COLORADO RIVER INVESTIGATIONS V

July-August 1986

By
Students and Staff of Geology 538-626
Northern Arizona University

Under the Supervision of

Stanley S. Beus
Professor, Northern Arizona University
Research Associate, Museum of Northern Arizona
and
Steven W. Carothers
Adjunct Professor, Northern Arizona University
Research Associate, Museum of Northern Arizona

Edited By

Gayle C. Weiss
SWCA, Environmental Consultants

Submitted To

Mr. Richard W. Marks, Superintendent
Grand Canyon National Park
Grand Canyon, Arizona

March 1987

TABLE OF CONTENTS

CHAPTER I

INTRODUCTION

Colorado River Investigations V presents results of a five-week, six-semester hour course (Geology 538-626) on the geology and biology of the Grand Canyon. Now in its fifth year, the course is offered each summer by Northern Arizona University in collaboration with the Museum of Northern Arizona and Grand Canyon National Park. While primarily designed to introduce teachers to the natural history of the Grand Canyon and to give them an opportunity to gather scientific information under the rigorous supervision of experienced researchers, the program also generates ongoing data about beach condition, vegetation, and aquatic and terrestrial fauna in the Colorado River corridor of the Grand Canyon.

In 1986, the course consisted of three weeks of classroom and laboratory instruction and about two weeks of field work, most of which was an 11-day research expedition down the Colorado River from Lees Ferry to Diamond Creek (July 29 - August 7). All field investigations were conducted under the supervision of Dr. Stanley S. Beus, a professor of geology at Northern Arizona University, or Dr. Steven W. Carothers, an adjunct professor at Northern Arizona University and an ecological consultant. Both scientists are Research Associates with the Museum of Northern Arizona.

The research reports are all at least partly outlined by students and offer the results of a variety of investigations. Some of the projects, most notably the beach profile and human impact studies, have been underway since the course was first offered in 1982. The studies conducted in 1985 and 1986 are of special significance because they further document changes in Grand Canyon beach conditions after the exceptional high water flows of 1983 and 1984. The data collected, when compared to data collected in the previous four years, provides information about the effects of unusually high water discharges on the post-dam, downstream (Grand Canyon) environment.

The 1986 investigations included studies of beach profile changes, sedimentary structures in river beaches and bars, beach sand-size analysis, turbidity values and concentration of total dissolved solids of the river water, temperature gradients along the beaches, harvester ant densities on camping beaches, reptile distribution, human impact on camping beaches, and a frequency report on river raft-groups and aircraft sightings along the 11 day expedition.

1986

CHAPTER II

BEACH PROFILE DATA FROM JULY-AUGUST 1986 SURVEYS IN GRAND CANYON

Stanley S. Beus, Rebecca Cardon, Frances Fulton, Al Pastrick, and Micheal Stock

INTRODUCTION

The topographic profile measurements made in late summer, 1986, are a continuation of long-term monitoring of selected campsite beaches. The available data now cover a 12-year period. Of the original 37 profiles on 20 beaches surveyed by Howard (1975) in 1974 and 1975, 8 profiles on 4 beaches (Unkar, 109-mile, Waltenburg Canyon, and Upper 124 1/2-Mile Canyon) are no longer monitored because the beaches are essentially removed or so reduced as to be no longer used as campsites. In the period 1983-1985, 6 additional beaches (Awatubi, Nevills Rapid, 122-Mile, Forster Canyon, Lower National Canyon, and 220-Mile) were added to the list.

PURPOSE

The purpose of this survey is to provide a record of topographic changes in beaches through time. This research may serve as a basis for management decisions by the National Park Service and Bureau of Reclamation in maintaining the beaches as a major resource to river recreationists in Grand Canyon.

METHODS

In 1986, 36 profiles on 18 beaches were surveyed. Most were done using a standard surveying transit. At a few sites, notably Lower National Canyon beach at mile 166.6, a theodolite was used and three new profiles were established. Table 1 summarizes the number of beach profiles surveyed in the past 12 years. Table 2 presents a comparison of the loss or gain of vertical feet of beach sand between 1986 and 1985.

Selected individual beach profiles, particularly those with measurable changes in the past year, are shown in Figures 1-3, 5-17, and 19-22. The amount of gain or loss in vertical fill of sand is shown in the bar graphs in Figure 23. In each case, the inner-shoreward and outer-riverward, half of the profile is represented by a separate bar.

DISCUSSION

The results of the profile measurements presented in Table 2 and Figure 22, indicate a gradual depletion of sand on most of the beaches studied between 1985 and 1986. Eight profiles on 5 beaches showed a modest net gain of 0.2 to 5.0 feet of sand deposition. However, 17 profiles on 13 beaches showed a net loss of 0.3 to nearly 4 feet of sand. At one beach, Lower Lava Falls (180.9-mile), the loss was attributed to a flash flood in the summer of 1986. Seven profiles on 7 different beaches showed little or no change from 1985. The slight gain shown at Nevills Rapid (75-mile), appears to be the result of wind-blown sandridges moving transverse to the shoreline.

As indicated from the 1984 and 1985 data (Beus and others, 1986), there appears to be a continuing deterioration of the beaches due to erosion by the river and possibly other dynamic erosive processes. A notable exception is the small beach at 190 Mile, where up to 4 feet of sand was added along most of the profile. The CS 2 profile at Upper Granite, (93.2-mile), which experienced both major erosion in 1983 and 1984, and substantial deposition in 1985 (Fig. 9), appears to have stabilized in 1986. However, CS 1 profile at Upper Granite shows continued erosion. The beach is nearly gone except for a footpath width (Fig. 8).

CONCLUSIONS

It seems probable that with the present controlled flow of the Colorado River, which precludes heavy sediment-loaded floods, the beach sands will be gradually lost by erosion. In the past 12 years, the only substantial departure from this appears to be the unexpected high water spills of 1983 and 1984, which produced substantially more deposition than erosion on the beaches being monitored (Beus and others, 1985). Lesser high water flows in 1985 may have added sediment to the few beaches that showed a net gain between 1985 and 1986. Perhaps occasional high water "spills" through Glen Canyon Dam may be necessary to maintain the beaches as a recreational resource in the Grand Canyon.

Table 1. Beach profiles surveyed.

River Mile	Beach Name	Number of Profiles Measured 1974	1975	1980	1982	1983	1984	1985	1986
L18.2	Upper 18 Mile Wash		2			2	2	2	2
L19.3	19 Mile Wash		2	1		2		2	2
L34.7	Nautiloid Canyon	2	2			2	2	2	2
R53.0	Lower Nankoweap	3	3	1		1	3	2	1
R61.8	Mouth of Little Colorado	1		1		1	1	1	2
L65.5	Tanner Mine	2		2		2	2	2	2
R72.2	Unkar Indian Village (gone)	1	1	3		2	1		
L75	Nevills Rapid (New 1984)						2	2	2
L81.1	Grapevine	2		2		2	1	2	2
L87.1	Lower Suspension Bridge		2	1				1	
L93.2	Upper Granite Rapid	2		1		2	2	2	2
R109.4	109 Mile (gone)	2				1	2		
R112.2	Waltenberg Canyon (gone)	1		1		1	1		
R120.1	Blacktail Canyon	2		2	1	2	2	2	2
R122	122 Mile Beach (new 1985)							2	2
R122.8	Forster Canyon (new 1983)					3	3	3	3
L124.4	Upper 124 1/2 Canyon (gone)	2				1	1		
R131	Bedrock Rapid	2		2		2	2	2	2
L151.6	The Ledges	2	2			1	2	2	
L166.5	National Canyon		2	1		1	2	2	
L166.6	Lower National (new 1985)							2	5
L180.9	Lower Lava Falls	2		2		2	2	2	2
L190.2	190 Mile		1	1			1	1	1
L208.8	Granite Park	2	2	2	1	2	2	2	2
L220	220 Mile Beach (new 1985)							2	2

1974,1975 data from Howard (1975)
1980 data from Dolan (1981)
1982 data from Beus and others (1982)
1984 data from Beus and others (1984)
1985 data from Beus and others (1986)
1986 data from this report

Table 2. Summary of loss or gain in vertical feet of beach sand on Colorado River beaches between 1985 and 1986.

Beach	Profile	Inner	Outer
L18.2	CS 1	0	-0.5
	CS 2	0	-2.0
L19.3	No data in 1986		
L34.7	CS 1	0	0
	CS 2	-1.25	-2.5
R53.0	CS 1	No data in 1986	
	CS 2	-0.5	+0.5
R59.8	CS 1	-1.25	-1.75
R61.8	CS 1	-2.0	-1.5
	CS 2	new 1986	
L65.5	CS 1	-0.5	-0.75
	CS 2	0	-0.2
R72.2	No data in 1986		
L75.0	CS 1	+1.5	+1.5
	CS 2	+0.2	-0.1
L81.1	CS 1	+1.0	-0.75
	CS 2	+0.75	-0.25
L87.1	No data in 1986		
L93.2	CS 1	-1.5	-0.3
	CS 2	-0.25	-0.5
R109.4	No data in 1986, beach gone		
R112.2	No data in 1986, beach gone		
R120.1	CS 1	-0.5	-0.2
	CS 2	0.0	0.0
R122	CS 1	+0.75	+9.75
	CS 2	+2.0	+1.5
L122.8	CS 1	+1.5	+1.0
	CS 2	0.0	0.0
	CS 3	0.0	+0.3
L124.4	No 1986 data, beach much reduced		
R131	CS 1	-1.0	-0.2
	CS 2	0.0	0.0
R151.6	No data in 1986		
L166.5	No 1986 data, beach mostly rocks		
L166.6	CS 1	0.0	0.0
	CS 2	0.0	-1.75
	CS 3	New 1986	
	CS 4	New 1986	
	CS 5	New 1986	
R180.4	CS 1	-0.25	-0.25
	CS 2	-3.75	-3.0 Flash flood
L190.2	CS 1	+5.0	+3.5 !!
L208.1	CS 1	0.0	+0.2
	CS 2	0.0	-1.0
R220	CS 1	+0.75	-0.75
	CS 2	0.0	-0.3

LIST OF TABLES

Table

LIST OF FIGURES

Figure

21. CS 1 at 220-mile

22. CS 2 at 220-mile

23. Graphic summary of gain or loss of beach sand on 18 beaches surveyed in 1986.

REFERENCES

Beus, S. S., and others. 1982. A study of beach profiles as a measure of erosion. In Beus, S. S. and Carothers, S. W. (eds.), Colorado River Investigations I. Northern Arizona University/Museum of Northern Arizona manuscript report submitted to Grand Canyon National Park, p. 16-19.

Beus, S. S., and others. 1984. Changes in beach profiles along the Colorado River in Grand Canyon, 1974-1983. In Beus, S. S. and Carothers, S. W. (eds.), Colorado River Investigations II, July-August, 1984. Northern Arizona University/Museum of Northern Arizona manuscript report submitted to Grand Canyon National Park, p. 23-84.

Beus, S. S., and others. 1986. Changes in selected beach profiles along the Colorado River, Grand Canyon, 1984-1985. In House, D. A. (ed.), Colorado River Investigations IV, July-August, 1985. Northern Arizona University/Museum of Northern Arizona manuscript report submitted to Grand Canyon National Park, p. 3-69.

Dolan, R. 1981. Analysis of the erosional trends of the sedimentary deposits in Grand Canyon. Manuscript report submitted to the Bureau of Reclamation, Water and Power Resources Service, Durango, Colorado, 22 p.

