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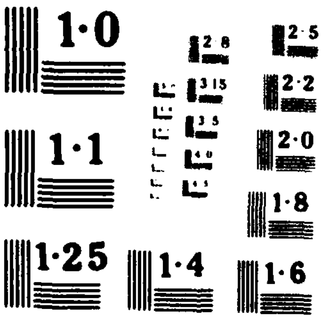
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Laboratory Investigation of Vane Dike River Control Structures

MRD Hydraulic Laboratory Series Report No. 11

Mead Hydraulic Laboratory
Mead, Nebraska

September 1984

US Army Corps of Engineers
Missouri River Division

Report #11
Project C5592
Disk 282-C

DEPARTMENT OF THE ARMY

CORPS OF ENGINEERS

LABORATORY INVESTIGATION OF VANE DIKE RIVER CONTROL STRUCTURES

Conducted at
Mead Hydraulic Laboratory
Mead, Nebraska

U.S. Army Engineer District, Omaha, Nebraska
U.S. Army Engineer District, Kansas City, Missouri
Missouri River Division, Omaha, Nebraska

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MRD Hydraulic Laboratory Series Report No. 15, Laboratory Investigation of Scour Downstream of Grade Control Sills on West Fork Ditch

MRD Hydraulic Laboratory Series Report No. 16, Laboratory Investigation of Missouri River Crossing Upstream of Bushwacker Bend

MRD Hydraulic Laboratory Series Report No. 17, Laboratory Investigation of the Browers and Snyder Bend

Also available for loan:

Condensed time lapse movies summarizing laboratory investigations with narratives for:

Report No. 1
Report No. 7
Report No. 8
Report No. 9
Report No. 11

Time lapse movies of model tests without narratives for:

Report No. 7
Report No. 8
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Report No. 10
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Report No. 16

I. INTRODUCTION

1. Presented in this report are the results of a model study on river training structures called vane dikes. The studies were performed at the Mead Hydraulic Laboratory by personnel of the Omaha District Hydraulics Section. Work was reviewed and guidance provided by the Channel Stabilization and Hydraulics Sections of the Omaha and Kansas City Districts and Missouri River Division, Corps of Engineers.

2. Vane dikes are defined as river training structures which are not attached to the river bank nor to each other. Some advantages of a vane dike system over conventional river training works are as follows:

(a) They are effective in directing the river flow away from channel banks that are subject to bank erosion, thereby creating and/or preserving shallow water areas.

(b) Less construction material is required than for continuous revetments and dikes.

(c) They lend themselves to "stage construction." By installing one structure at a time, beginning at an upstream location, the resulting impact on the river can be used to indicate the best location and orientation of subsequent structures.

3. This investigation was concerned with vane dike applications along concave river bends. The concave (outside) bank line of a river is normally subject to a sharp angle of attack due to the crossing effect of channel flows. This can result in severe erosion to unprotected bank lines as seen in the upper mid section of Plate 1.

4. The purpose of this investigation was to determine the relative effects of vane dikes on the flow distribution and bed configuration of a typical Missouri River bend. Different structure arrangements were tested to determine the optimum vane dike configuration by which the flow could be diverted away from the bank. Tests were also conducted to determine the effectiveness of the vane dike structures in the removal of point bars along convex banks and the variations in the sediment deposition landward (wet lands) of the vane dikes under various combinations of vane and gap lengths. Items investigated included:

(a) The angle of the vane structure relative to the flow.

(b) The relative length of the vane structure.

(c) The ratio of the length of vane to the length between vanes (gap length).

5. <u>DESCRIPTION OF PROTOTYPE BEND</u>. Yankton Bend, located near Yankton, South Dakota on the Missouri River approximately 5 miles downstream from

Gavins Point Dam, was selected as the prototype bend to be modeled. See Plate 1. This bend was considered to be a typical example of an eroding bend in the structurally uncontrolled portion of the upper Missouri River and field data were readily available for model verification. The bend extends from the U.S. Highway 81 Bridge at Missouri River mile 806.0 upstream to River mile 808.7 (1960 mileage). The banks of Yankton Bend are basically uncontrolled except for a crossing structure at river mile 808.5. The bend is representative of a typical uncontrolled upper Missouri River bend with an erosion zone along the concave bank and a point bar along the convex bank.

II. MODEL CONSTRUCTION AND OPERATING PROCEDURES

6. The Mead model basin construction techniques, similitude criteria, measurement procedures and bed material are detailed in the MRD Hydraulic Laboratory Series Report No. 1. Report No. 1 also describes the test procedures and model verification procedures used in the model studies conducted at the Mead Laboratory facilities.

7. The model layout of Yankton Bend is shown on Plate 2. The model was constructed using scale ratios of 1:25 in the vertical and 1:150 in the horiontal. The graduated boundary on Plate 2 is the same as that indicated by the solid line on Plate 1 and represents the outer basin walls of the flume. The model river bank lines were constructed from sheet metal covered with a textured material to simulate the prototype bank roughness and to create a nonerodible bank line. The bed material had a uniform gradation and consisted of finely ground walnut shells with a specific gravity of 1.3 and a median diameter of 0.3 mm. Water surface monitoring (WSM) devices were located on 10-foot centers through the middle of the design channel as shown on Plate 2. The water surface elevation at the mid-point of the model was monitered by a water control device and maintained at a constant elevation by adding or extracting water from the closed system. The average model water depth was 0.33 feet. The bank to bank model width, measured at the crossing structure, was about 8.3 feet. This was also the design width used to establish the structure azimuth line through the bend. A discharge of 1.52 cfs was maintained in the model to simulate typical summer navigation releases of 28,000 cfs from Gavins Point Dam. The water and sediment were recirculated from the lower end of the basin to the upper end. The channel flow distribution at the model inlet was controlled through the use of louvers. The vane dike structures were fabricated from sheet metal of three different lengths; 2 feet, 3 feet, and 5 feet. They were covered with a carpet padding having a waffle-like texture, which simulated the roughness of the prototype stone. The projections on the padding were approximately 1 inch long by 1/4 inch deep.

8. Model tests were usually completed in a 24-hour period. The model was set up and the test started in the afternoon and the model would run throughout the night. This allowed sufficient time for the bed configuration and sediment transport to reach equilibrium.

9. Prior to each test, the channel bed was leveled. This insured similar starting conditions for each test and permitted comparisons of tests with

different structure configurations and observations of differences in scour and deposition through the model bend. Vane dike structures were then placed in predetermined locations. The model was slowly filled with water to eliminate possible surging effects which could have altered the bed, and the model test was started. Channel cross sections were taken after each run, using a sonic sounder and an X-Y plotter. The data obtained from the channel cross sections were then used to develop contour maps of the bed. Plates 4 through 8 show bed contour maps of selected test runs.

10. Beginning with run 46, the procedure was changed so as to be more representative of natural prototype processes. Vane dikes were placed in the model only after the verification condition (left bank flow with point bar in the center of the test area) had been duplicated. Placement of individual vanes then proceeded at 2-hour intervals (about 1 week prototype time), starting at the upstream end of the test area. This permitted observation of the progressive impact of individual vane dikes and was more representative of the sequential installation of prototype dikes. Velocity measurements were also taken during selected runs riverward and landward of each vane dike structure in order to determine the percent of flow both landward and riverward of the structures. All vane dikes were removed at the end of each run and the bed of walnut shells was leveled in preparation for the next run.

III. DISCUSSION ON TESTS AND DATA ANALYSIS

11. Collected laboratory data consisted of channel cross sections obtained with the sonic sounder, point velocity measurements, water surface elevations, sediment discharge, and water discharge values. Channel cross sections were obtained at the end of each run at 23 stations through the test area. The cross sections provided information on the bed configuration, from which bed contour maps were drawn, and on the hydraulic parameters involving channel area and depth. The bed contour maps illustrate the scouring and deposition which occurred in the channel. Analysis of the ability of the vane dike to deflect the flow at different placement angles, structure lengths and gap lengths was made, utilizing the bed contour maps.

12. Time lapse movies were taken of the model during each run and were useful in observing the depositional processes involved with the various placement geometries of the vane dikes. A movie film summarizing the study with a typed narrative as well as time lapse movies of all the runs are available and may be obtained from the Omaha District Hydraulics Section.

13. The model study consisted of two series of tests in addition to the model verification tests. In the first series of tests, laboratory personnel concentrated on determining the effect of the vane dike placement angle on the flow distribution and bed configuration. In the second series of tests the effect that different combinations of vane dike and gap lengths had on directing the flow along the desired channel alignment was investigated.

14. Plates 4 through 8 show some of the bed contour maps developed from cross section profiles. Data on these maps provide a comparison between the various runs. The contours indicate model depths below the water surface.

These data were not reduced to prototype dimensions so that they might have general usage. Conversion to other scale ratios may be accomplished by the following relationships:

$$D_r = \frac{0.33}{D_p} \qquad \text{(Average Depth of all model runs = 0.33 ft.)} \qquad (1)$$

$$L_r = \frac{8.3}{L_p} \qquad \text{(Design Width of Channel in model = 8.3 ft.)} \qquad (2)$$

where D_r = Depth ratio
D_p = Depth of prototype
L_r = Length ratio (based on final or design width)
L_p = Length of prototype (final or design width)

15. Plate 4, Figure 1, shows the prototype bed contour map of 17 April 1974 while Figure 2 shows the bed contour map from Run 25. Run 25 was a typical verification run (see Photo 1). Verification runs were performed periodically during the first series of tests to ensure that the model was functioning properly. A verification run preceded each run during the second series of runs (Runs 41-53).

16. Whereas Plate 4, Figure 2 (Run 25) represents an existing condition, Plate 5, Figure 1 (Run 24), presents the maximum change in the flow distribution and bed configuration which could be expected to occur. Run 24 had a continuous revetment *(no gap) along* the structural azimuth line (see Photo 2). A well defined channel developed riverward of the revetment and the point bar receded from the center of the test area. Runs 24 and 25 represent the two model extremes and were used to qualitatively compare the results of other tests.

17. <u>SERIES 1</u>. In the first series of tests, Runs 3 through 40, the placement angle of each vane dike in a single test was the same for each structure and was measured from the structural azimuth line (see Plate 3). The pivot point of each structure in these tests remained the same while the structures were rotated through a series of angles from 0° to 180°. In Runs 3 through 18, 5-foot vane lengths with variable gap lengths were used, while for Runs 19 through 40, 2-foot vane lengths with 2-foot gap lengths were used. Gap length is illustrated on Plate 3. The objective of these tests was to determine the effect of different placement angles on the thalweg and on the deposition or scour in the zone landward of the vane dikes.

18. Plate 6, Figure 1 shows the resulting bed contour map for Run 12, containing 5-foot vane lengths with 5-foot gap lengths. The structures were placed parallel to the flow (0° angle). A narrow channel formed riverward of the vane dikes with corresponding point bar removal; however, the majority of the flow passed through the upstream gaps and concentrated along the concave bank (see Photo 5). Some deposition occurred landward of the vane structures.

19. Plate 5, Figures 2 and 3, shows the effects of large placement angles (see Photos 3 and 4). In both runs heavy scour occurred near the upstream

structure with the flow passing landward between structures. This may be attributed to both the placement angle and spacing of the structures. Table 1 gives the results of the first test series.

TABLE 1

Results of Various Vane Dike Placement Angles

Placement angle	Comments
0°	Very little influence on channel flow.
7°	Minor influence on channel flow with some sediment deposition landward of vanes.
15°	Channel flow riverward and parallel to vane alignment with considerable deposition landward of vanes.
30°	Flow around both sides of vanes in upper portion of model. Accumulative influence of vanes forced channel flow (thalweg) toward convex bank in lower portion of model.
60° to 150°	Flow disrupted. Vanes acted as obstacles to flow with localized sediment deposition behind vanes. Considerable flow with deep gut along concave bank line.

As indicated above, a placement angle of 15° to the flow would produce the most deposition landward of the vane dikes. The deflection of the flow is riverward of the vanes and there is deposition of sediment landward of the vane dikes.

20. <u>SERIES II</u>. The second series of tests (runs 41 to 53) were all conducted with the vane dikes placed at an angle of 15° to the flow direction since that was determined in the first series of tests to be the optimum angle with respect to deposition landward of the vane dikes. Tests were conducted with 2-foot and 3-foot vane lengths and with various gap length to vane length ratios of 1, 1.5, and 2. The ratio of gap length to vane length, R_g, is defined as:

$$R_g = \frac{L_g}{L_v} \tag{3}$$

L_g = Length of gap
L_v = Length of vane dike

During some of the tests after the vane dikes had been placed in the model and the model stabilized, velocity measurements were taken to show the percent of flow landward and riverward of the structures. These measurements along with the cross section areas provided a means of determining the overall effectiveness of the various vane dike configurations.

21. Plates 6, 7, and 8 contain selected runs from the second series. In general for a constant R_g value the shorter vane-lengths increase the total amount of sediment deposited landward of the vane dike structures. However on Plate 6 there appears to be less sediment deposited landward of the 2-foot vane dikes in Figure 3 than landward of the 3-foot vane dikes in Figure 2. This is due to the fact that for the R_g values less than about 1.5 the sediment is deposited immediately behind the gaps and effectively blocks the flow from continuing landward. Obviously, the smaller the R_g value, the smaller the amount of flow landward of the structures (See Photos 8-10). Plate 9 shows the percent of flow area landward, P_f, of the vane dikes for 2 and 3-foot vane dikes for various R_g values at midbend and at the downstream end of the bend.

22. The P_f values on Plate 9 represent the percent of flow area landward of the vane dikes. The P_f values are also used to show the percentage of discharge landward of the vane dikes as indicated on Figure 2. Specifically, P_f is defined as:

$$P_f = \frac{A_L}{A_T} \times 100\% \qquad (4a)$$

or

$$P_f = \frac{Q_L}{Q_T} \times 100\% \qquad (4b)$$

where P_f = Percent of area or discharge landward of vane dikes
A = Flow area
Q = Discharge
L = Subscript referring to landward zone
T = Subscript referring to total amount

23. Referring to Plate 9, Figure 1, it may be seen that the P_f value at midbend decreases as the R_g value decreases for both the 3-foot and 2-foot vane dikes. At the downstream end of the bend (Figure 2), the R_g values vs P_f values based on area double back on themselves. This appears to contradict the P_f values based on discharge and what was found at midbend (Figure 1). This is not a contradiction but simply illustrates the fact that for R_g values less than about 1.5 the flow through the dike system is reduced so drastically that most of the suspended sediment is immediately deposited adjacent to and landward of the dikes. This reduces the flow even more and the deposition becomes a secondary barrier to the flow. Consequently very little sediment is deposited in the channel area near the bankline and downstream end of the bend. This area is occupied by water but the velocity is very low. Figure 2 also illustrates that for the same R_g value the smaller vane lengths cause more sediment deposition. This is probably caused by the

accumulative effect of the constriction losses, since there would be more flow ways with shorter vanes. This same condition probably occurrs at mid-bend also, but because of this particular bend geometry or measurement inaccuracies the differences were not detectable.

24. Plate 8, and Photos 11 and 12 are included to indicate the time dependency of the depositional process of material landward of the vane dike structures. All runs had identical vane lengths, gap lengths, and placement angles. The model run times for the bed contour maps shown on Plate 8 are progressively greater and the development of the bars landward of the structures can be seen as time elapsed. Similarly, the removal of the point bar and deepening of the channel riverward is apparent.

25. A flood flow equivalent to 50,000 cfs was also simulated to determine what effect overtopping of the vane dikes had on the deposits landward of the structures. From this test it was determined that the channel tended to center itself on the vane dike structures with an equal amount of flow on each side of the structures. The overtopping of the dikes caused the deposits adjacent to the vanes to be removed. When the discharge was returned to normal the deposits behind the vane dikes returned.

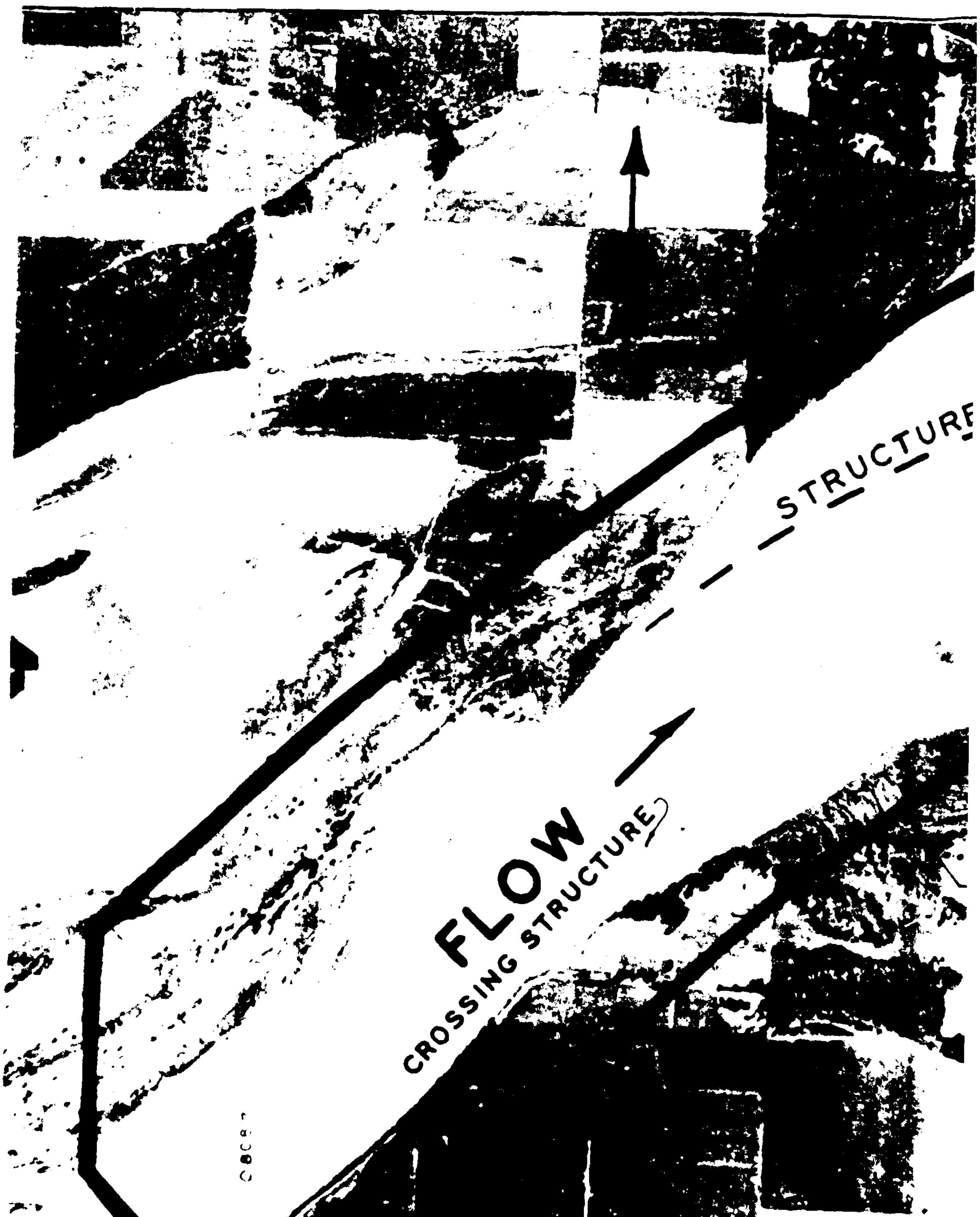
IV. CONCLUSIONS

26. Vane dikes are effective in directing riverflow away from channel banks subject to bank erosion and therefore can help create and/or preserve shallow water areas (wet lands). Vane dikes also require less construction material than continuous revetment and lend themselves to stage construction which allows the river to indicate the best location and orientation of subsequent structures.

27. The best ratio, R_g, of gap length to vane length depends on the type of results desired for the area landward of the vane dikes (see Plate 9). If backwater areas or a large area of shallow water are desired for environmental reasons, short vane lengths with an R_g value of 1 are recommended. This would cause a backwater area at the downstream end of a bend where little or no sediment is deposited. If moderate amounts of deposition and flow are desired throughout the landward side of the vane dikes, then longer vane lengths and an R_g value of 1.5 or greater are recommended. A large uniform deposit in the area landward of the vane dikes would result if the R_g value of 1.5 were used with short vane lengths. In general as vane length increases, control of the river and deposition decreases.

28. Alternative placements and orientation of vane dike structures could be used at specific sites to accomplish different objectives such as reclamation or maintenance and/or development of wetland environments (see Table I). This model study indicated that a wide variety of riverine conditions can be produced using vane dikes. Also a high degree of channel control may be achieved using this technique and one can successfully manage the river flow distribution and the bed configuration through judicious selection of vane lengths and gap lengths. It was also determined that a placement angle of about 15° to the flow for the vane dike structure produced the most deposition landward.

29. It is apparent that the amount of material required to construct the vane dikes increases as the R_g value decreases. However, reducing the length of the vane, while maintaining the R_g value, significantly influences the overall flow and bed configuration landward of the vane dikes, but essentially the same quantity of material will be used to construct the vanes.

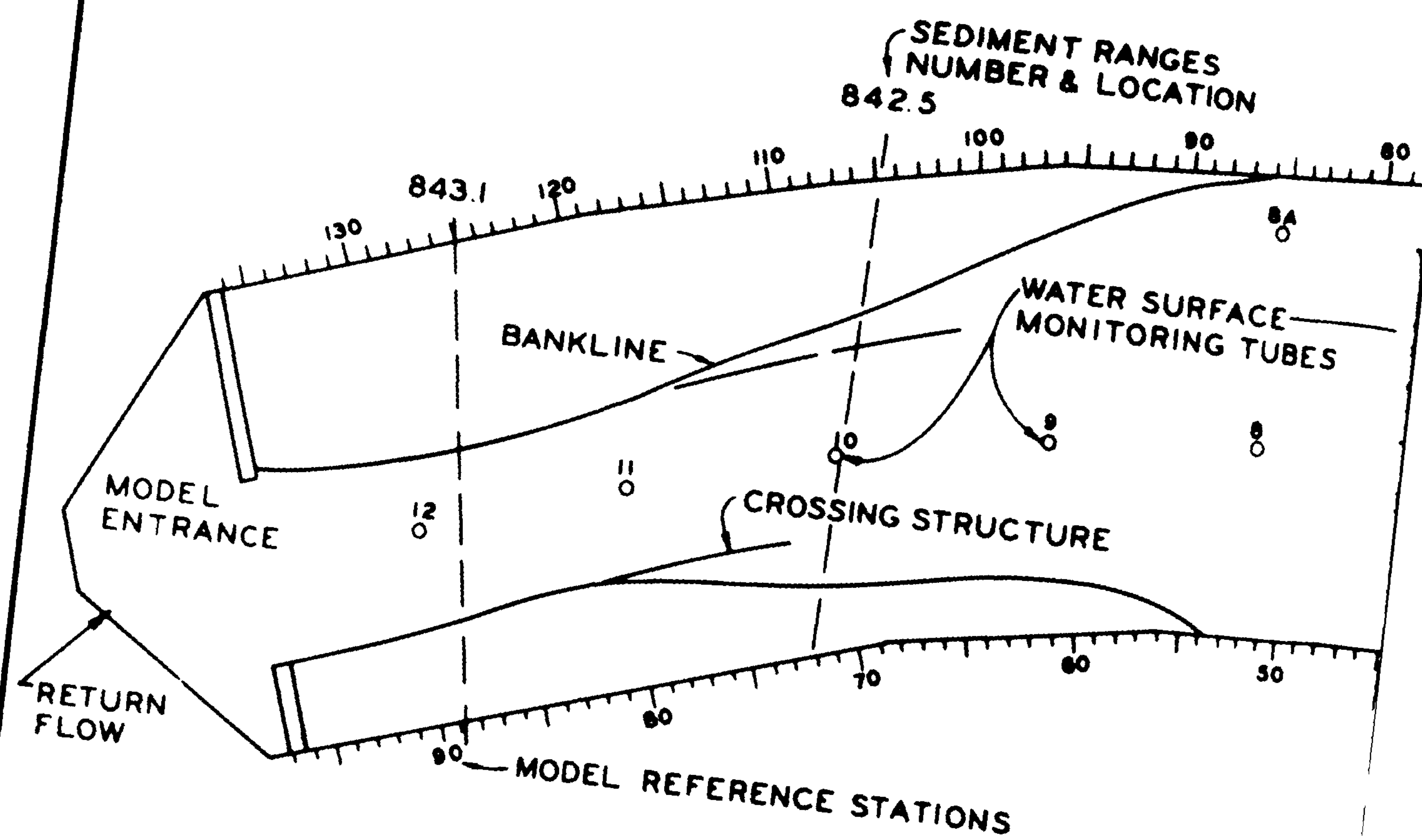

STRUCTUR
FLOW
CROSSING STRUCTURE

MISSOURI RIVER DESIGN STUDY

VANE DIKE STUDY
AERIAL PHOTOGRAPH OF
YANKTON BEND

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

PLATE 1


SEDIMENT RANGES
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843.1
130
120
110
100
90
80
8A
WATER SURFACE
MONITORING TUBES
BANKLINE
9
8
10
11
12
MODEL
ENTRANCE
CROSSING STRUCTURE
RETURN
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70
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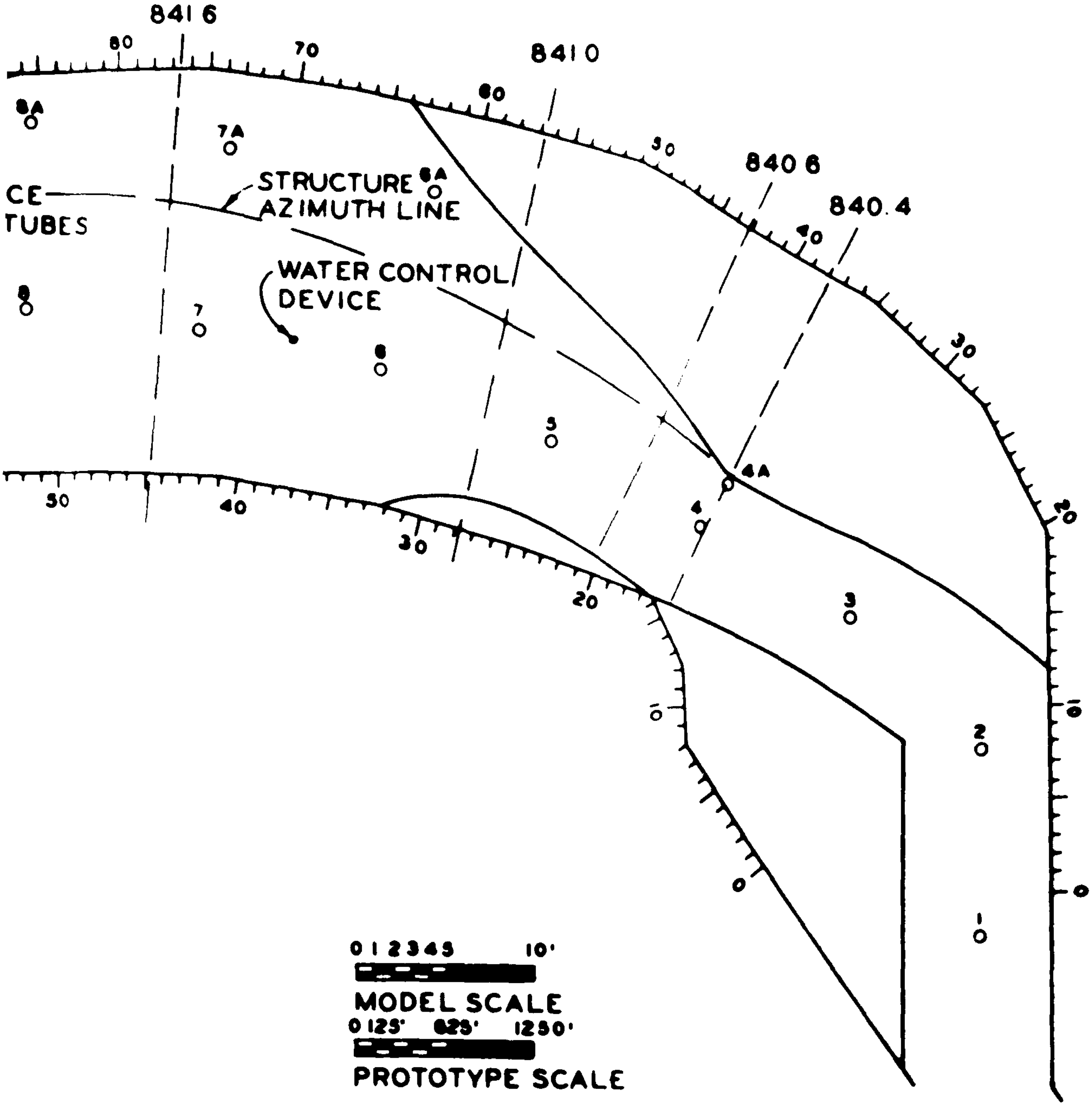
50
80
90
MODEL REFERENCE STATIONS



