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# Bedform and Flow Relationships, Little Missouri River Near Medora, North Dakota

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BEDFORM AND FLOW RELATIONSHIPS,
LITTLE MISSOURI RIVER
NEAR MEDORA, NORTH DAKOTA

A senior thesis prepared by Richard E. Halle for the Geology Department of the University of North Dakota in partial fulfillment of the requirements for the Degree of Bachelor of Science in Geology.
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Frank Karner
(Advisor)

ABSTRACT

Data concerning flow conditions over known bedforms in the Little Missouri River were used to seek relationships between the two. The flow parameters that were measured included: current velocity, depth, water temperature, and suspended-load concentration. A bedload sample was also taken at each bedform. The median grain size of the sand fraction of the bedload sample was measured with a recording settling tube. Three relationships (velocity: depth, Reynolds number: Froude number, Reynolds number: median grain size of sand) were moderately successful in separating ripples from dunes but failed to isolate plane bed. The use of velocity near the bed to calculate the Froude number results in a relatively small Froude number. The choice of formulas to calculate the Froude number also has a large effect on its size.

In future studies the slope of the water surface should be measured and viscosity should be determined with a viscosimeter.

INTRODUCTION

Crossbeds in sedimentary rocks have long been used to infer paleoflow directions, current velocities, and water depths. Several studies of the bedforms that produce these crossbeds have been made in flumes (Simons, Richardson, Albertson, 1961). The studies point out some relationships between flow and bedforms, but they are the result of special conditions: the water in a flume is restricted between smooth vertical walls; depths are usually shallow; bed configuration is uniform across the bottom; and factors affecting water viscosity are often held constant (Colby & Scott, 1965). Shouldn't data gathered from natural streams be more realistic? This project was undertaken in the Little Missouri River during the summer of 1971. It was supervised by Dr. Arthur Jacob and supported by National Science Foundation Undergraduate Research Participation grant GY-8753.

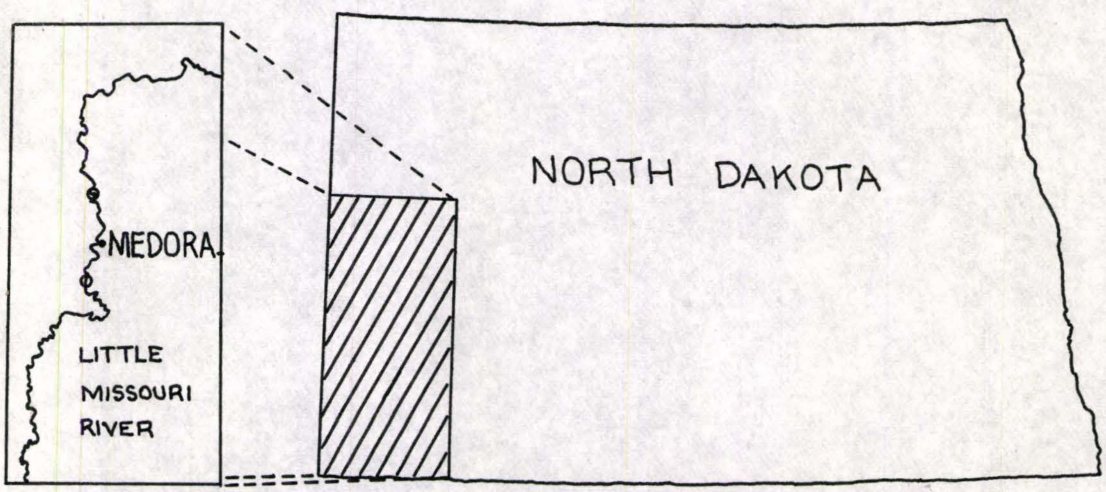



FIG. 1.--Map showing study areas as circles on Little Missouri River.

# METHODS
## Field Methods

Samples were collected wherever bedforms were found in the study areas. The study areas, marked on Figure 1, are two approximately one mile long stretches of the river chosen for easy accessibility.

The important flow parameters (Simons, Richardson, and Nordin, 1965) which were measured include: current velocity, depth, water temperature, and suspended load. The water surface slope should have been measured but wasn't. A sample of the bedload was taken and the bedform recorded at each point. All measurements were made while wading in the river. Equipment used included: velocity meter; thermometer; water sampler; preweighed filter papers; funnel; three beam balance; plastic sandwich bags; notebook; and waterproof laundry pen. The small things were carried in a carpenter's apron.

The procedure was to wade out from shore until an identifiable bedform was found by feeling the bottom with hand or foot. It was then given a sample number and the water depth, velocity and temperature were measured. The bedload sample was taken and finally any notes and a description of the bedform were recorded.

The velocity was measured with a Price Current Meter borrowed from the U. S. Geological Survey office in Bismarck, North Dakota. The support rod of the meter was marked so it could be used to determine the depth of the water.

Water samples were taken with a device (DH48) borrowed from the U. S. Geological Survey office in Grand Forks. The water sample was weighed and the suspended load filtered out on filter papers of known weight. When the dried suspended load was weighed a parts-per-million-by weight suspended-load concentration was calculated by the formula: sediment wt. x $10^6$/total wt.

The bedload sample was taken by scooping a hand-full of material from the bottom. Then it was dropped into a plastic sandwich bag and sealed. A slip of paper with the sample number written on it was then placed with the bag full of sediment into another plastic bag. The samples were carried in a cloth sack hung from the belt. Care was taken not to dig too deep and to grasp the sample very tightly while bringing it to the surface. Lack of attention to these details would make the sample worthless because of contamination or winnowing. Since it requires a minimum of equipment this method is very convenient. I don't know of a mechanical device that does a better job.

## Laboratory Methods

The bedload samples were later dried and sieved to remove silt and clay. The sand and total silt-clay portions were weighed and used to calculate the percentage of silt and clay in the total sample. The sand portion was then run through a settling tube identical to one described by Felix (1969) except that the release mechanism is different. The device used was made of slats that could be rotated about their long axis. When the slats were horizontal they held sediment but when they were rotated $45^{\circ}$ the sediment slid off to settle through the tube. The tube contained distilled water at a temperature of $22^{\circ}C$.

A computer program written by me and used to calculate Froude and Reynolds numbers is given in Appendix I.

# RESULTS AND INTERPRETATION

## General

The data, Froude numbers, and Reynolds numbers are given in Appendix II and plotted on Figures 2, 3, and 4.