Howard, A. D. 1975. Establishment of bench mark study sites along the Colorado River in Grand Canyon National Park for monitoring of beach erosion caused by natural forces and human impact. University of Virginia Grand Canyon Study. Technical Report No. 1, 14 p.

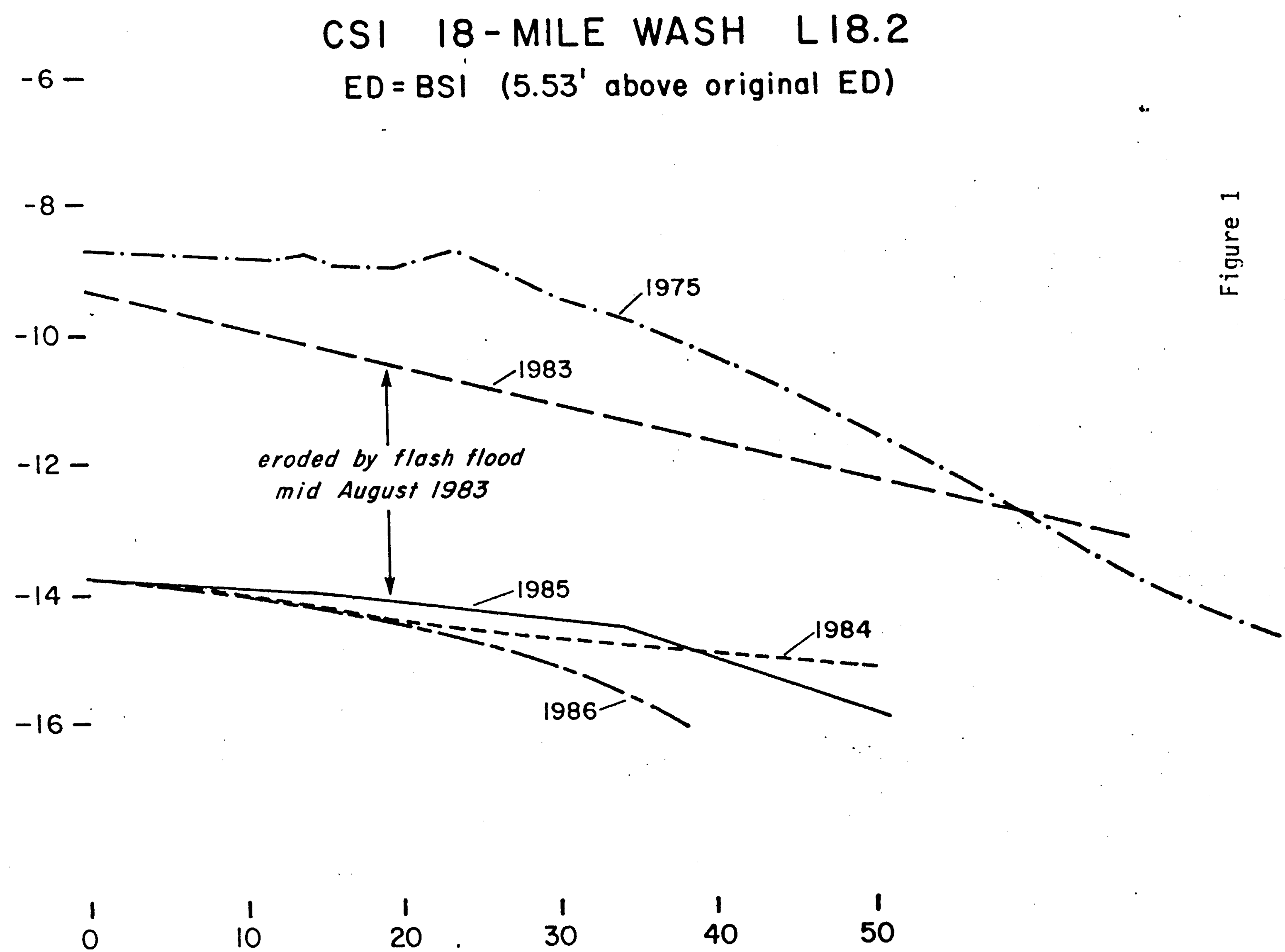

CSI 18-MILE WASH L18.2
ED=BSI (5.53' above original ED)
-6
-8
-10
-12
-14
-16
0
10
20
30
40
50
1975
1983
eroded by flash flood
mid August 1983
1985
1984
1986

