EFFECT OF SCOUR ON SUBMARINE PIPELINE

by

Hsieh W. Shen

Prepared for

The Shell Pipe Line Corporation
Houston, Texas

Engineering Research Center
Colorado State University
Fort Collins, Colorado

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Mr. E. Q. Milz, Manager
Research and Development Laboratory
Shell Pipe Line Corporation
Shell Building
P. O. Box No. 2648
Houston, Texas 77001

Subject: Effect of Scour on Submarine Pipeline.

Dear Sir:

I am pleased to transmit two copies of our results for the studies of the effect of scour on submarine pipeline. Color slides (Figures la, 3, 4, and 5 of Appendix B) will be forwarded to you when available - next week.

My report on "The effect of scour on the external loading of submarine pipeline" was mailed to Mr. D. E. Broussard, Supervisor, Marine Technology-Pipelines, Shell Pipe Line Corporation, on July 14, 1967.

I have enjoyed the opportunity to work with Dr. J. L. Chao, of your Company, on this assignment and would be pleased to be of further service to you.

Very truly yours,

Hsieh W. Shen
Associate Professor of
Civil Engineering

Enclosures:
1. Purchase Order 09282, Project 73611
2. Reprints "The effect of Scour on Submarine Pipeline"
3. Copy of a letter to Mr. D. E. Broussard, July 14, 1967
4. Sediment size distribution used in Flume A.

P.S. Movie Film being sent under separate cover.

TABLE OF CONTENTS

I. INTRODUCTION

The effect of scour on submarine pipeline is not well understood. The pertinent literature on this subject was presented in a report titled "The effect of scour on the external loading of submarine pipeline" for the Shell Pipe Line Corporation by H. W. Shen, in July 1967. After discussion with Dr. J. L. Chao of the Shell Pipe Line Corporation, a laboratory testing program with the objectives as given in Section II of this report was initiated and completed in the research laboratory of Colorado State University. The purpose of this report is to summarize these findings.

II. OBJECTIVES

A. Visual observation of scour process in the neighborhood of a submarine pipeline - with particular attention focusing in the following two points:

1. The effect of dunes on scour depth.
2. Physical dimension of the scour hole.

B. Measurements of the sediment-water mixture concentration in the vicinity of the sand bed.

III. APPARATUS

A. Flume A: As shown in Figure 1 of Appendix A, a steel - aluminum, recirculating flume 6 ft wide and 60 ft long was used. The depth of the flume in the approach section was 4.0 ft and the recess section was 5.5 ft deep.

B. Flume B: This recirculating flume is 2 ft wide by 60 ft long and 2 ft deep.

C. Test pipes: Steel Pipe 1 - 5ft - 11 3/4 in. long and 6 5/8 in. outside diameter.

Steel Pipe 2 - 1 ft - 11 in. long and 3 in. outside diameter.

D. Velocity distribution of the approached flow was measured by a pitot tube connected to a pressure transducer.

IV. EXPERIMENTAL RESULTS

A. Velocity distribution of the approached flow. As shown in Figure 2, the velocity is relatively uniform in the transverse direction in Flume A.

B. Visual observation of scour process. The following three series of tests were made:

1. The first series of experiments was made to study the behavior of pipe when the pipe was essentially resting on the sediment bed.

   Hydraulic condition: (in Flume A):

   Flow depth 1.6 ft to 2.6 ft.

   Average flow velocity: at the approached section:

   1.6 to 2.6 ft per second.

   Sediment size: d_{50} (50% is finer)

   = 0.46 m.m.

   Result: As shown in Figures 3, 4, and 5, the pipe followed the bottom contour of the ocean floor. The pipe was fully burried below the trough of the sand dunes. The black ink mark on the glass panel of the flume as shown in these figures indicates the original position of the pipe.

2. The second series of tests was made to study the behavior of pipe when the pipe was rigidly supported by wire above. In this case, the position of the pipe could not be moved by the flow.

   Hydraulic condition: (in Flume A).

   Flow depth: 1.6 ft to 2.6 ft.

Average flow velocity at the approached section:

1.6 to 2.6 ft per second.

Sediment size: d_{50} (50% is finer)
= 0.46 m.m.