## Velocity: Depth

A simple graph with velocity on one axis and depth on the other is shown in Figure 2. The different bedforms are distinguished by symbols as indicated in the legend.

Froude number.--The solid diagonal lines connect equal Froude numbers. The Froude numbers are unusually small because the velocity was measured near the bed. Mean velocity is usually used in this calculation. For a given velocity near the bed, which should be most significant, the mean velocity increases with the depth of the stream (Colby, 1964, pA7). The amount this affects Froude number is unknown but must be considerable because the dune field in Figure 2 extends down to about 0.15 while Simon, Richardson, Albertson (1961, pA59) found them ranging only down to about 0.30.

Two accepted formulas exist for the Froude number.

$$F = V^2/GD$$
(Allen, 1970, p.21)

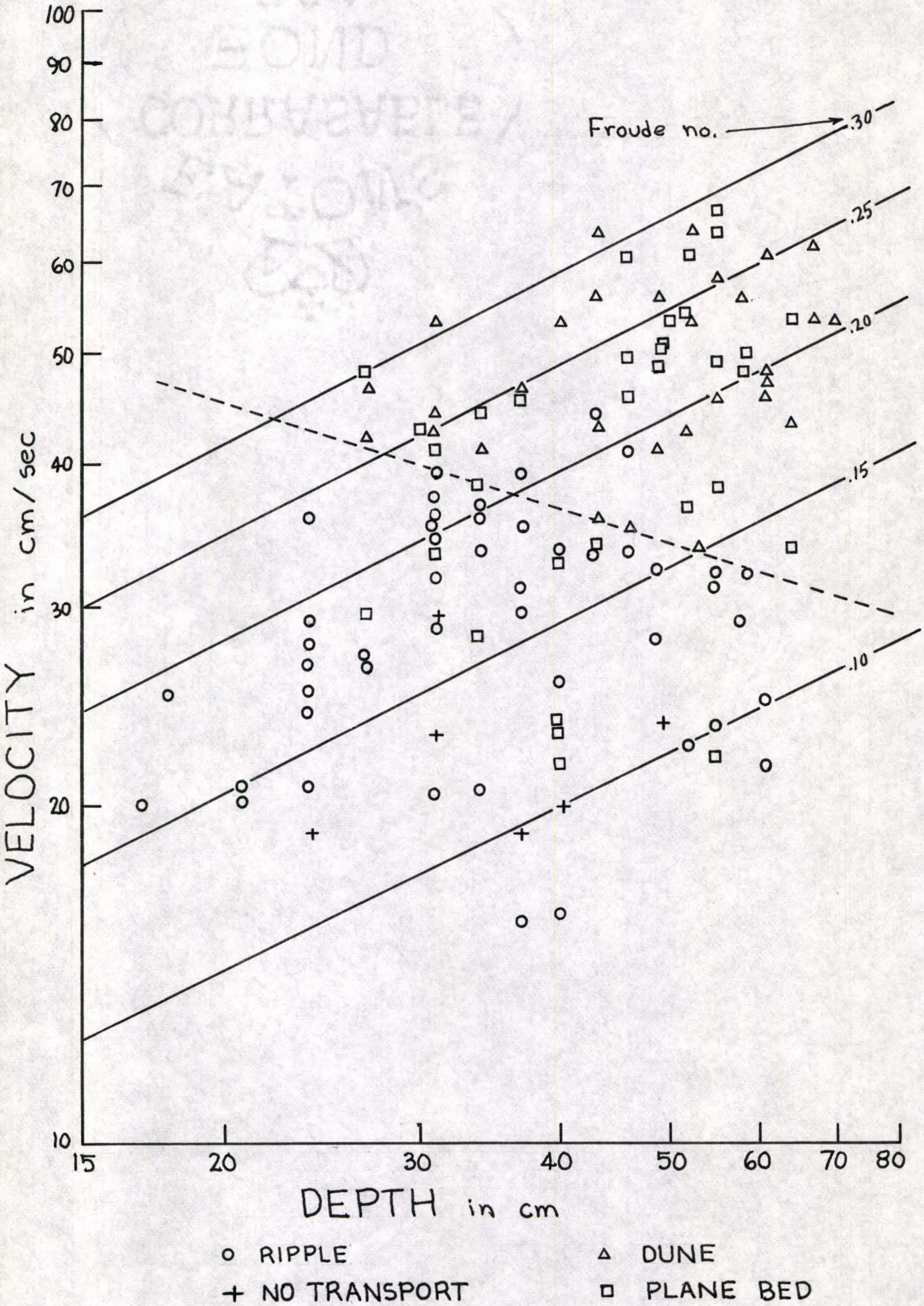
$$F = V/\sqrt{GD}$$
(Simons, 1963, p.286)

When the velocity and depth have values such that the Froude number is one they are equal: with V = 3ft/sec, D = 9/32.2ft.

$$F = V^2/GD = 1.0 \qquad F = V/\sqrt{GD} = 1.0$$

But if the Froude number is not one they are not equal: with V = 2ft/sec, D = 9/32.2ft

FIG. 2.--Graph of Current Velocity versus Depth.



$$F = V^2/GD = 0.444... \qquad F = V/\sqrt{GD} = 0.666...$$

with V = 4ft/sec, D = 9/32.2ft

$$F = V^2/GD = 1.777... \qquad F = V/\sqrt{GD} = 1.333$$

If the Froude number is less than one the value for $V^2/GD$ is less than the value for $V/\sqrt{GD}$ . If the Froude number is greater than one the value for $V^2/GD$ is greater than the value for $V/\sqrt{GD}$. Changing the depth had an effect opposite to changing the velocity. Below are some examples where the depth changes.

V = 3ft/sec, D = 8/32.2ft

$$F = V^2/GD = 1.125 \qquad F = V/\sqrt{GD} = 1.08$$

V = 3ft/sec, D = 10/32.2ft

$$F = V^2/GD = 0.90 \qquad F = V/\sqrt{GD} = 0.97$$

Both values were calculated but only $V/\sqrt{GD}$ was plotted on the graphs because the values were considerably larger and easier to use. (Appendix II)

Dune-ripple relationship.--The dashed line on Figure 2 is an inferred boundary between a dune field and a ripple field. Simons, Richardson, Albertson (1961, p. 59) have a similar diagram plotted with some flume data. In that diagram the fields of the bedforms are roughly bounded by lines connecting equal Froude numbers. In Figure 2 the inferred boundary runs at a large angle to the Froude number lines. Their data was limited to depths of 30 cm (about 1 ft) or less, data for Figure 2 is poor at those shallow depths and good for depths up to 70 cm. The boundary in Figure 2 dips steeply to the right indicating that at greater depths the dune bed configuration can form at lower velocities. If there were more data at shallow depths the boundary between ripples and dunes would probably drop to the left like in Simons' (1961) Figure 22. When the depths became too shallow for ripples or dunes to form the transition to the upper flow regime would be reached.