Figure 1

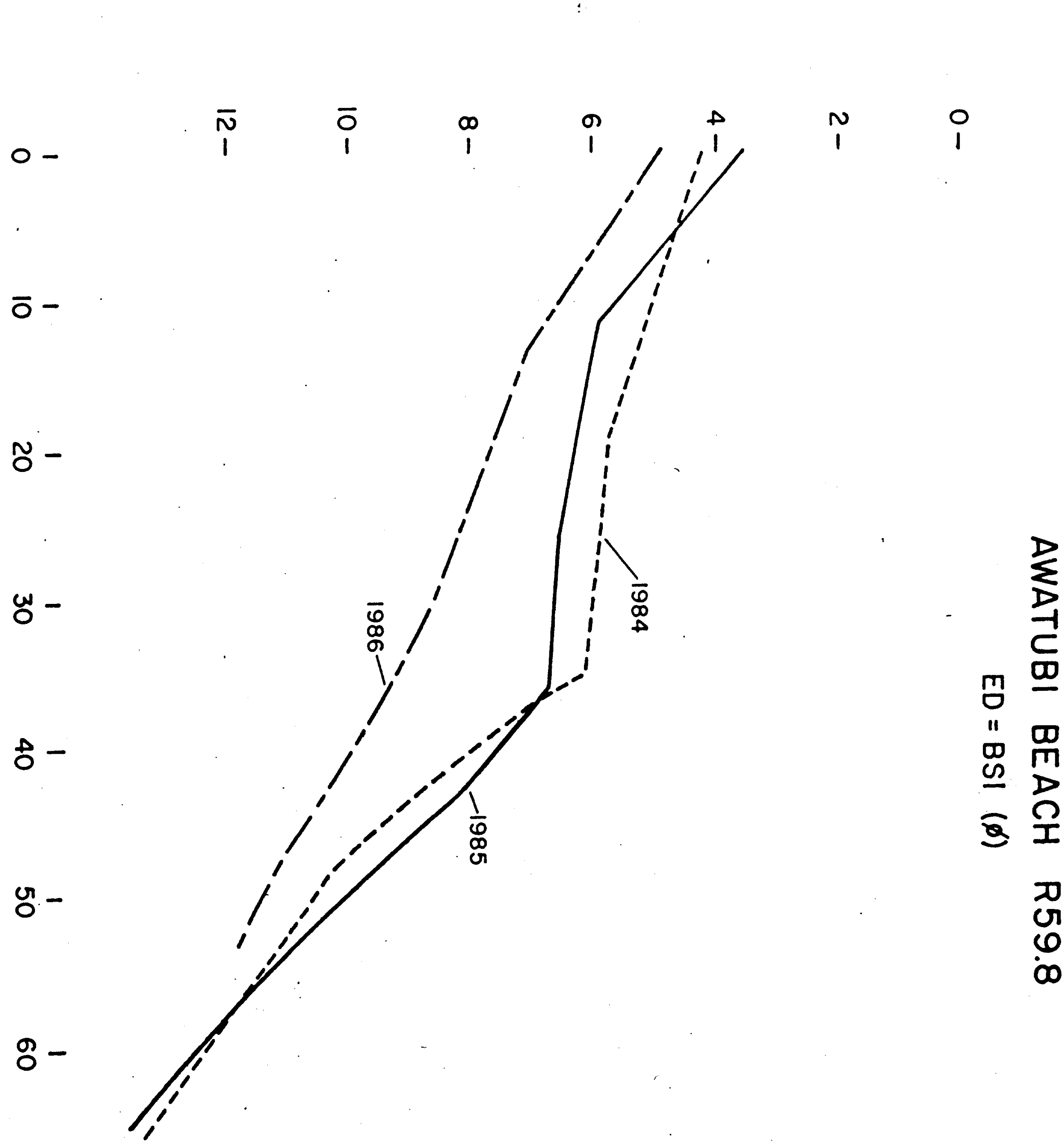

AWATUBI BEACH R59.8
ED = BSI (ø)
0
2
4
6
8
10
12
0
10
20
30
40
50
60
1984
1985
1986

Figure 2

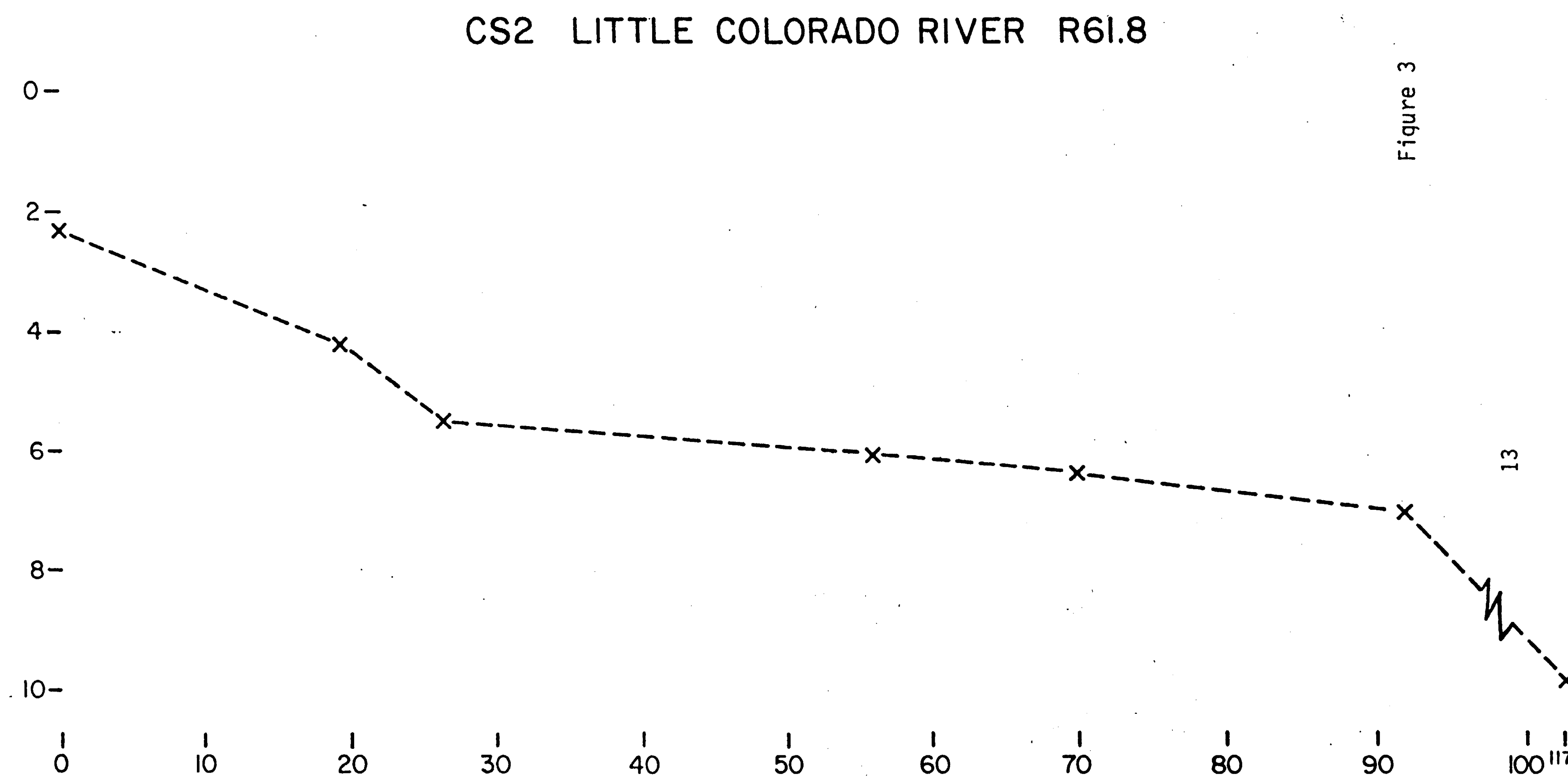

CS2 LITTLE COLORADO RIVER R61.8