MISSOURI RIVER DESIGN STUDY

VANE DIKE STUDY

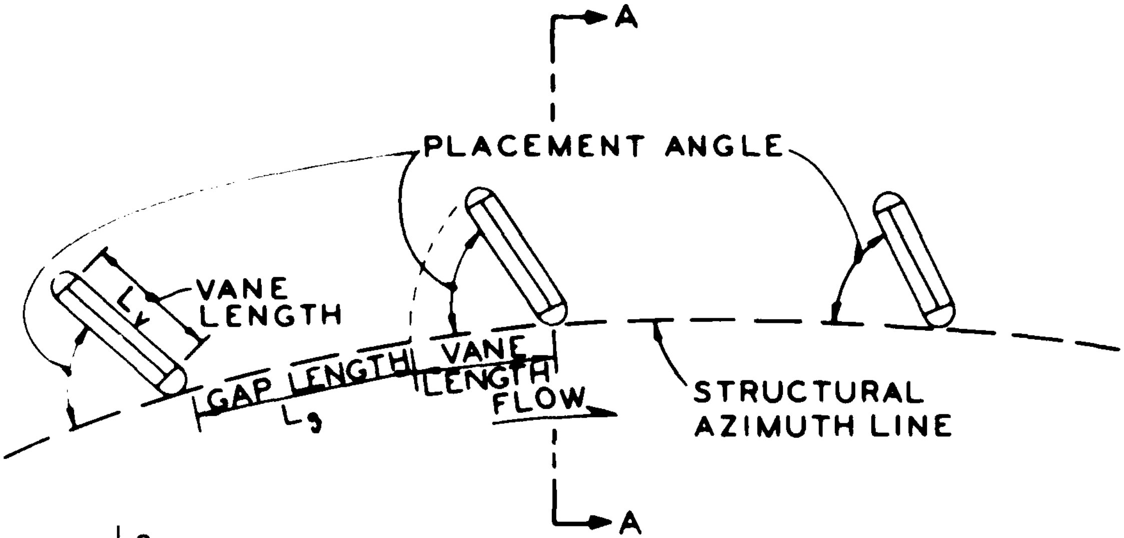
MODEL LAYOUT

U S ARMY ENGINEER DISTRICT, OMAHA

CORPS OF ENGINEERS

OMAHA, NEBRASKA

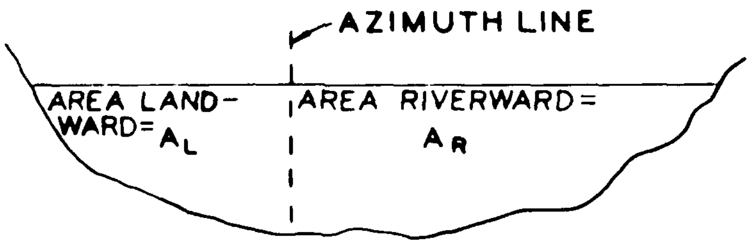
PLATE 2



$$R_g = \frac{L_g}{L_V}$$

TYPICAL VANE DIKE APPLICATION
(PROTOTYPE OR MODEL)

FIG 1



$$A_T = A_R + A_L \qquad P_f = \left(\frac{A_L}{A_T}\right) 100\%$$

SECTION A-A

FIG 2

MISSOURI RIVER DESIGN STUDY

VANE DIKE STUDY

STRUCTURAL ALIGNMENT

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OMAHA, NEBRASKA

PLATE 3

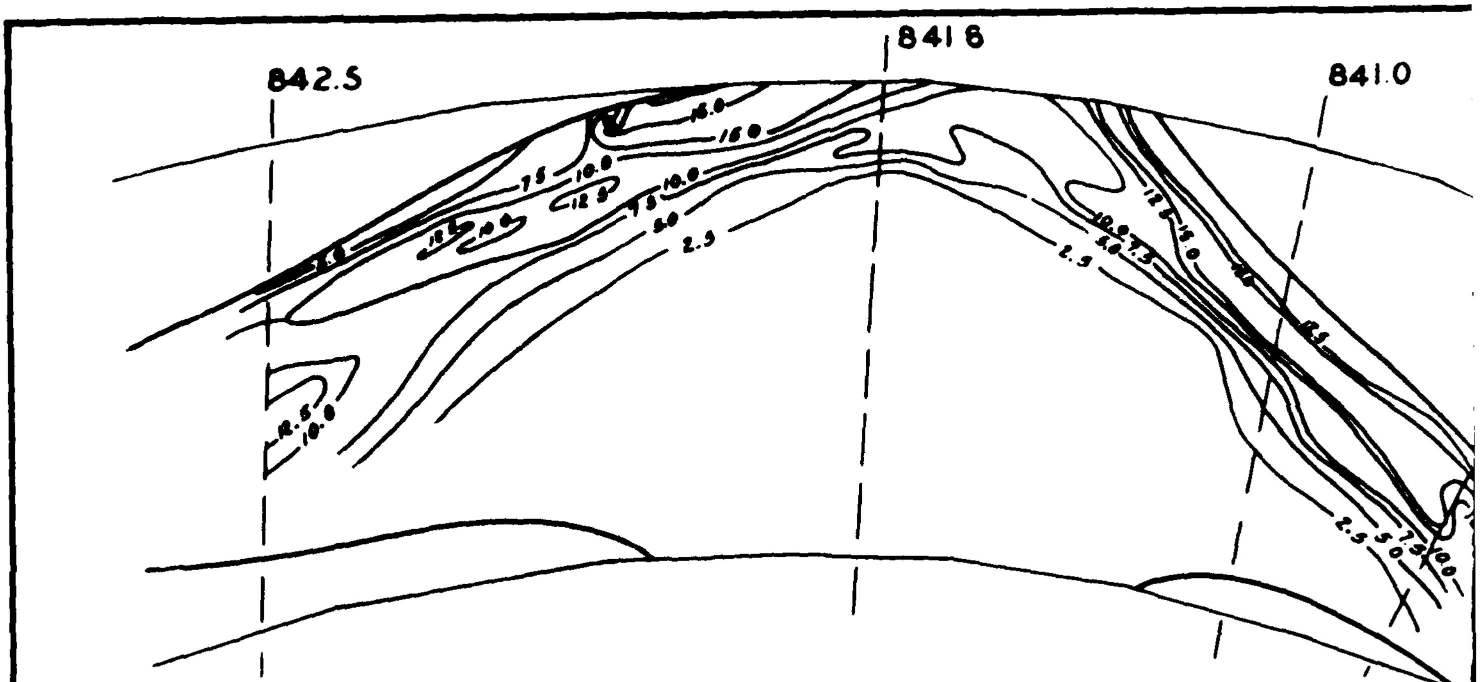

Figure 1 - Bed Contour Map of prototype from survey of 16, 17 April 1974

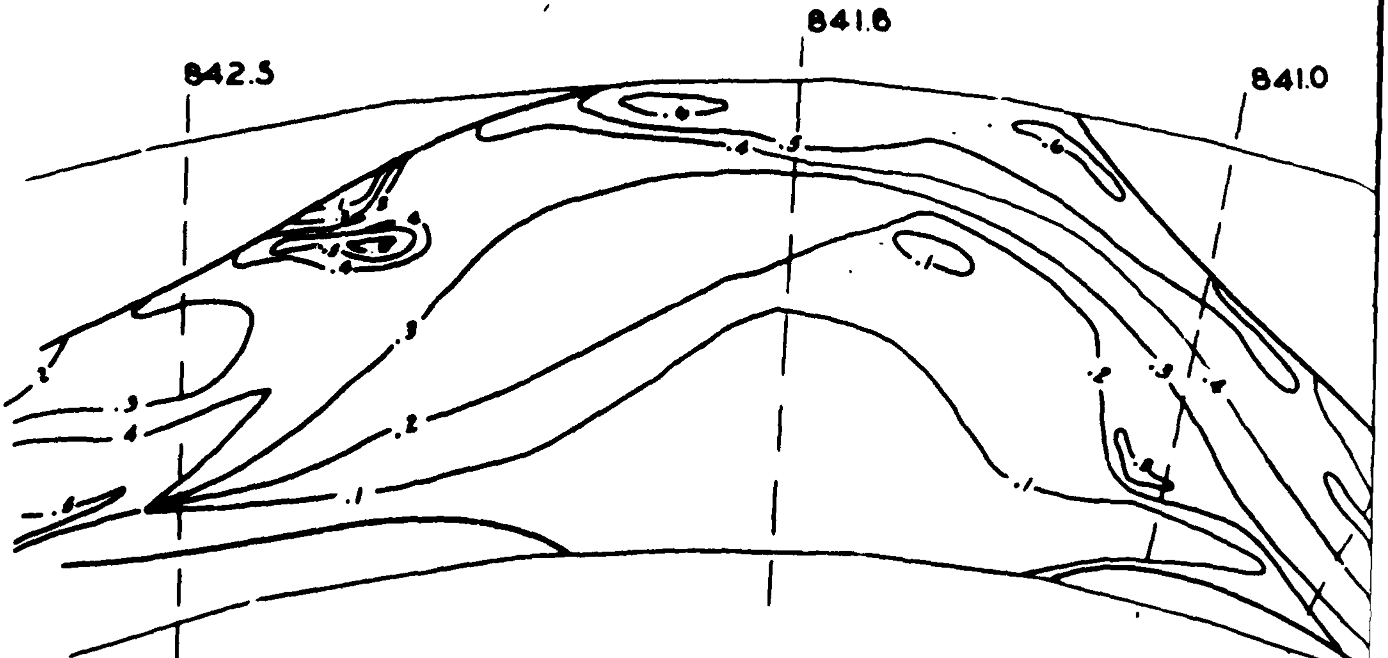

Figure 2 - Bed Contour Map, Model Run 25, no structures

PROTOTYPE SCALE IN FEET
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MODEL SCALE IN FEET
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NOTES:

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3. DASH LINES INDICATE LOCATI
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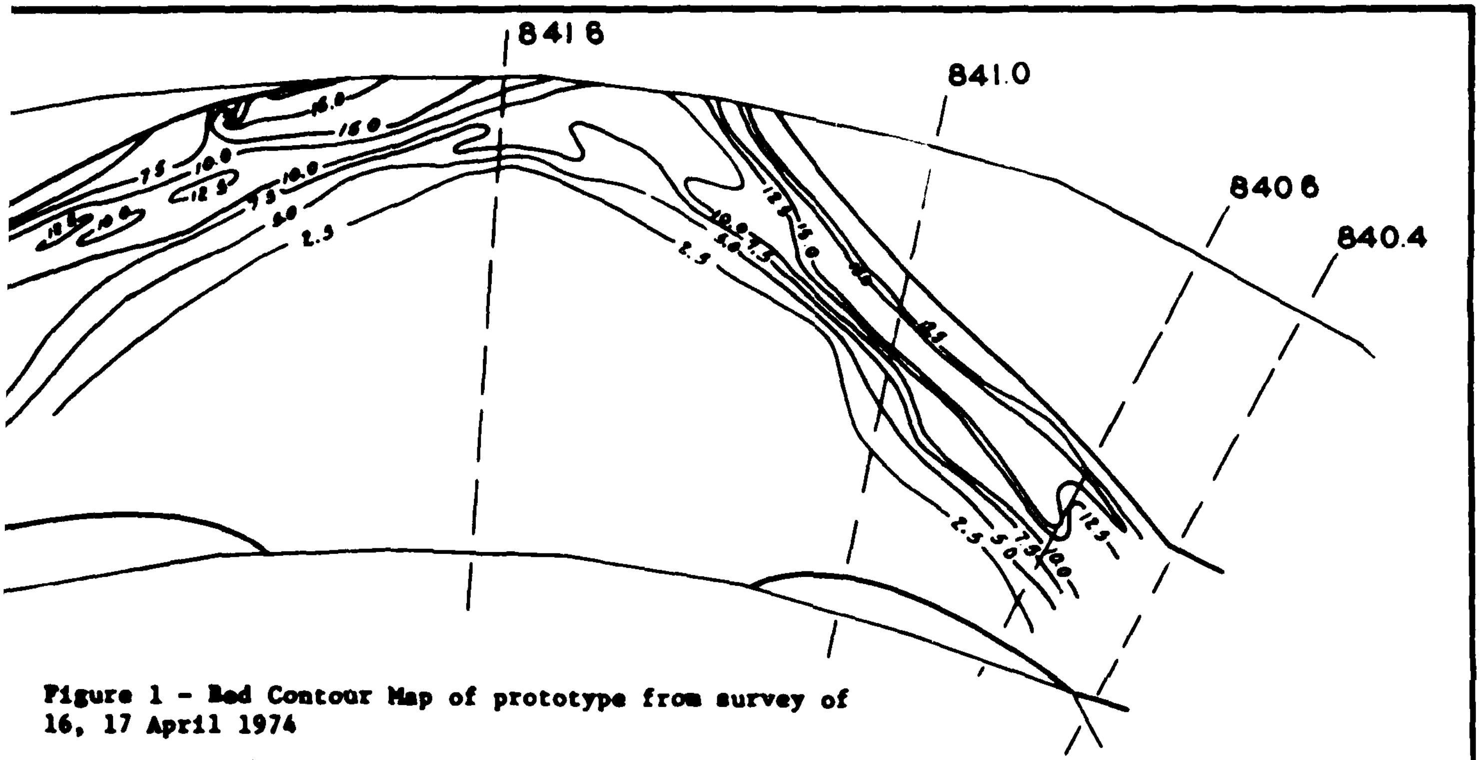

Figure 1 - Bed Contour Map of prototype from survey of 16, 17 April 1974

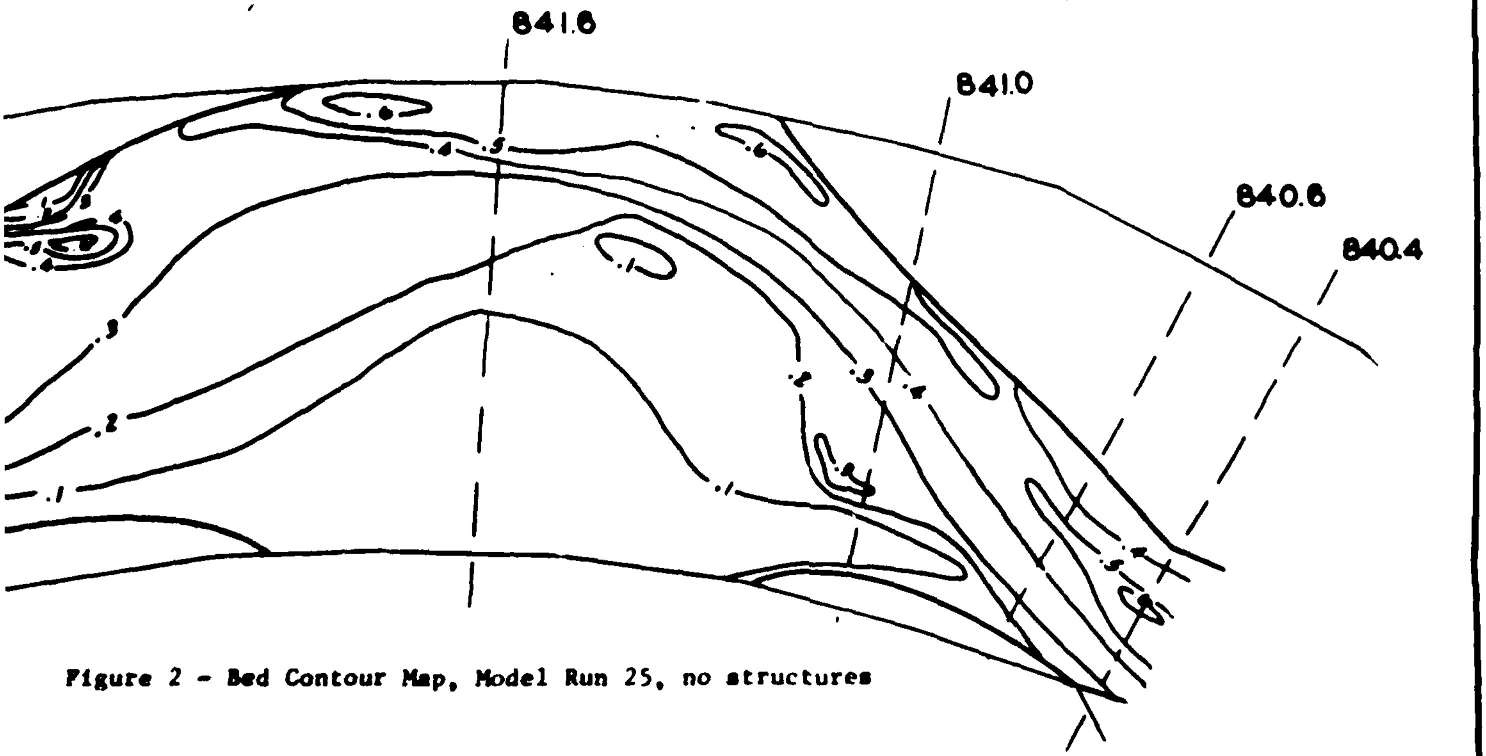

Figure 2 - Bed Contour Map, Model Run 25, no structures

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NOTES:

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2. NUMBERS BY DASHED LINES ARE 1941 RIVER MILES.
3. DASH LINES INDICATE LOCATION OF PROTOTYPE

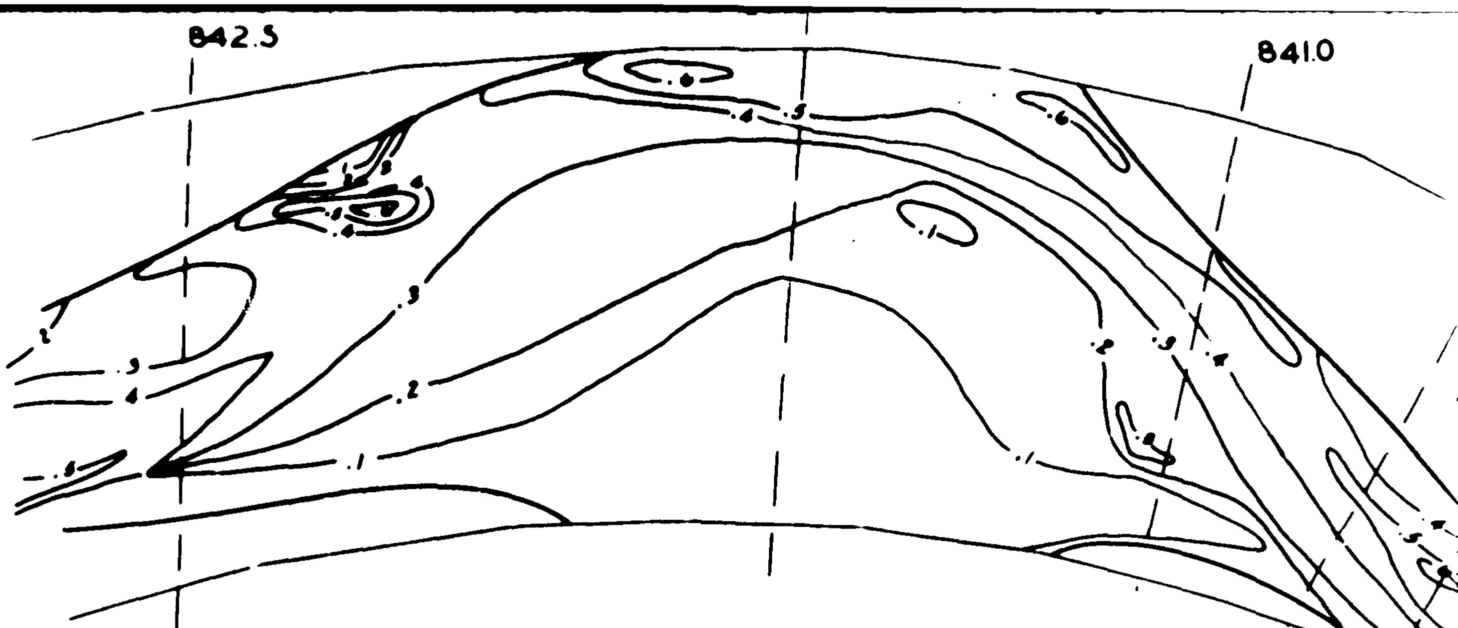

Figure 2 - Bed Contour Map, Model Run 25, no structures

PROTOTYPE SCALE IN FEET
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MODEL SCALE IN FEET
0 2 4 6 8 10

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OR TENTHS OF FEET.
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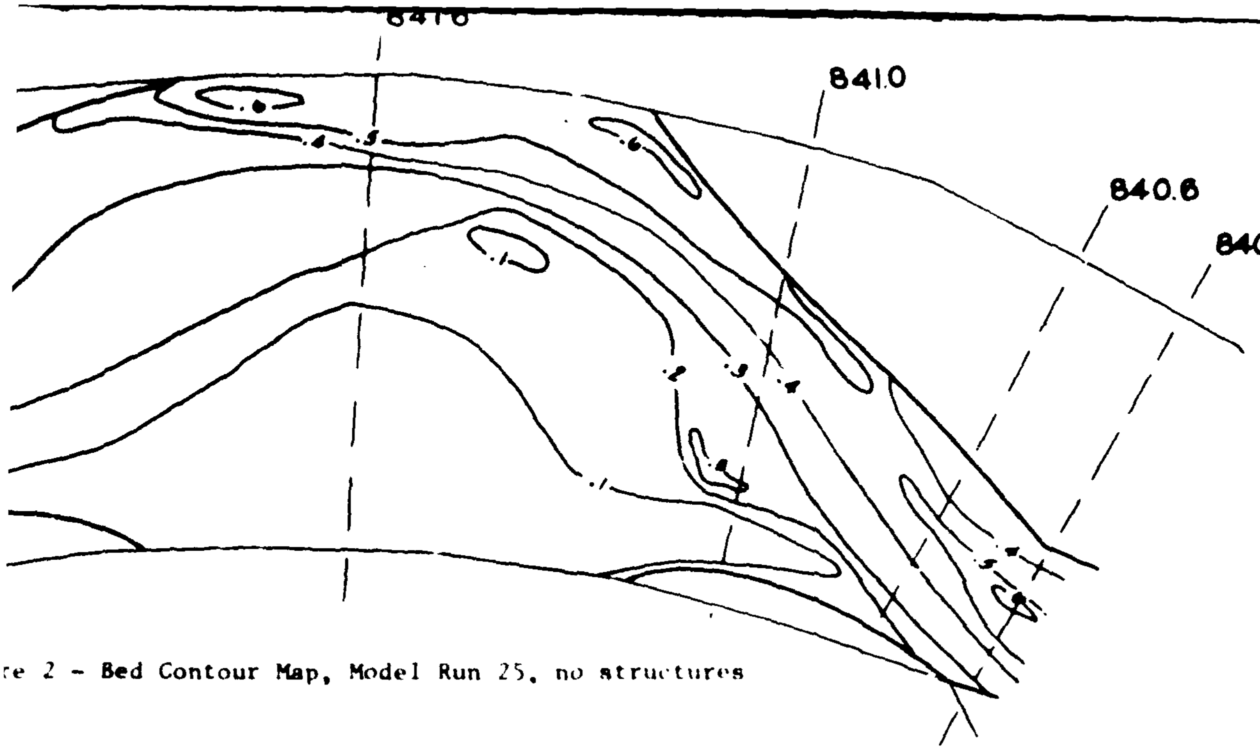

re 2 - Bed Contour Map, Model Run 25, no structures

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NOTES:

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3. DASH LINES INDICATE LOCATION OF PROTOTYPE SEDIMENT RANGE LINES.