Other bedforms.--Plane bed data plotted irregularly throughout Figure 2. It seems obvious that more complicated methods will be needed to determine their relationships. The samples taken where there was no transport plot low in the ripple field.

Comments.--Despite the fact that it ignores both water viscosity and grain size of the bedload this simple graph did separate the ripple and dune fields.

Reynolds no.: Froude no.

The dimensionless Reynolds number takes into consideration the viscosity of the water. A graph by Simons, Richardson and Haushild (1963, p.G-17, Fig. 6) relating kinetic viscosity to water temperature and suspended load was used to determine the viscosity. The Reynolds number is calculated by the formula Re = Velocity x Depth/Kinematic viscosity.

Figure 3 is a plot of Reynolds number against Froude number. The results are quite similar to those of Figure 2. Plane bed and no transport were omitted so the relationship between ripples and dunes would be clearer. The separation is more distinct in this graph and the grouping is tighter. The consideration of viscosity seems to have improved the accuracy somewhat.

Reynolds no.: Median Grain Size of Sand

One more factor that should be considered is the size of the material transported as bedload. When the Reynolds number is plotted against median grain size of the sand fraction of the bedload the

FIG. 3.--Graph of Reynolds number versus Froude number.

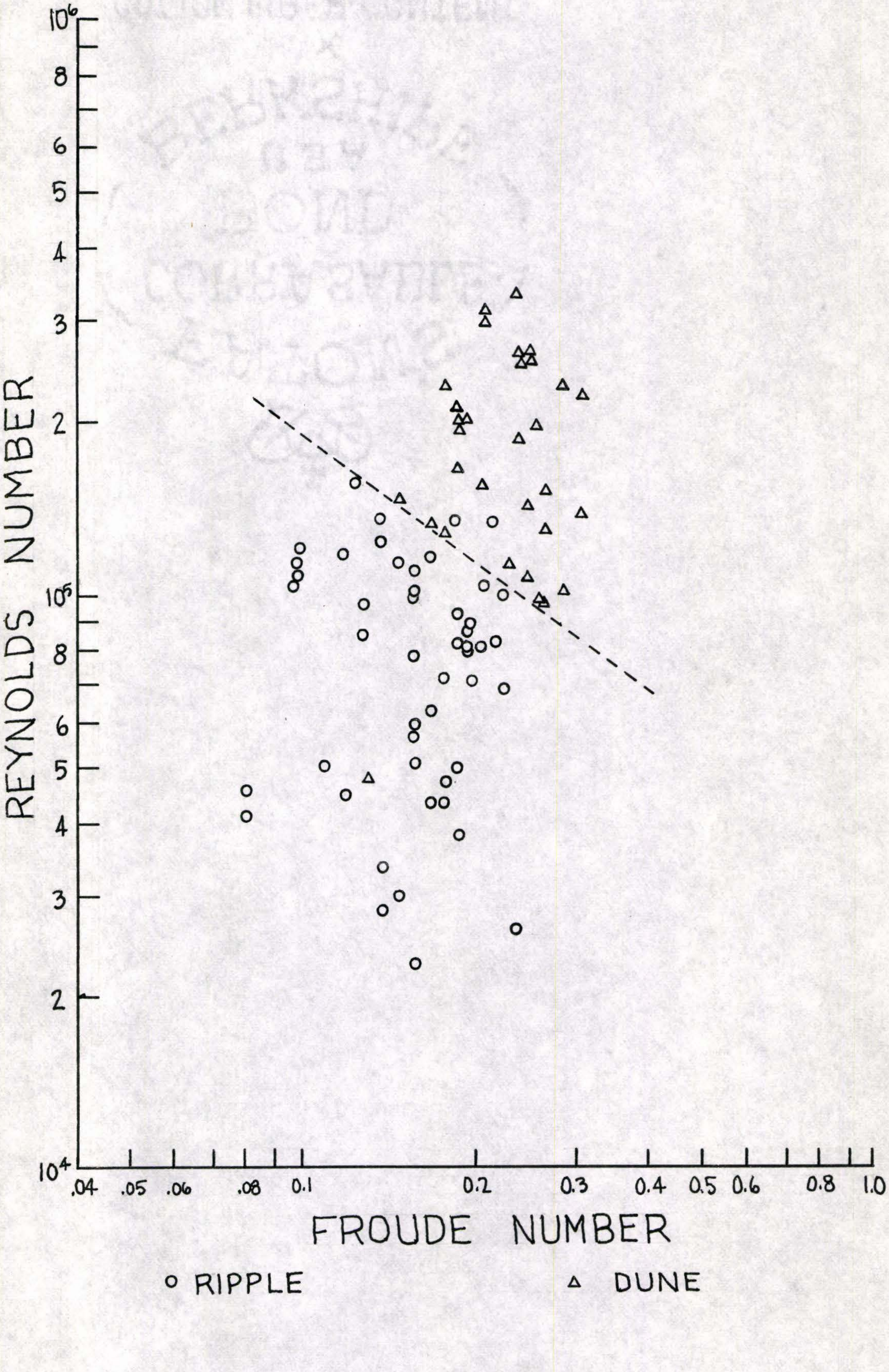
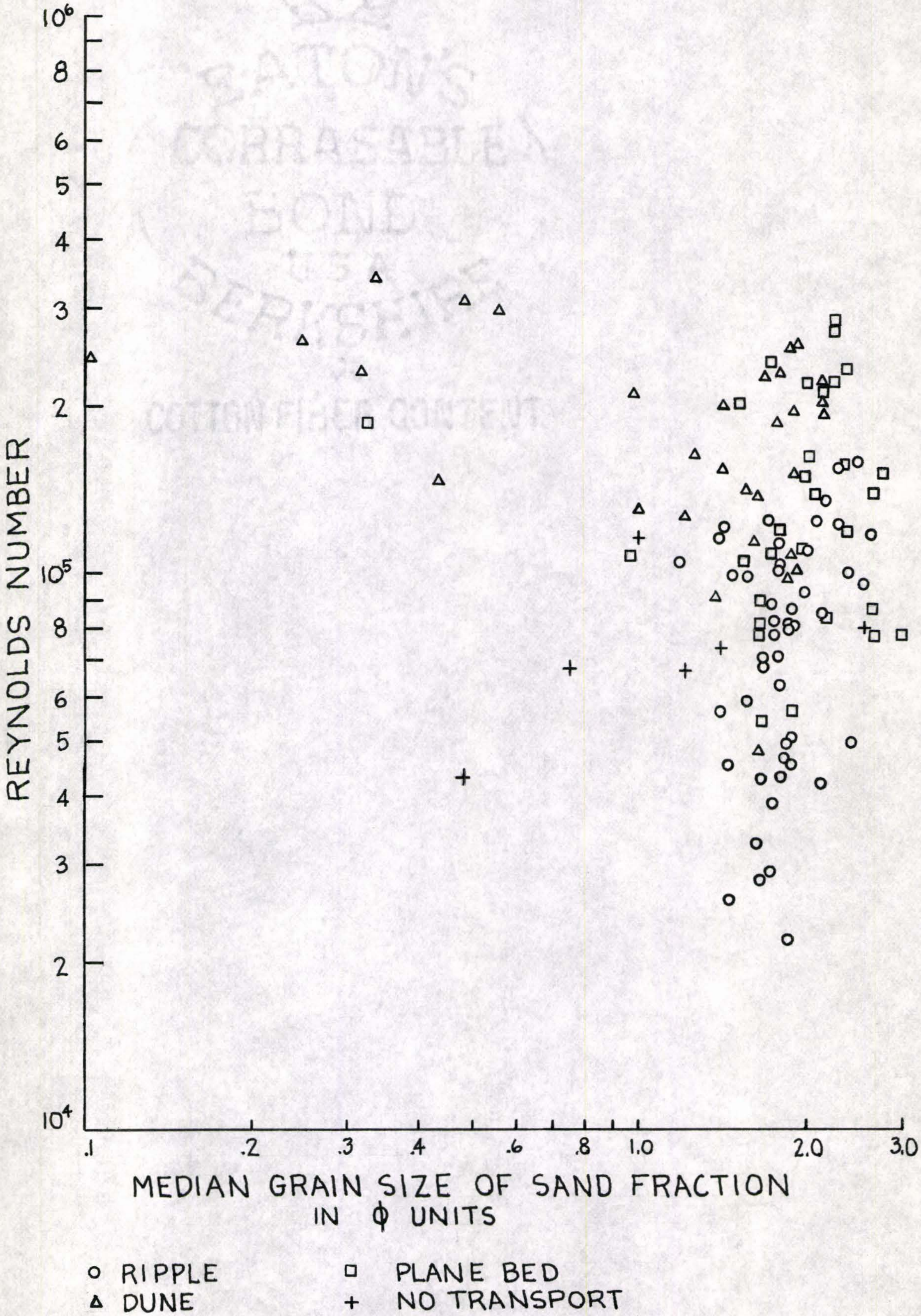