0
2
4
6
8
10
0
10
20
30
40
50
60
70
80
90
100
117

Figure 3

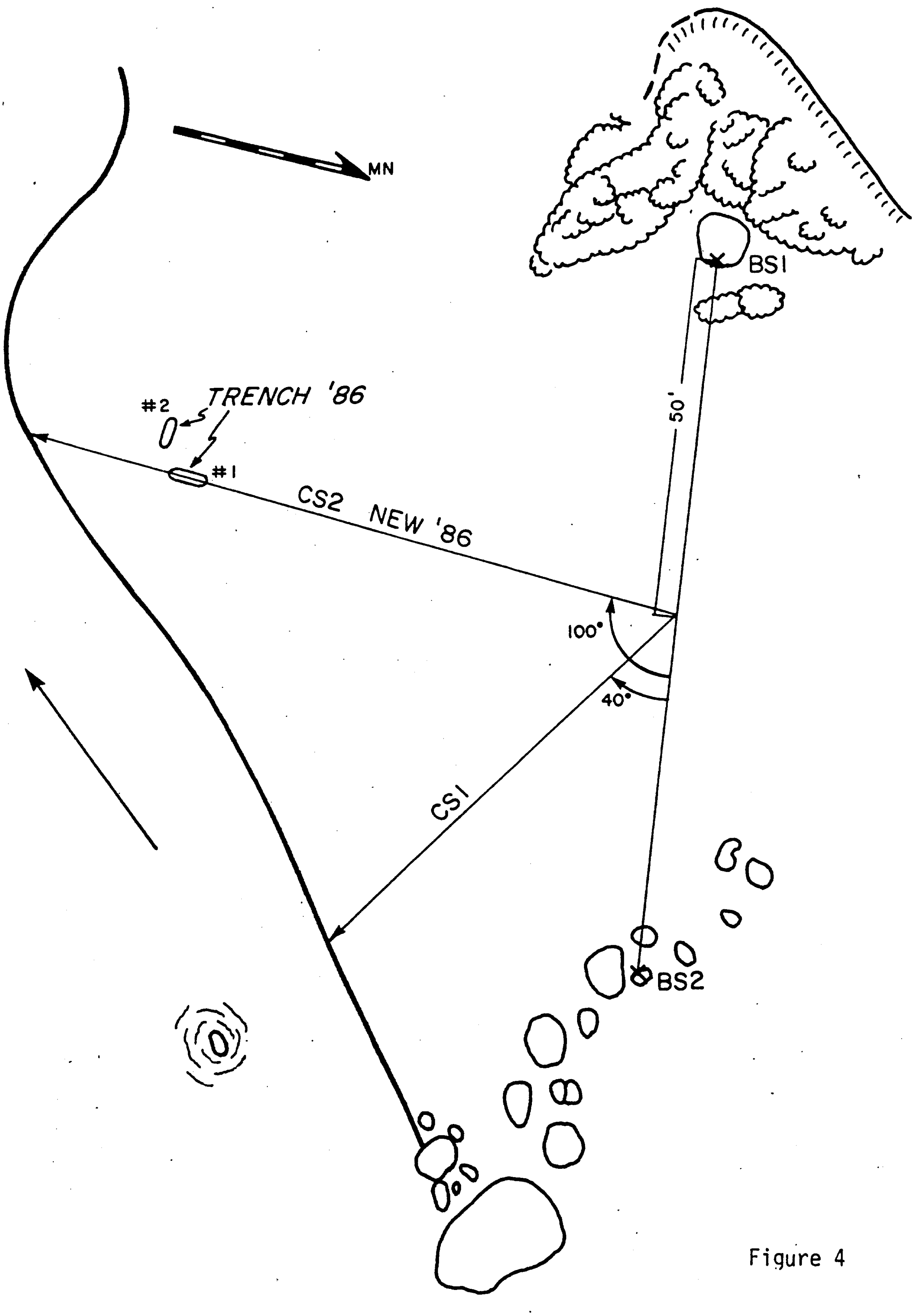


Figure 4

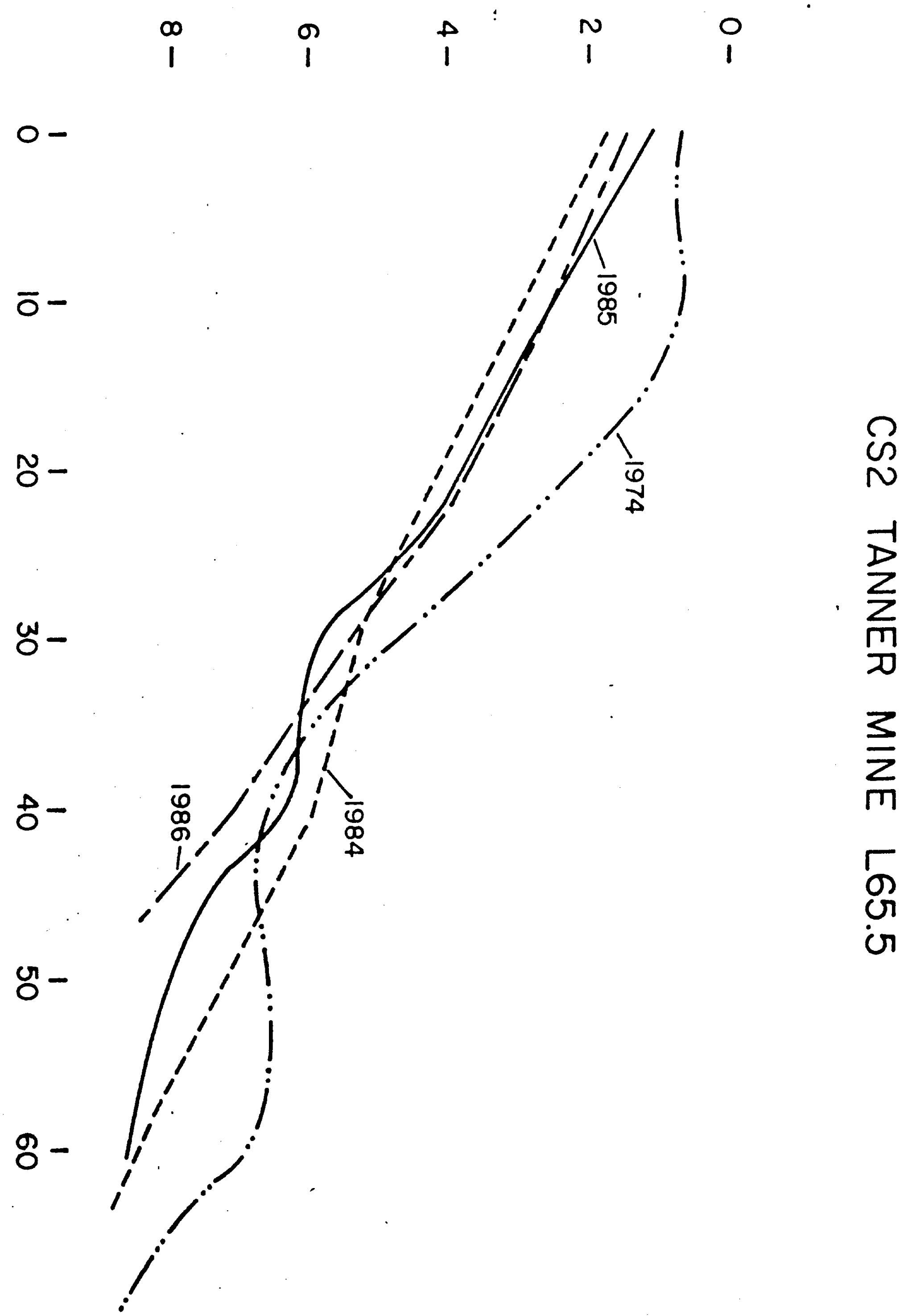
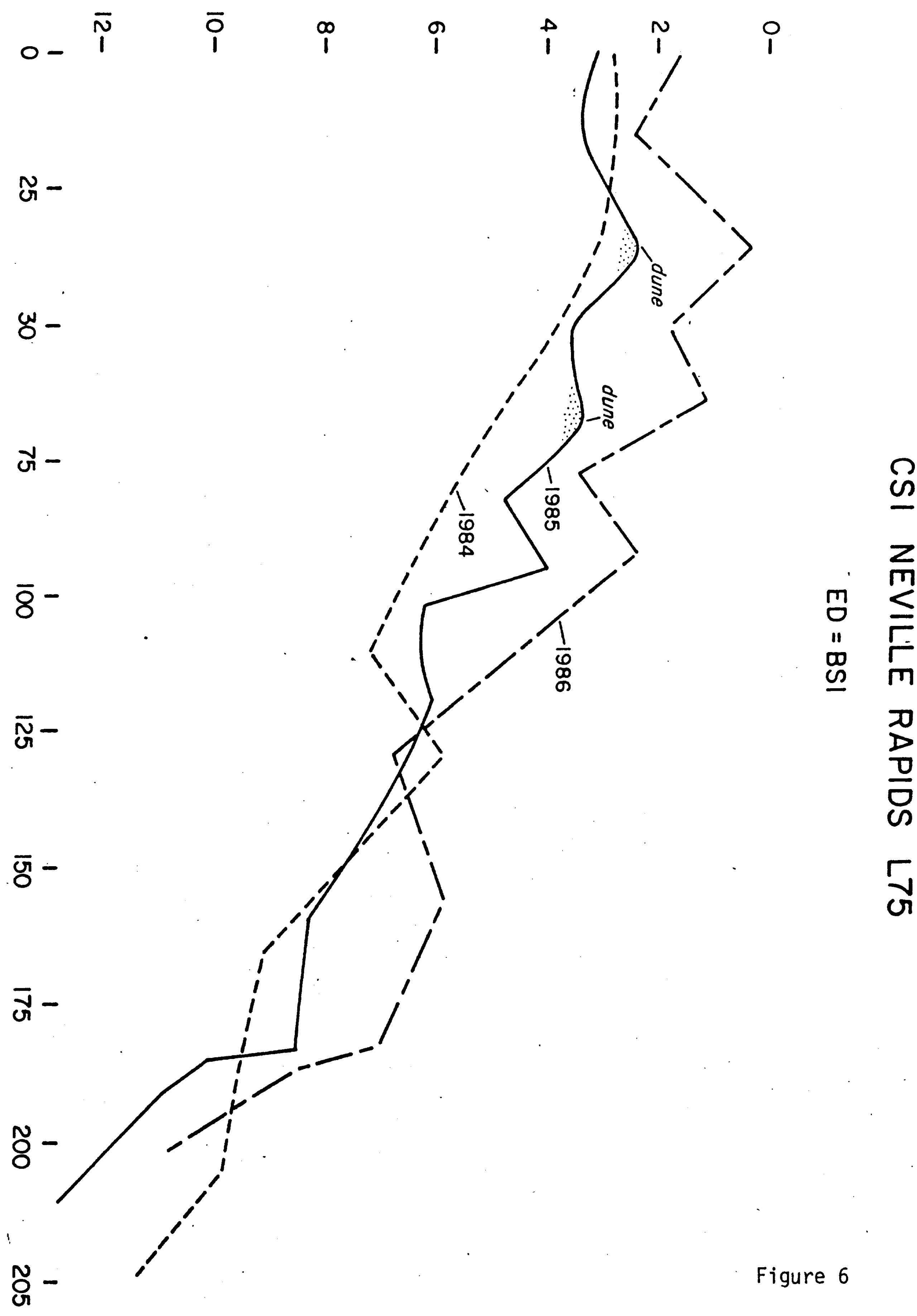