Result: Figures 6, 7, and 8, show the sediment bed pattern for t = 30, 40 , and 50 seconds after the pipe was inserted.

The average velocity was 2.5 ft per second and the flow depth was 1.7 ft. Figure 9 gives the transverse pattern after the water was drained.

The maximum scour depth d_s, which is defined as the vertical distance between the center line of the pipe and the lowest elevation of bed, was always less than 1.5 diameter of the pipe in our tests. (See Figure 12).

3. The third series of tests was made to study the maximum scour depth under high velocity: (Flume B).

Flow depth. 0.46 ft

Average velocity of the approached flow: 5.3 ft per second.

Sediment size: d_{50} (50% is finer)
= 0.34 m.m.

Result: As shown in Figure 10, the maximum scour depth was 3 inches, which was the diameter of the tested pipe.

The sand bed was essentially flat in this case.

C. Sediment - water mixture concentration. The sediment-water mixture concentration depends on the sediment size as well as the flow conditions.

1. Flume B:

Flow depth - 0.46 ft.

Average velocity of the approached flow: 5.3 ft per second.

Sediment size: d_{50} = 0.34 m.m.

Maximum sediment concentration near the bed

= 0.4% by weight.

2. Recent unpublished results obtained by Dr. R. Rathbun of the U. S. Geological Survey in an 8-ft flume at the Colorado State University Hydraulic Laboratory:

Flow depth: 1.60 ft.

Average velocity of the approached flow: 5.5 ft per second.

Sediment size: d_{50} = 0.23 m.m.

Maximum sediment concentration at 0.1 ft from the bed = 1.8 % by weight.

Concentration	Distance from bed
1.8%	0.1 ft
0.8	0.2
0.4	0.3
0.2	0.4

The difference between the two studies (C-1, and C-2) indicates that the sediment concentration is extremely sensitive to the size of sediments. Higher concentration corresponded to smaller sand size.

V. CONCLUSIONS

A. If the pipe is supported on the ocean floor, and the average ocean floor elevation does not change (no general degradation), the lowest elevation that the top of the pipe would reach would be within one radius of the pipe below the lowest point of the dune as shown in Figure 11.

B. If the vertical position of the pipe is fixed, maximum scour depth underneath the pipe in a plane bed would be 1.5 the diameter of the pipe as shown in Figure 12.

C. If the vertical position of the pipe is fixed, maximum scour depth underneath the pipe in a dune bed would be the larger of the following two values: 1) 1/2 dune + 1/2 d or 2) 1.5 d.

D. Maximum sediment concentration varied greatly with distance from the bed and the sediment size even under the same hydraulic conditions. Since a great deal of flocculating fine particles exist on the ocean floor, it is difficult to estimate the density of the mixture to calculate the drag force on the pipe. The American Society of Civil Engineers' Task Committee (Journal of Pipeline Division, Am.S.C.E., Proc. Paper 2755, February 1961), recommended to use 100 lbs/ft^3 as the specific weight of the sediment-fluid mixture for the calculation of buoyancy sediment force. This 100 lbs/ft^3 would be equivalent to a concentration of about 20% by weight. I believe that it is reasonable to assume that 100 lbs/ft^3 would be the specific weight of the sediment-fluid mixture for design purposes.