MISSOURI RIVER DESIGN STUDY

VANE DIKE STUDY

BED CONTOUR MAPS

PROTOTYPE & MODEL COMPARISON

U.S. ARMY ENGINEER DISTRICT, OMAHA

CORPS OF ENGINEERS

OMAHA, NEBRASKA

3

PLATE 4

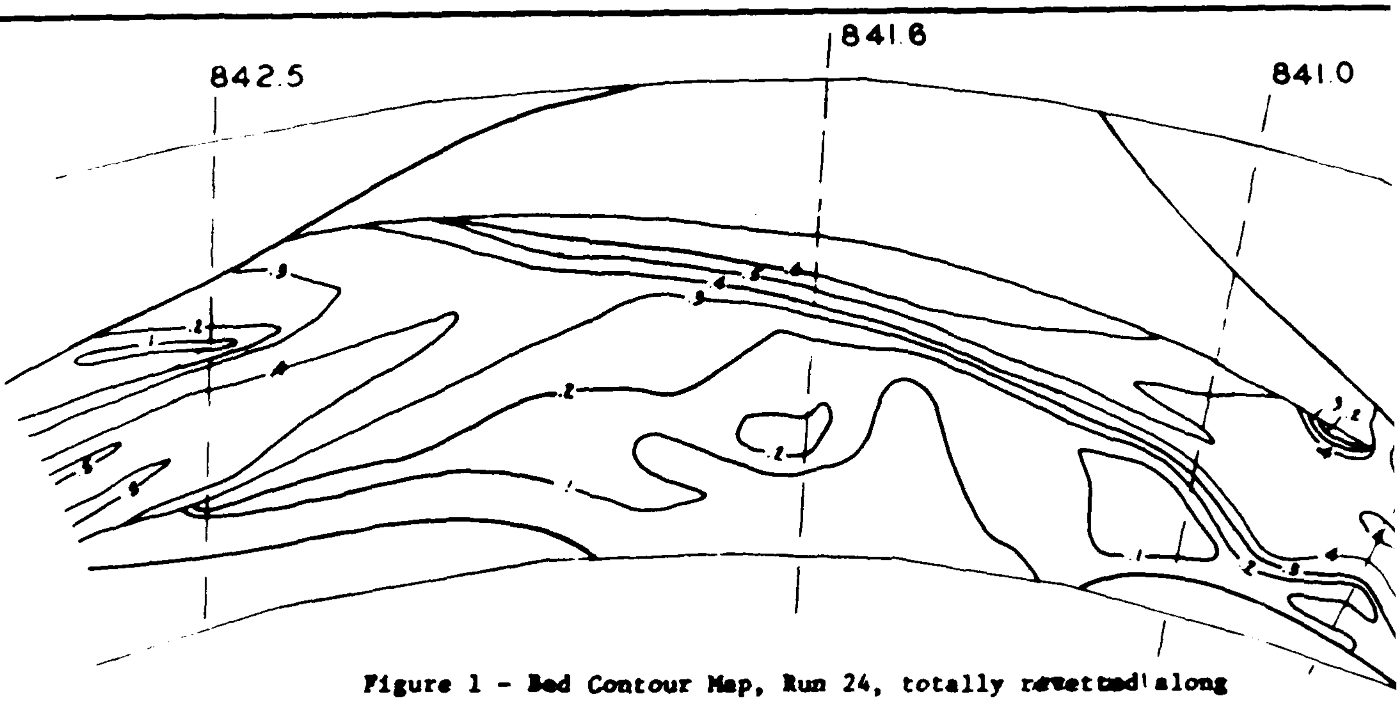


Figure 1 - Bed Contour Map, Run 24, totally revetted along concave side.

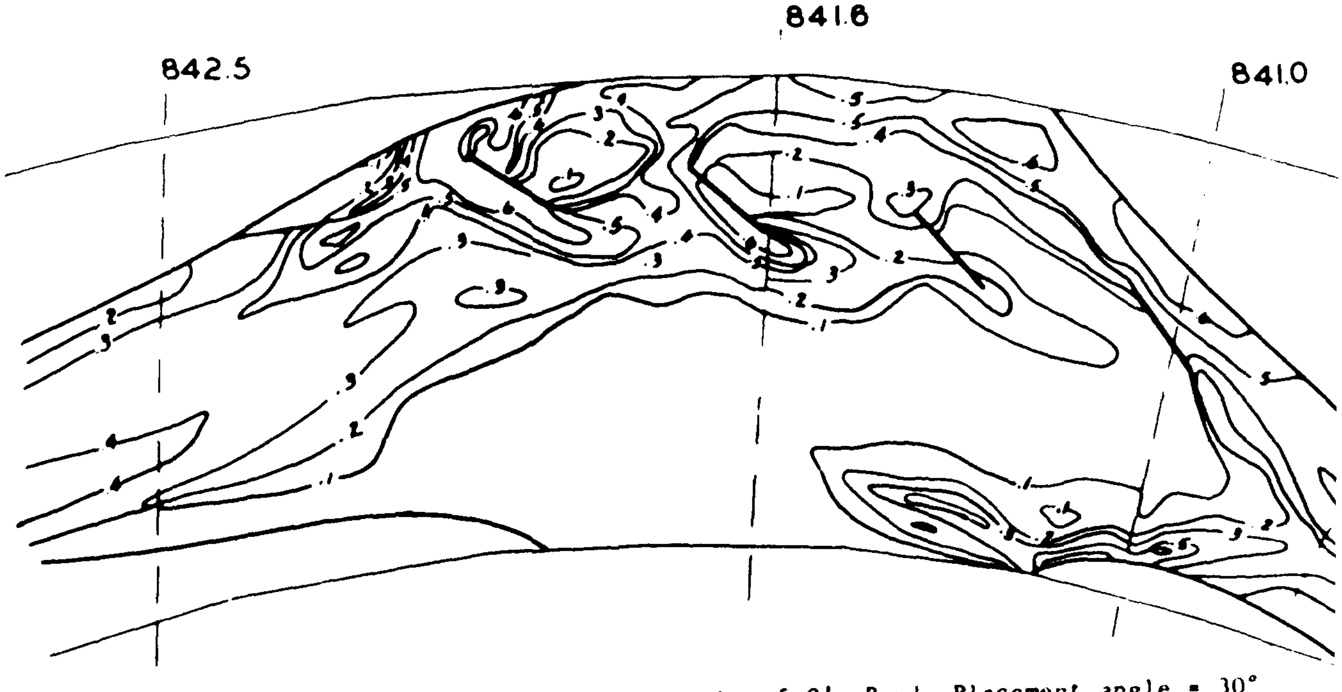
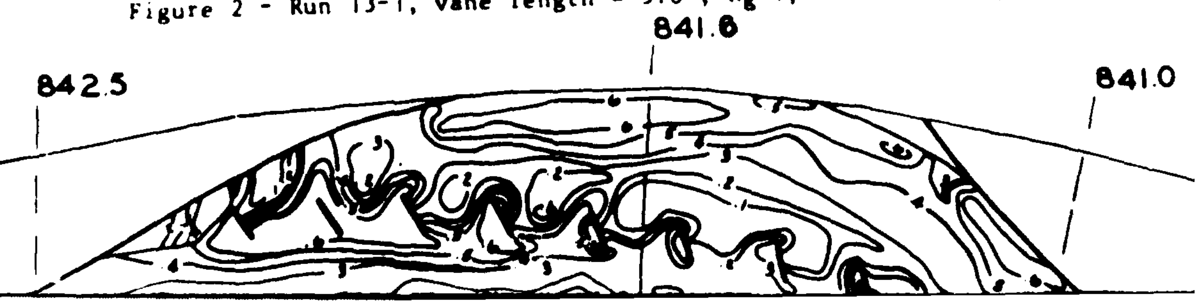
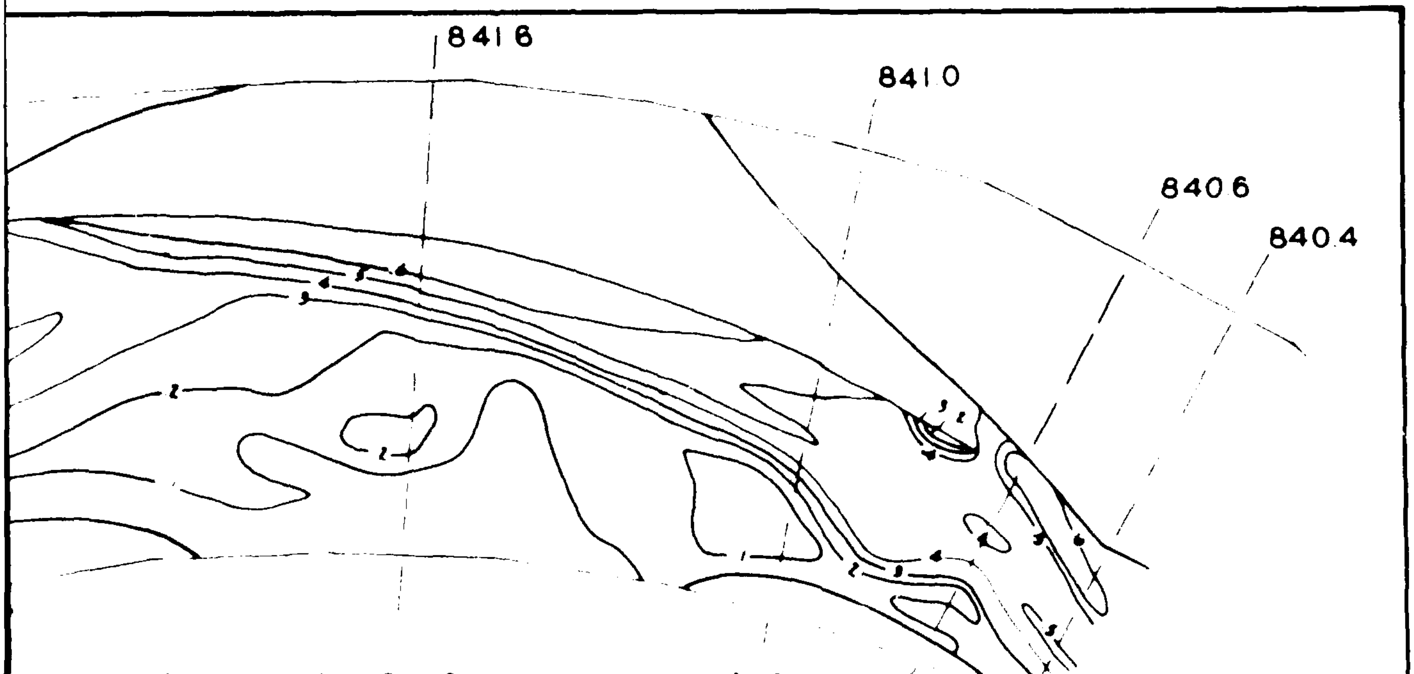
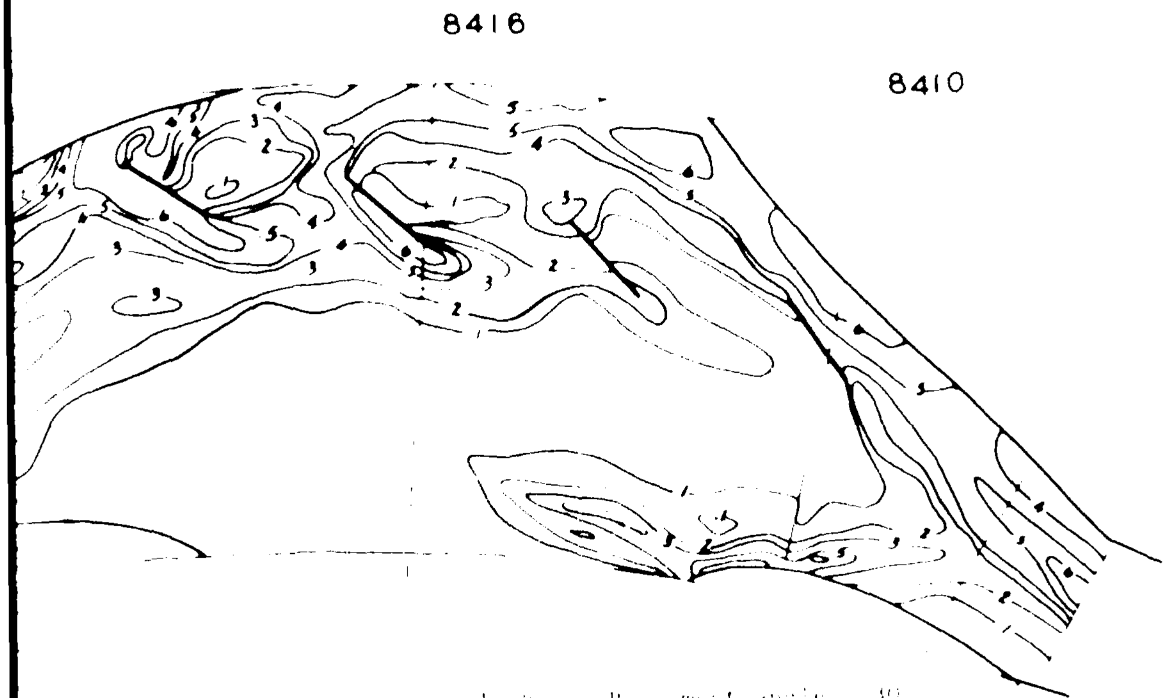


Figure 2 - Run 13-1, vane length = 5.0', R_g=1, Placement angle = 30°

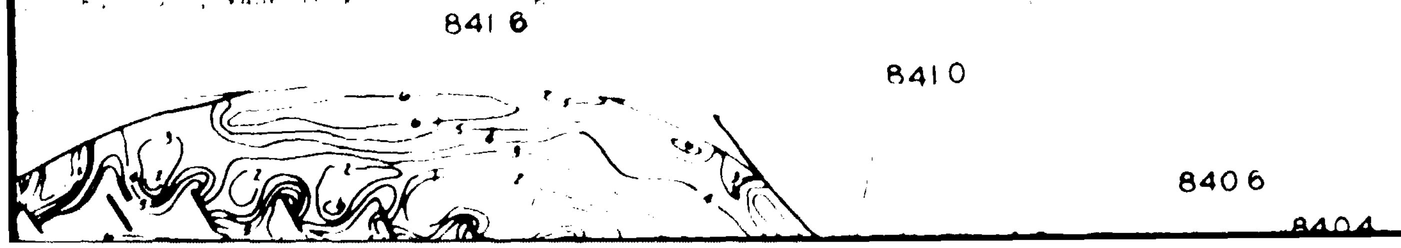




ure 1 - Bed Contour Map, Run 24, totally revetted along
cave side.



[illegible] vane length [illegible] placement angle [illegible]



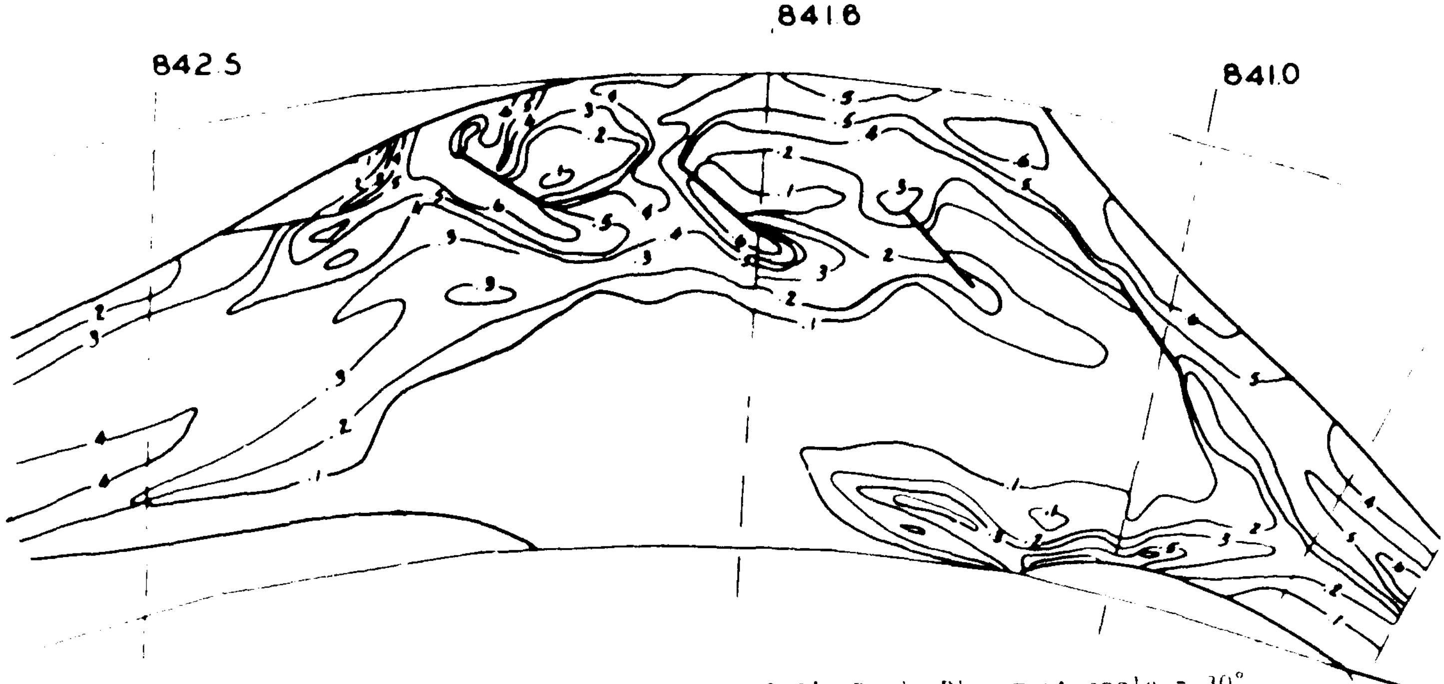


Figure 2 - Run 13-1, vane length = 5.0', R_g=1, Placement angle = 30°

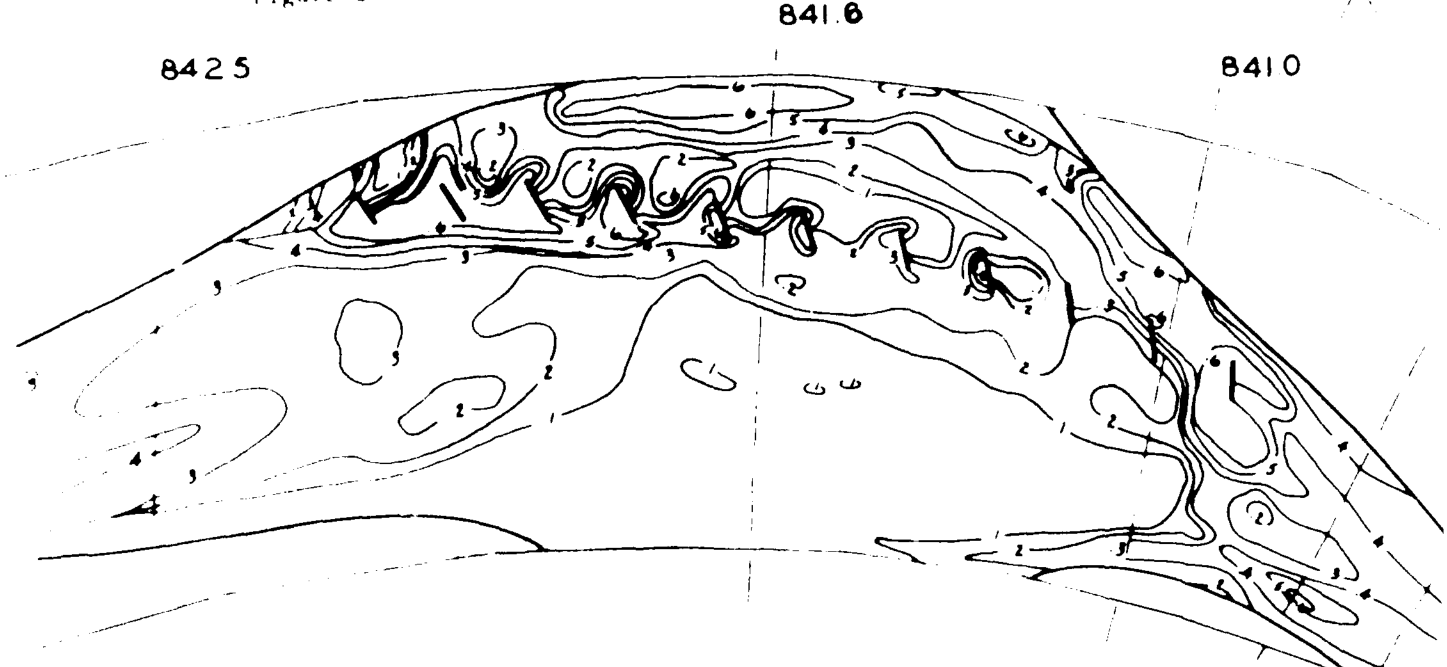


Figure 3 - Run 2[illegible], vane length = 2.0', R_g=1.5, Placement angle = 60

NOTE: NUMBERS ALONG CONT
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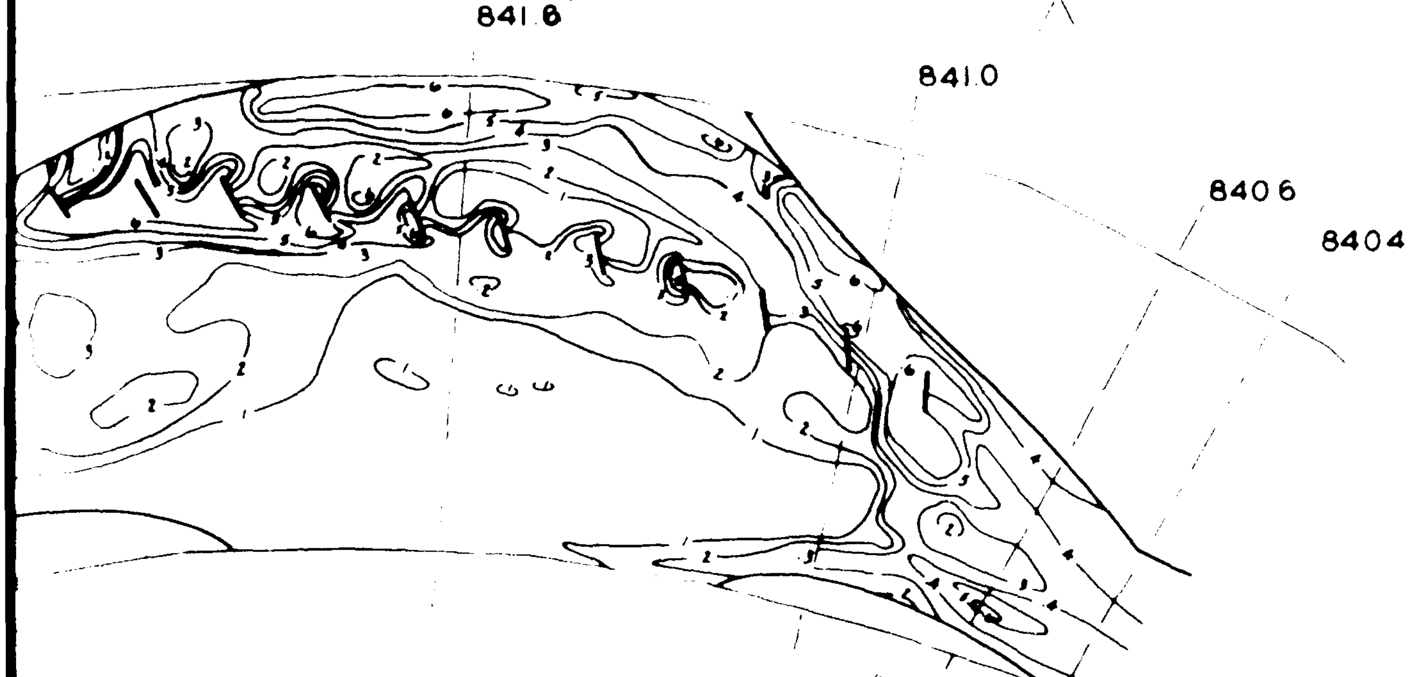
... 2 - Run 13-1, vane length = 5.0', R_g=1, Placement angle = 30°



... Run 2..., vane length = 2.0', R_g=1.5, Placement angle = 60°

NOTE: NUMBERS ALONG CONTOURS ARE WATER DEPTHS IN TENTHS OF FEET

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MISSOURI RIVER DESIGN STUDY

VANE DIKE STUDY

BED CONTOUR MAPS

U.S. ARMY ENGINEER DISTRICT, OMAHA

CORPS OF ENGINEERS

OMAHA, NEBRASKA

PLATE 5

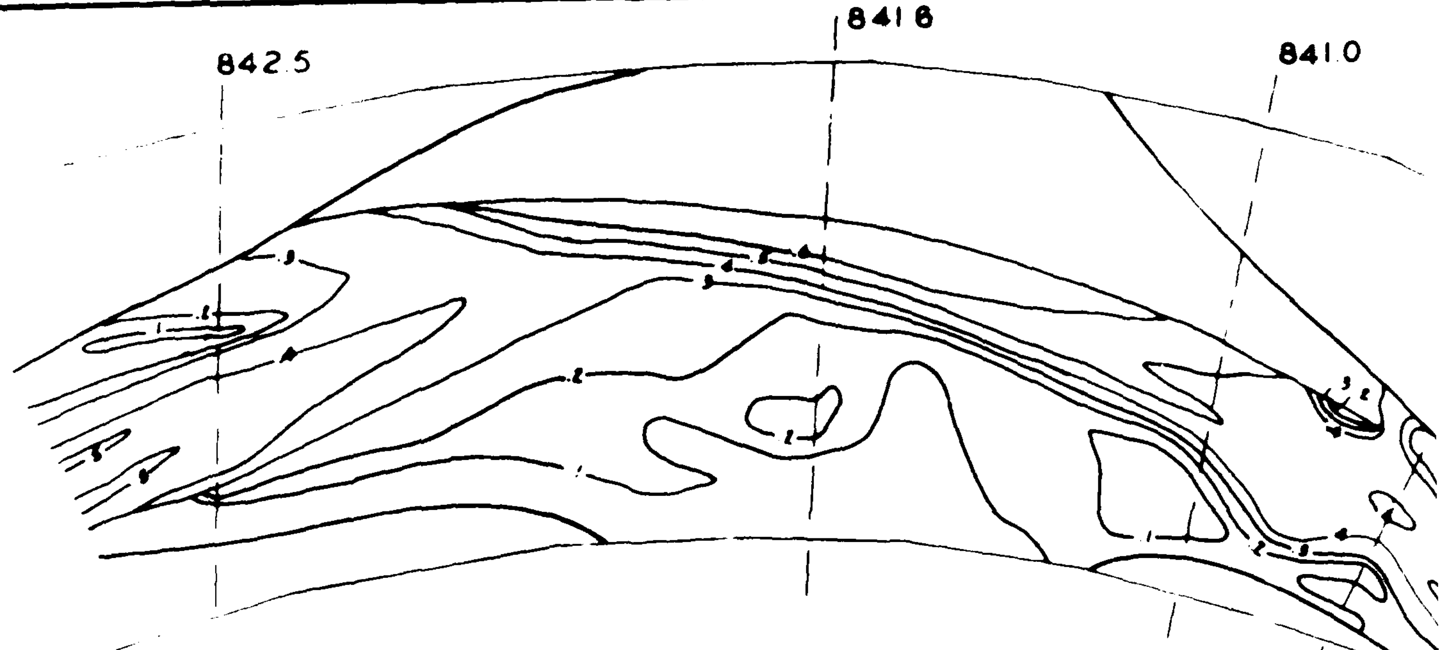


Figure 1 - Bed Contour Map, Run 24, totally revetted along concave side.

