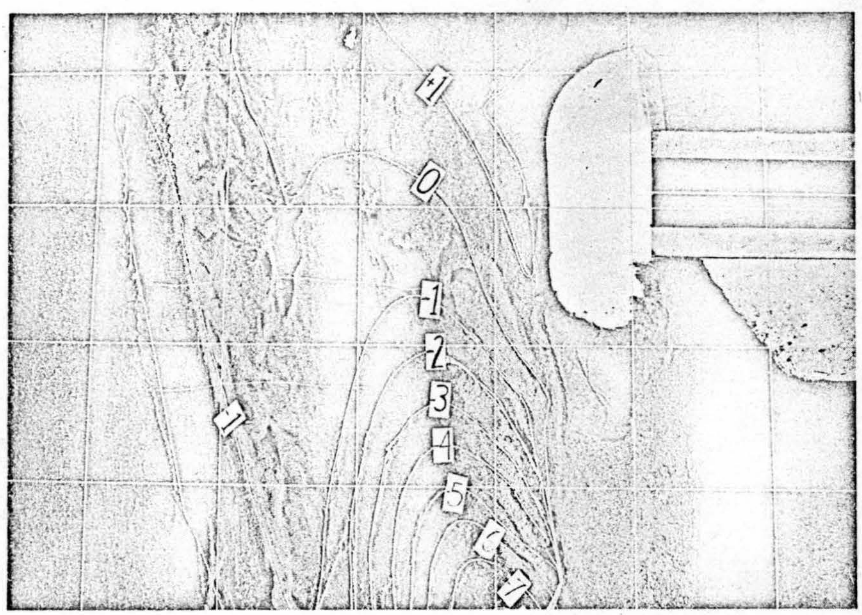


Figure 23 Scour at abutment with straight spur dike at the abutment. L = 3.41 ft. Contour interval is 0.1 ft.

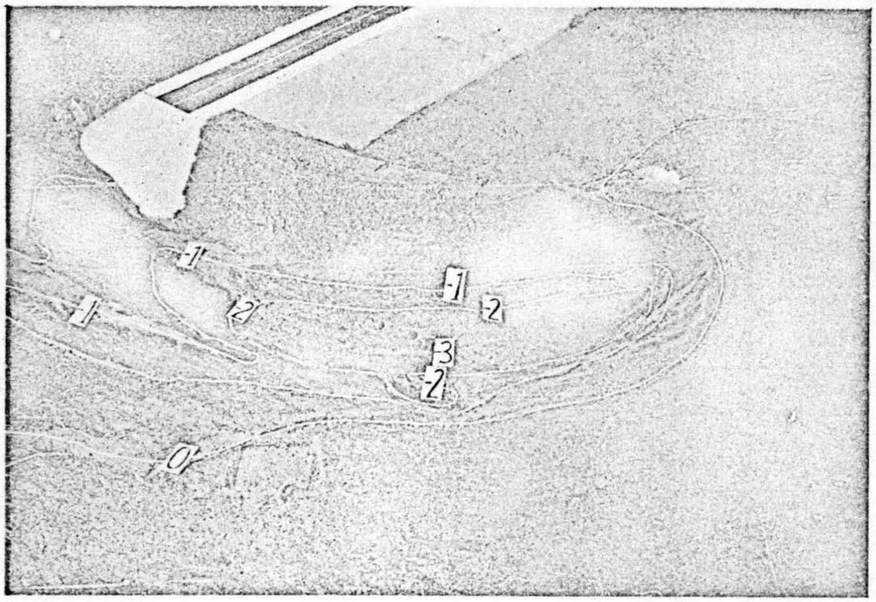


Figure 24 Scour with 3:1 elliptical spur dike.
L = 3.41 ft. Contour interval is 0.1 ft.

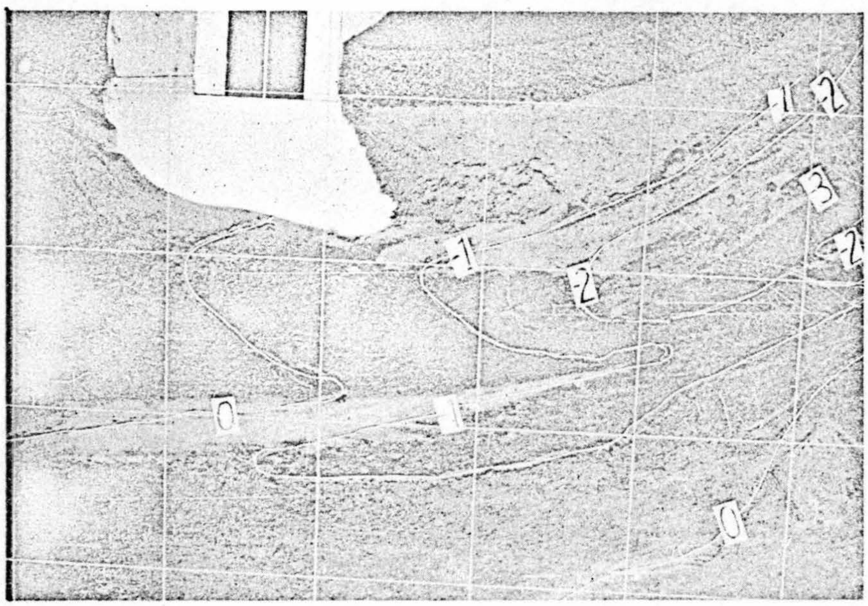


Figure 25 Scour with 3:1 elliptical spur dike.
L = 3.41 ft. Contour interval is 0.1 ft.

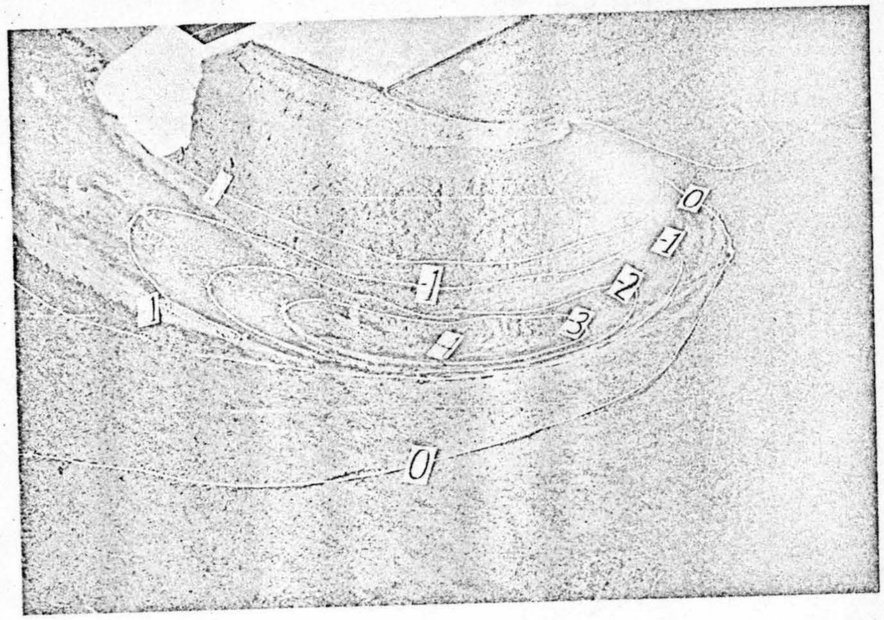



Figure 26 Scour with 2 1/2 : 1 elliptical spur dike. L = 3.41 ft. Contour interval is 0.1 ft.