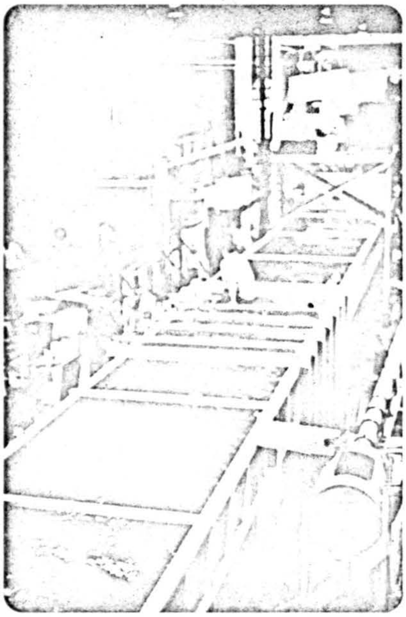


Fig. I Flume A Flow from Top to Bottom

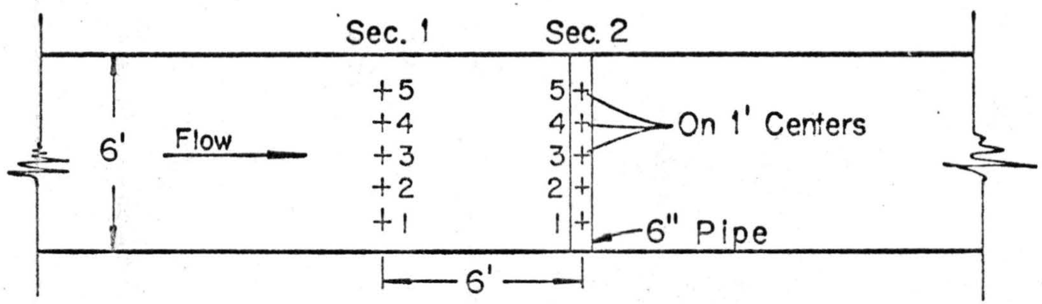


Fig. 2a Flume A

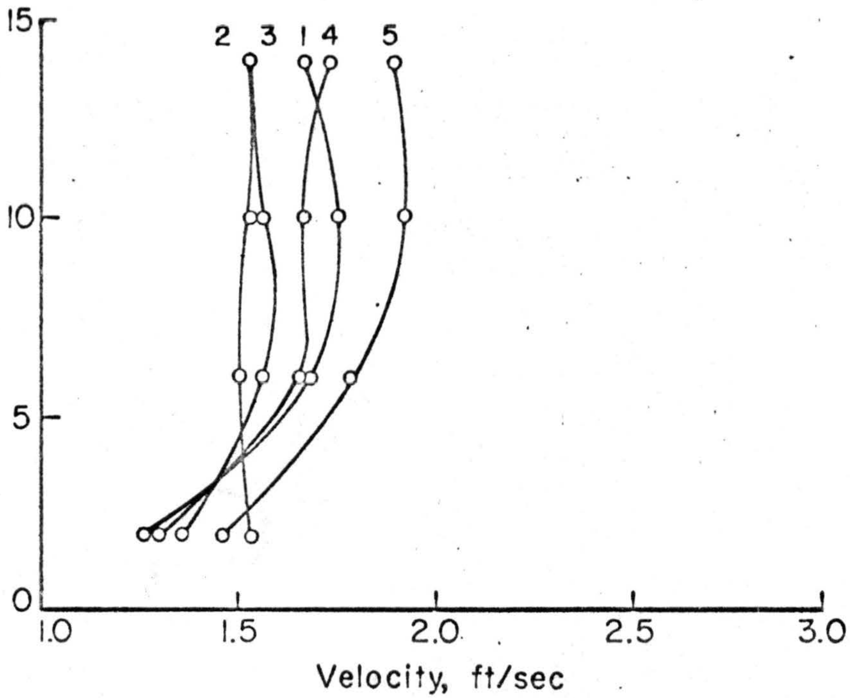


Fig. 2b Velocity Profiles at Section 1

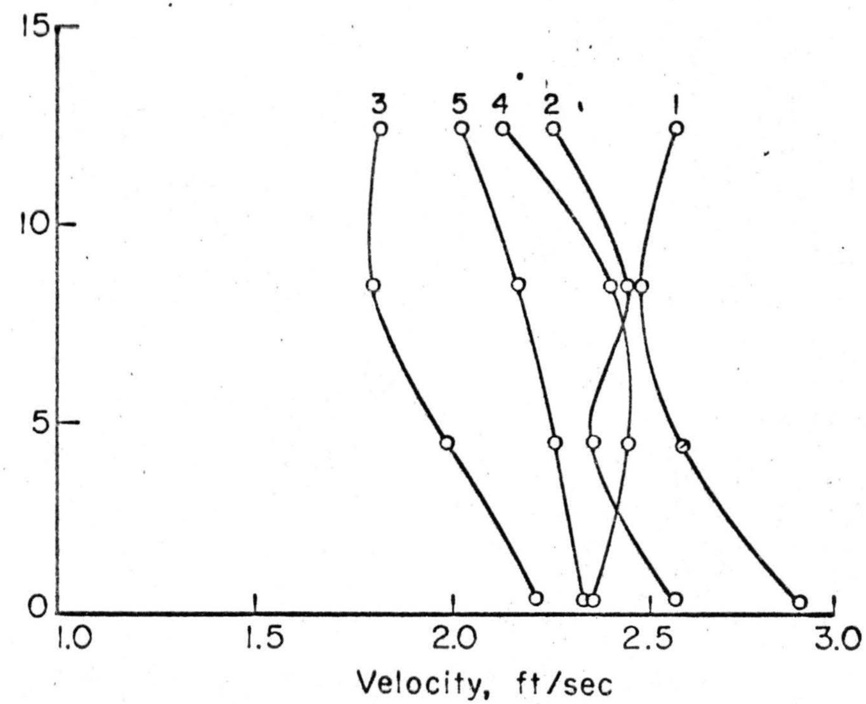
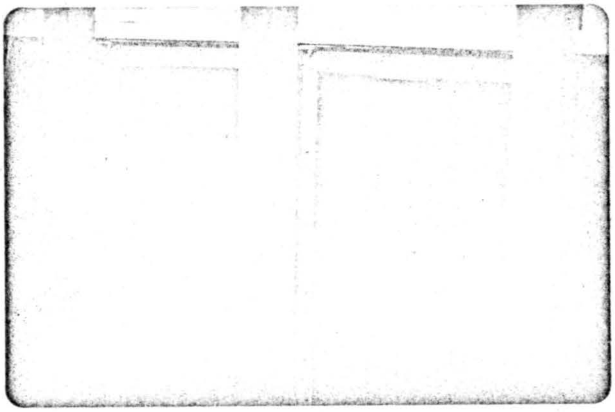