FIG. 4.--Graph of Reynolds number versus Median Grain Diameter of Sand.



factors of current velocity, depth, water viscosity, and grain size of the bedload are taken into consideration. Figure 4 is the result of this plot. Simons and Richardsons' (1963, p. 299) Figure 4 does show some similarities in the positions of ripple and dune fields if equal grain sizes on the two graphs are lined up, but it is not a good match.

On Figure 4 the ripple field is terminated on the left by the 1.0 phi grain size. This grain size is thought to be about the maximum size that ripples can form in (Allen, 1970, p. 79).

There is some concentration of plane bed in the fine grain sizes. These samples generally have a higher percentage of silt and clay that may have some effect on erodability and certainly on the cohesion of the grains.

## DISCUSSION

A simple plot of velocity against depth worked well to separate ripples from dunes but left plane bed scattered. The plane bed in the dune field may have been confused with tops of bars. The mixing of plane bed and ripples in the graph is interesting considering the number of times ripple crossbeds and plane beds are found mixed in rocks.

Perhaps more complicated plots that consider bed slope and fall velocity are needed to isolate plane bed. Future studies of this type should certainly measure slope. The use of a viscosometer would also be a great improvement over the rather uncertain method of measuring temperature and suspended load to find apparent viscosity from graphs. Colby and Scott (1965) do not have much confidence in Simons' (1963, p. C17) graph that shows the effect of "bentonite" and temperature on apparent kinematic viscosity.

Field studies of this type could be better handled by two people since measuring slope requires the use of a level and rod.