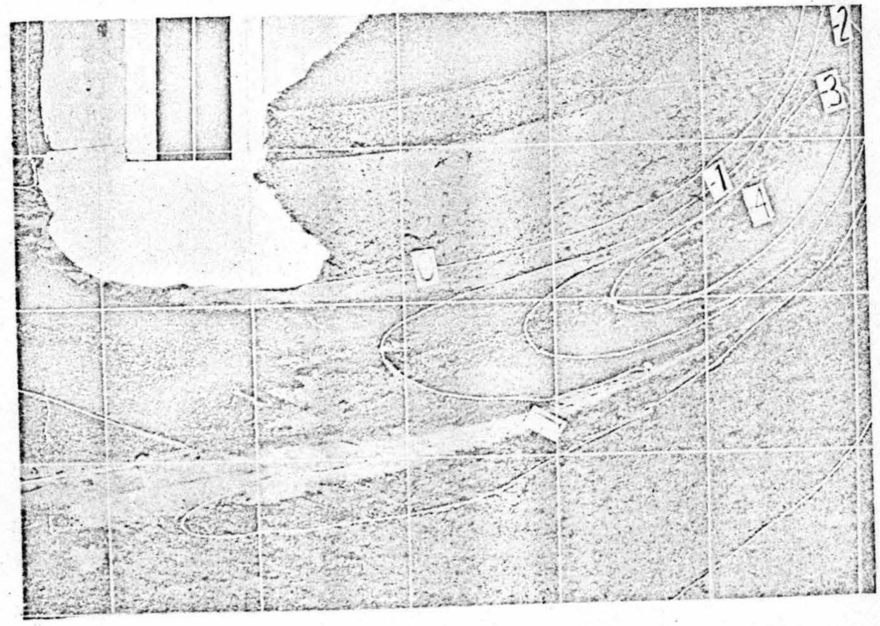



Figure 27 Scour with 2 1/2 : 1 elliptical spur dike. L = 3.41 ft. Contour interval is 0.1 ft.

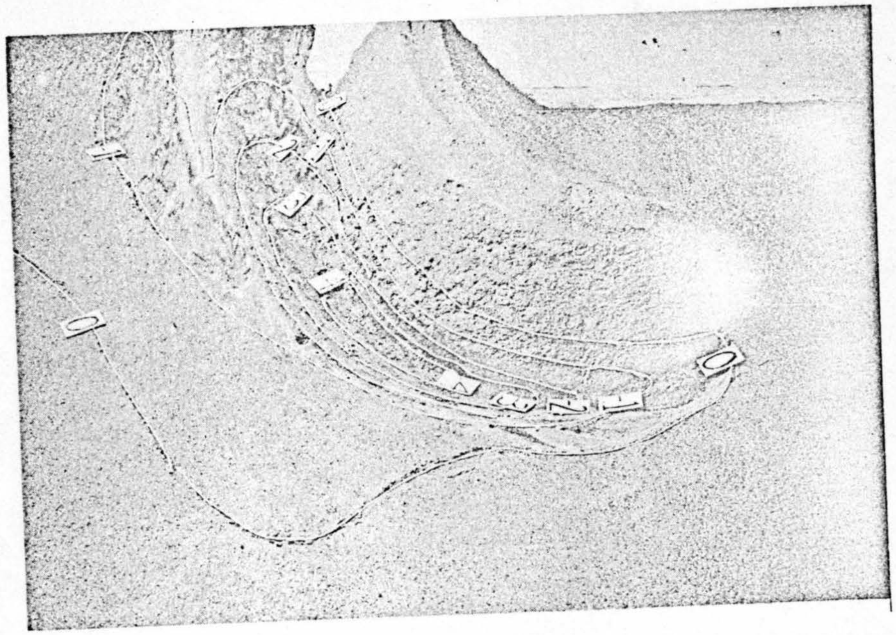


Figure 28 Scour with 2:1 elliptical spur dike.
L = 3.41 ft. Contour interval is 0.1 ft.

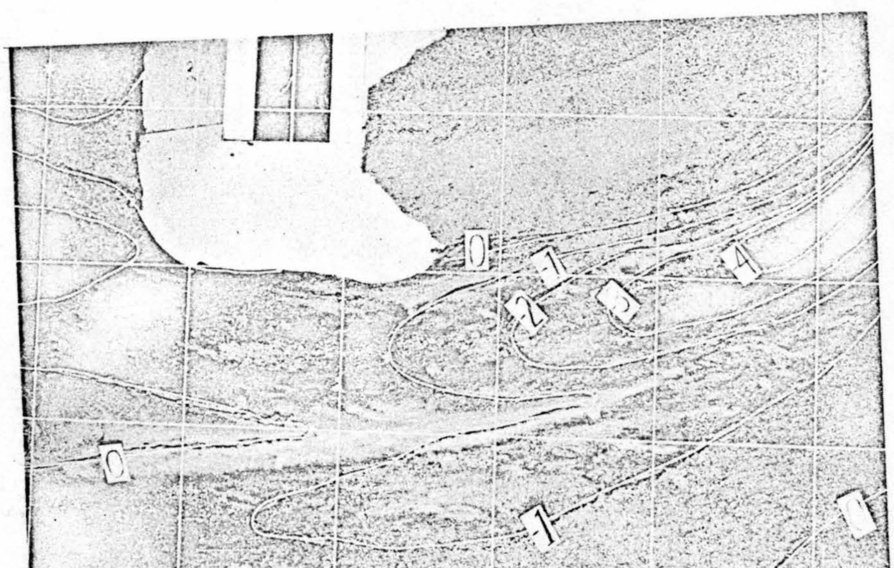


Figure 29 Scour with 2:1 elliptical spur dike.
L = 3.41 ft. Contour interval is 0.1 ft.

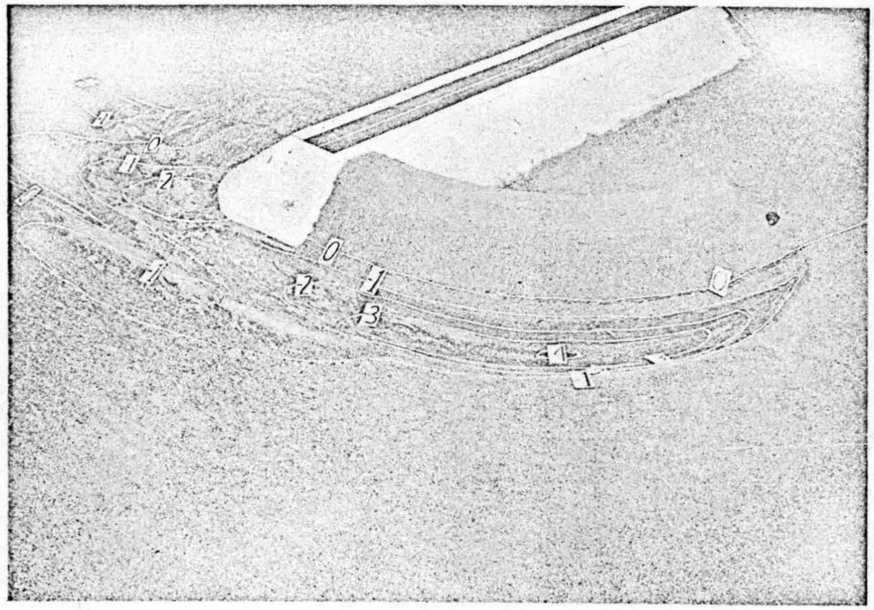


Figure 30 Scour with 1 1/2 : 1 elliptical spur dike. L = 3.41 ft. Contour interval is 0.1 ft.