Fig. 2c Velocity Profiles at Section 2

Fig. 2 Velocity Profiles in Flume A



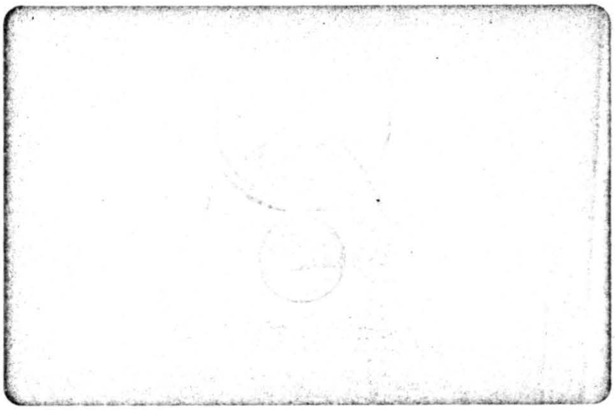


Fig. 3 Flume A — Series I—a

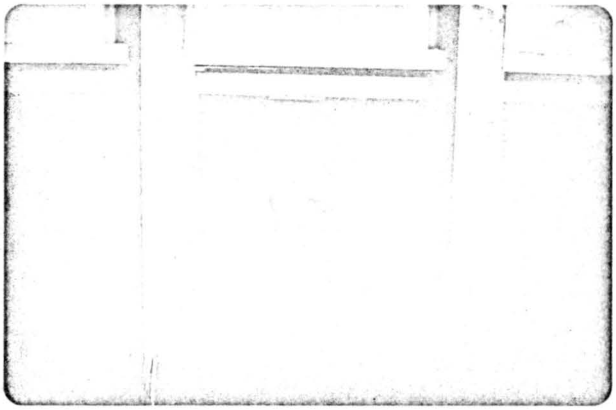


Fig. 4 Flume — Series I—b

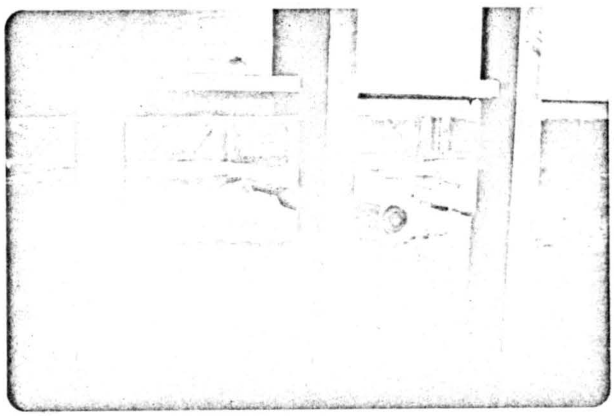