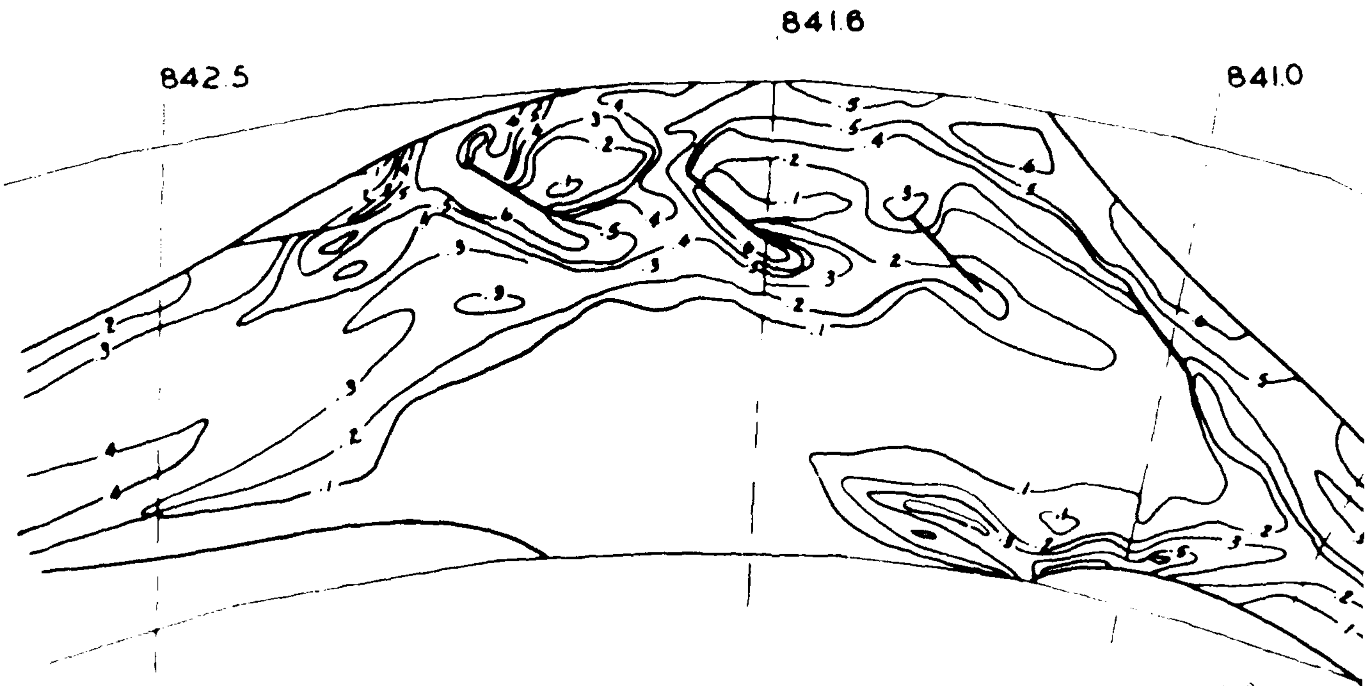
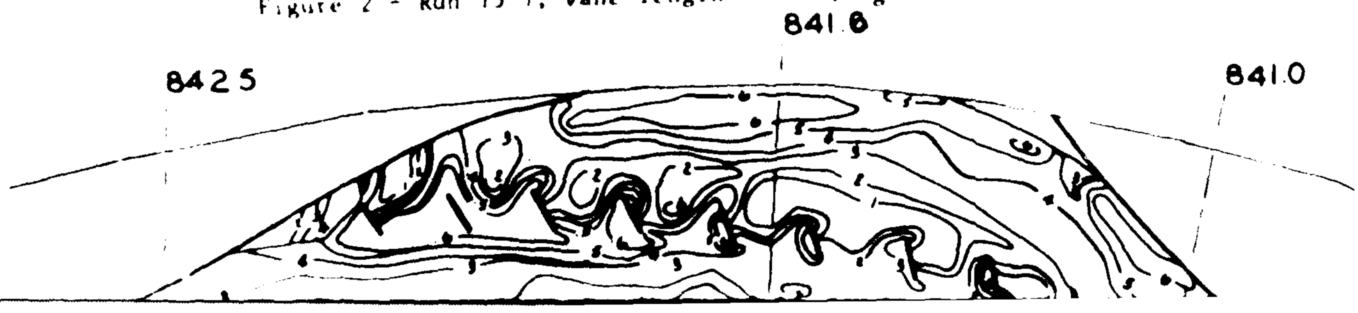


Figure 2 - Run 13-1, vane length = 5.0', Rg=1, Placement angle = 30°



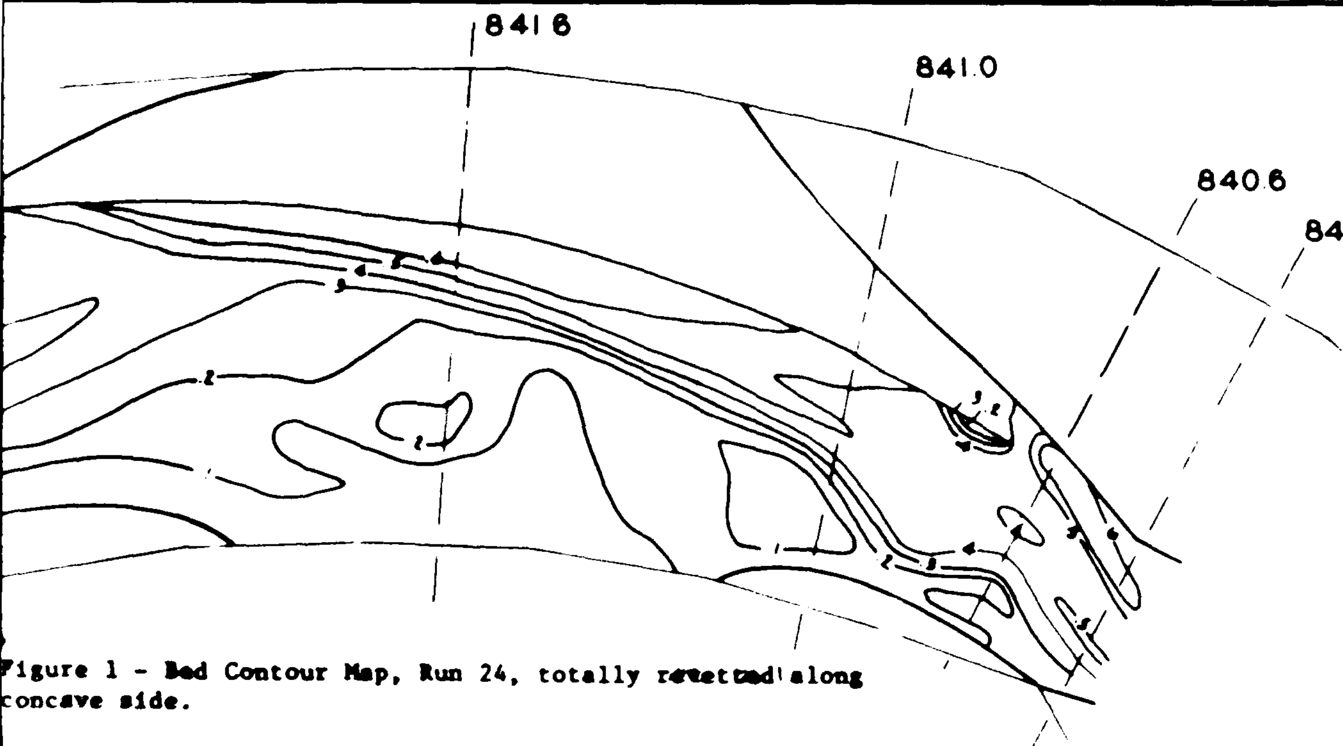
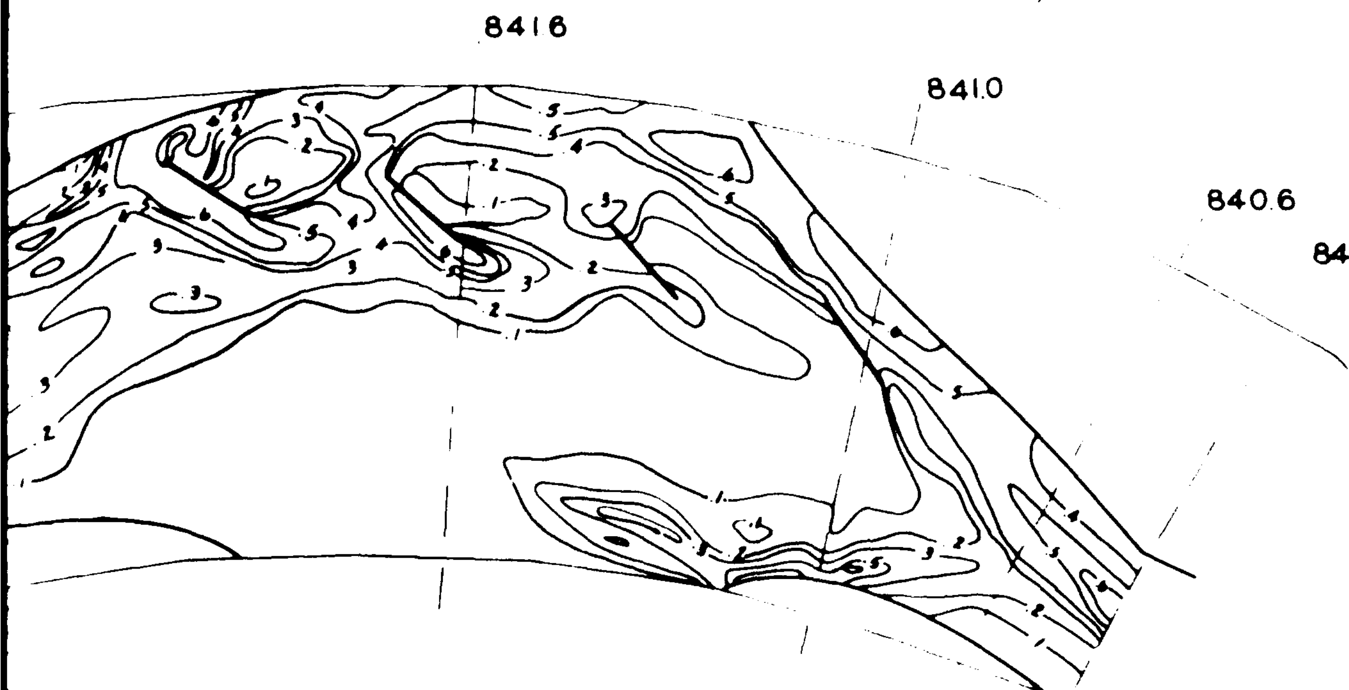


Figure 1 - Bed Contour Map, Run 24, totally revetted along concave side.



re 2 - Run 13-1, vane length = 5.0', R_g=1, Placement angle = 30°

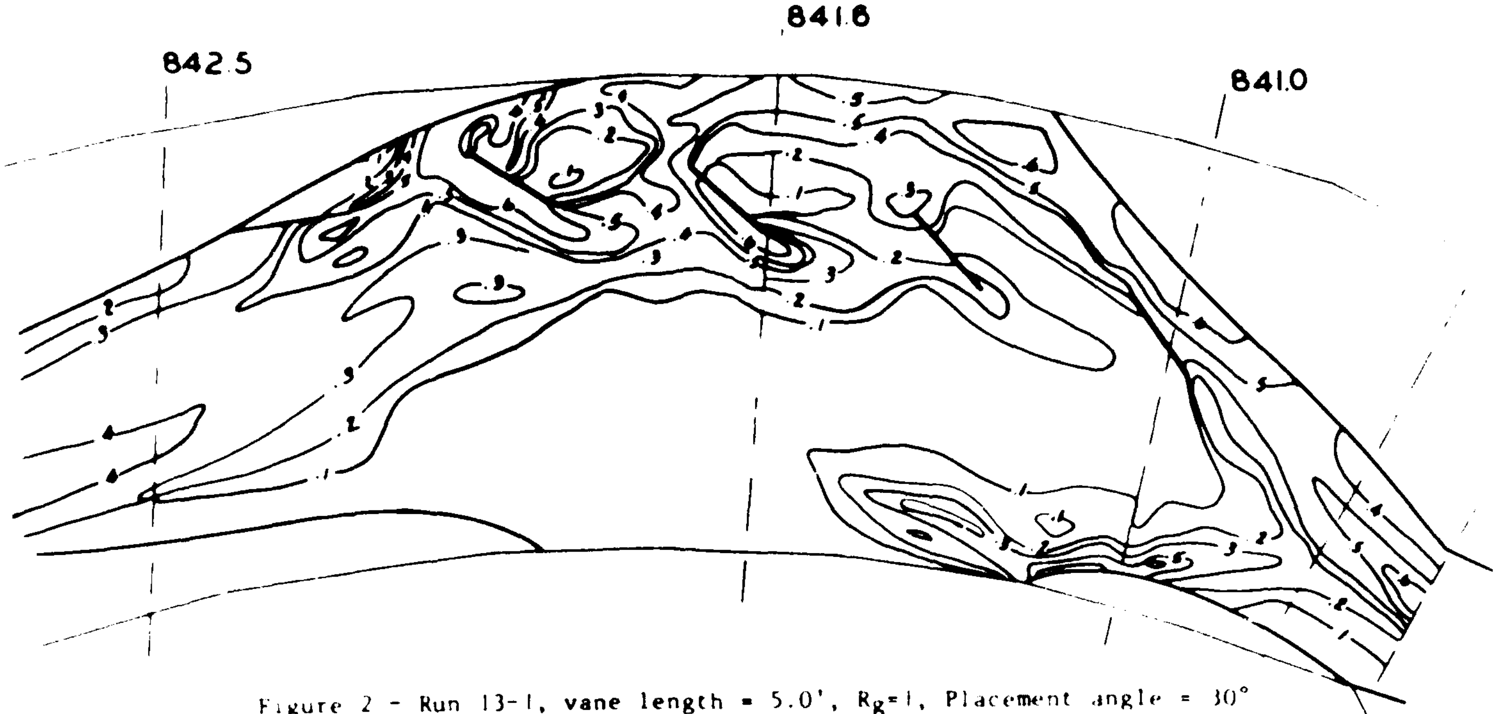


Figure 2 - Run 13-1, vane length = 5.0', R_g=1, Placement angle = 30°

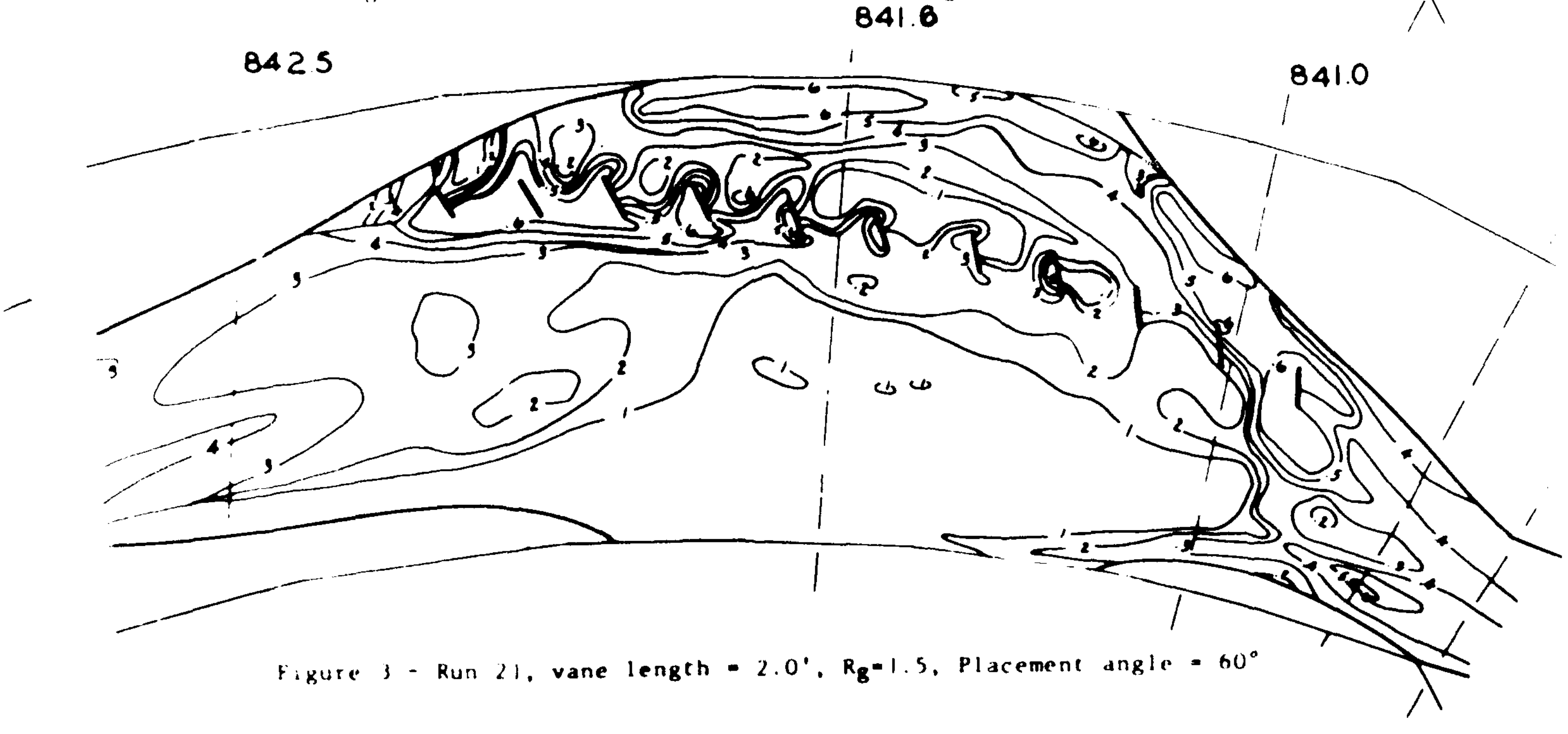


Figure 3 - Run 21, vane length = 2.0', R_g=1.5, Placement angle = 60°

NOTE: NUMBERS ALONG CONTOU
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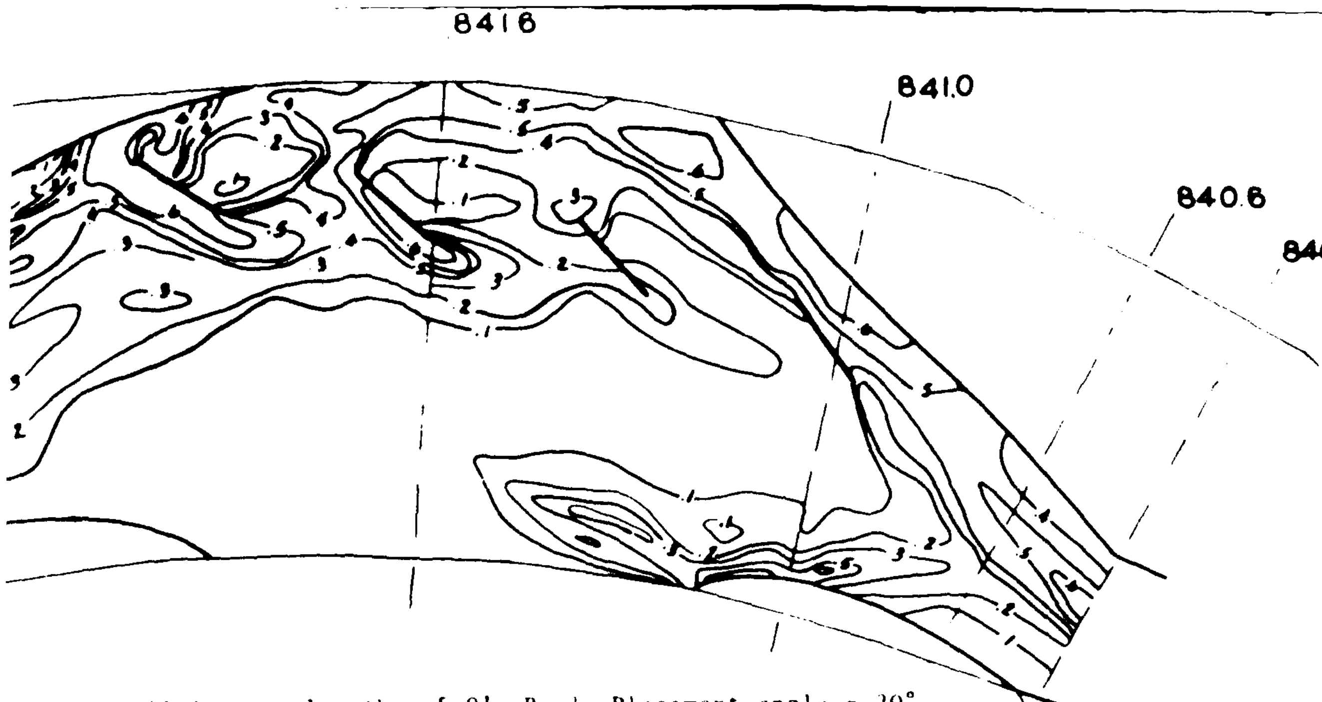
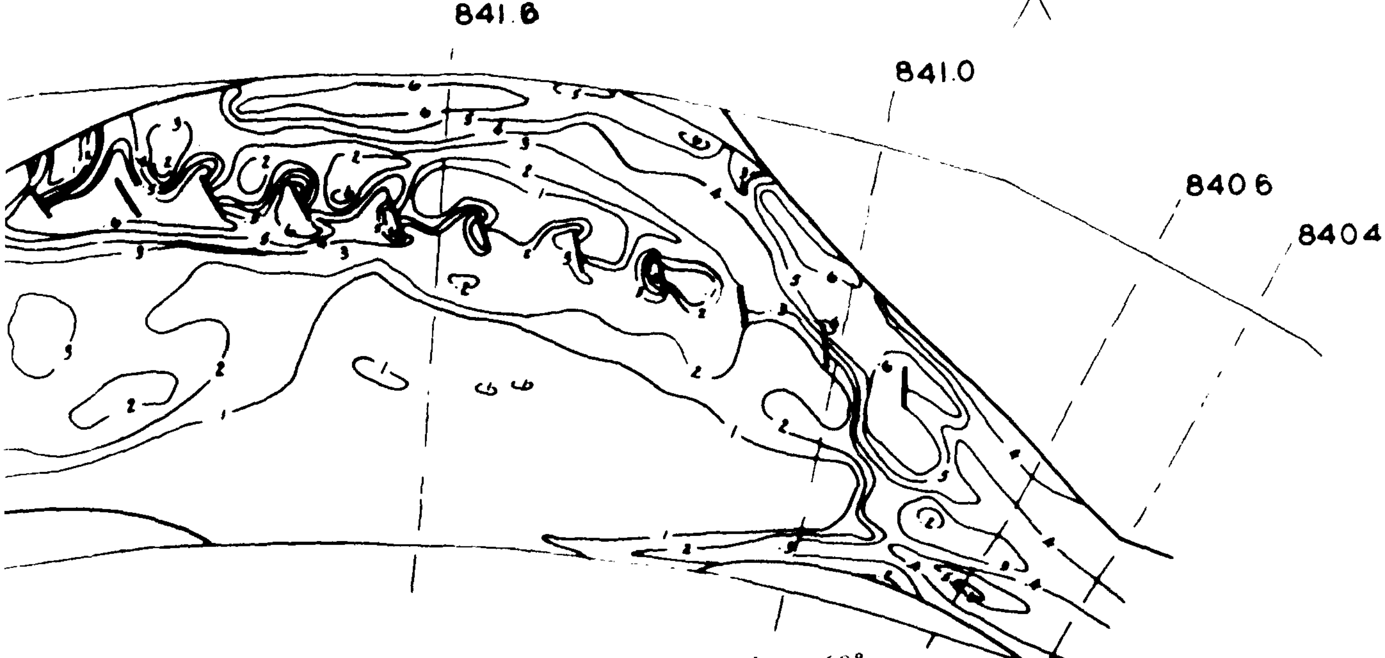