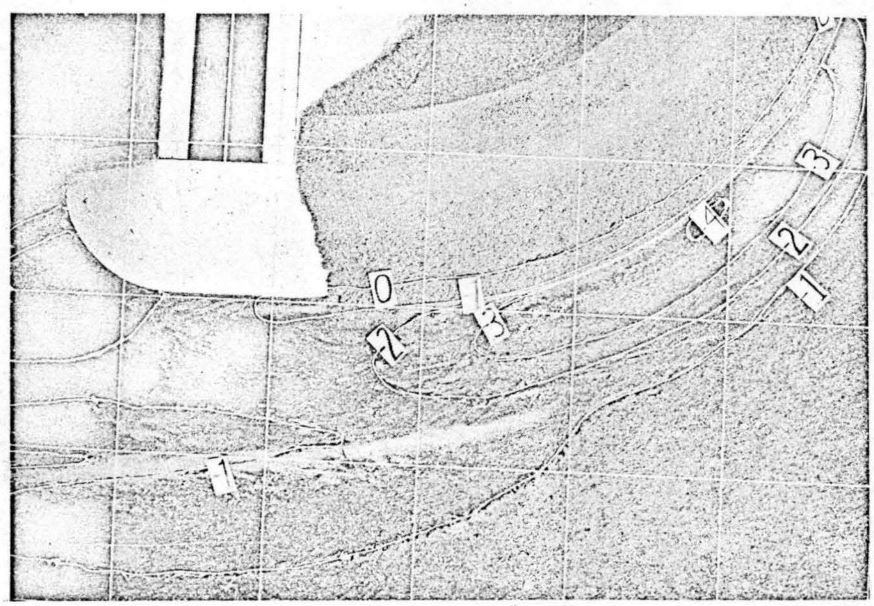


Figure 31 Scour with 1 1/2 : 1 elliptical spur dike. L = 3.41 ft. Contour interval is 0.1 ft.

Utilizing a 2 1/2 : 1 spur dike of the foregoing tests, a single test was made to study the ext ent of rip rap protection required on the nose of the spur dike. Figures 32 and 33 give the results of this test. Comparison of Figures 32 and 26 will indicate that the scour hole has moved slightly down stream in Figure 32, although the depth of scour is unchanged. This phenomenon is probably due to the fact that rip rap was placed on the channel bed adjacent to the dike, as well as on the side slopes of the dike. This created a discontinuity in bed roughness causing a scour hole to develop where bed resistance was the least. There is a possibility that the scour hole could develop downstream of any rip-rapped section, and more studies are required before any conclusion can be made.

The studies conducted and discussed thus far involve only a condition with an idealized uniform approach flow condition. Actually in practice very seldom would there be such a case encountered. More often quantity of flow on the flood plain may exceed the flow on the main channel although the discharge per unit length on the flood plain may be less than that for the main channel flow. Therefore, in order to simulate this condition in the model a condition of non-uniform distribution of flow should be established across the width of the flume. For any systematic study this distribution of flow should be controlled.

However, to simply determine if there might be measurable difference in the effect on the geometry of the spur dike, a single test was made for non-uniform flow in the approach section. This test involved deflecting an appreciable quantity of flow along the highway embankment. The method with which this was done can be seen in the motion-picture film. A board was placed at an angle in the flume to deflect more flow against the embankment. No measurement was made to determine the ratio of the quantity of flow approaching the opening and that along the embankment. The result of the test is shown in Figures 34 and 35. With this non-uniform flow condition, a different scour pattern was developed. The scour hole was located at the nose of the spur dike and no significant local scour effects were discernable at the bridge opening. In fact, at the abutment there was some deposition of material.

To determine if size of opening had an effect on spur dike geometry, a 4 foot opening was tested. The total discharge was reduced to 2.4 c.f.s. Thus, the unit discharge through the opening remained 0.6 c.f.s. per foot. The depth was the same as the other tests at 0.4 ft. Figures 36 and 37 show the scour with embankment only and Figures 38 and 39 show scour for a 2 1/2 : 1 elliptical dike 2.28 ft. long. It is seen that scour for both tests is substantially reduced from tests with the 8 foot opening. This is not a fair comparison however, because for the last two tests, the flume was made 12 feet wide, so that the unit discharge in the approach channel was not comparative to previous tests. See Figure 3. The average approach velocity was reduced to about 0.5 ft. per sec., as opposed to 0.75 ft. per sec. for the 8 ft. wide opening. These last two tests show only that approach flow condition has a definite effect on the geometry of spur dikes and on scour at the abutments.

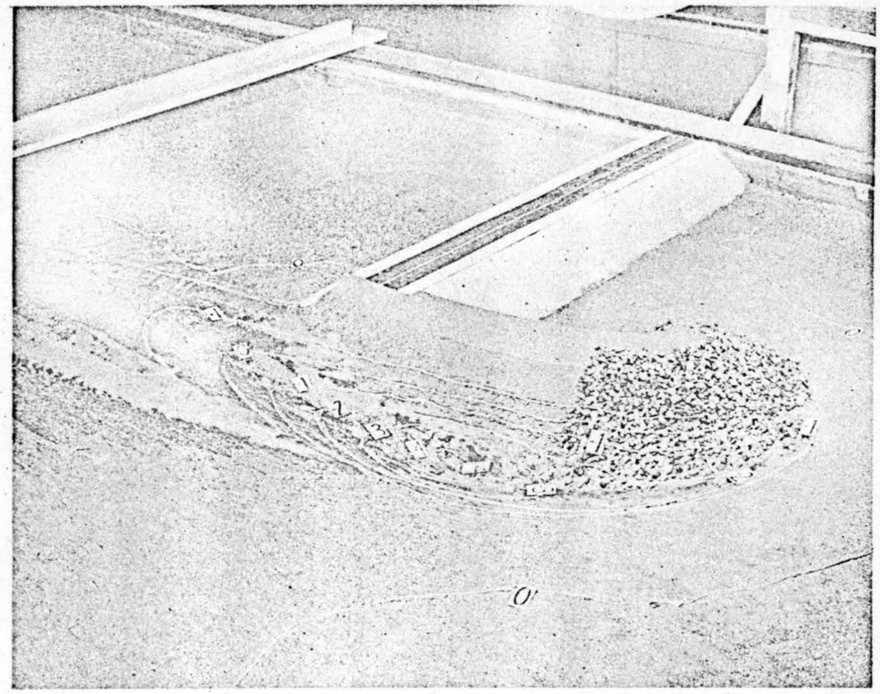


Figure 32 Scour with 2 1/2 : 1 elliptical spur dike. L = 3.41 ft. Rip rap protection around nose of spur dike. Contour interval is 0.1 ft.

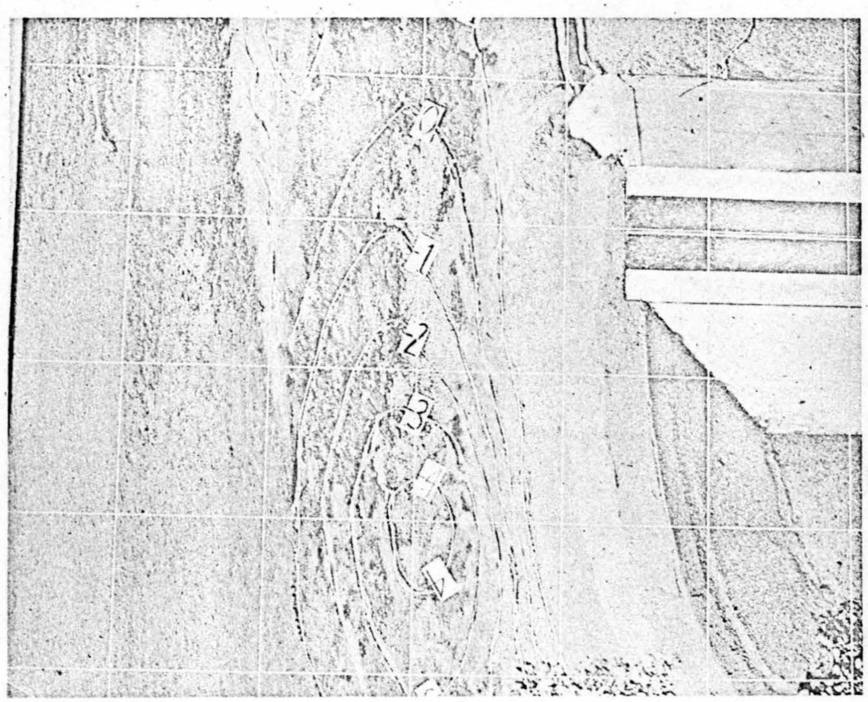


Figure 33 Scour with 2 1/2 : 1 elliptical spur dike. L = 3.41 ft. Rip rap protection around nose of spur dike. Contour interval is o.1 ft.