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APPENDIX I

Computer Program used to Calculate

Reynolds and Froude numbers

```
C     THIS PROGRAM WILL COMPUTE FROUDE AND REYNOLDS NUMBERS AND IS SET UP
C     TO USE DATA IN THE METRIC SYSTEM**TEMPERATURE IS IN CENTIGRADE
      G=980.0
      WRITE(3,60)
   60 FORMAT(' ',' JSNO  BFORM  SMGS  F   AF     IR        IRT')
    1 READ(1,10)JSNO,BF,RM,BPSC,SMGS,TEMP,SUSLD,DEPTH,VEL,WKVISC
   10 FORMAT(I6,2A4,F4.1,1X,F4.2,1X,F4.1,2X,F7.1,2X,F4.1,2X,F4.1,1X,F4.
     &2)
C     JSNO IS THE SAMPLE NUMBER;BF,RM IS THE BEDFORM;BPSC IS THE PERCENT
C     SILT-CLAY IN THE BED;SMGS IS THE MEDIAN GRAIN SIZE OF SAND IN BED;
C     TEMP IS THE WATER TEMPERATURE;SUSLD IS THE SUSPENDED LOAD IN PARTS
C     PER MILLION BY WEIGHT;DEPTH IS IN CM;VEL IS VELOCITY IN CM/SEC;
C     WKVISC IS KINEMATIC VISCOSITY IN ENGLISH UNITS X 100,000
      IF(JSNO)3,3,2
C     THE FROUDE NUMBER CALLED F IS BEST FOR FROUDE NUMBERS LESS THAN ONE
C     F = VELOCITY DIVIDED BY THE SQUARE ROOT OF THE QUANTITY (ACCELARAT
C     ION OF GRAVITY TIMES THE DEPTH)
    2 F=VEL/SQRT(G*DEPTH)
C     THE FROUDE NUMBER AF IS BEST FOR THOSE GREATER THAN ONE
C     AF = VELOCITY SQUARED DIVIDED BY THE QUANTITY(ACCELARATION OF GRAV
C     ITY TIMES DEPTH)
      AF=VEL*VEL/(G*DEPTH)
C     HERE VISCOSITY IS CHANGED TO METRIC UNITS
      WKVISC=WKVISC*0.0093
C     REYNOLDS NUMBER = VELOCITY TIMES DEPTH DIVIDED BY THE KINEMATIC
C     VISCOSITY
```

```
C     THE REYNOLDS NUMBER IR USES A VALUE FOR KINEMATIC VISCOSITY FROM
C     THE DATA DECK**THIS VALUE CAN BE INTERPRETED FROM A GRAPH BY SIMONS
C     (1963) USGS WTR SUPPLY PAPER 1498-G,P47
      IR=VEL*DEPTH/WKVISC
C     THE REYNOLDS NUMBER IRT ONLY CONSIDERS TEMPERATURE TO DETERMINE
C     THE KINEMATIC VISCOSITY
      IF(TEMP.GE.10.0.AND.TEMP.LE.15.6)GO TO 4
      IF(TEMP.GE.15.7.AND.TEMP.LE.21.1)GO TO 5
      IF(TEMP.GE.21.2.AND.TEMP.LE.26.7)GO TO 6
    4 TVISC=1.3*0.0093
      GO TO 7
    5 TVISC=1.1*0.0093
      GO TO 7
    6 TVISC=1.0*0.0093
    7 IRT=VEL*DEPTH/TVISC
      WRITE(3,50)JSNO,BF,RM,SMGS,F,AF,IR,IRT
   50 FORMAT(' ',I6,2A4,F4.2,1X,F4.2,1X,F4.2,1X,I10,1X,I10)
      GO TO 1
    3 STOP
      END
```

APPENDIX II

Data collected and Reynolds numbers

and Froude numbers calculated

BASIC DATA

| SMPL. NO. | DEPTH cm | VELOCITY cm/sec | TEMP °C | SUSPENDED LOAD(PPM) | SILT-CLAY % | BED FORM |
|---|---|---|---|---|---|---|
| 270513 | 43 | 33.2 | 21 | 13200 | 0 | ripple |
| 270516 | 31 | 20.5 | 21 | 13200 | 0 | ripple |
| 290514 | 37 | 29.7 | 18 | 8220 | 0 | ripple |
| 290515 | 34 | 33.8 | 18 | 8220 | 0 | ripple |
| 290516 | 34 | 36.9 | 18 | 8220 | 0 | ripple |
| 290517 | 27 | 26.5 | 18 | 8220 | 0 | ripple |
| 290518 | 24 | 29.2 | 18 | 8220 | 0 | ripple |
| 290519 | 24 | 25.4 | 18 | 8220 | 0 | ripple |
| 010605 | 24 | 20.9 | 12.5 | 2125 | 0 | ripple |
| 010606 | 31 | 28.7 | 12.5 | 2125 | 0 | ripple |
| 010607 | 24 | 26.9 | 12.5 | 2125 | 0 | ripple |
| 010608 | 21 | 20.9 | 12.5 | 2125 | 0 | ripple |
| 010609 | 21 | 20.1 | 13 | 2125 | 0 | ripple |
| 010610 | 17 | 20.1 | 13 | 2125 | 0 | ripple |
| 010613 | 31 | 34.4 | 13.5 | 2125 | 0 | ripple |
| 010615 | 24 | 27.8 | 15 | 2125 | 0 | ripple |
| 010618 | 31 | 37.5 | 15 | 2125 | 0 | ripple |
| 010619 | 37 | 39.3 | 15 | 2125 | 0 | ripple |
| 010624 | 40 | 16.1 | 15.5 | 2125 | 0 | ripple |
| 010625 | 37 | 15.8 | 15.5 | 2125 | 0 | ripple |
| 010632 | 49 | 32.6 | 16 | 2125 | 0 | ripple |
| 020616 | 46 | 33.8 | 18 | 4230 | 0 | ripple |
| 020617 | 46 | 41.1 | 18 | 4230 | 0 | ripple |
| 020618 | 43 | 44.5 | 18 | 4230 | 0 | ripple |
| 020620 | 37 | 35.4 | 18 | 4230 | 0 | ripple |
| 020621 | 34 | 36.0 | 18 | 4230 | 0 | ripple |
| 020622 | 55 | 31.4 | 18.5 | 4230 | 0 | ripple |
| 020623 | 31 | 35.4 | 18.5 | 4230 | 0 | ripple |
| 020624 | 31 | 32.0 | 18.5 | 4230 | 0 | ripple |
| 020625 | 31 | 36.0 | 18.5 | 4230 | 0 | ripple |
| 020626 | 31 | 35.4 | 18.5 | 4230 | 0 | ripple |
| 080602 | 61 | 23.7 | 16.5 | 4385 | 16.9 | ripple |
| 080604 | 58 | 29.4 | 16.5 | 4385 | 62.0 | ripple |
| 080607 | 49 | 28.3 | 17 | 4385 | 4.9 | ripple |
| 080608 | 55 | 32.3 | 17 | 4385 | 2.1 | ripple |
| 090602 | 34 | 20.9 | 18 | 5423 | 13.5 | ripple |
| 110601 | 59 | 32.3 | 20 | 2886 | 2.1 | ripple |
| 110632 | 61 | 24.9 | 22 | 2886 | 3.2 | ripple |
| 110633 | 40 | 25.9 | 22 | 2886 | 8.7 | ripple |
| 280603 | 24 | 36.0 | 20 | 2865 | 0 | ripple |
| 290602 | 31 | 39.3 | 21.5 | 3000 | 0 | ripple |
| 300601 | 12 | 25.5 | 23 | 3403 | 0 | ripple |
| 300602 | 18 | 25.2 | 23 | 3403 | 0 | ripple |
| 300603 | 27 | 27.2 | 23 | 3403 | 0 | ripple |
| 300605 | 40 | 33.8 | 23 | 3403 | 0 | ripple |
| 010705 | 37 | 31.4 | 21 | 1117 | 0 | ripple |
| 010709 | 52 | 22.7 | 25 | 817 | 0 | ripple |
| 010711 | 55 | 23.7 | 26 | 817 | 0 | ripple |
| 040707 | 24 | 24.3 | 24 | 352 | 0 | ripple |