Fig. 5 Flume A — Series I - C

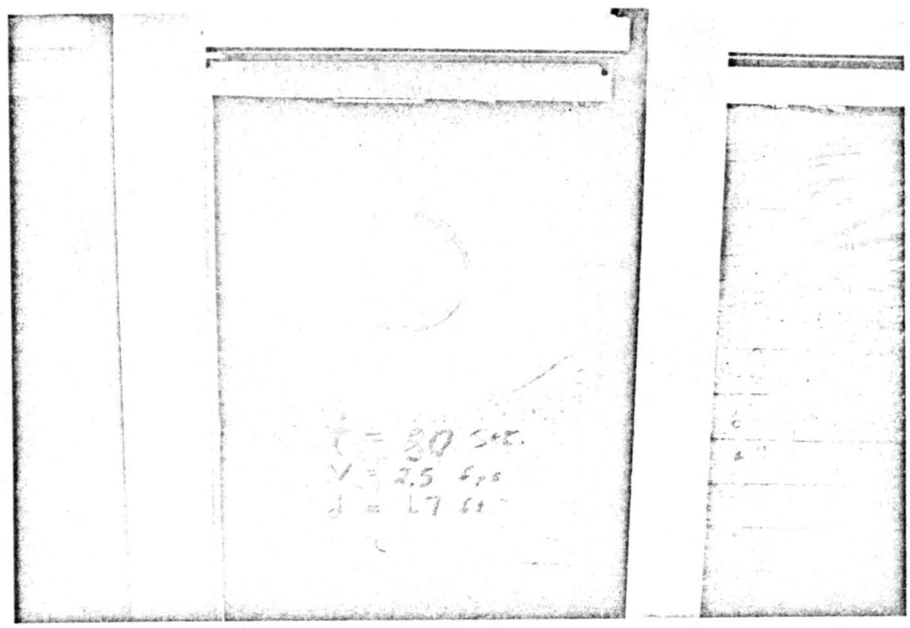


Fig. 6 Bed Pattern after 30 seconds (FlumeA & Series 2)

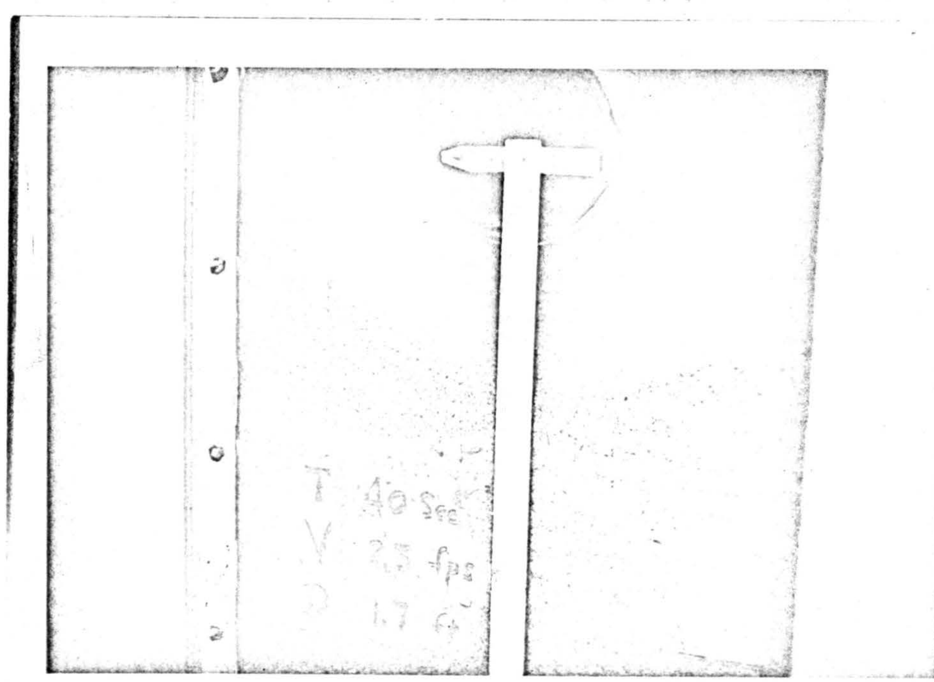


Fig. 7 Bed Pattern after 40 seconds (Flume A & Series 2)