· 2 - Run 13-1, vane length = 5.0', R_g=1, Placement angle = 30°



- Run 21, vane length = 2.0', R_g=1.5, Placement angle = 60°

NOTE: NUMBERS ALONG CONTOURS ARE WATER DEPTHS IN TENTHS OF FEET

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MISSOURI RIVER DESIGN STUDY

VANE DIKE STUDY

BED CONTOUR MAPS

U.S. ARMY ENGINEER DISTRICT, OMAHA

CORPS OF ENGINEERS

OMAHA, NEBRASKA

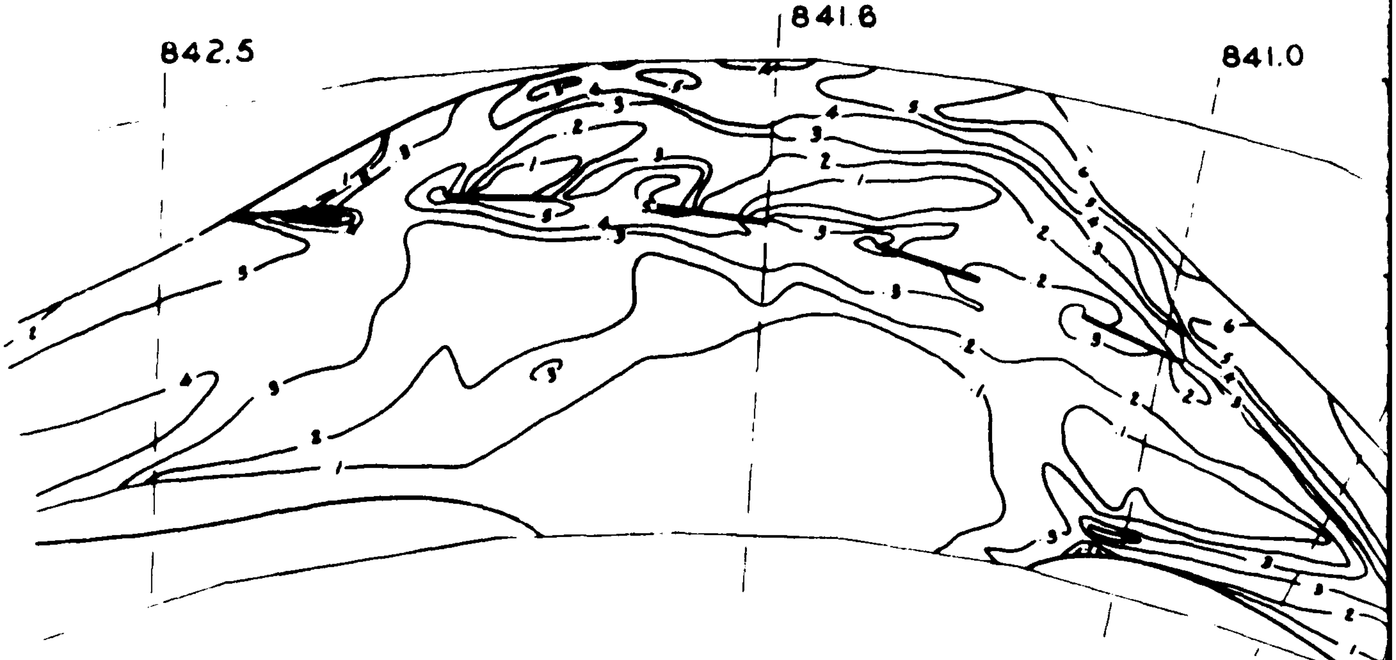


Figure 1 - Run 12, vane length = 5.0', R_g=1, Placement angle = 0°

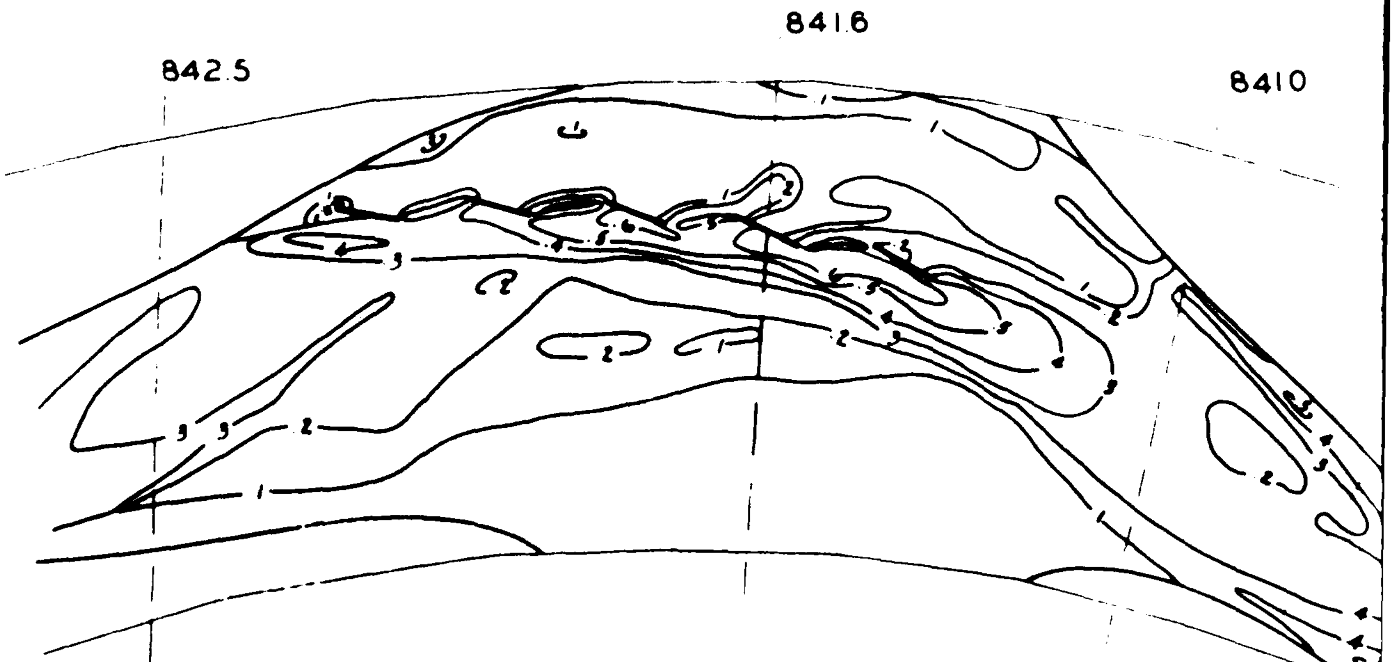
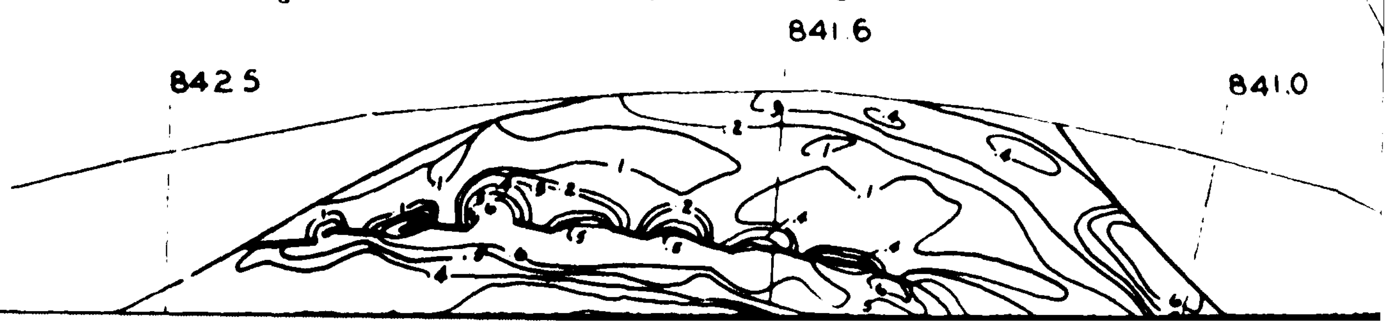
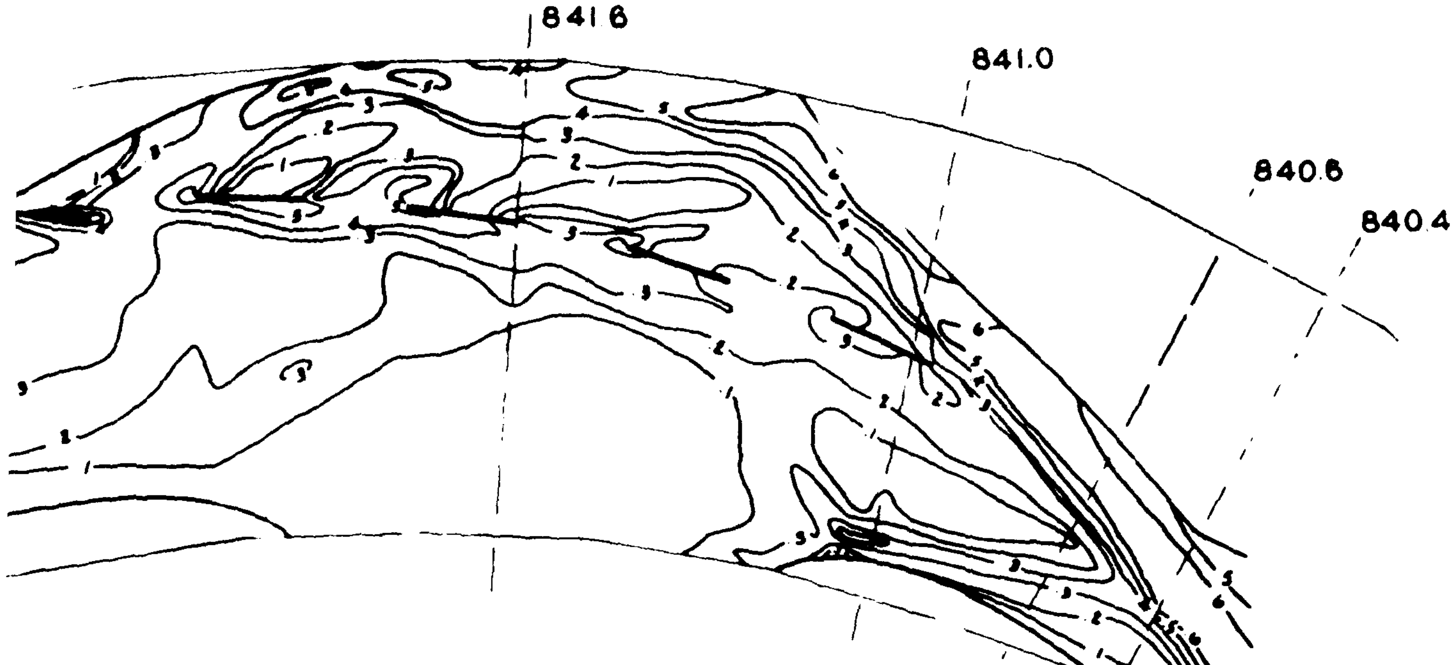
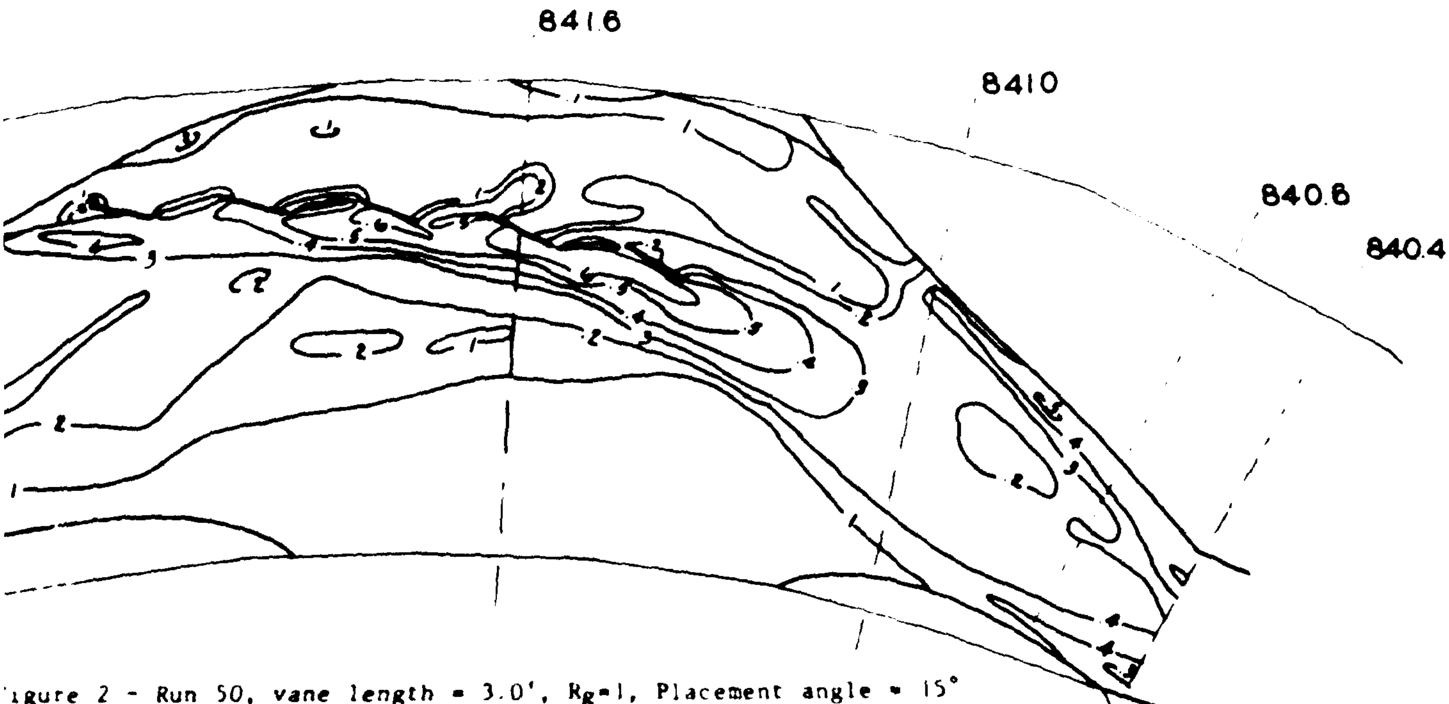


Figure 2 - Run 50, vane length = 3.0', R_g=1, Placement angle = 15°

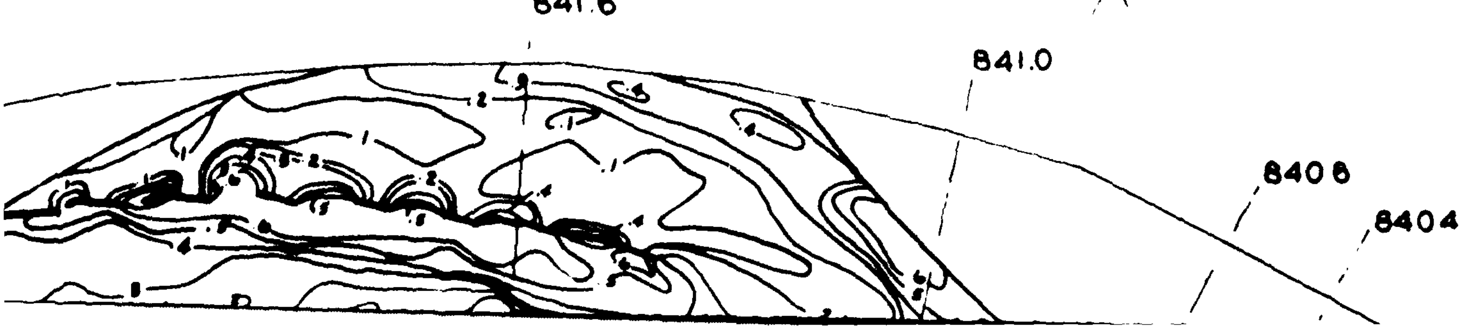




gure 1 - Run 12, vane length = 5.0', R_g=1, Placement angle = 0°



igure 2 - Run 50, vane length = 3.0', R_g=1, Placement angle = 15°



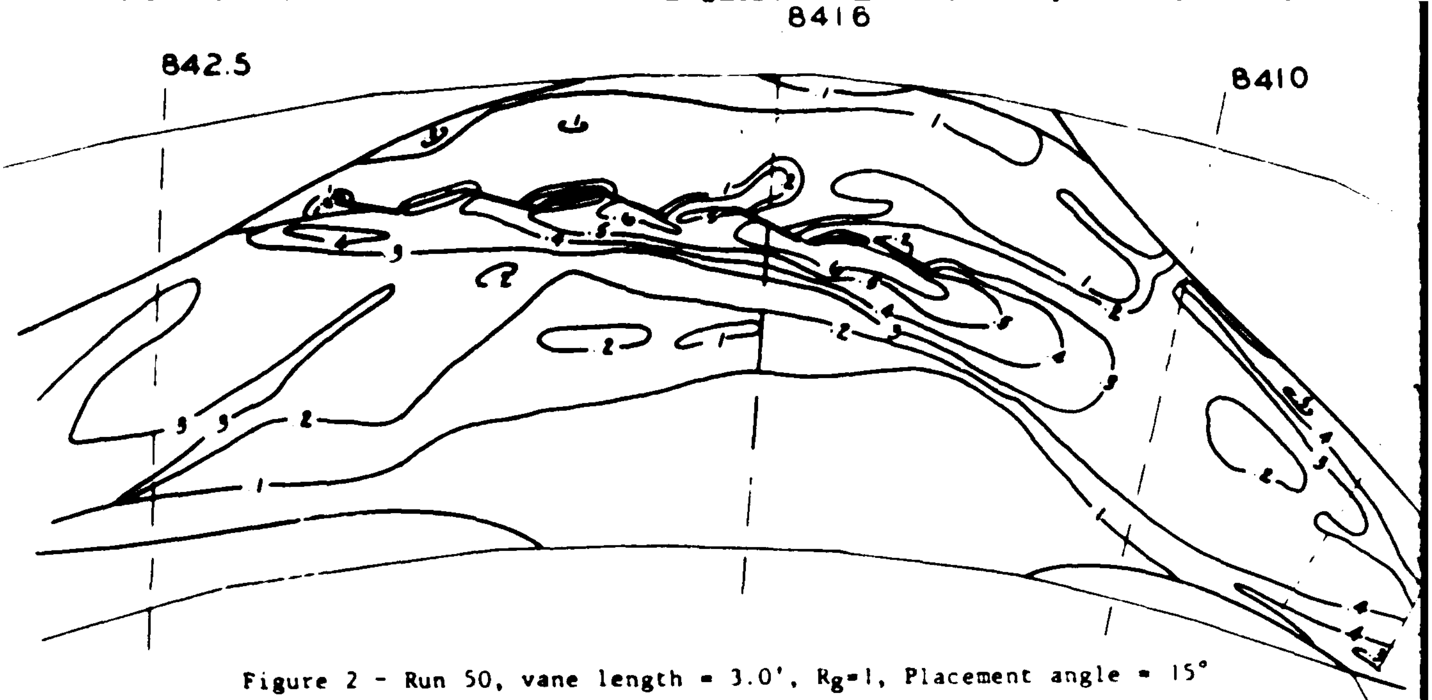


Figure 2 - Run 50, vane length = 3.0', Rg=1, Placement angle = 15°

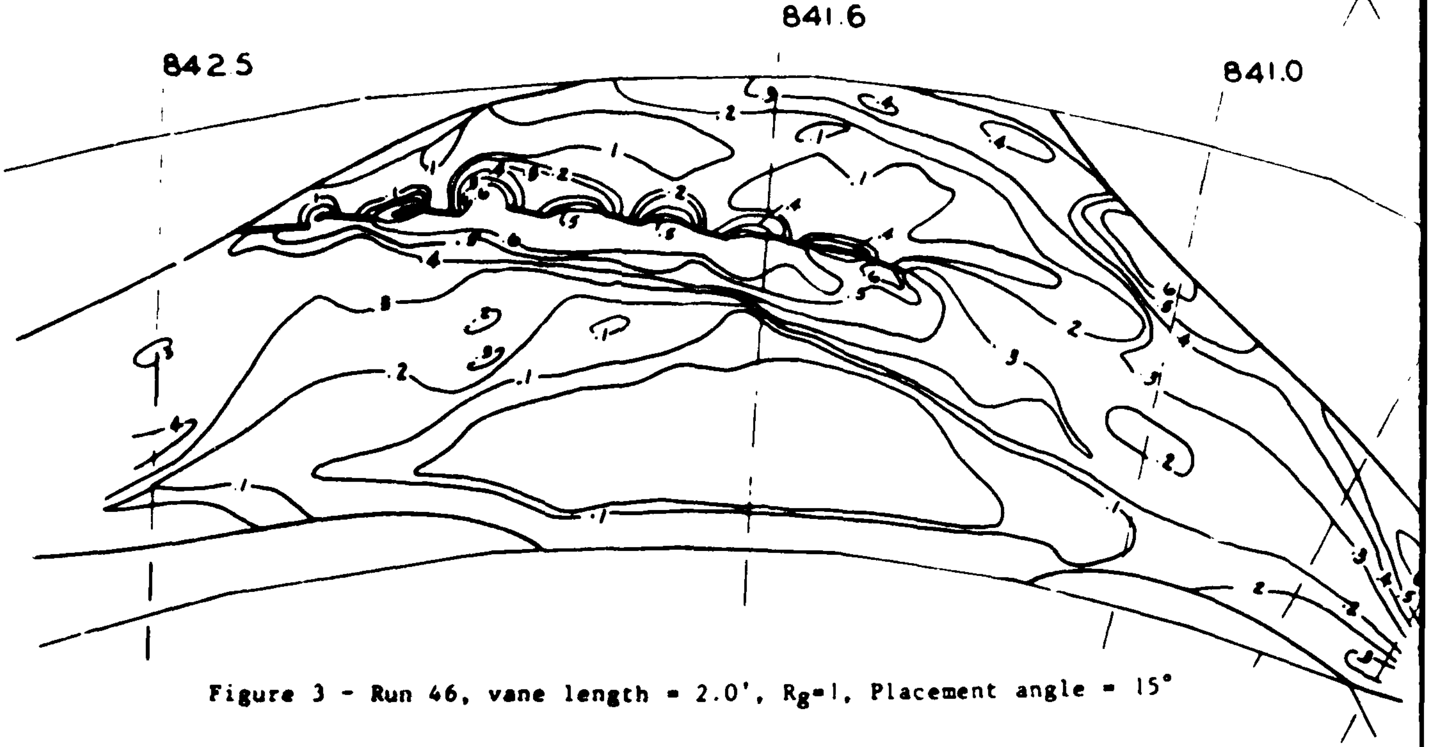


Figure 3 - Run 46, vane length = 2.0', Rg=1, Placement angle = 15°

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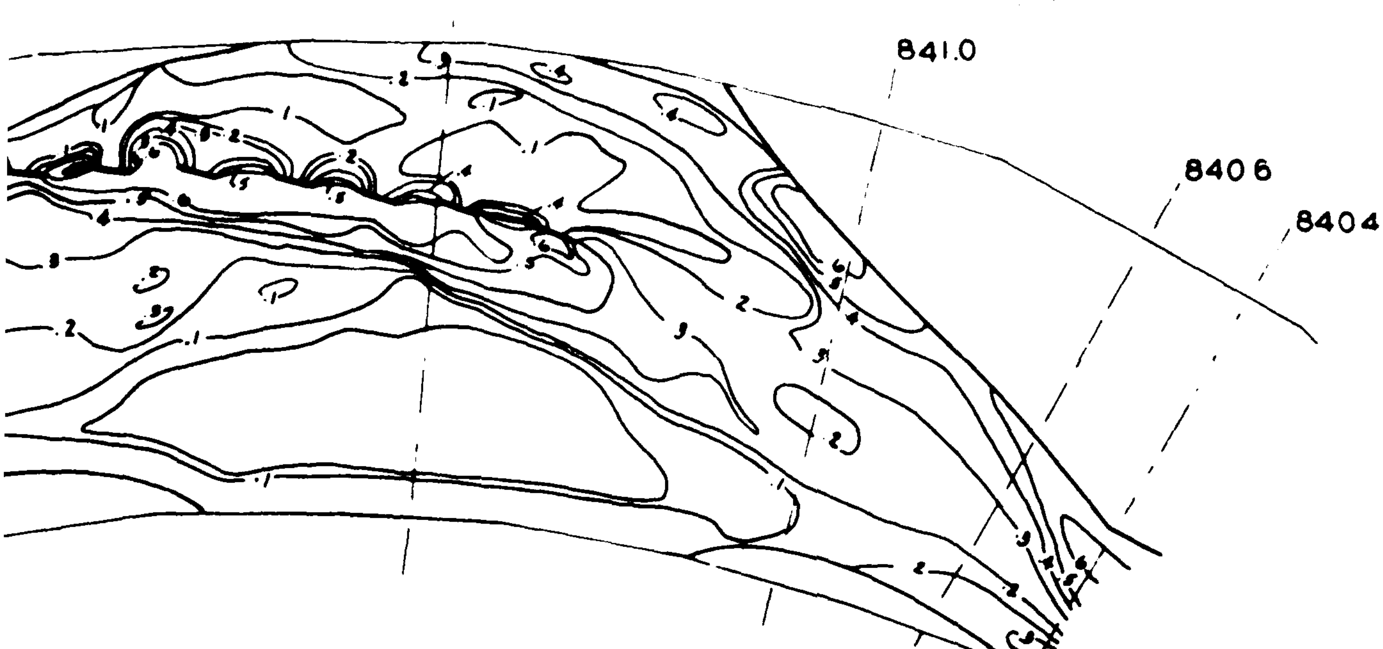
2 - Run 50, vane length = 3.0', Rg=1, Placement angle = 15°