BASIC DATA

| SMPL. NO. | MEDIAN G.S.-$\phi$ | VISC $\nu x10^5$ | FROUDE $V/\sqrt{GD}$ | FROUDE $V^2/GD$ | REYNOLDS TEMP.&SL | REYNOLDS TEMP |
|---|---|---|---|---|---|---|
| 270513 | 1.81 | 1.50 | 0.16 | 0.03 | 102258 | 139550 |
| 270516 | 1.47 | 1.50 | 0.12 | 0.01 | 45483 | 62121 |
| 290514 | 1.77 | 1.50 | 0.16 | 0.02 | 78774 | 107419 |
| 290515 | 1.78 | 1.50 | 0.19 | 0.03 | 82366 | 112366 |
| 290516 | 1.77 | 1.50 | 0.20 | 0.04 | 89892 | 122639 |
| 290517 | 1.93 | 1.50 | 0.16 | 0.03 | 51290 | 69941 |
| 290518 | 1.92 | 1.50 | 0.19 | 0.04 | 50215 | 68504 |
| 290519 | 1.83 | 1.50 | 0.17 | 0.03 | 43656 | 59589 |
| 010605 | 1.66 | 1.60 | 0.14 | 0.02 | 33656 | 41488 |
| 010606 | 1.63 | 1.60 | 0.16 | 0.03 | 59785 | 73589 |
| 010607 | 1.69 | 1.60 | 0.18 | 0.03 | 43333 | 53399 |
| 010608 | 1.79 | 1.60 | 0.15 | 0.02 | 29462 | 36302 |
| 010609 | 1.68 | 1.60 | 0.14 | 0.02 | 28280 | 34913 |
| 010610 | 1.88 | 1.60 | 0.16 | 0.02 | 22903 | 28263 |
| 010613 | 1.71 | 1.60 | 0.20 | 0.04 | 71613 | 88205 |
| 010615 | 1.88 | 1.50 | 0.18 | 0.03 | 47742 | 55186 |
| 010618 | 2.19 | 1.50 | 0.22 | 0.05 | 83333 | 96153 |
| 010619 | 1.82 | 1.50 | 0.21 | 0.04 | 104194 | 120273 |
| 010624 | 1.93 | 1.50 | 0.08 | 0.01 | 46129 | 53267 |
| 010625 | 2.15 | 1.50 | 0.08 | 0.01 | 41828 | 48354 |
| 010632 | 1.82 | 1.50 | 0.15 | 0.02 | 114409 | 156148 |
| 020616 | 2.03 | 1.50 | 0.16 | 0.03 | 111398 | 151984 |
| 020617 | 2.13 | 1.50 | 0.19 | 0.04 | 135484 | 184809 |
| 020618 | 2.06 | 1.50 | 0.22 | 0.05 | 137097 | 187048 |
| 020620 | 2.03 | 1.50 | 0.19 | 0.03 | 93870 | 128035 |
| 020621 | 1.92 | 1.50 | 0.20 | 0.04 | 87742 | 119648 |
| 020622 | 1.75 | 1.47 | 0.14 | 0.02 | 126237 | 168817 |
| 020623 | 1.91 | 1.47 | 0.20 | 0.04 | 80215 | 107272 |
| 020624 | 1.81 | 1.47 | 0.18 | 0.03 | 72473 | 96969 |
| 020625 | 1.93 | 1.47 | 0.21 | 0.04 | 81613 | 109091 |
| 020626 | 1.90 | 1.47 | 0.20 | 0.04 | 80215 | 107272 |
| 080602 | 2.44 | 1.53 | 0.10 | 0.01 | 101505 | 141319 |
| 080604 | 2.65 | 1.53 | 0.12 | 0.02 | 119785 | 166686 |
| 080607 | 2.61 | 1.53 | 0.13 | 0.02 | 97419 | 135552 |
| 080608 | 2.34 | 1.53 | 0.14 | 0.02 | 124839 | 173656 |
| 090602 | 2.48 | 1.50 | 0.11 | 0.01 | 50860 | 69462 |
| 110601 | 2.34 | 1.30 | 0.13 | 0.02 | 157527 | 186285 |
| 110632 | 2.11 | 1.30 | 0.10 | 0.01 | 125591 | 163322 |
| 110633 | 2.21 | 1.30 | 0.13 | 0.02 | 85591 | 111397 |
| 280603 | 1.97 | 1.35 | 0.23 | 0.06 | 68817 | 84457 |
| 290602 | 1.51 | 1.30 | 0.23 | 0.06 | 100753 | 130999 |
| 300601 | 1.47 | 1.25 | 0.24 | 0.06 | 26237 | 32903 |
| 300602 | 1.78 | 1.25 | 0.19 | 0.04 | 38925 | 48774 |
| 300603 | 1.81 | 1.25 | 0.17 | 0.03 | 63118 | 78967 |
| 010705 | 1.60 | 1.25 | 0.16 | 0.03 | 99892 | 113568 |
| 010709 | 1.21 | 1.20 | 0.10 | 0.01 | 105699 | 126924 |
| 010711 | 1.44 | 1.15 | 0.10 | 0.01 | 121828 | 140161 |
| 040707 | 1.42 | 1.10 | 0.16 | 0.03 | 56989 | 62709 |
| 300605 | 1.42 | 1.25 | 0.17 | 0.03 | 116236 | 145376 |