Figure 34 Scour with 2 1/2 : 1 elliptical spur dike. L = 3.41 ft. Rip rap protection around nose of spur dike. Non-uniform distribution of flow in the approach section.

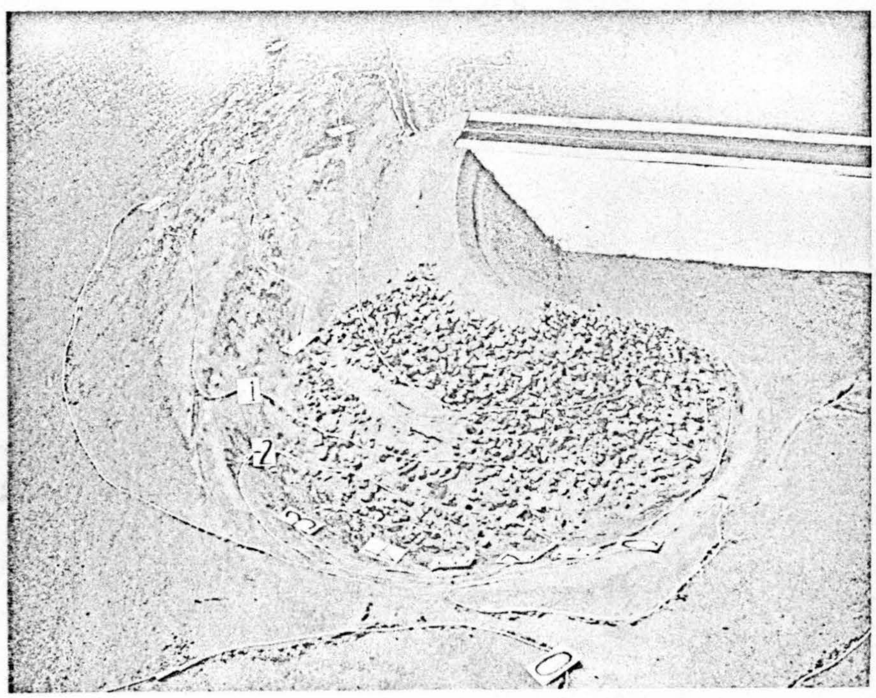


Figure 35 Scour with 2 1/2 : 1 elliptical spur dike. L = 3.41 ft. Rip rap protection around nose of spur dike. Non-uniform distribution of flow in the approach section.

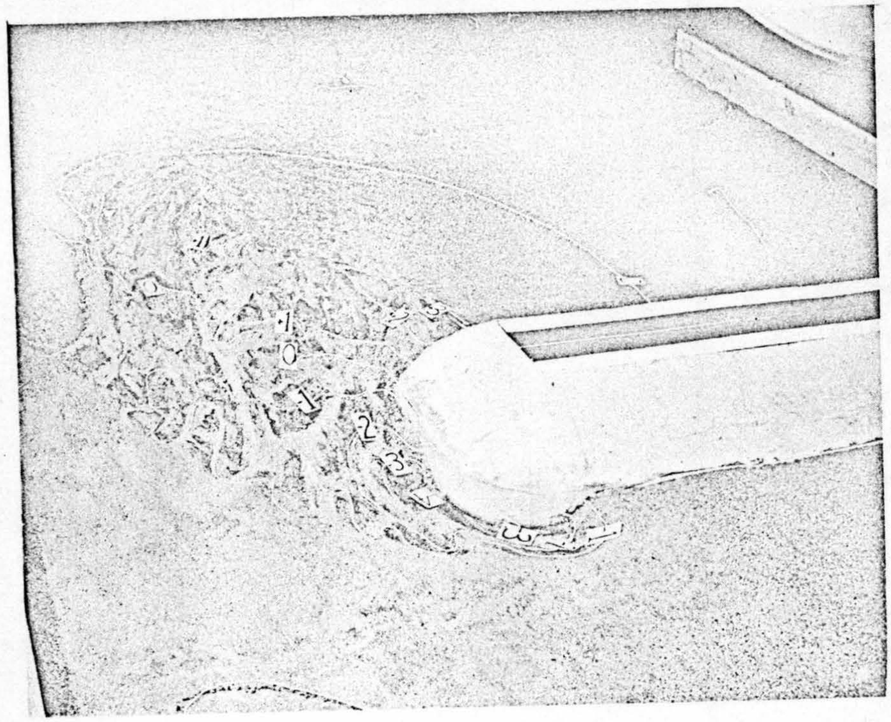


Figure 36 Scour with embankment only. Width of opening is 4 feet. Contour interval is 0.1 ft.

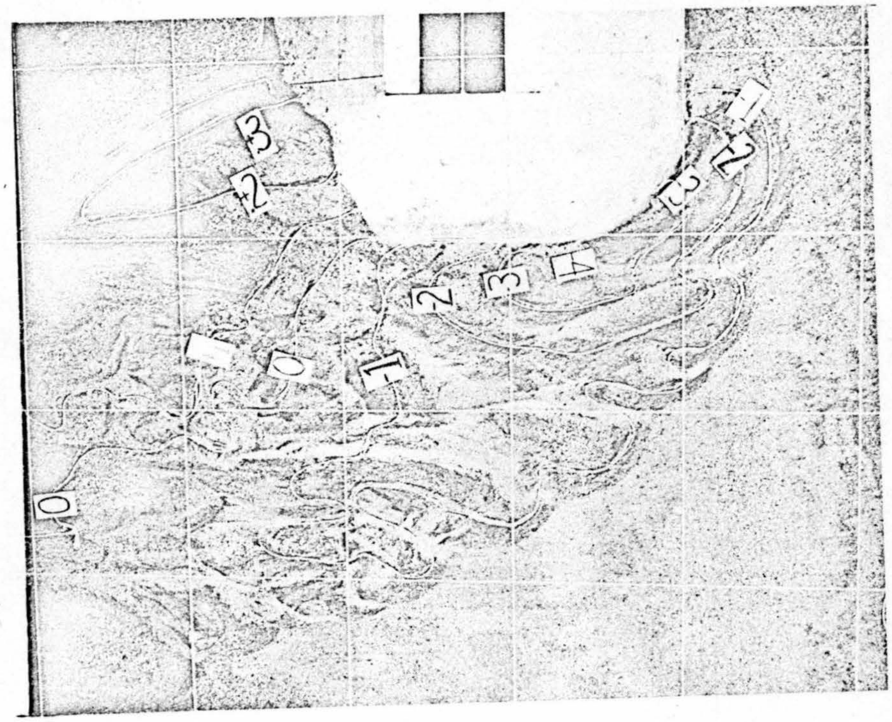


Figure 37 Scour with embankment only. Width of opening is 4 feet. Contour interval is 0.1 ft.