- Run 46, vane length = 2.0', Rg=1, Placement angle = 15°

NOTE: NUMBERS ALONG CONTOURS ARE WATER DEPTHS IN TENTHS OF FEET

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MISSOURI RIVER DESIGN STUDY

VANE DIKE STUDY

BED CONTOUR MAPS

U.S. ARMY ENGINEER DISTRICT, OMAHA

CORPS OF ENGINEERS

OMAHA, NEBRASKA

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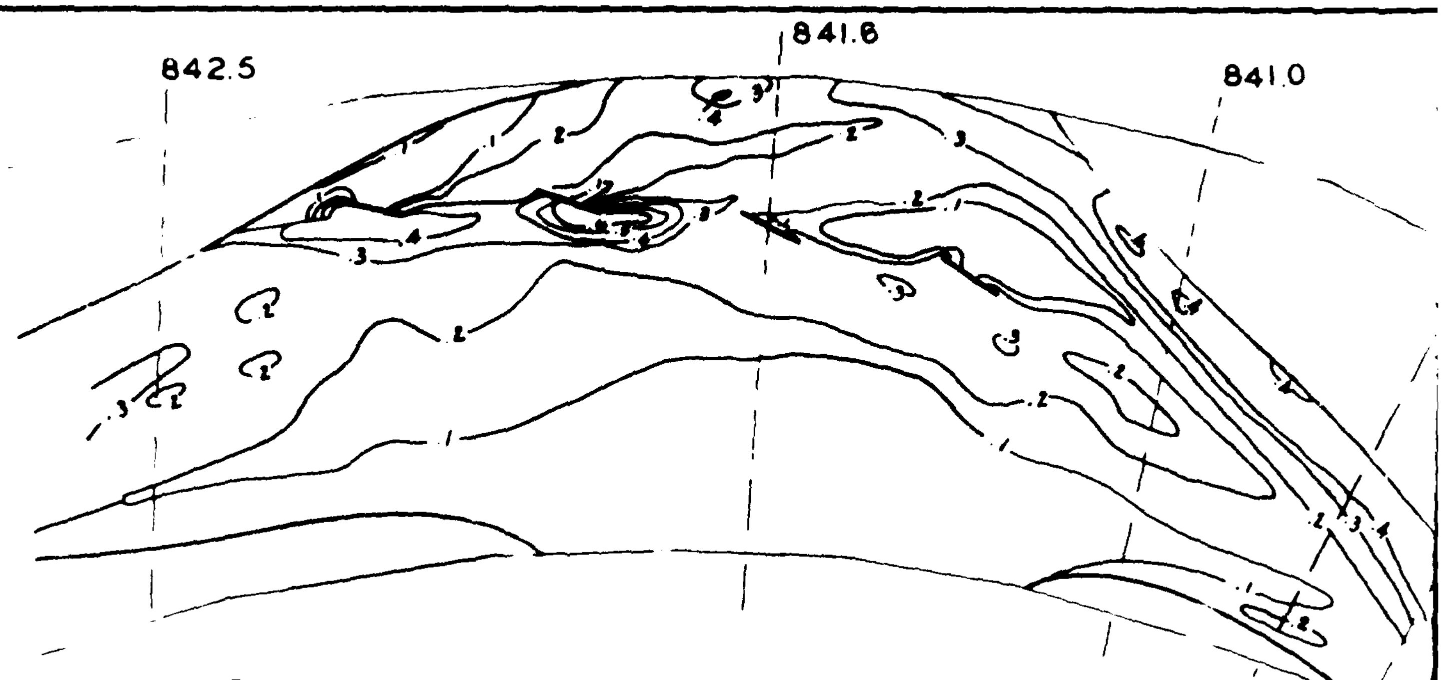


Figure 1 - Run 52, vane length = 3.0', R_g=2, Placement angle = 15°

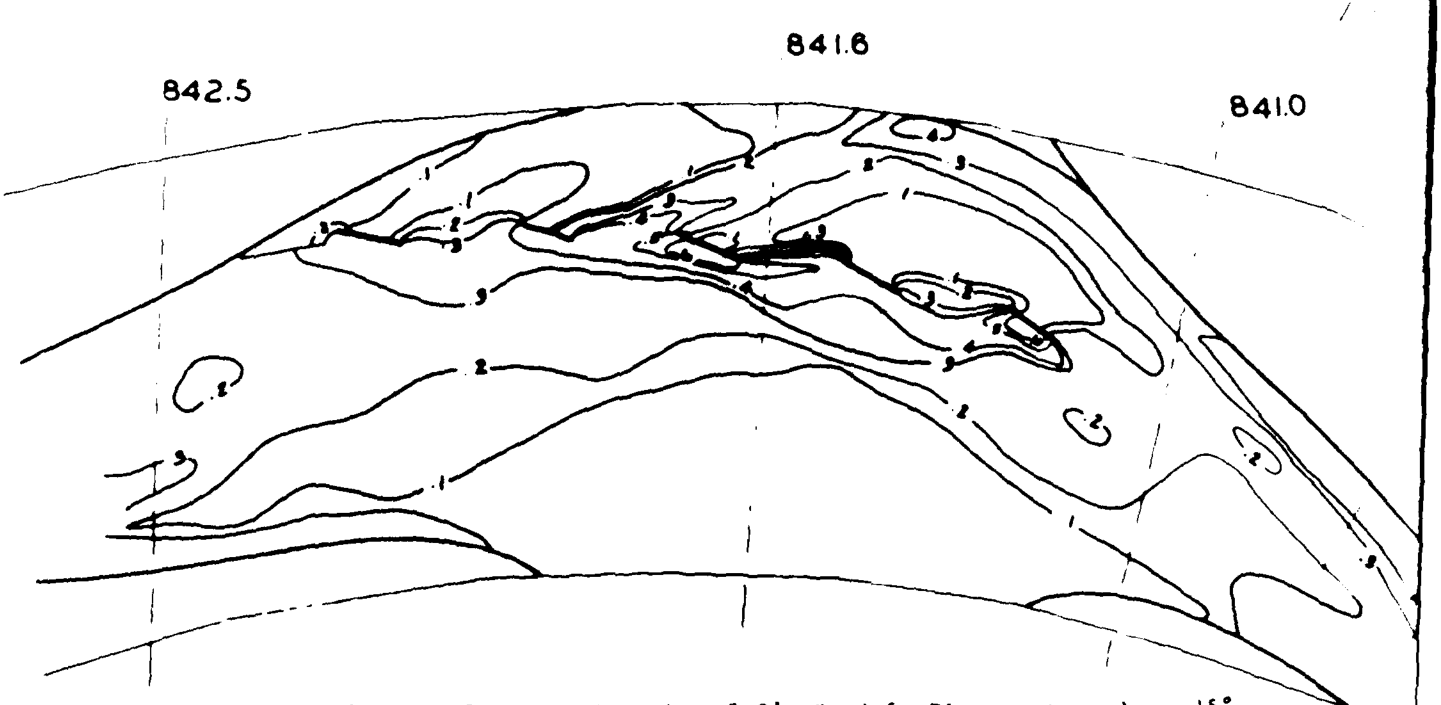
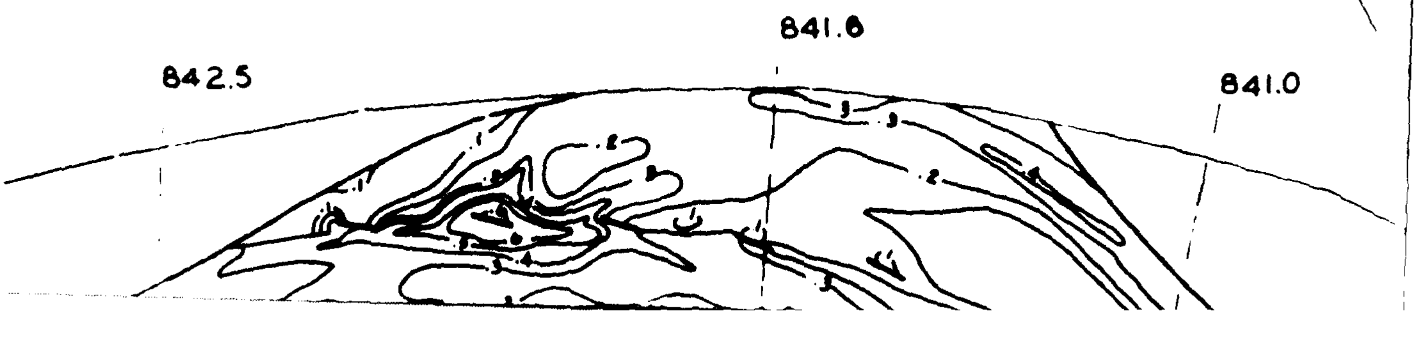
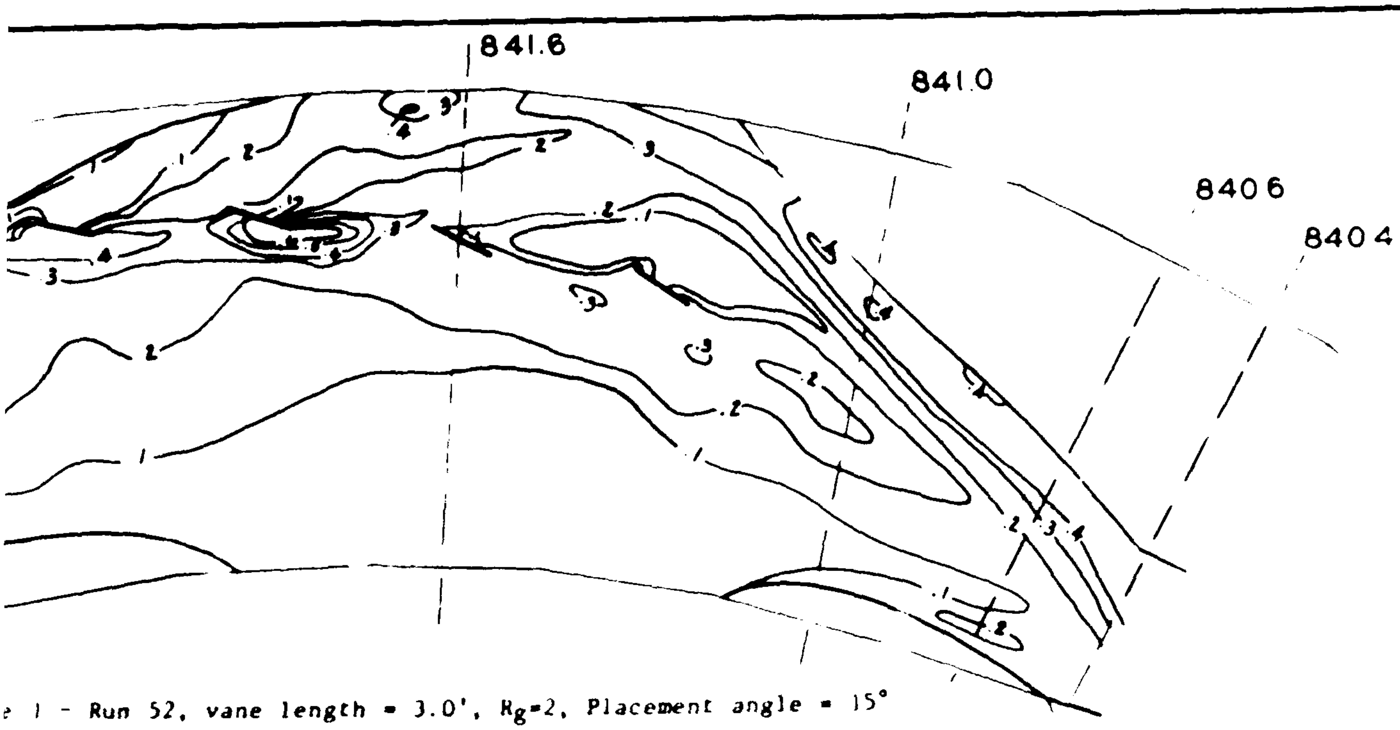
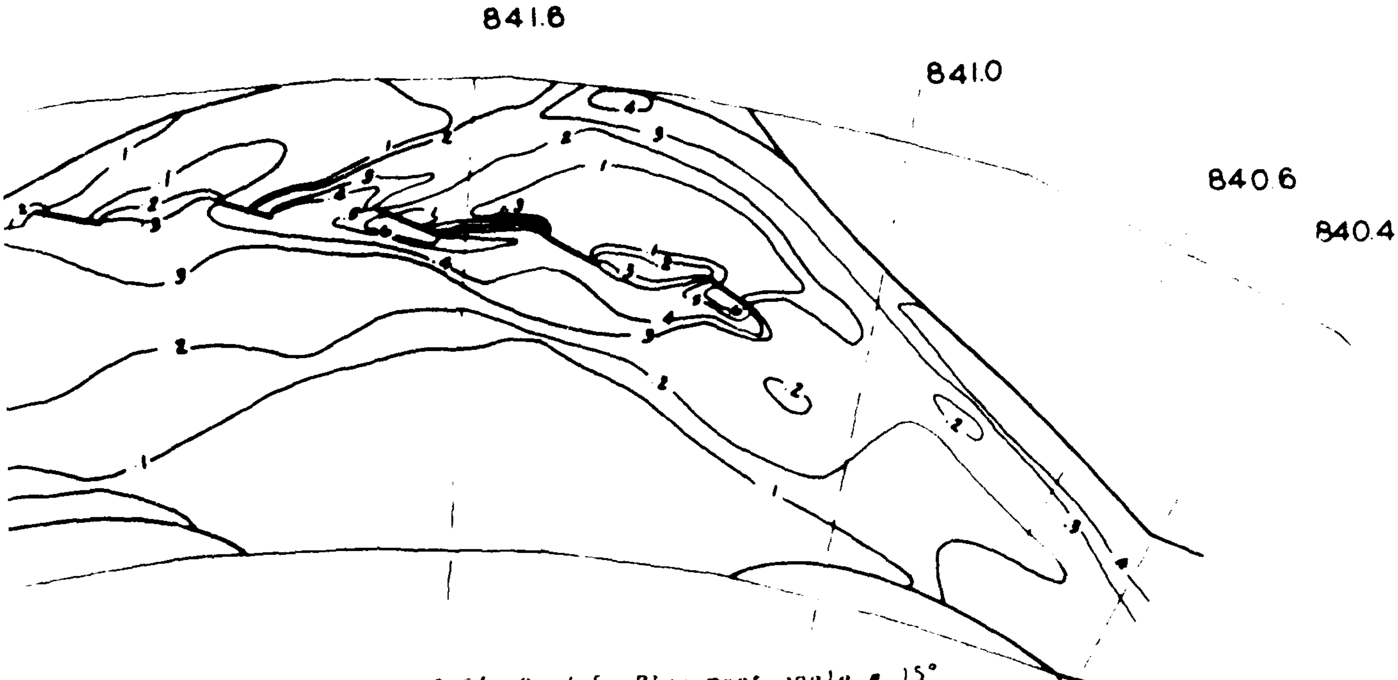