CS2 TANNER MINE L65.5
0
2
4
6
8
0
10
20
30
40
50
60
1974
1984
1985
1986

Figure 5



CSI NEVILLE RAPIDS L75
ED = BSI
0
2
4
6
8
10
12
0
25
30
75
100
125
150
175
200
205
dune
dune
1984
1985
1986

Figure 6

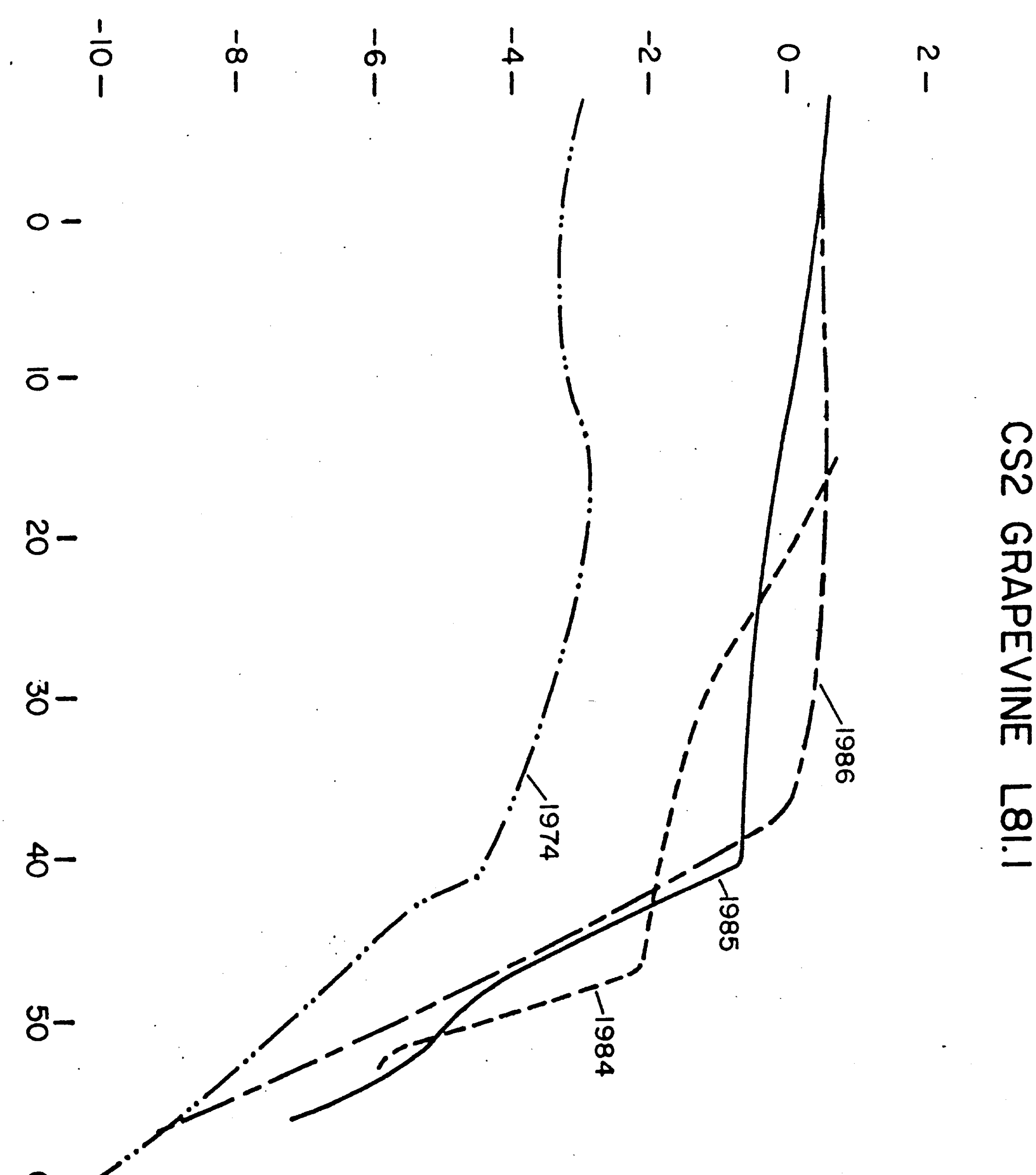

CS2 GRAPEVINE L81.1
2
0
-2
-4
-6
-8
-10
0
10
20
30
40
50
60
1974
1984
1985
1986

Figure 7

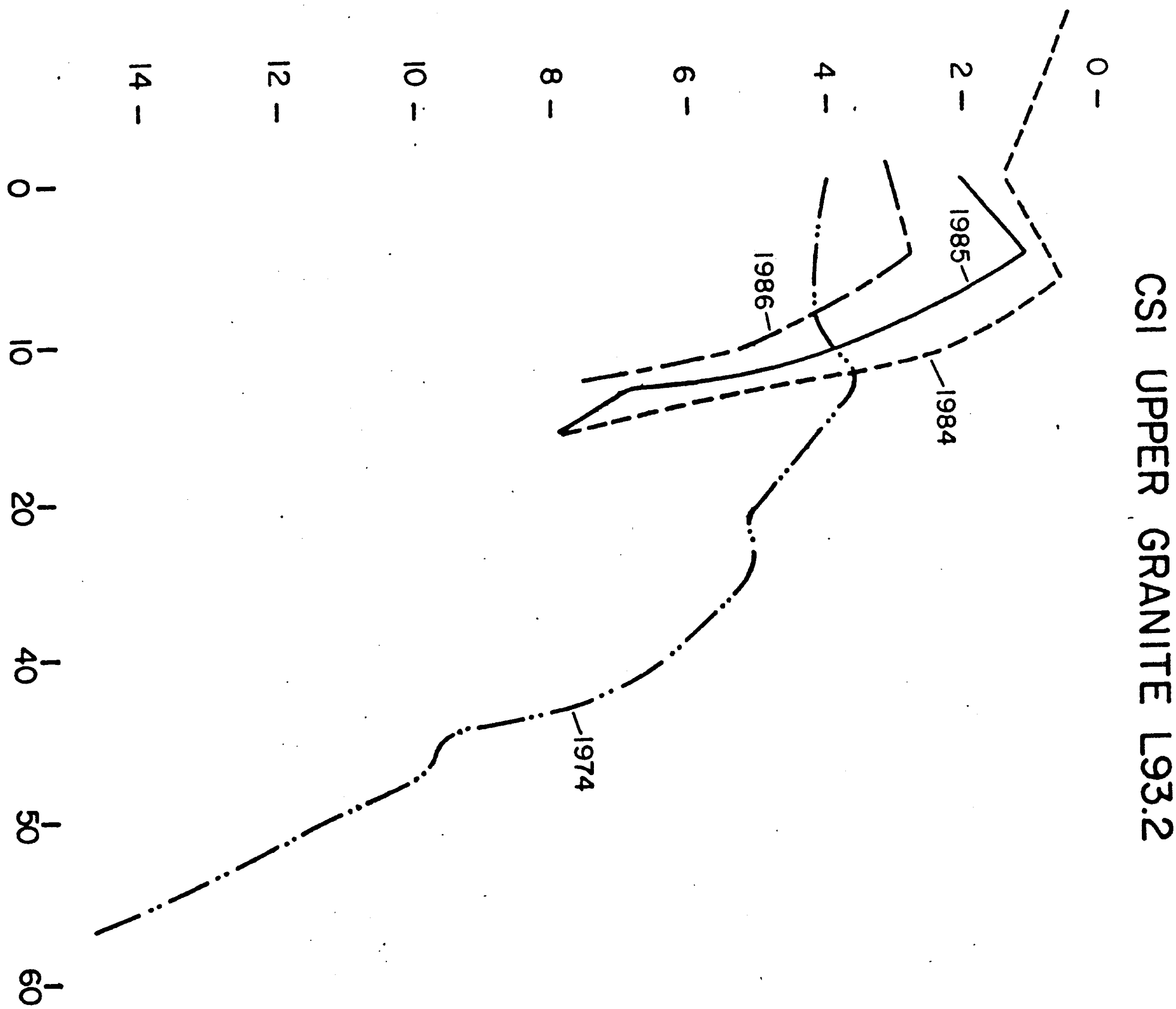

CSI UPPER GRANITE L93.2
0
2
4
6
8
10
12
14
0
10
20
40
50
60
1984
1985
1986
1974

Figure 8

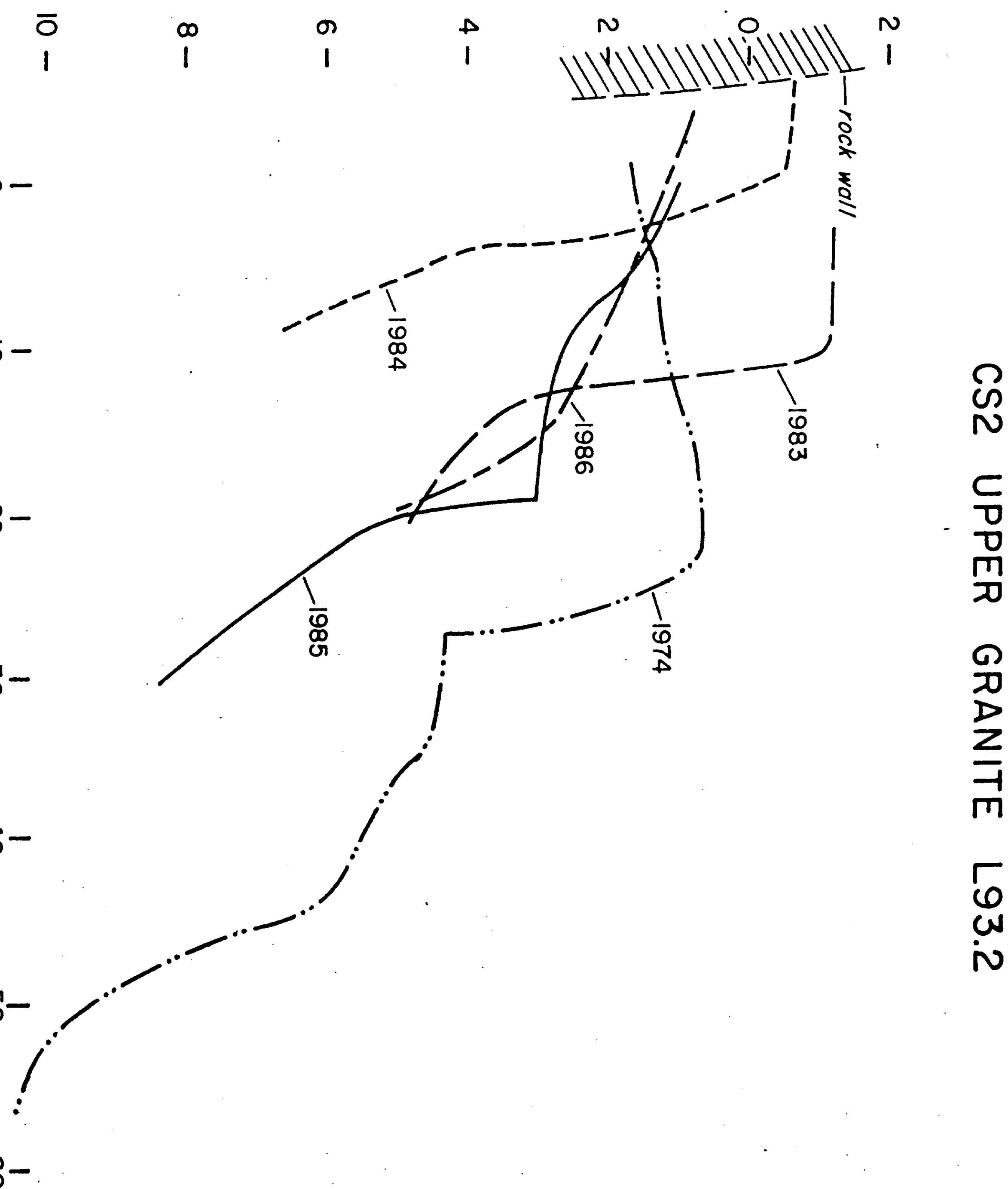
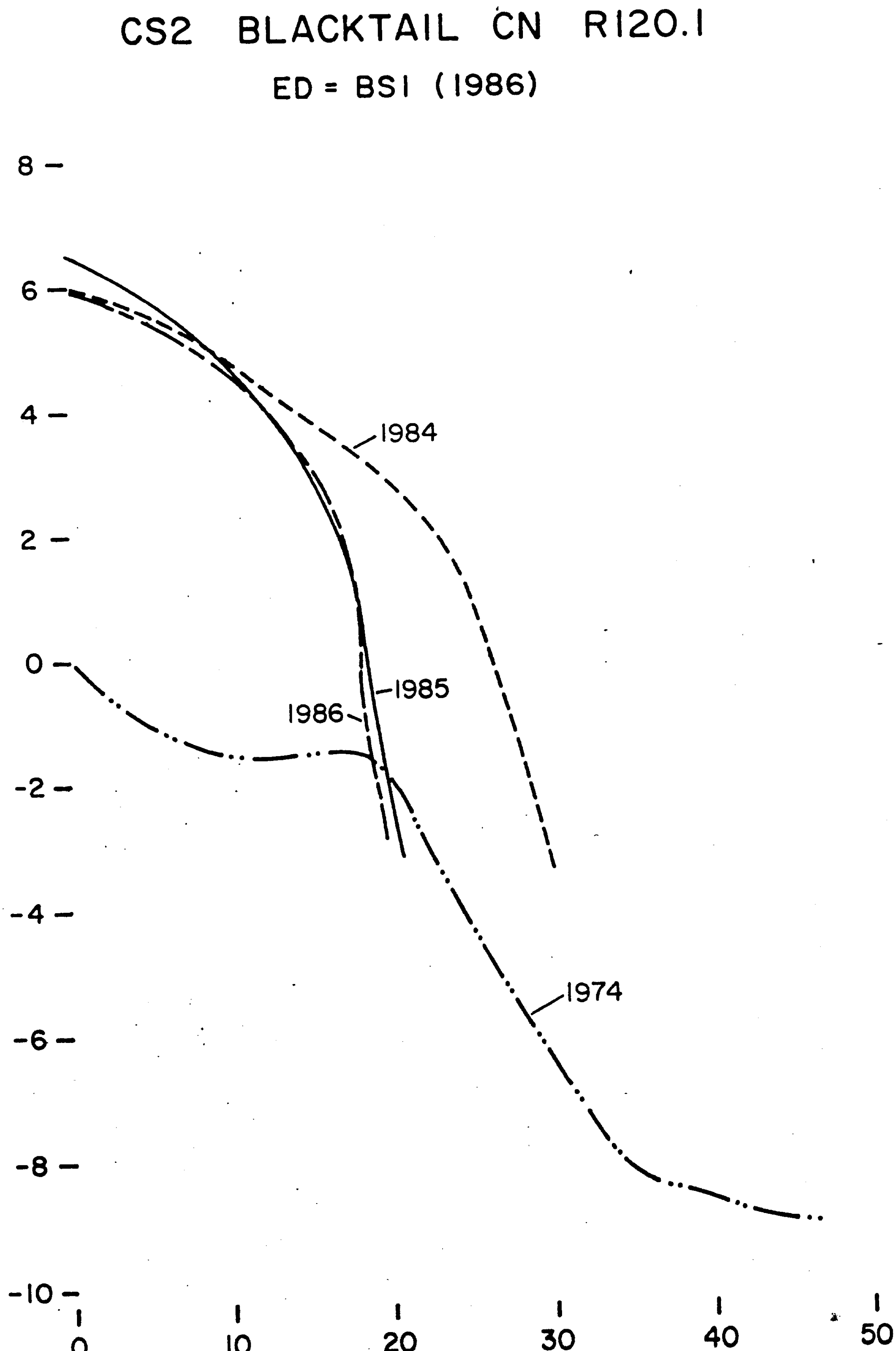

CS2 UPPER GRANITE L93.2
rock wall
1983
1984
1986
1985
1974
2
0
2
4
6
8
10
0
10
20
30
40
50
60

Figure 9


CS2 BLACKTAIL CN R120.1
ED = BSI (1986)
8
6
4
2
0
-2
-4
-6
-8
-10
1984
1985
1986
1974
0
10
20
30
40
50
Figure 10