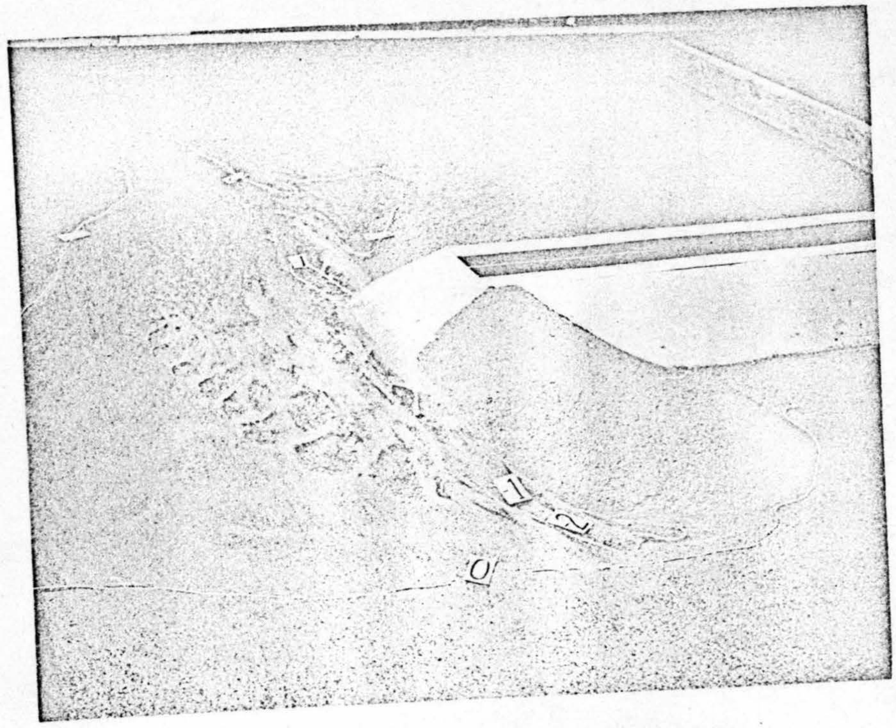


Figure 38 Scour with 2 1/2 : 1 elliptical spur dike. L = 2.28 ft. Width of opening was 4 feet. Contour interval is 0.1 ft.

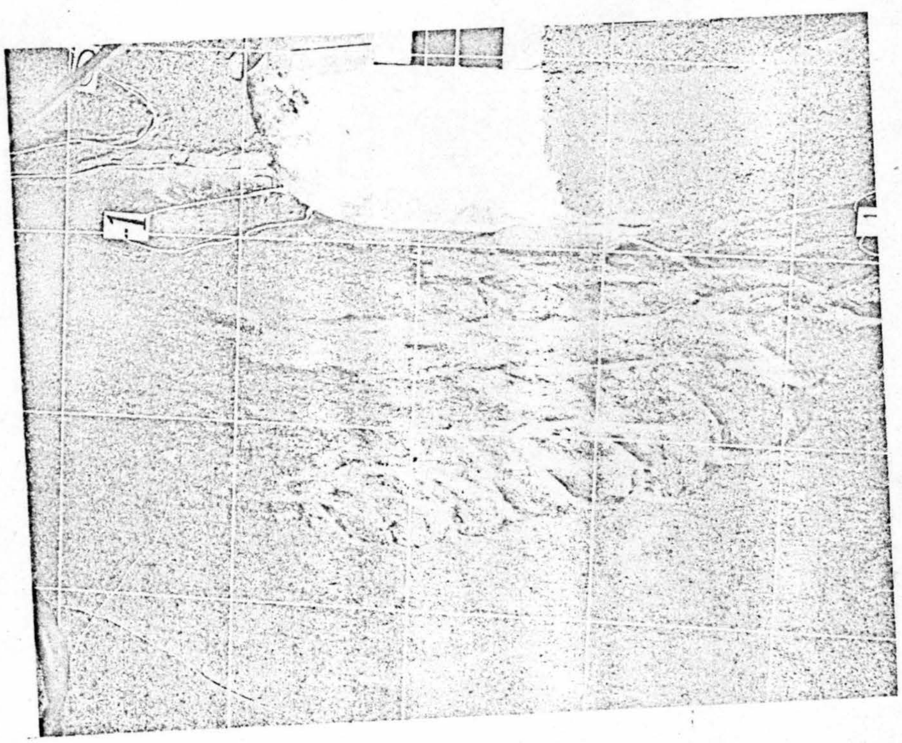


Figure 39 Scour with 2 1/2 : 1 elliptical spur dike. L = 2.28 ft. Width of opening was 4 feet. Contour interval is 0.1 ft.

# V SUMMARY

The first phase of the study was intended only to provide a qualitative analysis of the hydraulics of flow around spur dikes.

Scour occurs when velocities are large enough to develop forces to move bed material. These velocities augmented by local flow disturbances, such as eddies, can develop deep scour holes. When a stream channel is obstructed by a highway embankment, that portion of the flow that is obstructed is forced to flow around the abutment. The concentration of flow develops high velocities and eddies that scour the channel bed immediately adjacent to the abutment. Spur dikes can decrease this scour if the dikes are designed correctly.

The results of the tests reported herein, has shown that spur dikes should be placed at the abutment for maximum effectiveness. Although no conclusion was reached for determining the exact shape and length of spur dike for any particular installation, it was found that the first requirement for a spur dike is to disrupt the flow along the highway embankment and redirect it through the opening so that eddies in the immediate proximity of the abutment or spur dike will not develop. It is normal practice in designing bridges to establish bridge length on the hydraulic condition that unit discharge through the bridge opening is such that excessive scour velocities are not developed for some set frequency of flood discharge in the channel. The assumption used is that the total flow will be distributed fairly uniformly through the bridge opening. Frequently however, uniformity of flow does not exist and there is a concentration of flow near the abutments where the flow on the flood plain passes through a relatively small section of the bridge opening. Therefore, the second requirement is that spur dikes should distribute the flow from the flood plain more uniformly through the bridge opening and thus prevent concentration near the abutments, or in the adjacent bridge spans.

A spur dike to satisfy the first requirement must have the correct shape; and to satisfy the second must have adequate length. However, the two requirements on geometry are not separate and distinct, for the effect of dike length can be offset by dike shape. The elliptical spur dike with a small ratio of major to minor axes, or that approaching a circular form, eliminates eddy formation, but concentrates the flow near the abutment. On the other hand, a straight spur dike distributes the flow more adequately through the bridge opening, but developes flow separation and eddies at the end of the dike.

A median of these two extremes, say a 2 1/2 : 1 elliptical dike with adequate length does eliminate the eddies and does provide better flow distribution through the opening for a given flow condition, but with a different approach flow condition, as in Figures 34 and 35, a different spur dike geometry is required.