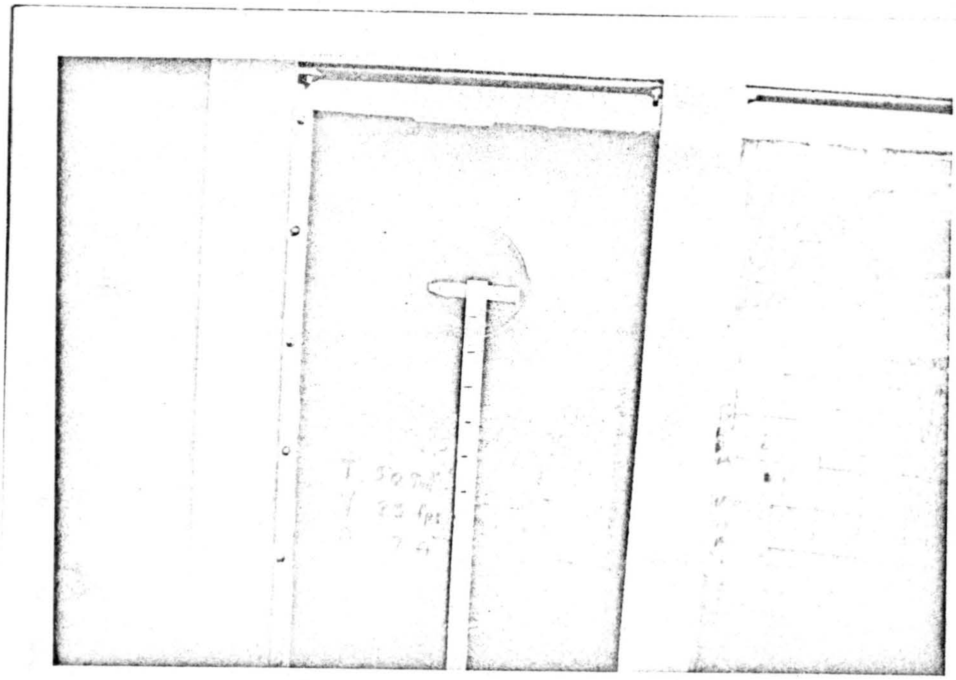


Fig. 8 Bed Pattern after 50 seconds (Flume A Series 2)

Fig. 9 Bed Pattern (Water had been drained, Flume A Series 2)