BASIC DATA

| SMPL. NO. | DEPTH cm | VELOCITY cm/sec | TEMP °C | SUSPENDED LOAD(PPM) | SILT-CLAY % | BED FORM |
|---|---|---|---|---|---|---|
| 270510 | 31 | 23.2 | 19 | 13200 | 0 | dune |
| 290511 | 61 | 46.0 | 18 | 10480 | 0 | dune |
| 290513 | 40 | 53.3 | 18 | 10480 | 0 | dune |
| 010602 | 52 | 53.3 | 12.5 | 1913 | 0 | dune |
| 010622 | 31 | 44.5 | 15.5 | 1913 | 0 | dune |
| 010626 | 49 | 56.1 | 15.5 | 1913 | 0 | dune |
| 020604 | 52 | 64.6 | 15 | 4230 | 0 | dune |
| 020605 | 61 | 61.3 | 15 | 4230 | 0 | dune |
| 020611 | 61 | 47.2 | 15 | 4230 | 0 | dune |
| 100608 | 61 | 58.5 | 18.5 | 3443 | 0 | dune |
| 100618 | 70 | 53.9 | 20 | 3443 | 0 | dune |
| 100620 | 67 | 53.9 | 20 | 3443 | 0 | dune |
| 100623 | 64 | 43.9 | 20 | 3443 | 0 | dune |
| 110616 | 53 | 33.8 | 21 | 2886 | 0 | dune |
| 130608 | 58 | 56.1 | 21 | 5089 | 0 | dune |
| 130627 | 55 | 46.0 | 23 | 5089 | 0 | dune |
| 130637 | 43 | 64.0 | 24 | 5089 | 0 | dune |
| 130638 | 55 | 58.5 | 24 | 5089 | 0 | dune |
| 130641 | 67 | 62.5 | 24 | 5089 | 0 | dune |
| 280605 | 31 | 43.0 | 20 | 2865 | 0 | dune |
| 280606 | 27 | 42.1 | 20 | 2865 | 0 | dune |
| 280607 | 27 | 46.9 | 20 | 2865 | 0 | dune |
| 290603 | 34 | 41.1 | 21.5 | 3000 | 0 | dune |
| 290604 | 31 | 53.9 | 21.5 | 3000 | 0 | dune |
| 290605 | 46 | 35.1 | 21 | 3000 | 0 | dune |
| 290606 | 37 | 46.9 | 21 | 3000 | 0 | dune |
| 290607 | 43 | 43.9 | 21 | 3000 | 0 | dune |
| 290608 | 43 | 36.0 | 21 | 3000 | 0 | dune |
| 290611 | 49 | 41.1 | 21.5 | 3000 | 0 | dune |
| 040721 | 52 | 43.0 | 25 | 352 | 0 | dune |
| 050704 | 43 | 56.1 | 25 | 662 | 0 | dune |
| 290510 | 64 | 33.8 | 18 | 10480 | 0 | plane |
| 290521 | 52 | 54.6 | 18 | 8220 | 0 | plane |
| 290523 | 34 | 44.5 | 18 | 8220 | 0 | plane |
| 010604 | 52 | 61.3 | 12 | 2125 | 0 | plane |
| 010620 | 37 | 46.0 | 15 | 2125 | 0 | plane |
| 010631 | 27 | 29.7 | 16 | 1913 | 0 | plane |
| 020615 | 46 | 46.0 | 18 | 4230 | 0 | plane |
| 020619 | 46 | 50.0 | 18 | 4230 | 0 | plane |
| 060601 | 40 | 32.9 | 17 | 19469 | 39.9 | plane |
| 080601 | 55 | 22.2 | 16.5 | 4385 | 55.6 | plane |
| 080605 | 55 | 38.4 | 16.5 | 4385 | 53.4 | plane |
| 100621 | 58 | 50.6 | 20 | 3443 | 0 | plane |
| 110603 | 52 | 36.9 | 20 | 2886 | 4.4 | plane |
| 110604 | 34 | 28.3 | 20 | 2886 | 5.4 | plane |
| 120622 | 58 | 48.2 | 23 | 3707 | 1.1 | plane |
| 130624 | 55 | 49.4 | 23 | 5089 | 0 | plane |
| 130631 | 49 | 49.4 | 23 | 5089 | 0 | plane |
| 130632 | 49 | 61.3 | 23 | 5089 | 0 | plane |

BASIC DATA

| SMPL. NO. | MEDIAN G.S.-$\phi$ | VISC $\nu x10^5$ | FROUDE $V/\sqrt{GD}$ | FROUDE $V^2/GD$ | REYNOLDS TEMP.&SL | REYNOLDS TEMP |
|---|---|---|---|---|---|---|
| 270510 | 1.66 | 1.60 | 0.13 | 0.02 | 48279 | 70303 |
| 290511 | 1.44 | 1.50 | 0.19 | 0.04 | 201075 | 274291 |
| 290513 | 1.93 | 1.50 | 0.27 | 0.07 | 152796 | 208406 |
| 010602 | 1.78 | 1.60 | 0.24 | 0.06 | 186237 | 229247 |
| 010622 | 1.86 | 1.50 | 0.26 | 0.07 | 98817 | 114102 |
| 010626 | 2.17 | 1.50 | 0.26 | 0.07 | 196989 | 227369 |
| 020604 | 1.82 | 1.57 | 0.29 | 0.08 | 230000 | 277849 |
| 020605 | 1.89 | 1.57 | 0.25 | 0.06 | 256021 | 309288 |
| 020611 | 1.93 | 1.57 | 0.19 | 0.04 | 197097 | 238147 |
| 100608 | 0.25 | 1.45 | 0.24 | 0.06 | 264632 | 348827 |
| 100618 | 0.49 | 1.30 | 0.21 | 0.04 | 312043 | 368817 |
| 100620 | 0.56 | 1.30 | 0.21 | 0.04 | 298602 | 353011 |
| 100623 | 0.31 | 1.30 | 0.18 | 0.03 | 232366 | 274643 |
| 110616 | 0.44 | 1.30 | 0.15 | 0.02 | 148172 | 175112 |
| 130608 | 0.00 | 1.40 | 0.24 | 0.06 | 249892 | 318064 |
| 130627 | 2.33 | 1.35 | 0.20 | 0.04 | 201505 | 272043 |
| 130637 | 2.32 | 1.33 | 0.31 | 0.10 | 222473 | 295914 |
| 130638 | 1.95 | 1.33 | 0.25 | 0.06 | 260108 | 345967 |
| 130641 | 0.34 | 1.33 | 0.24 | 0.06 | 338495 | 450267 |
| 280605 | 1.92 | 1.33 | 0.25 | 0.06 | 107742 | 130303 |
| 280606 | 1.40 | 1.33 | 0.26 | 0.07 | 91828 | 111114 |
| 280607 | 1.95 | 1.33 | 0.29 | 0.08 | 102366 | 123783 |
| 290603 | 1.64 | 1.30 | 0.23 | 0.05 | 115484 | 150258 |
| 290604 | 1.65 | 1.30 | 0.31 | 0.10 | 138172 | 179666 |
| 290605 | 1.01 | 1.30 | 0.17 | 0.03 | 133548 | 157830 |
| 290606 | 1.57 | 1.30 | 0.25 | 0.06 | 143441 | 169628 |
| 290607 | 1.44 | 1.30 | 0.21 | 0.05 | 156129 | 184526 |
| 290608 | 1.21 | 1.30 | 0.18 | 0.03 | 127957 | 151319 |
| 290611 | 1.28 | 1.30 | 0.19 | 0.04 | 166559 | 216548 |
| 040721 | 0.98 | 1.13 | 0.19 | 0.04 | 212688 | 280430 |
| 050704 | 1.71 | 1.13 | 0.27 | 0.07 | 229462 | 259387 |
| 290510 | 1.70 | 1.50 | 0.13 | 0.02 | 155054 | 211456 |
| 290521 | 1.54 | 1.50 | 0.24 | 0.06 | 203440 | 277536 |
| 290523 | 1.77 | 1.50 | 0.24 | 0.06 | 108387 | 147898 |
| 010604 | 2.03 | 1.60 | 0.27 | 0.07 | 222366 | 273796 |
| 010620 | 1.83 | 1.50 | 0.24 | 0.06 | 121935 | 140777 |
| 010631 | 1.92 | 1.50 | 0.18 | 0.03 | 57419 | 78387 |
| 020615 | 2.03 | 1.50 | 0.22 | 0.05 | 151613 | 206842 |
| 020619 | 2.06 | 1.50 | 0.24 | 0.06 | 164839 | 224829 |
| 060601 | 2.70 | 1.80 | 0.17 | 0.03 | 78602 | 128641 |
| 080601 | 2.69 | 1.50 | 0.10 | 0.01 | 87419 | 119354 |
| 080605 | 2.81 | 1.50 | 0.17 | 0.03 | 151290 | 206451 |
| 100621 | 1.75 | 1.30 | 0.21 | 0.05 | 242688 | 286881 |
| 110603 | 2.33 | 1.30 | 0.16 | 0.03 | 158710 | 187566 |
| 110604 | 1.71 | 1.30 | 0.16 | 0.02 | 79570 | 94056 |
| 120622 | 2.11 | 1.25 | 0.20 | 0.04 | 240430 | 300602 |
| 130624 | 2.23 | 1.37 | 0.21 | 0.05 | 213226 | 292150 |
| 130631 | 0.33 | 1.37 | 0.23 | 0.05 | 189892 | 260279 |
| 130632 | 2.42 | 1.37 | 0.28 | 0.08 | 235699 | 322978 |