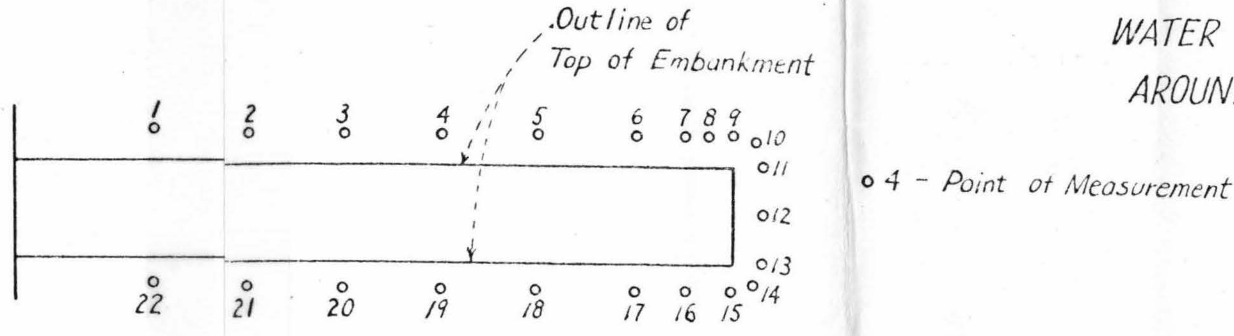
The first phase, as the pilot study, has provided a better understanding of spur dike performance and hydraulic behavior and some of the significant geometric factors. It has developed a guide for the subsequent phase of the study which is outlined below and from which criteria can be developed that will be useful for design of spur dikes:

1. Study effects of geometry for different flow quantities on the flood plain.
2. Study effects of geometry for different size bridge openings.
3. Study effects of different types of bridge abutments.
4. Determine the extent and location of rip rap protection required.

This outline is, necessarily, only a guide for intended study and the second phase will not be confined by or limited to those enumerated above. Time and other factors permitting, these studies will extend to other conditions that are considered desirable for developing design criteria.

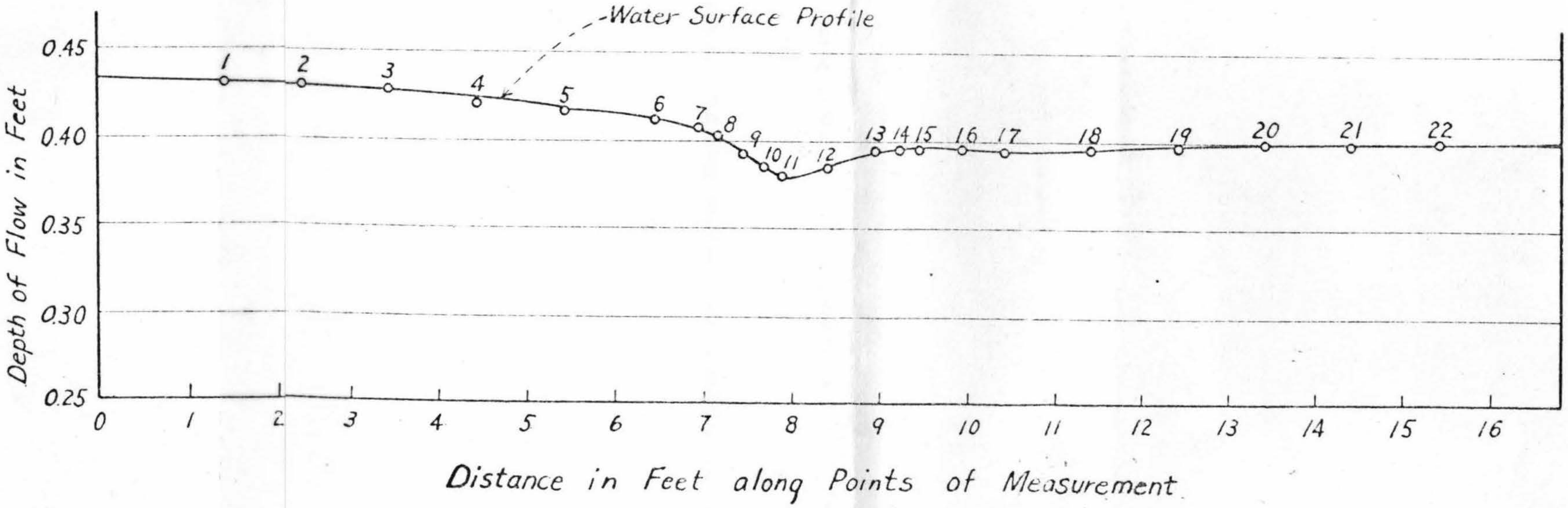
# APPENDIX

## WATER SURFACE PROFILE AROUND EMBANKMENT



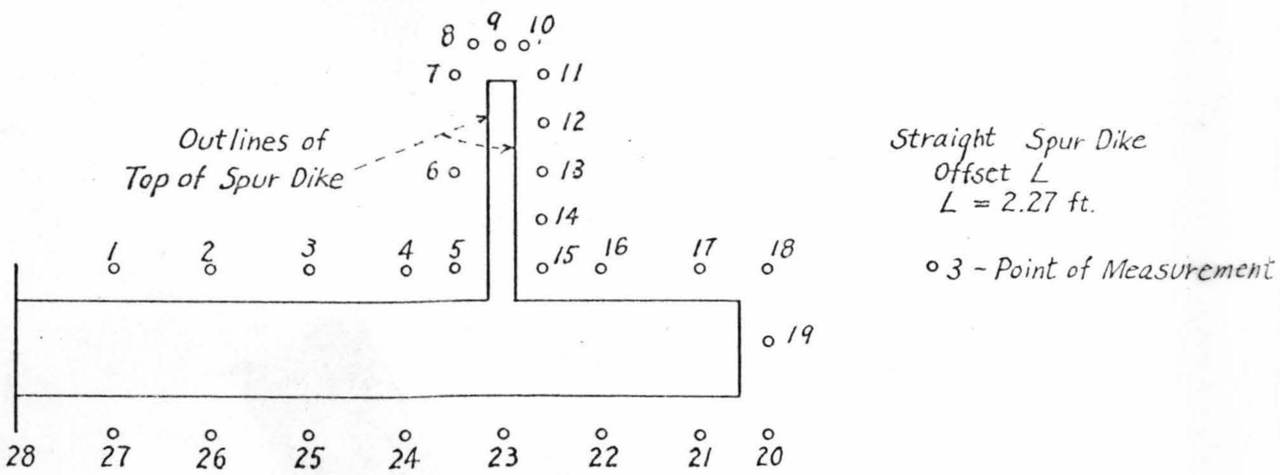

PLAN

Scale 1 in = 2 ft




H.A

## WATER SURFACE PROFILE AROUND SPUR DIKE AND EMBANKMENT

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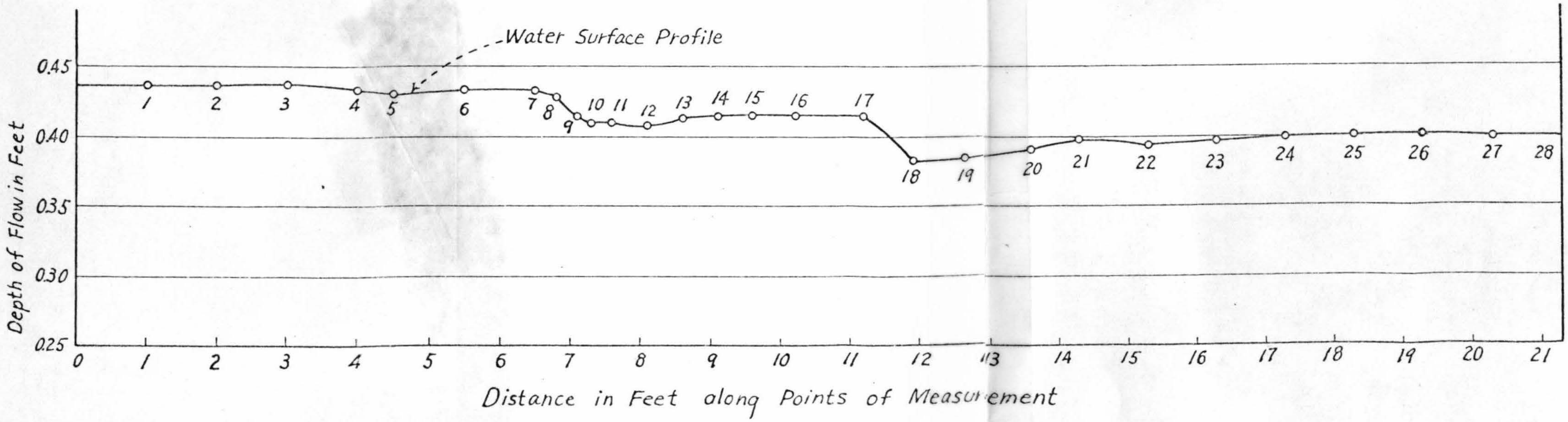
Scale 1 in. = 2 ft.