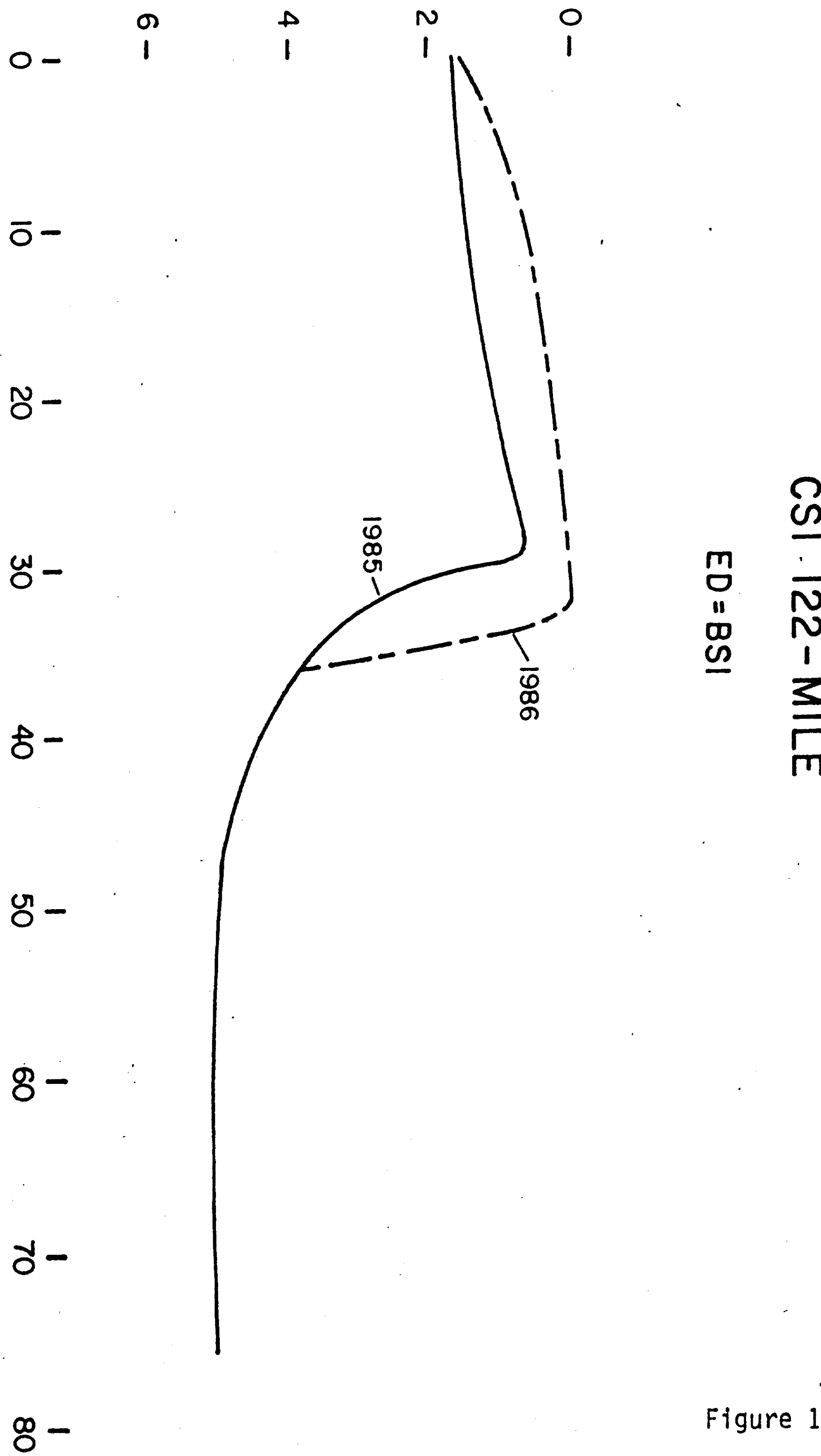


Figure 11

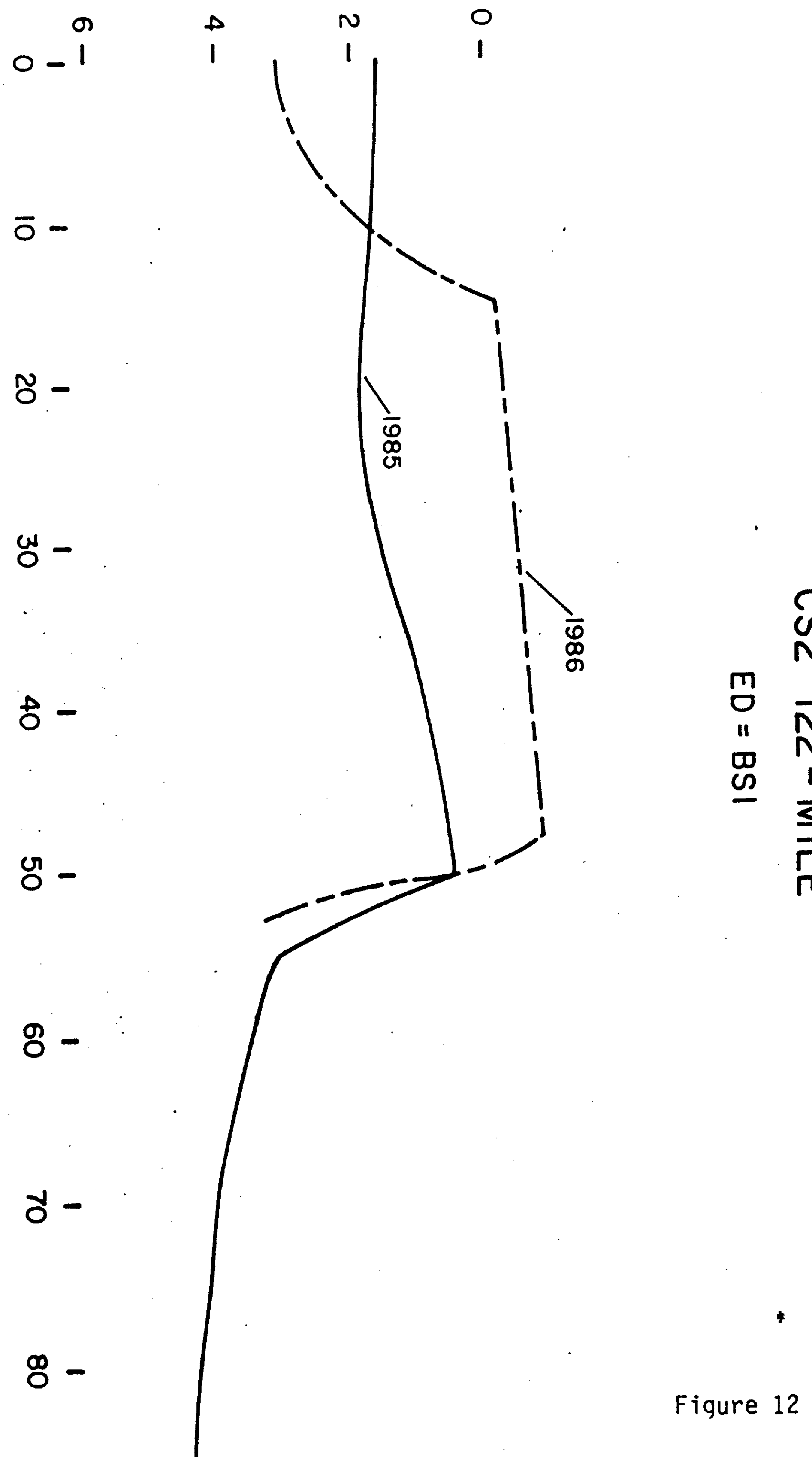


Figure 12

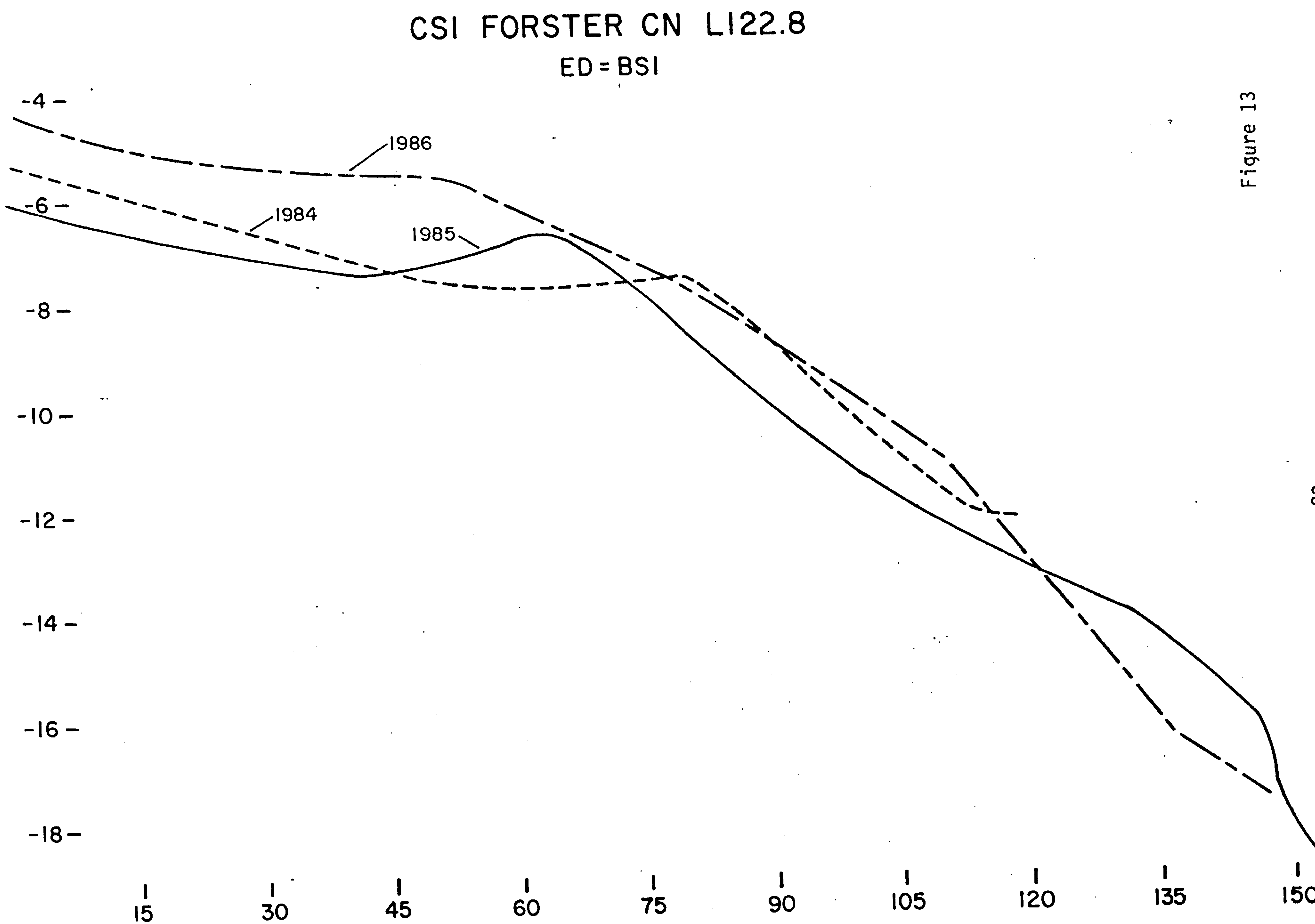

CSI FORSTER CN L122.8
ED=BSI
-4
-6
-8
-10
-12
-14
-16
-18
15
30
45
60
75
90
105
120
135
150
1986
1984
1985

Figure 13