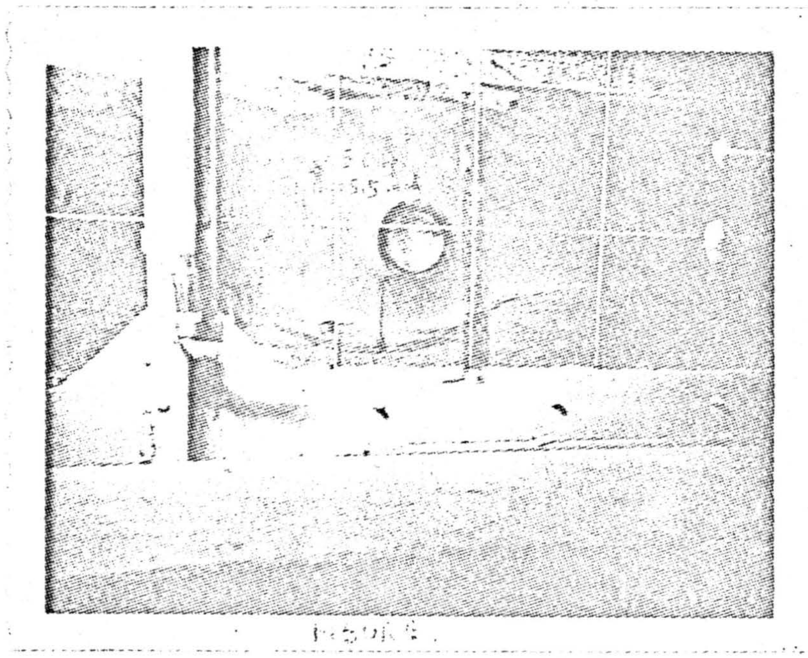


Fig. 10 Scour in Flume B
Flow Velocity 5.0 feet per second
Flow Depth 0.46 feet

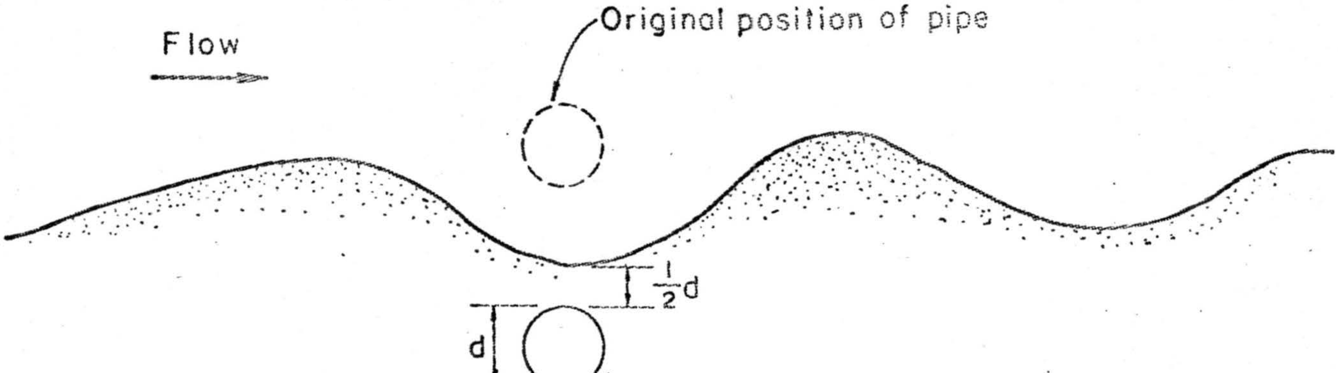


Fig. 11 Pipe Position in Dune Pattern

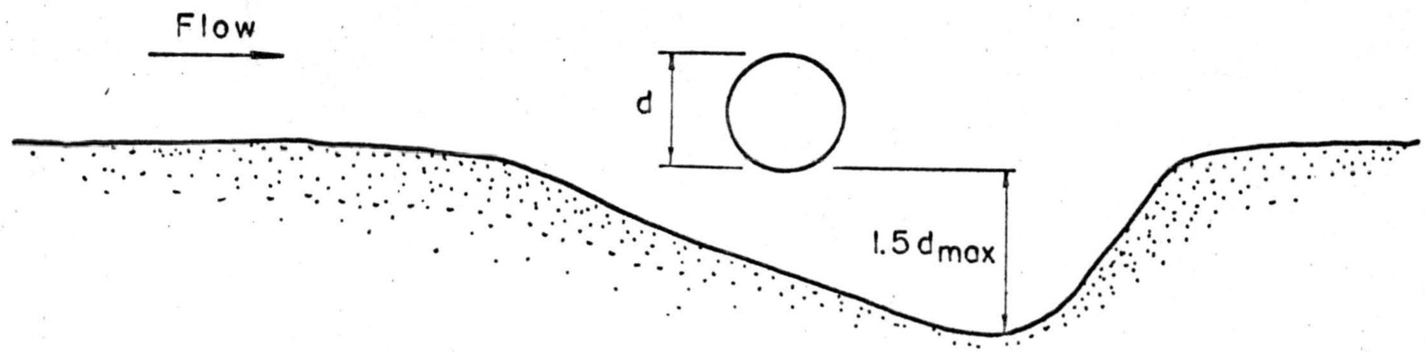


Fig. 12 Pipe Position in Plain Bed