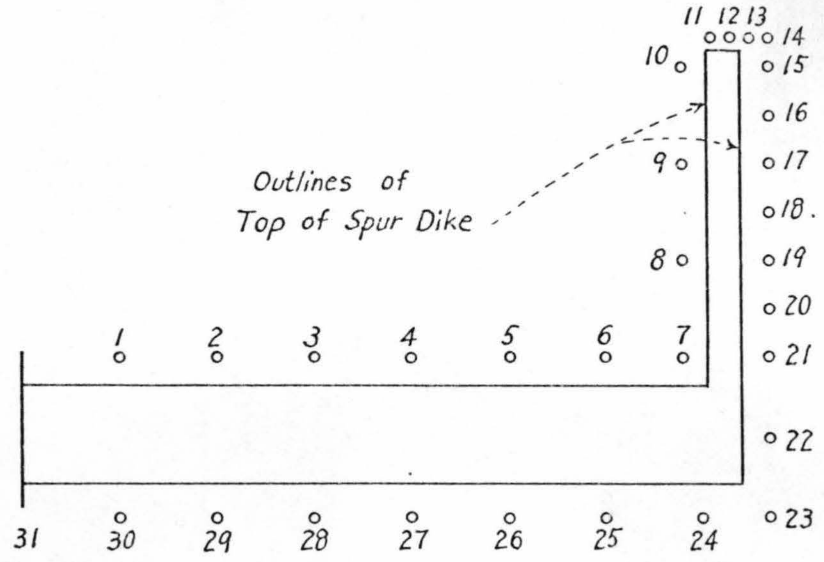



HA

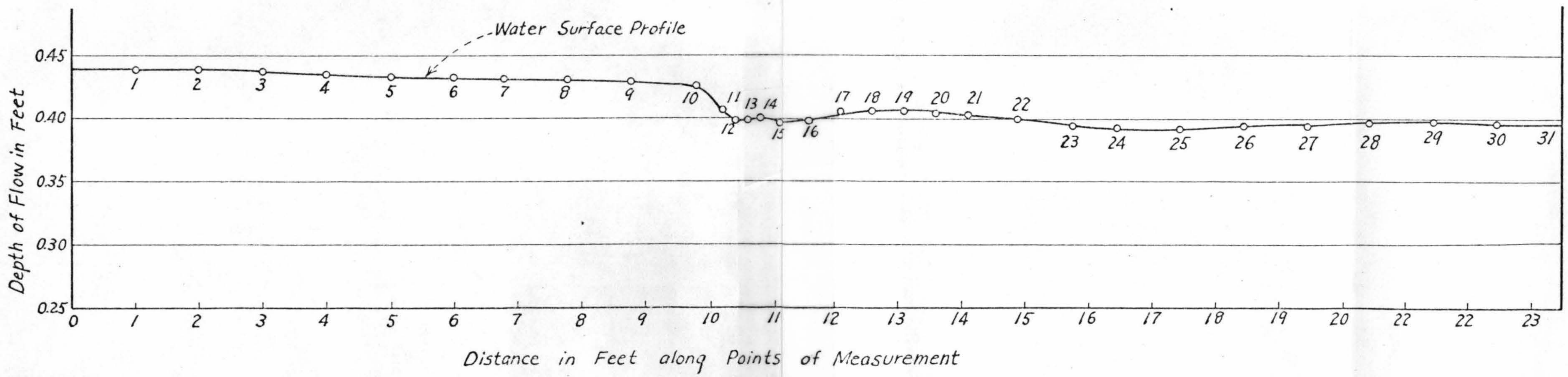
# WATER SURFACE PROFILE AROUND SPUR DIKE AND EMBANKMENT

Straight Spur Dike
L = 3.41 ft.

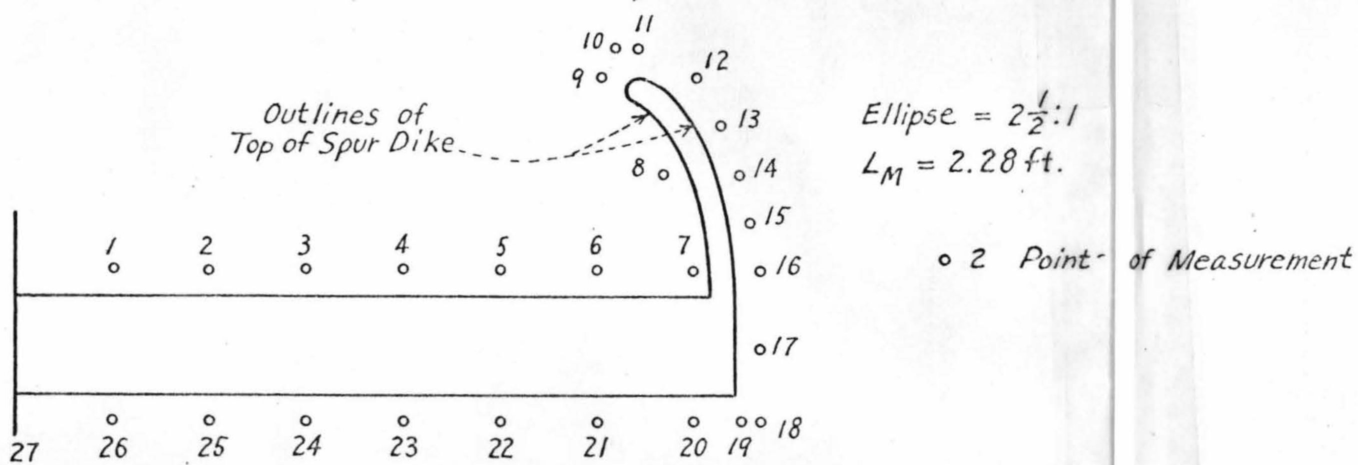
o 3 - Point of Measurement



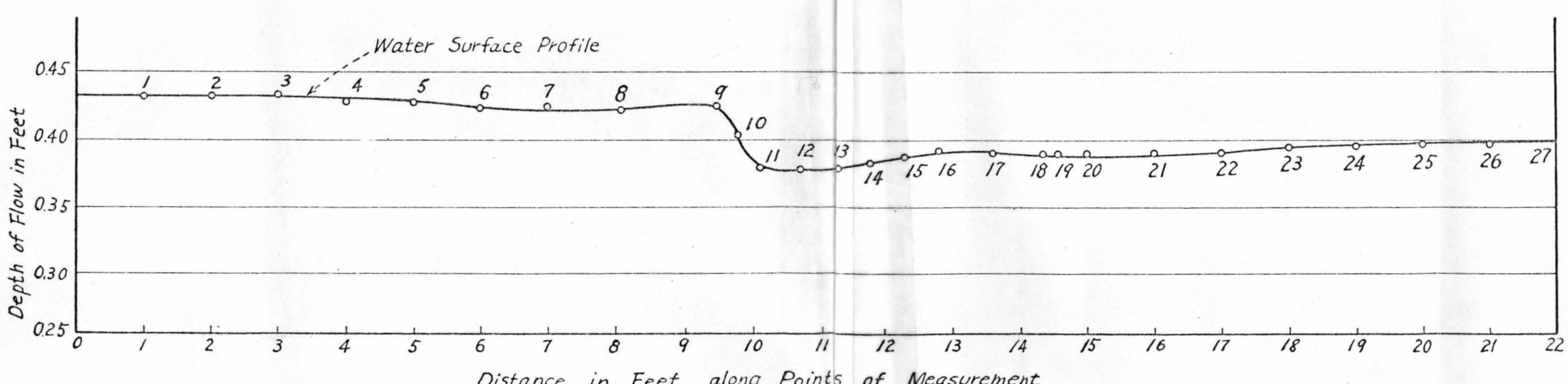

PLAN
Scale 1in. = 2 ft.