CS2 FORSTER CN LI22.8

ED = BSI

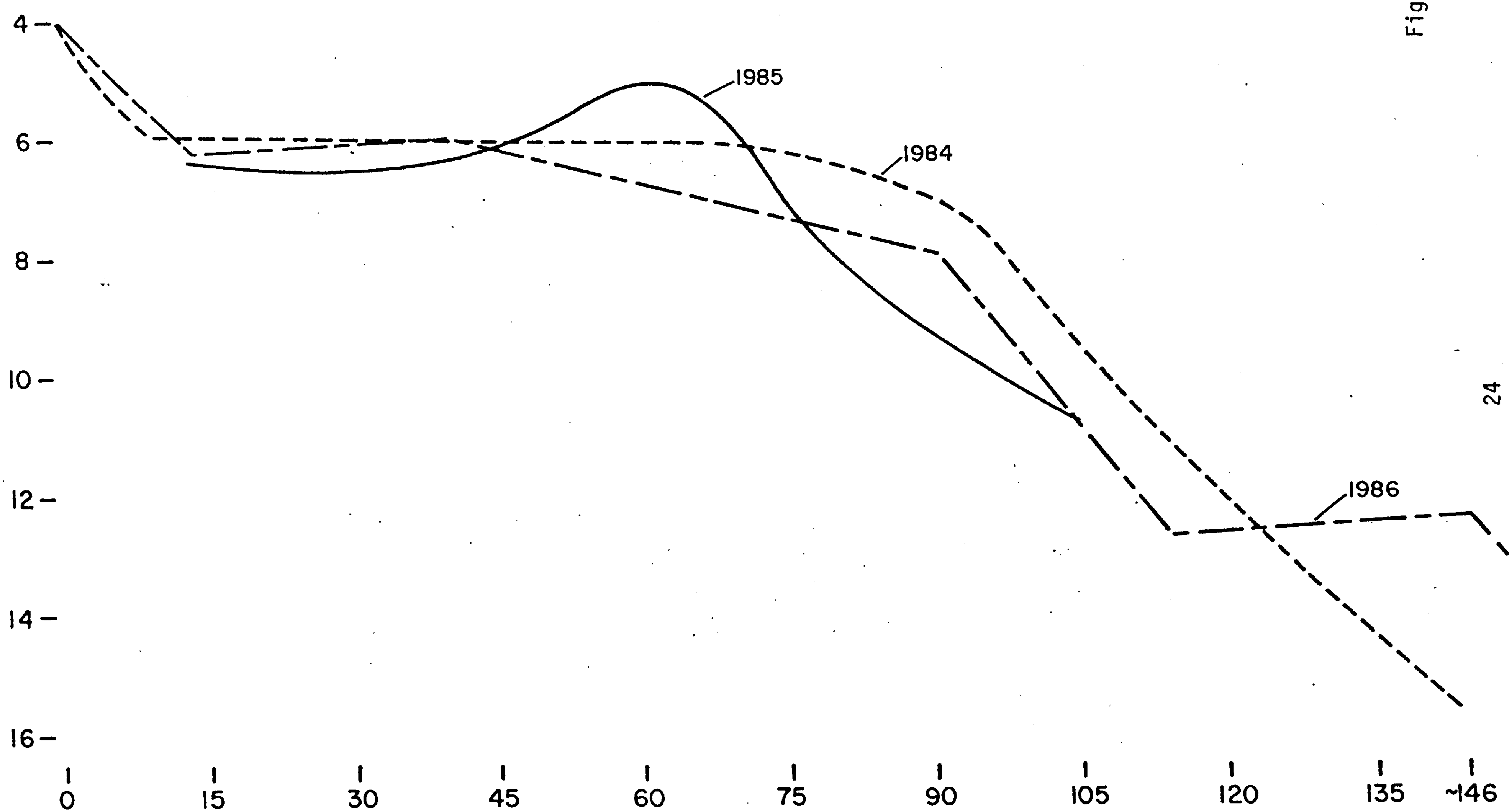


Figure 14

CS3 FORSTER CN L122.8

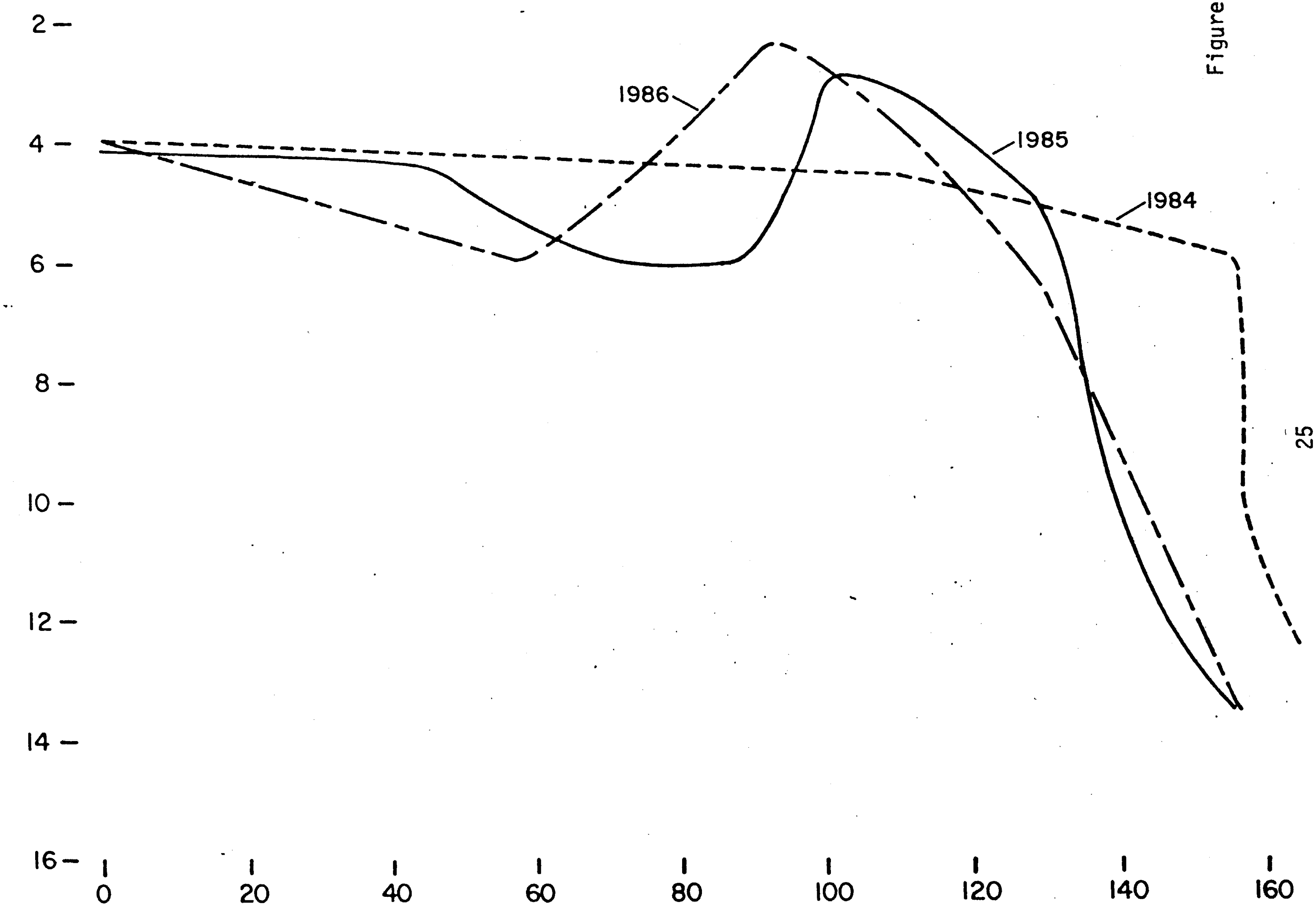


Figure 15

CSI LOWER NATIONAL LI66.6

ED=BS2

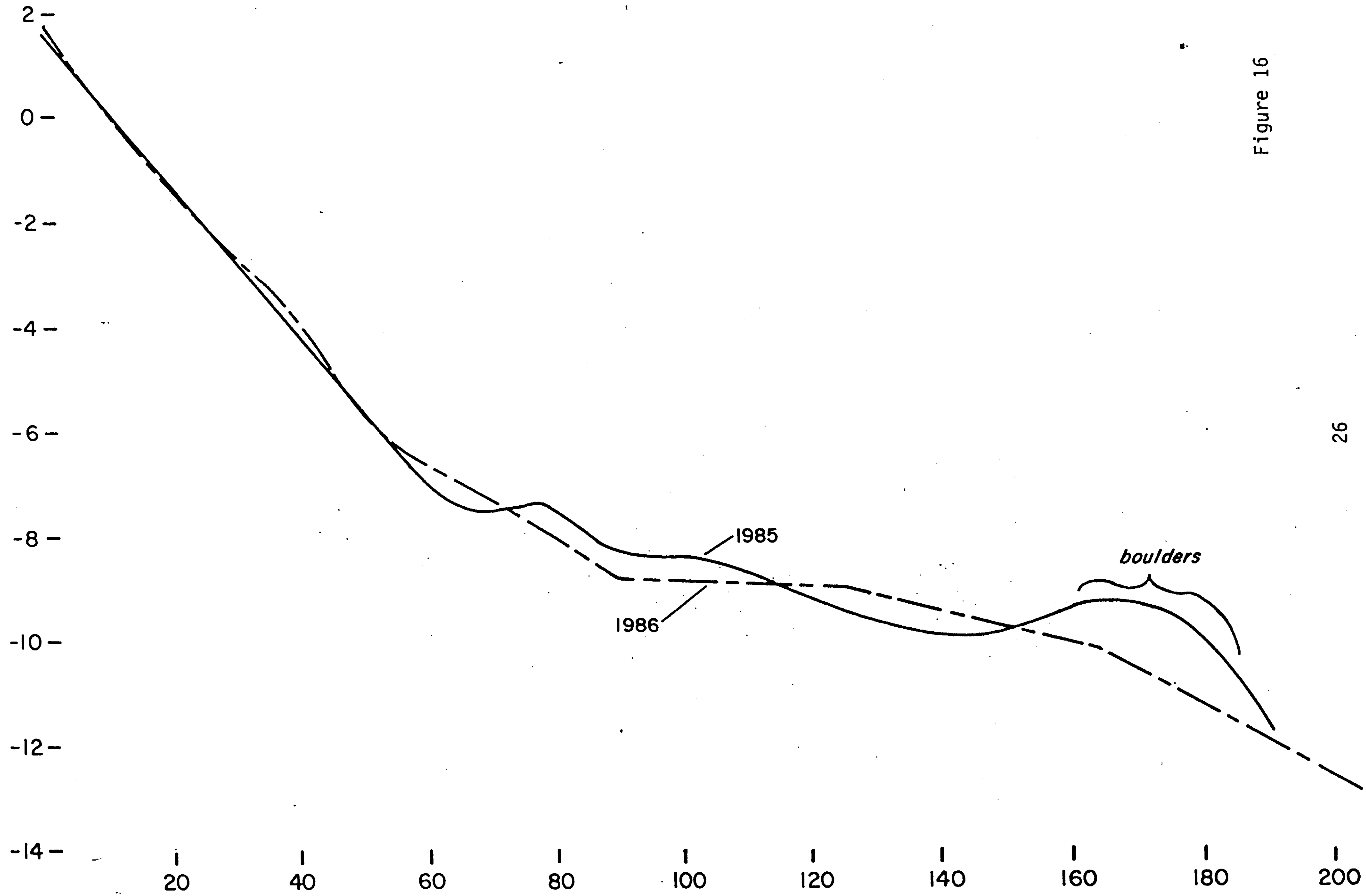
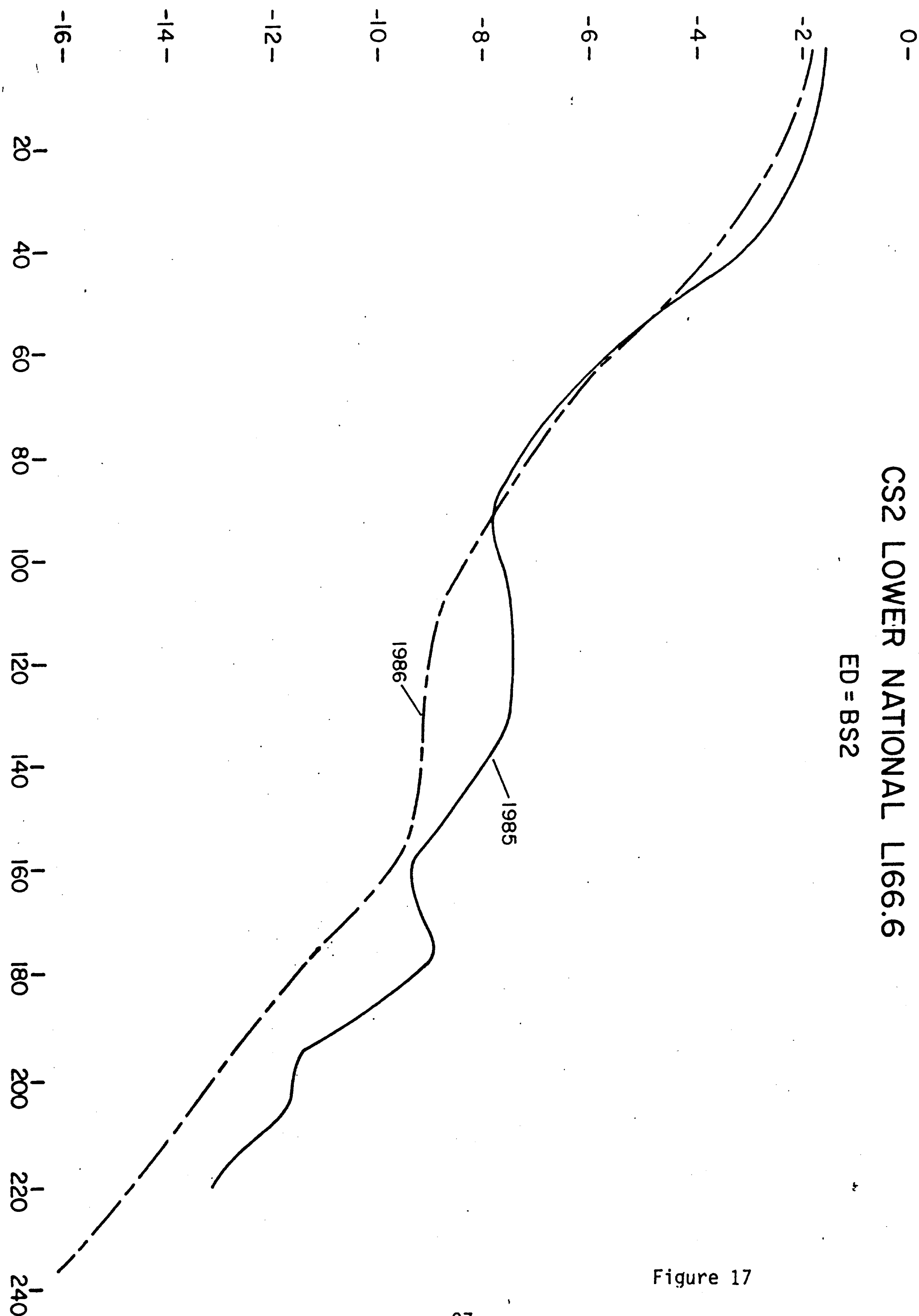