BASIC DATA

| SMPL. NO. | DEPTH cm | VELOCITY cm/sec | TEMP °C | SUSPENDED LOAD(PPM) | SILT-CLAY % | BED FORM |
|---|---|---|---|---|---|---|
| 130634 | 55 | 64.0 | 23 | 5089 | 0 | plane |
| 130635 | 55 | 67.4 | 23 | 5089 | 0.9 | plane |
| 130636 | 46 | 61.3 | 23 | 5089 | 0 | plane |
| 280608 | 31 | 43.0 | 20 | 2865 | 0 | plane |
| 280610 | 27 | 48.2 | 20 | 2865 | 0 | plane |
| 290609 | 34 | 38.4 | 21 | 3000 | 0.5 | plane |
| 300604 | 31 | 33.8 | 23 | 3403 | 0 | plane |
| 040701 | 40 | 21.8 | 24 | 445 | 0 | plane |
| 050603 | 52 | 61.3 | 16 | 36083 | 63.0 | plane |
| 050604 | 50 | 53.9 | 16 | 36083 | 32.7 | plane |
| 050605 | 64 | 53.9 | 17.5 | 36083 | 26.5 | plane |
| 050606 | 43 | 33.8 | 17.5 | 25372 | 93.4 | ?plane |
| 050601 | 21 | 7.7 | 16 | 25372 | 61.7 | notran |
| 070605 | 49 | 23.7 | 17 | 9580 | 24.7 | notran |
| 010704 | 31 | 29.5 | 21 | 1117 | 0 | notran |
| 040711 | 24 | 19.0 | 25 | 352 | 4.3 | notran |
| 040712 | 37 | 19.0 | 25 | 352 | 1.4 | notran |
| 040713 | 40 | 20.1 | 25 | 352 | 0 | notran |
| 040714 | 34 | 35.4 | 25 | 352 | 0 | ?notran |

| SMPL. NO. | MEDIAN G.S.-$\phi$ | VISC $\nu x10^5$ | FROUDE $V/\sqrt{GD}$ | FROUDE $V^2/GD$ | REYNOLDS TEMP.&SL | REYNOLDS TEMP |
|---|---|---|---|---|---|---|
| 130634 | 2.29 | 1.37 | 0.28 | 0.08 | 276237 | 378494 |
| 130635 | 2.29 | 1.37 | 0.29 | 0.08 | 290860 | 398602 |
| 130636 | 2.25 | 1.37 | 0.29 | 0.08 | 221290 | 303204 |
| 280608 | 1.90 | 1.33 | 0.25 | 0.06 | 107742 | 130303 |
| 280610 | 1.57 | 1.33 | 0.30 | 0.09 | 105161 | 127214 |
| 290609 | 0.98 | 1.30 | 0.21 | 0.04 | 107957 | 127624 |
| 300604 | 1.70 | 1.25 | 0.19 | 0.04 | 90108 | 112666 |
| 040701 | 1.70 | 1.15 | 0.11 | 0.01 | 81505 | 93763 |
| 050603 | 2.69 | 2.40 | 0.27 | 0.07 | 142796 | 311593 |
| 050604 | 2.43 | 2.40 | 0.24 | 0.06 | 120645 | 263441 |
| 050605 | 2.53 | 2.30 | 0.22 | 0.05 | 161183 | 337204 |
| 050606 | 3.02 | 2.00 | 0.16 | 0.03 | 78065 | 142072 |
| 050601 | 2.69 | 2.05 | 0.05 | 0.0- | 8387 | 15806 |
| 070605 | 2.55 | 1.55 | 0.11 | 0.01 | 80538 | 113519 |
| 010704 | 1.21 | 1.40 | 0.17 | 0.03 | 70215 | 89394 |
| 040711 | 0.48 | 1.10 | 0.12 | 0.02 | 44516 | 49032 |
| 040712 | 0.75 | 1.10 | 0.10 | 0.01 | 68710 | 75591 |
| 040713 | 1.44 | 1.10 | 0.10 | 0.01 | 78495 | 86451 |
| 040714 | 1.06 | 1.10 | 0.19 | 0.04 | 117634 | 129419 |