Figure 2 - Run 51, vane length = 3.0', R_g=1.5, Placement angle = 15°

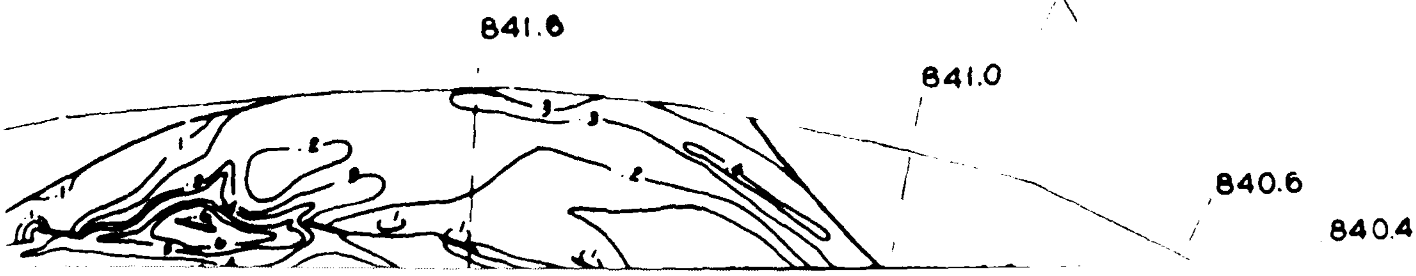




e 1 - Run 52, vane length = 3.0', R_g=2, Placement angle = 15°



re 2 - Run 51, vane length = 3.0', R_g=1.5, Placement angle = 15°



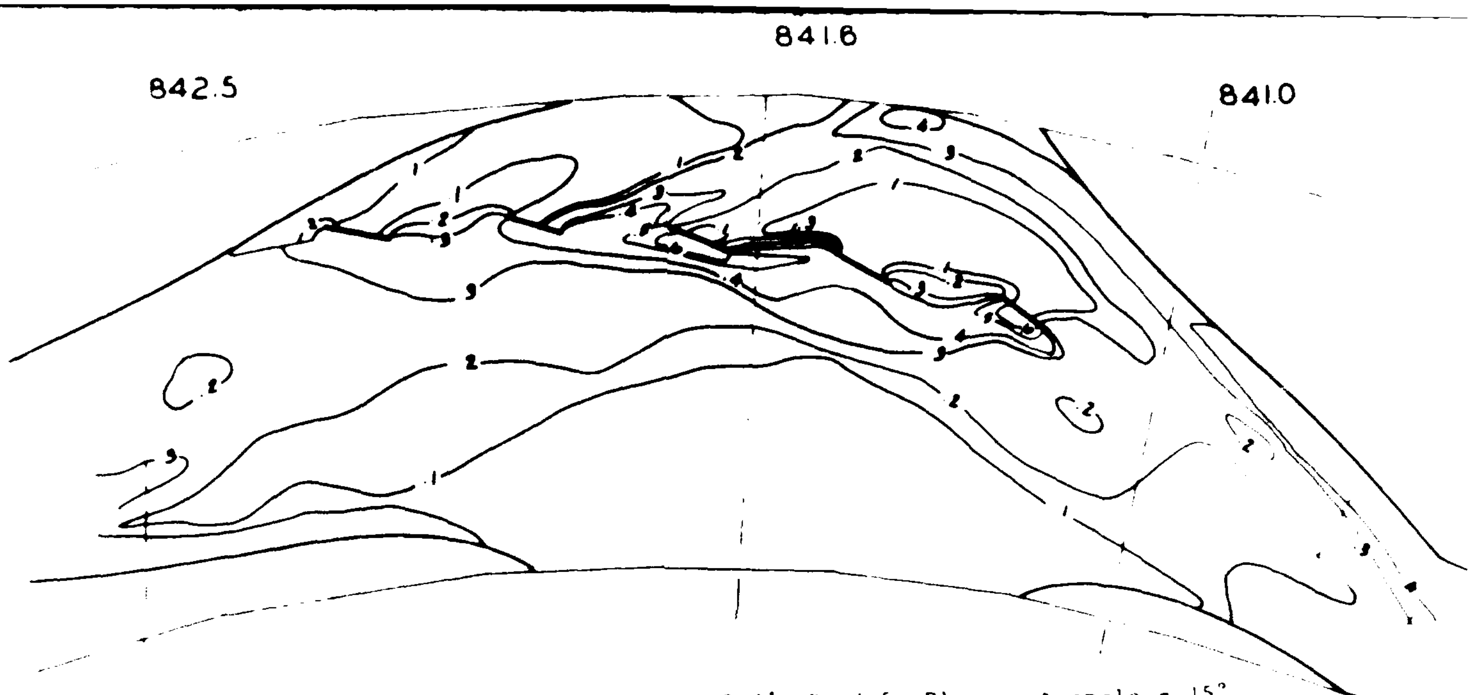


Figure 2 - Run 51, vane length = 3.0', Rg=1.5, Placement angle = 15°

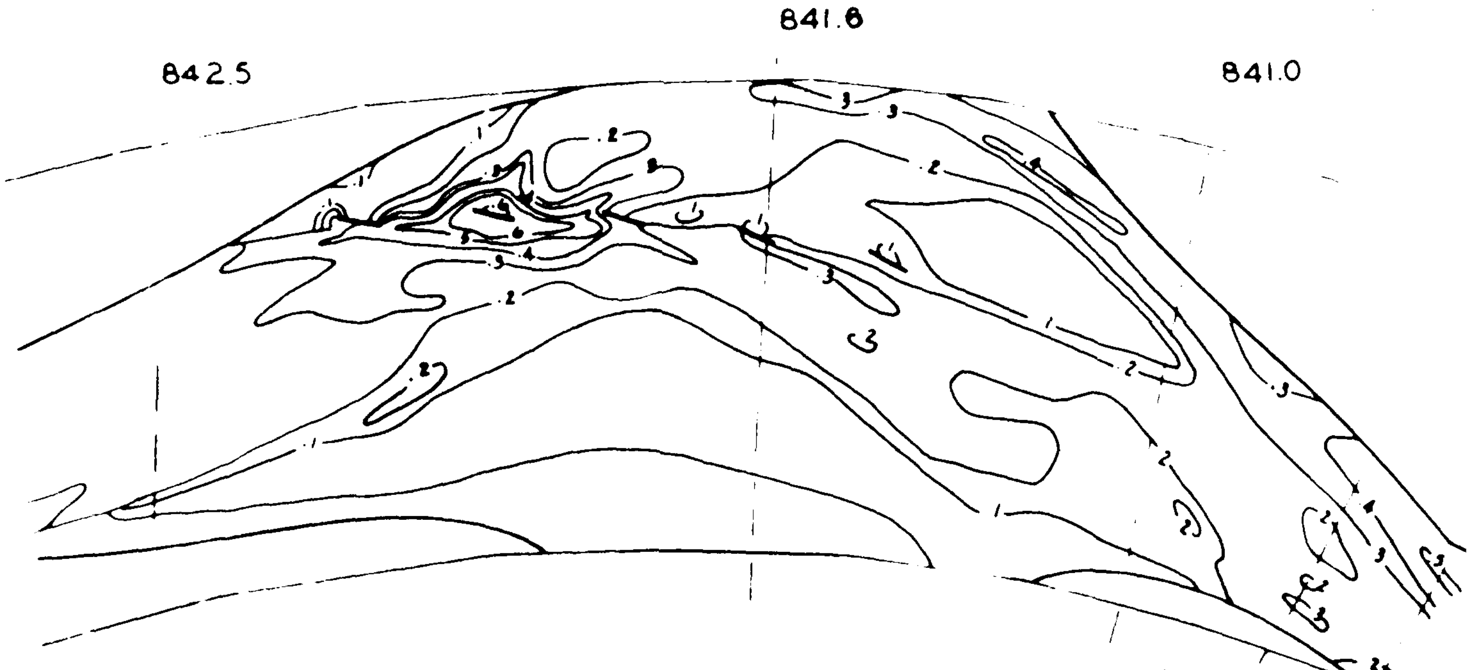


Figure 3 - Run 49, vane length = 2.0', Rg=2, Placement angle = 15°

NOTE: NUMBERS ALONG CONT(
WATER DEPTHS IN TENT

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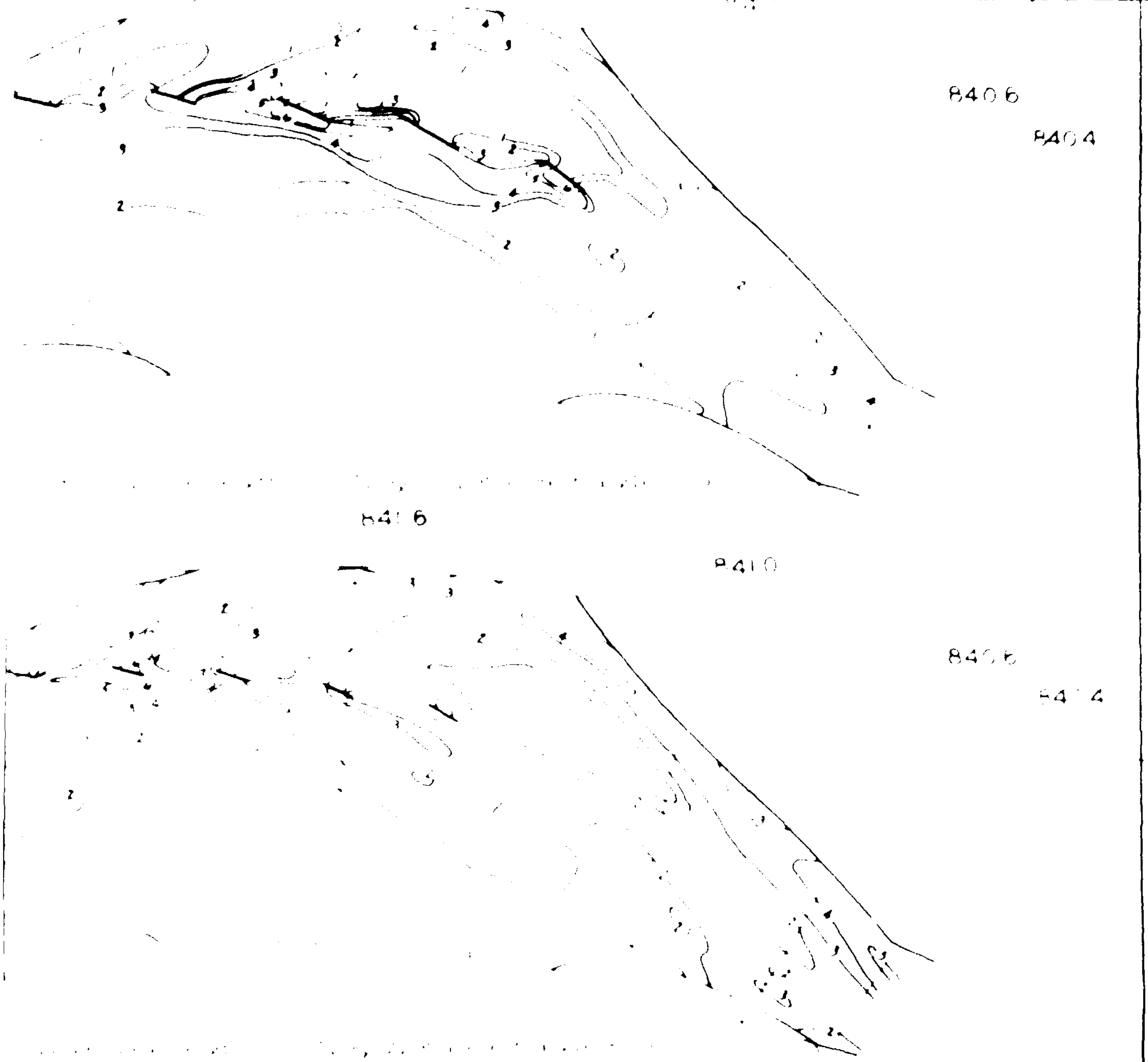


NOTE: NUMBERS ALONG CONTOURS ARE WATER DEPTHS IN TENTHS OF FEET

MISSOURI RIVER DESIGN STUDY

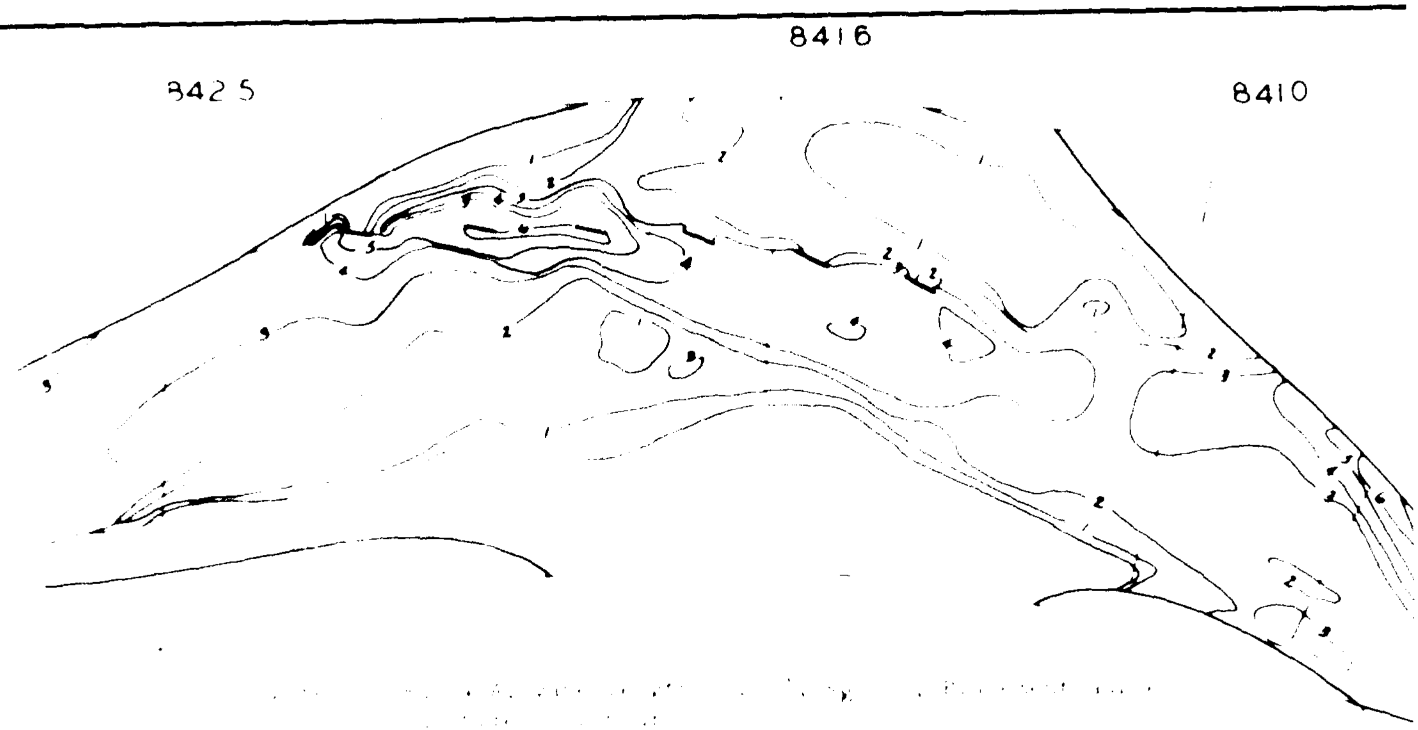
VANE DIKE STUDY

BED CONTOUR MAPS

U.S. ARMY ENGINEER DISTRICT, OMAHA

CORPS OF ENGINEERS

OMAHA, NEBRASKA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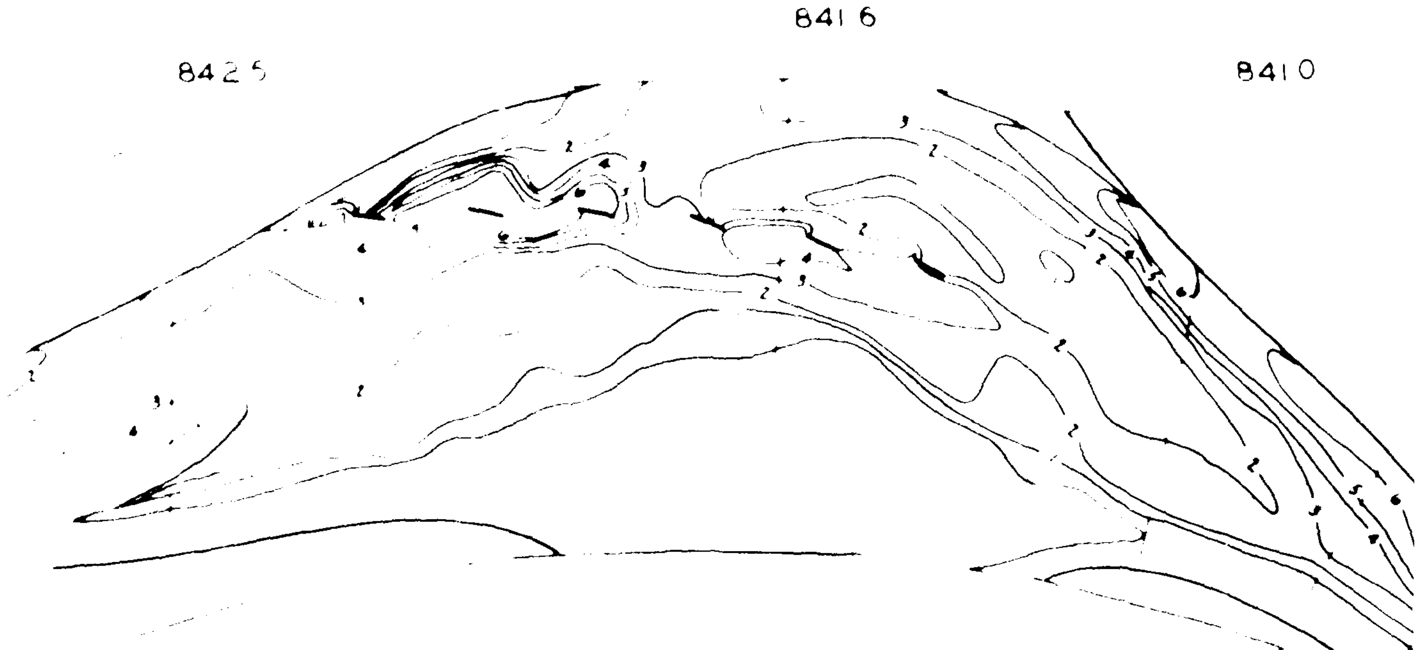
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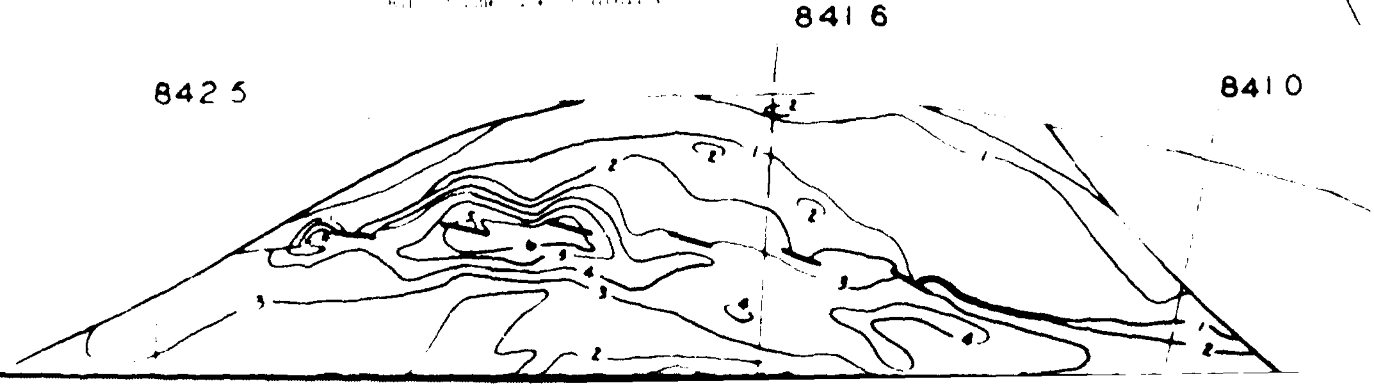
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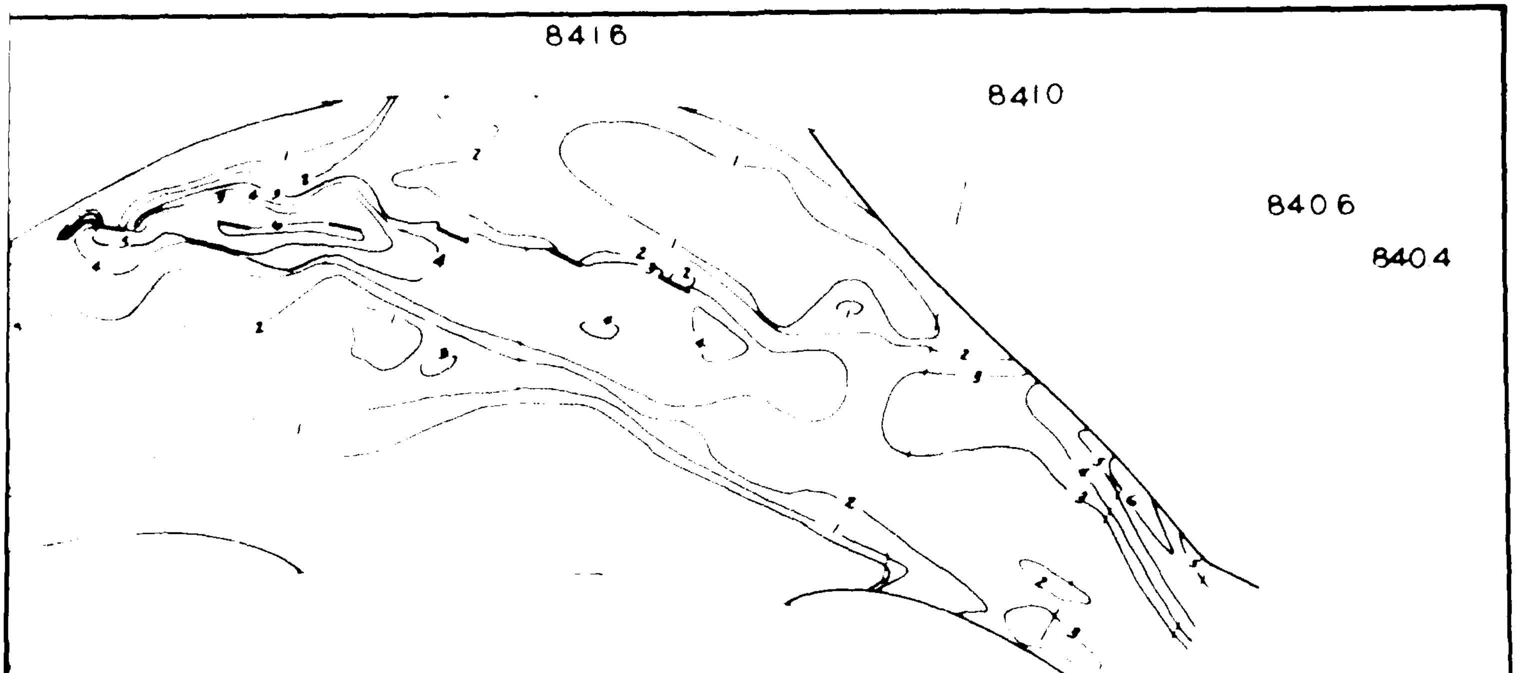
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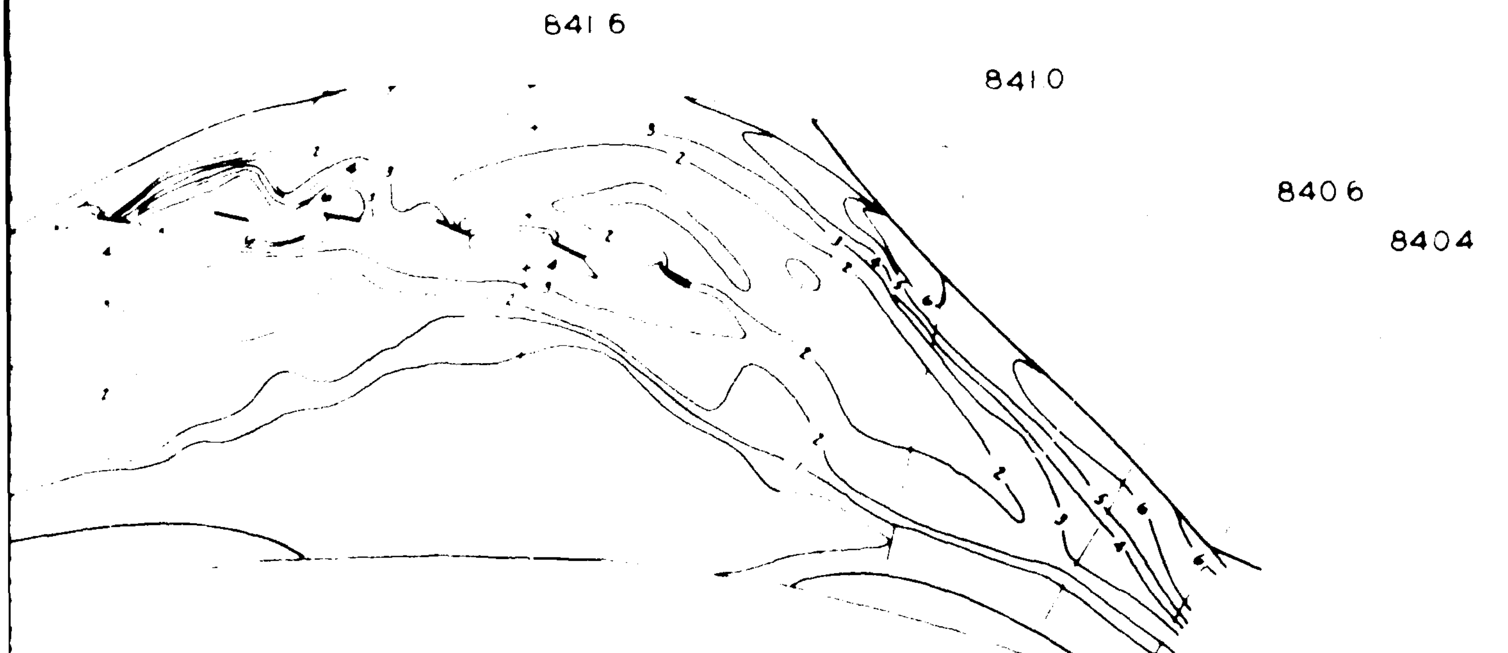
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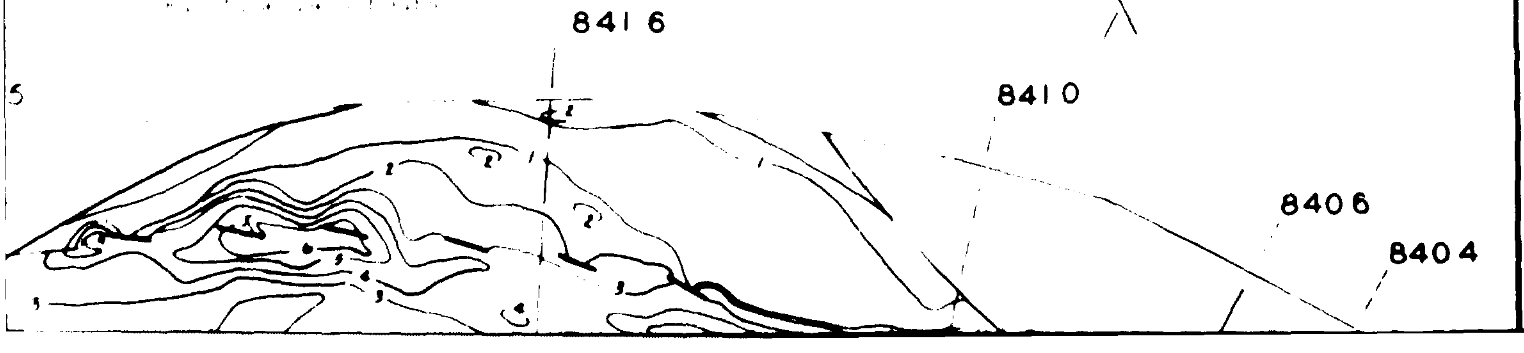
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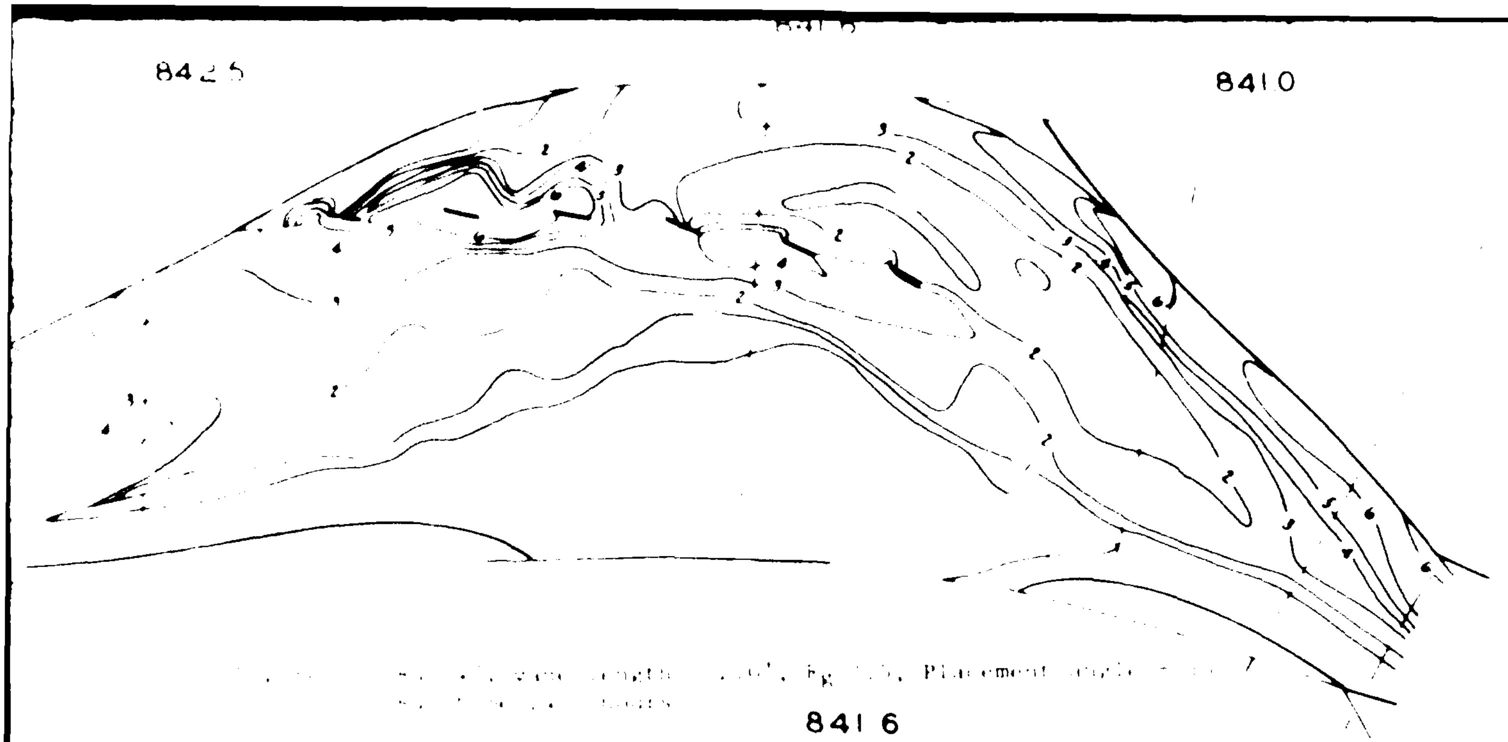
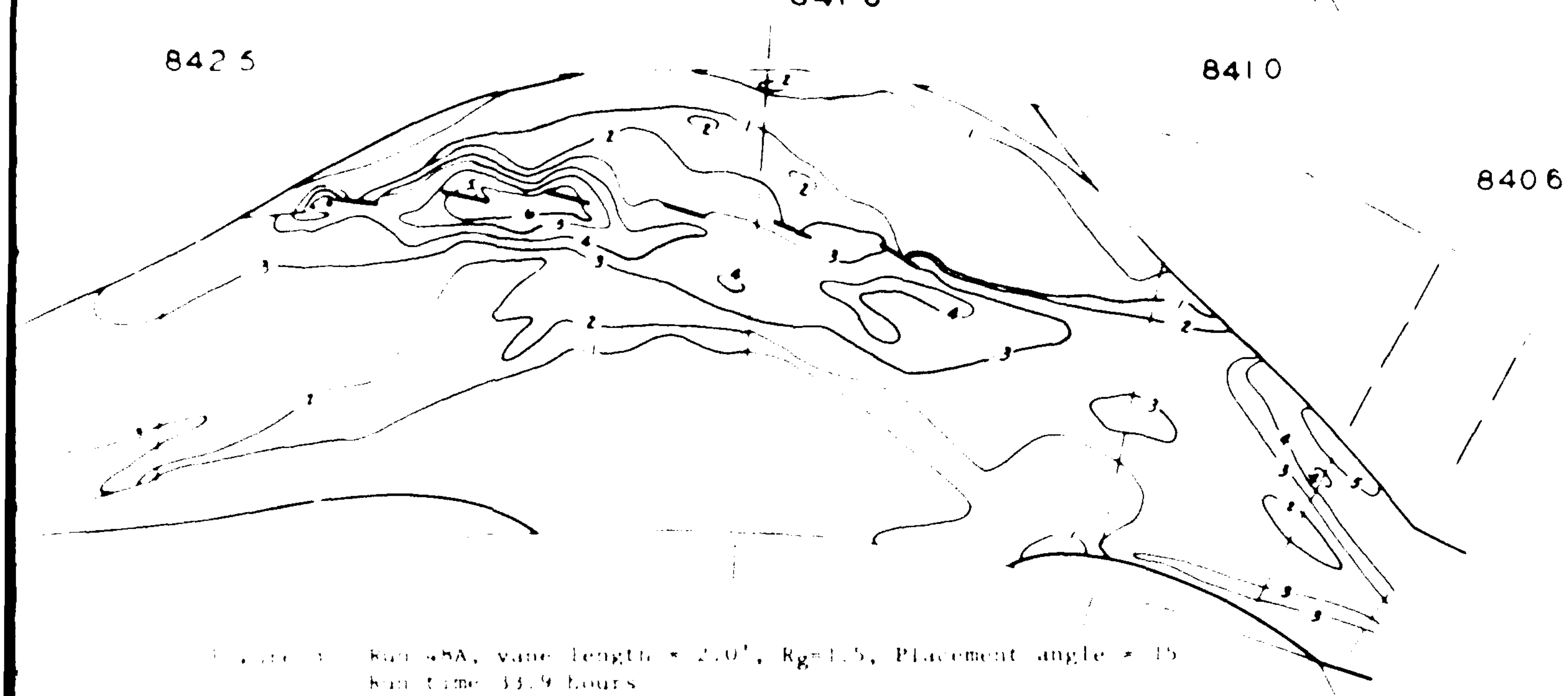