# WATER SURFACE PROFILE
# AROUND
# SPUR DIKE AND EMBANKMENT




PLAN
Scale 1 in. = 2 ft.

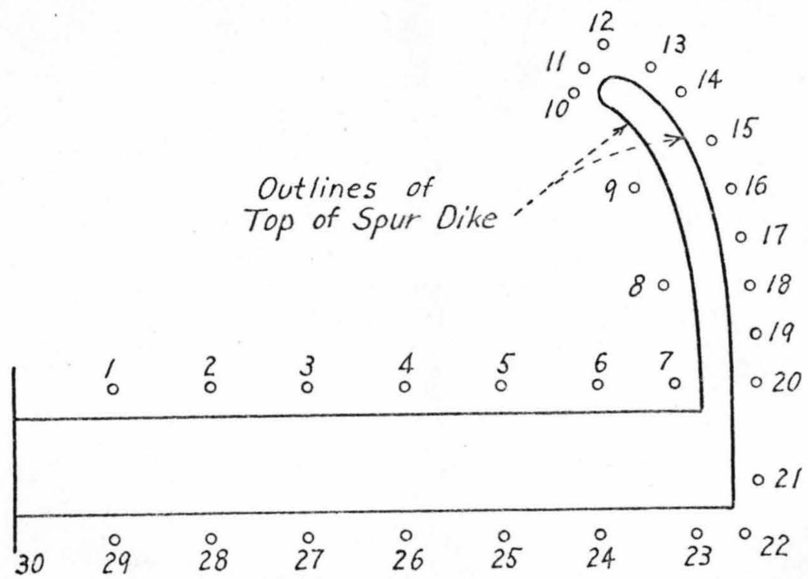



H.A.

## WATER SURFACE PROFILE AROUND SPUR DIKE AND EMBANKMENT

Ellipse = 3:1
$L_M$ = 3.41 ft.

o 2 - Point of Measurement

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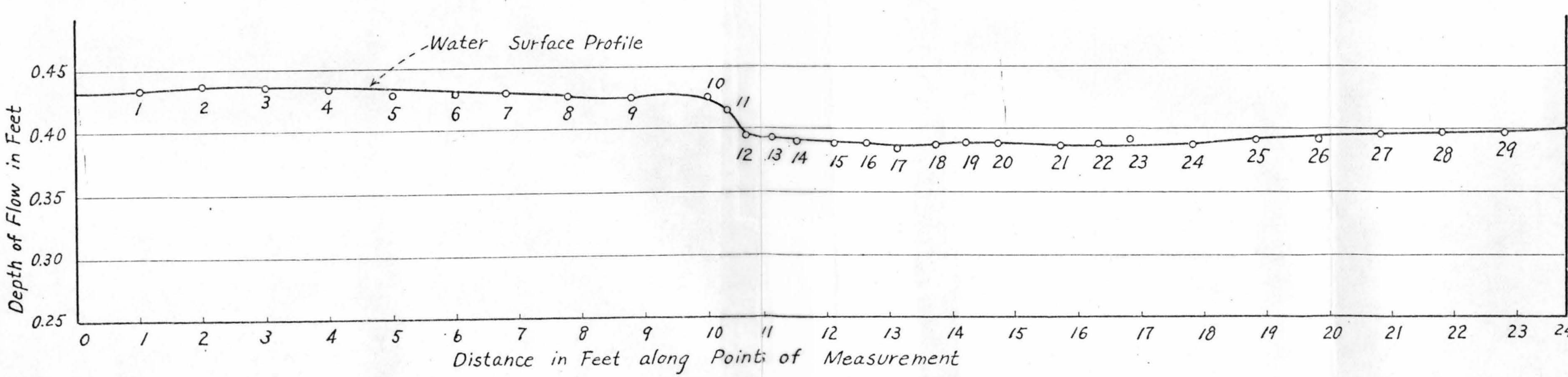
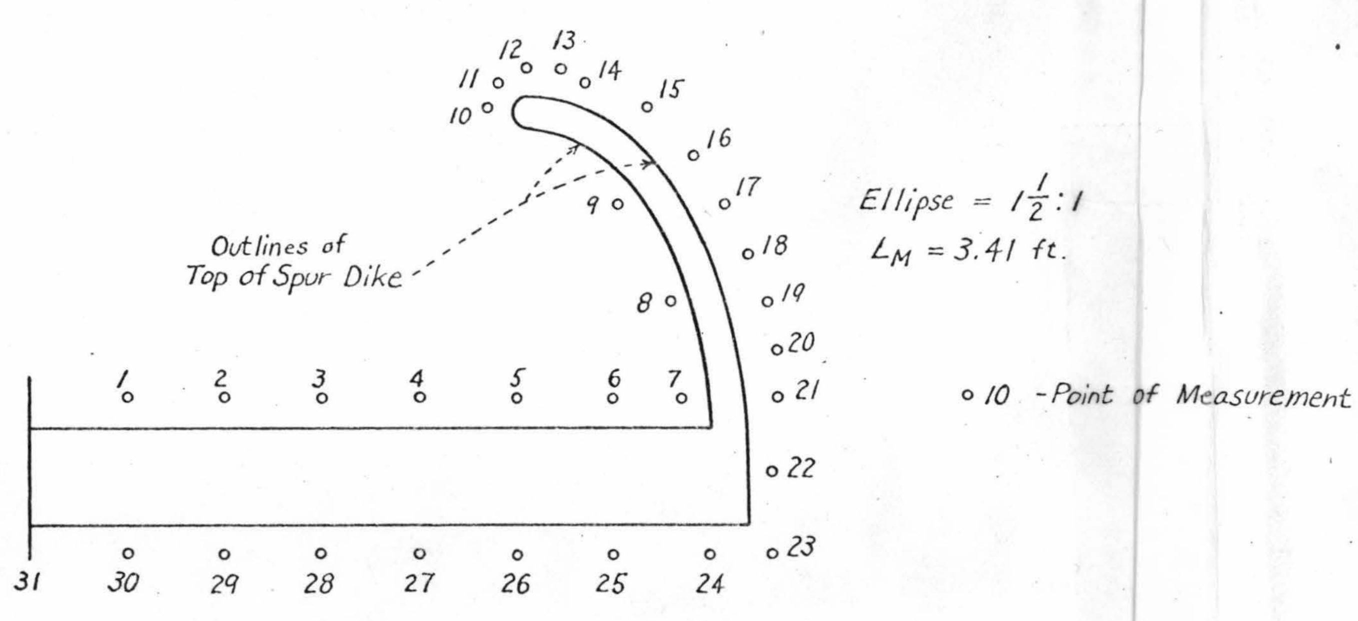



H.A.

# WATER SURFACE PROFILE AROUND SPUR DIKE AND EMBANKMENT




PLAN
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