[illegible] vane length [illegible], Rg [illegible], Placement angle [illegible]
[illegible] hours



[illegible] Run [illegible]A, vane length = 2.0', Rg=1.5, Placement angle = 15
Run time 33.9 hours

NOTE: NUMBERS ALONG CONTOURS A[illegible]
WATER DEPTHS IN TENTHS OF [illegible]

MODEL SCALE IN FEET

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CORPS OF ENGINEERS

OMAHA, NEBRASKA

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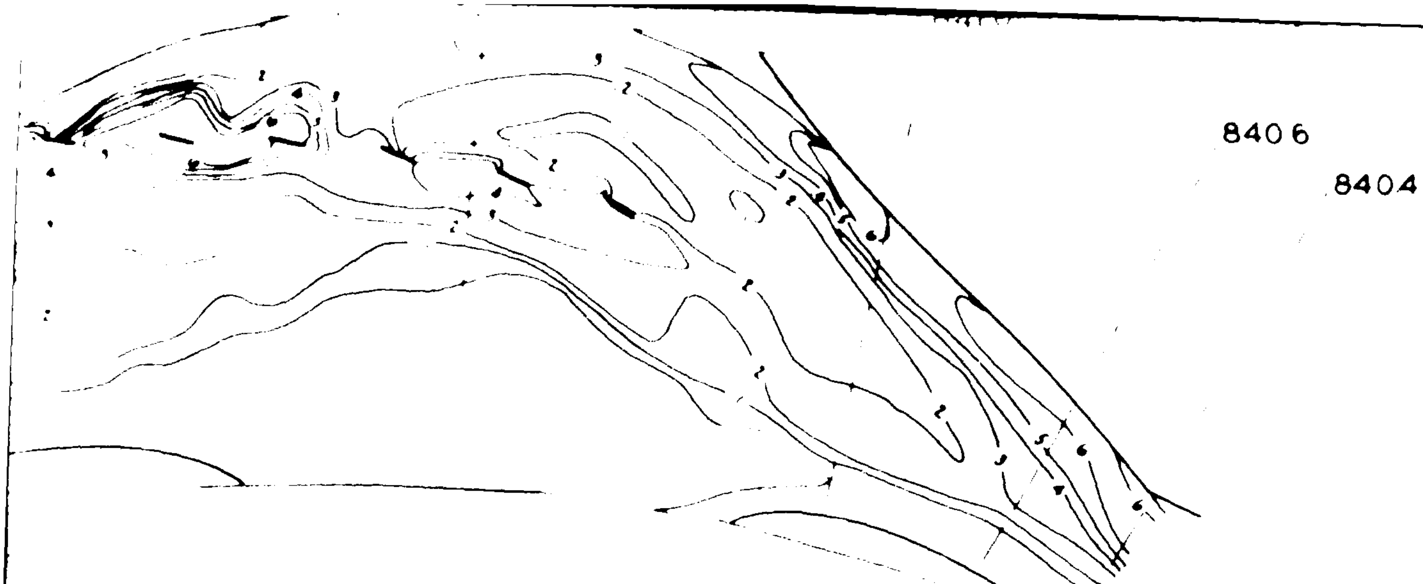
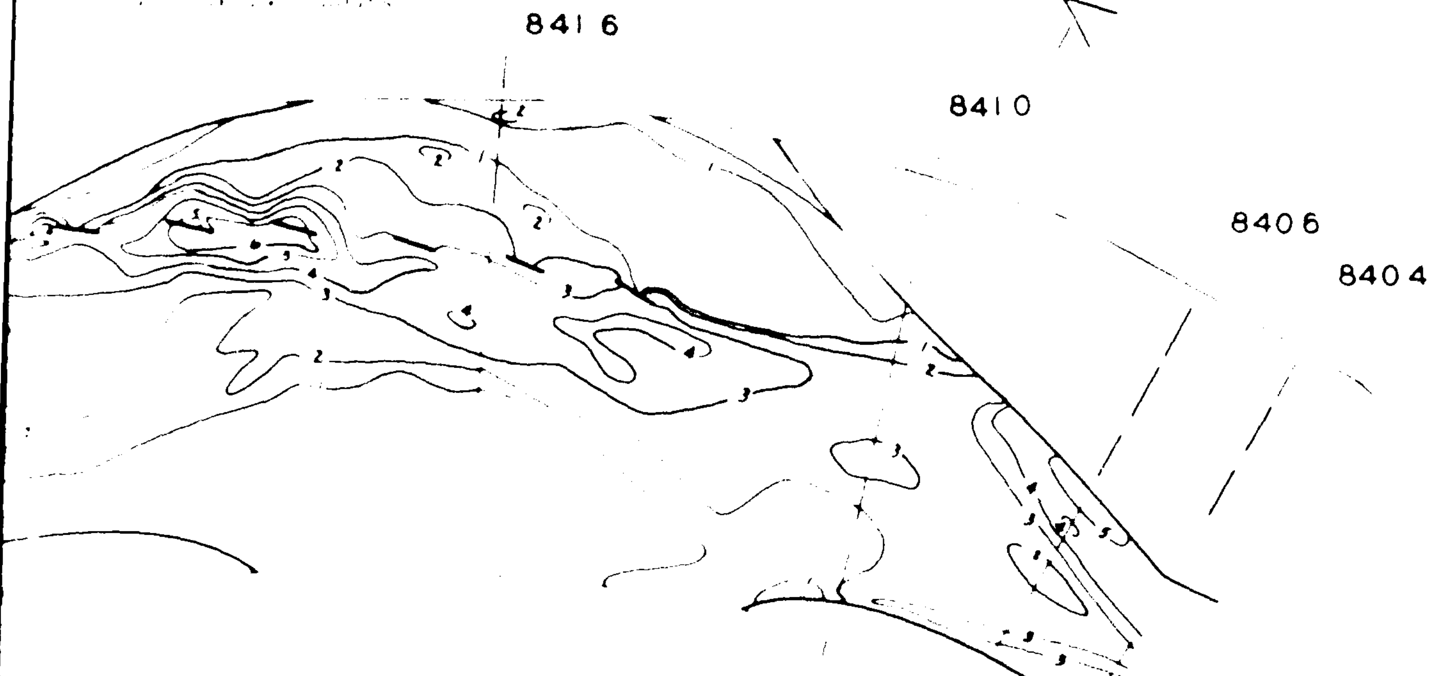


[illegible], E_g [illegible], Placement angle = [illegible]
[illegible]



[illegible], E_g [illegible], Placement angle = 15°
[illegible]

NOTE: NUMBERS ALONG CONTOURS ARE WATER DEPTHS IN TENTHS OF FEET

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MISSOURI RIVER DESIGN STUDY

VANE DIKE STUDY

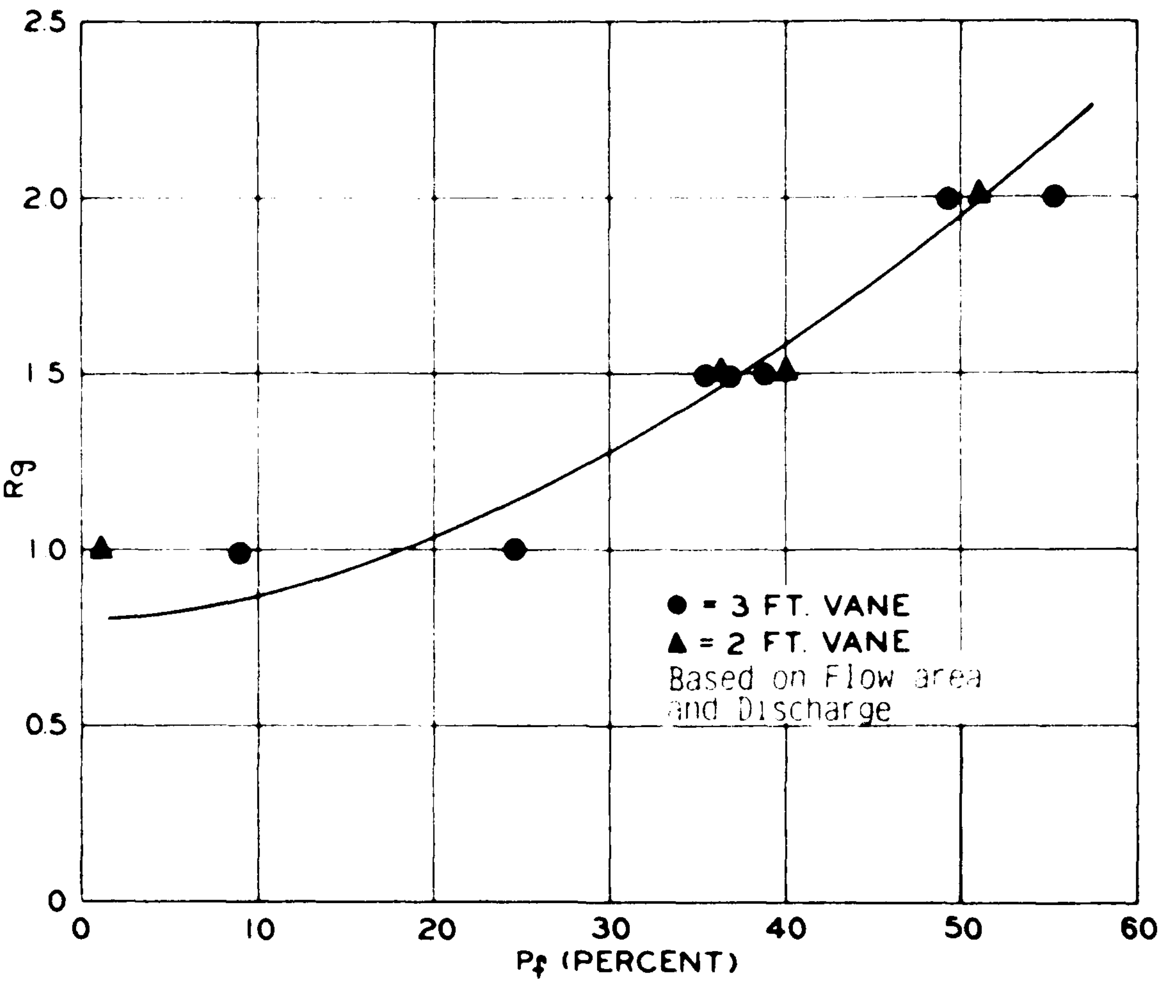
BED CONTOUR MAPS

U.S. ARMY ENGINEER DISTRICT, OMAHA

CORPS OF ENGINEERS

OMAHA, NEBRASKA

PLATE 8



MID-BEND(RIVER MILE 806.8)

FIG 1

$R_g = \frac{L_g}{L_v}$ $\quad P_f = \frac{A_L}{A_t}$

L_g = Length of gap (see

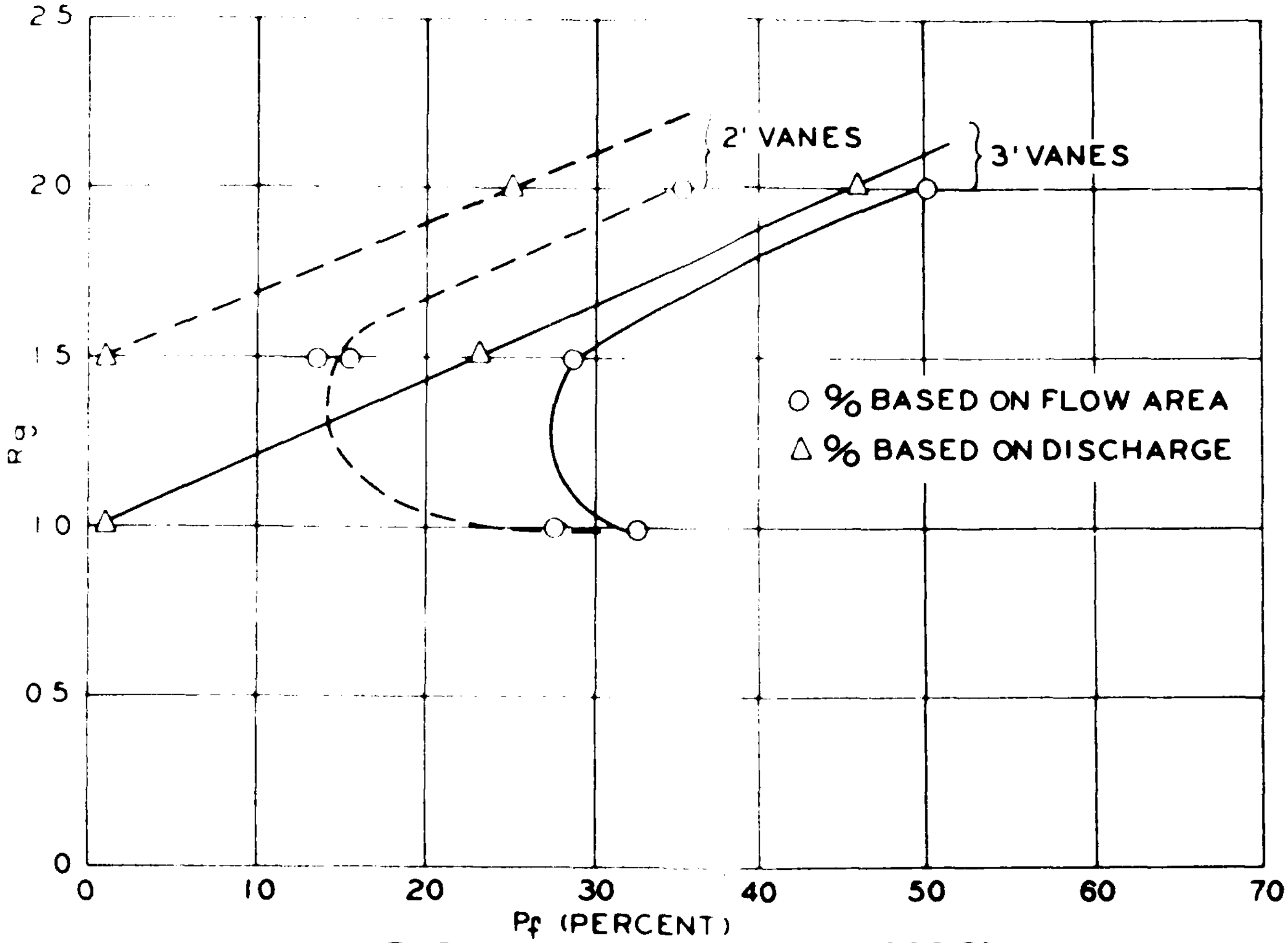
L_v = Length of vane dik

A_L = Flow area landward

A_t = Total Flow area at

Q_L = Discharge landward

Q_t = Total discharge



END OF BEND(RIVER MILE 806.2)

FIG 2

$P_f = \frac{A_L}{A_t}$ or $P_f = \frac{Q_L}{Q_t}$

NOTE Placement Angle constant at 15°

...h of gap (see Plate 3)
...h of vane dike (see Plate 3)
...area landward of vane dike
... Flow area at cross section
...arge landward of vane dikes
... discharge

MISSOURI RIVER DESIGN STUDY
VANE DIKE STUDY
R_g VALUE VS P_f VALUE
U.S ARMY ENGINEER DISTRICT OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

APPENDIX B

PHOTOGRAPHS

Photo 1. View Upstream in model from Range Number 841.0 showing bed configuration of verification Run 25 after 20.7 hours. Note point bar in upper left of photo and deep channel identified by ponded water along bank line at right of photo.

Photo 2. View upstream from Range Number 841.0 at the end of Run 24 showing bed configuration which could be expected if continuous revetment were to be placed along the desired alignment. Note well defined channel along riverward face of the revetment, and point bar in previous photo missing from center of test area.

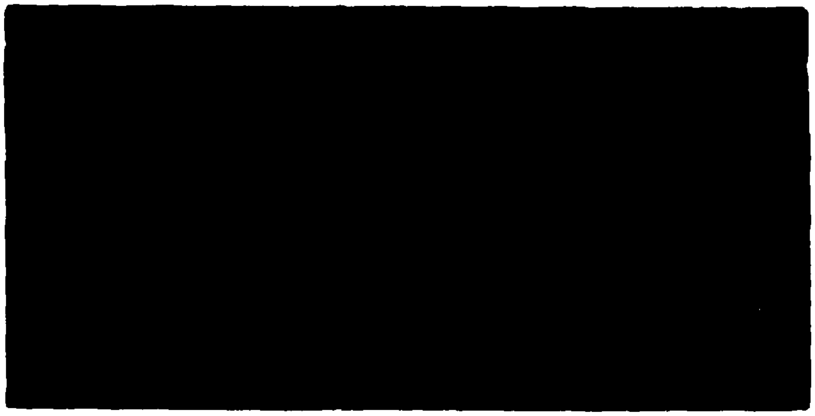


Photo 3. View upstream from Range Number 841.0 at the end of Run 13-1 showing bed configuration resulting from 5 foot vane dikes at 30° placement angle and 5-foot gaps. Note heavy scour at upstream structures with flow passing around both sides of upstream structures.

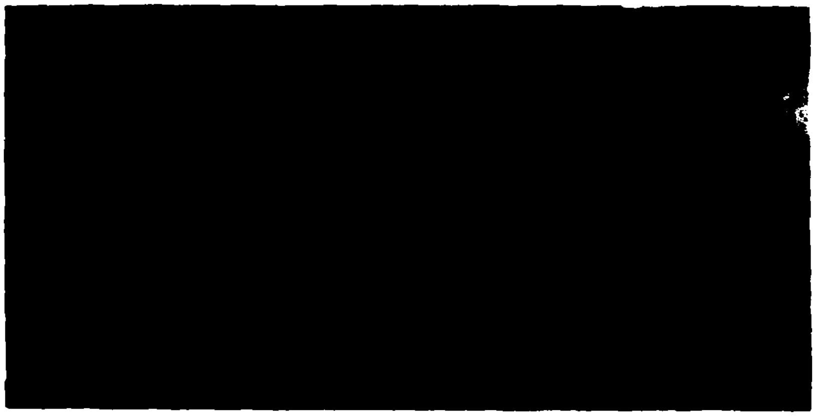


Photo 4. View upstream from Range Number 841.0 at end of Run 21 showing bed configuration resulting from 2-foot vane dikes at 60° placement angle and 3-foot gaps. Even though sediment accumulated between vane dikes, this arrangement had minimal effect on flow distribution. Note deep channel along bank line at right of photo.

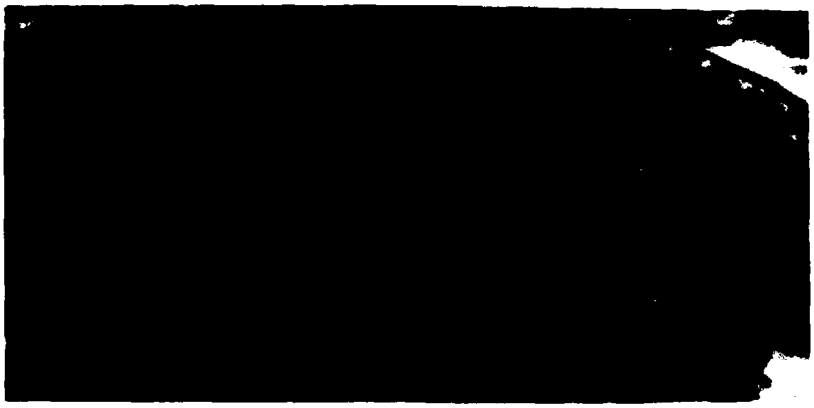


Photo 5. View upstream in model from Range Number 841.0 at end of Run 12 showing bed configuration resulting from 5-foot vane dikes at 0° placement angle with 5-foot gap lengths. Majority of flow passed through upstream gaps and concentrated along concave bank. Note small channel riverward of vanes with corresponding point bar removed and some sediment deposition landward of vane structures

Photo 6. View upstream in model from Range Number 841.0 at end of Run 50 showing bed configuration resulting from 3-foot vane dikes at 15° placement angle with 3-foot gaps. Note well developed channel riverward of vane structures and sediment deposition behind vane dike structures.

Photo 7. View upstream in model from Range Number 841.0 at end of Run 46 showing bed configuration resulting from 2-foot vane dikes at 15° placement angle and 2-foot gaps. Channel riverward of structures is not as well defined as in Run 50 (See Photo 6). Note sediment deposition behind vane dike structures.

Photo 8. View upstream in model from Range Number 841.0 at end of Run 52 showing bed configuration resulting from 3-foot vane dikes at 15° placement angle with 6-foot gaps. Approximately half the flow passes landward of the vane dike structures.

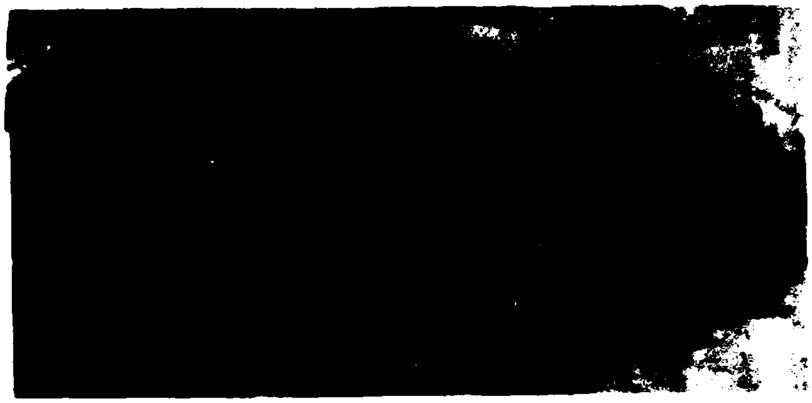


Photo 9. View upstream in model from Range Number 841.0 at end of Run 51 showing bed configuration resulting from 3-foot vane dikes at 15° placement angle and 4.5-foot gaps. Well developed channel riverward of vane dike structures chute developed between second and third structures with considerable flow landward of structures.

Photo 10. View upstream in model from Range Number 841.0 at the end of Run 49 showing the bed configuration resulting from 2-foot vane dikes at 15° placement angles and 4-foot gaps. No well defined channel riverward of structures with about half the flow landward of the upstream structures.

Photo 11. View upstream in model from Range Number 841.0 at the end of Run 47 showing bed configuration resulting from 2-foot vane dikes at 15° placement angle and 3-foot gaps. Channel is well defined riverward of structures but scour around upstream structures is visible. Run time 24.5 hours.

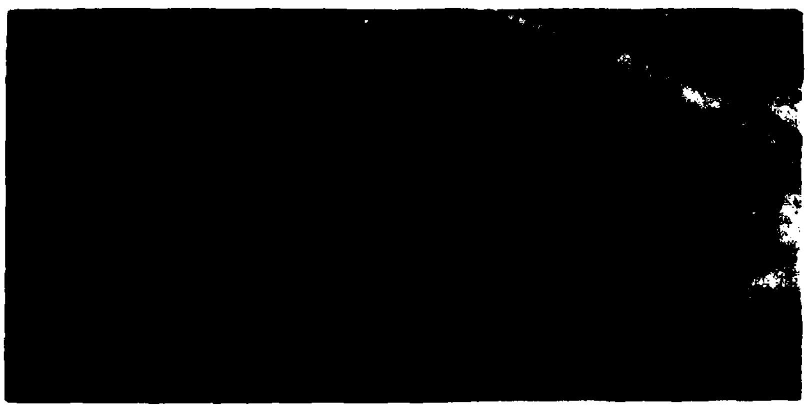


Photo 12. View upstream in model from Range Number 841.0 at the end of Run 48 showing bed configuration resulting from identical vane lengths and placement shown in Photo 11 but a run time of 33.9 hours. Note development of bars landward of structures and point bar removal as well as widening and deepening of the channel riverward of the channel with increased run time.

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