Figure 16



CS2 LOWER NATIONAL LI66.6
ED = BS2
1985
1986
0
-2
-4
-6
-8
-10
-12
-14
-16
20
40
60
80
100
120
140
160
180
200
220
240

Figure 17

LOWER NATIONAL BEACH L 166.6

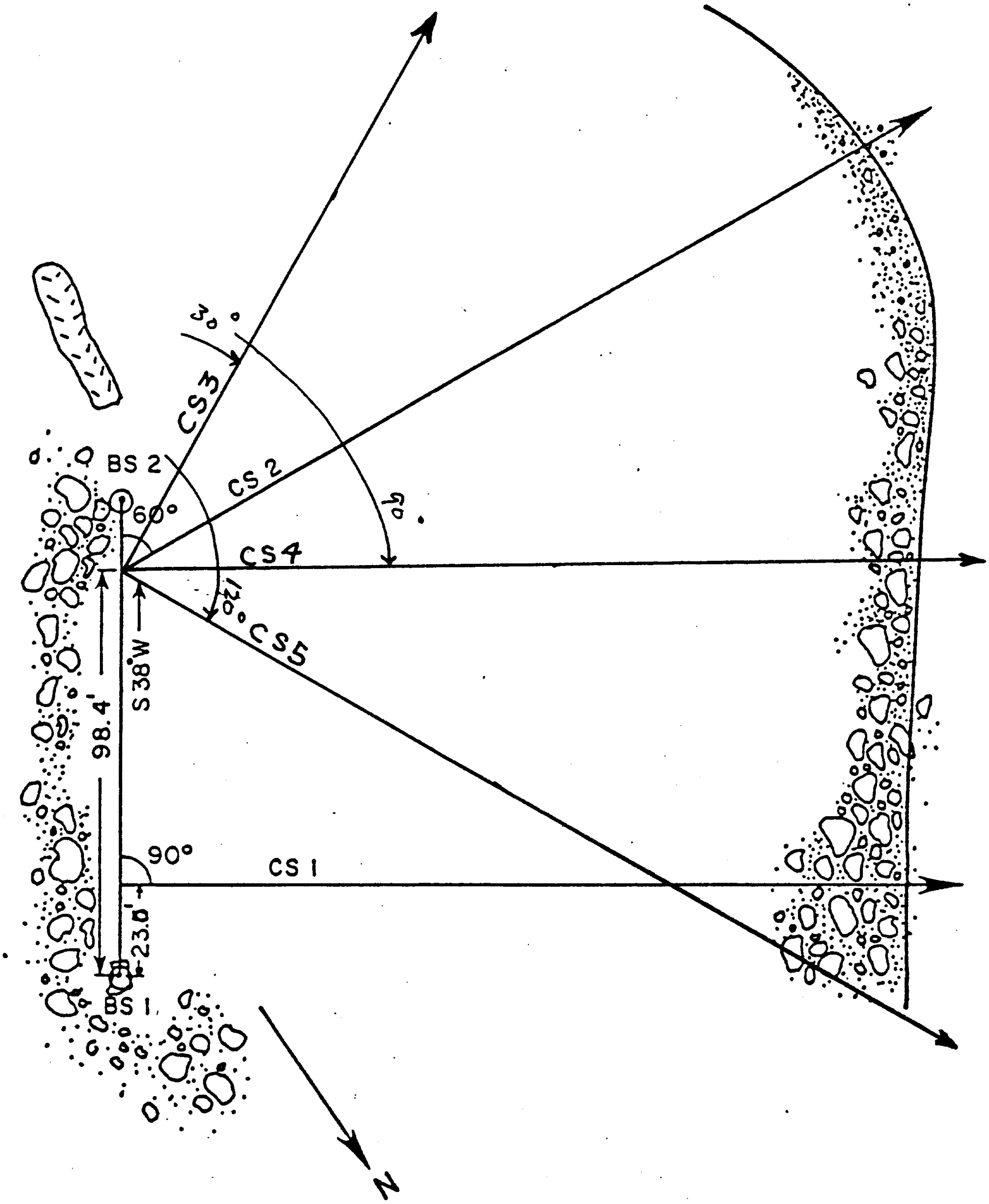


Figure 18

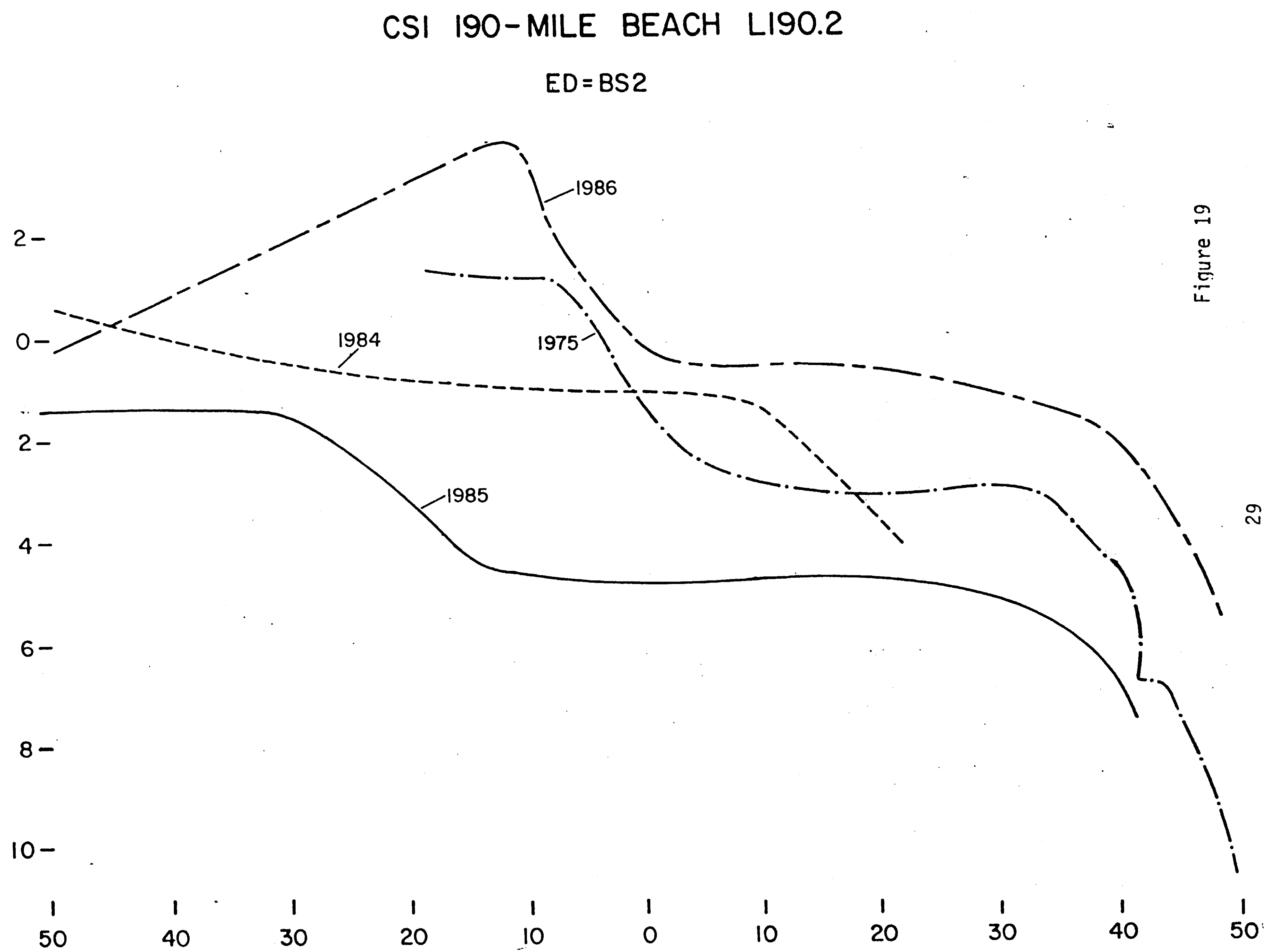

CSI 190-MILE BEACH L190.2
ED=BS2
1986
1975
1984
1985
2
0
2
4
6
8
10
50
40
30
20
10
0
10
20
30
40
50

Figure 19

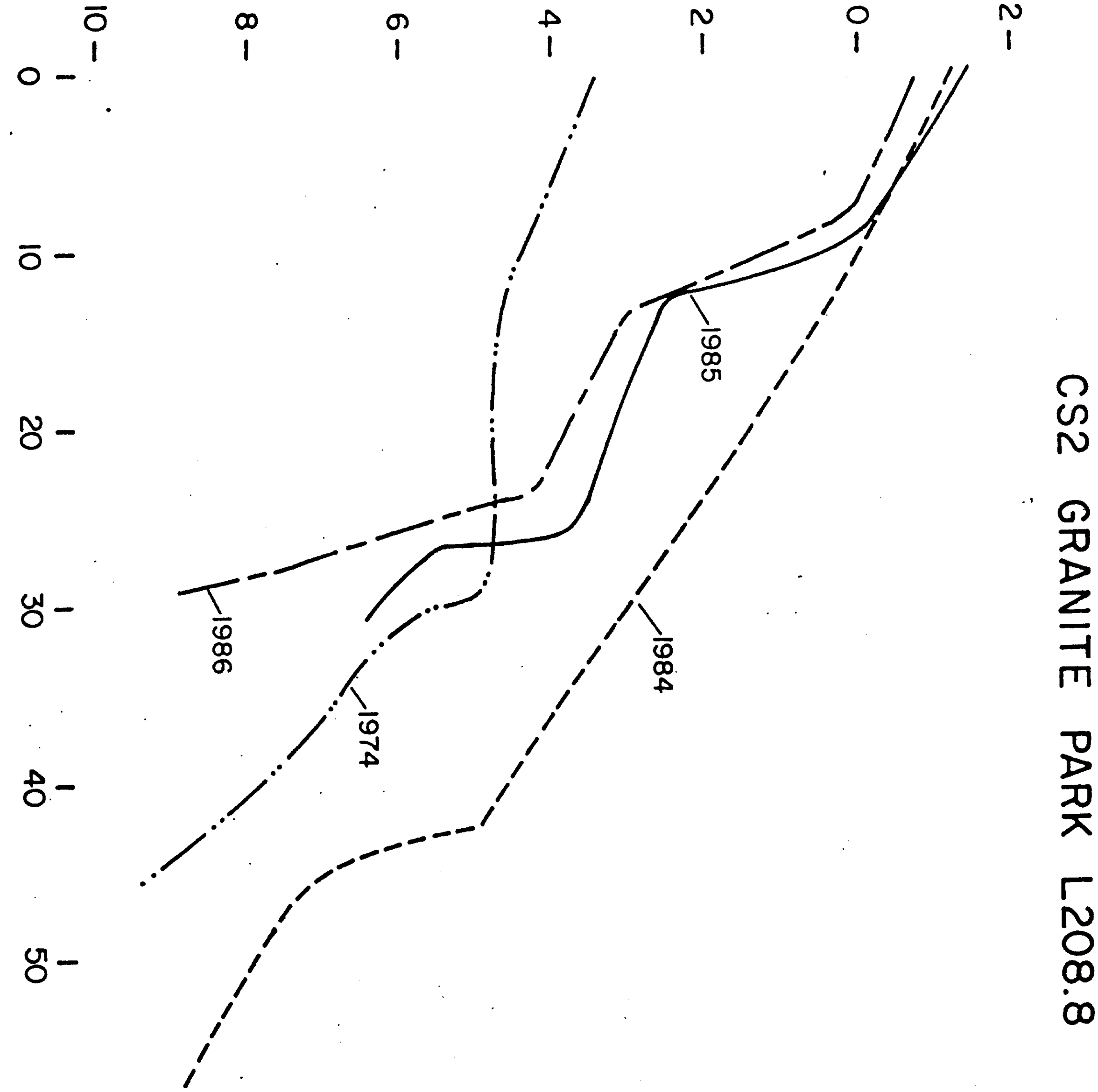

CS2 GRANITE PARK L208.8
2
0
2
4
6
8
10
0
10
20
30
40
50
1985
1984
1986
1974

Figure 20

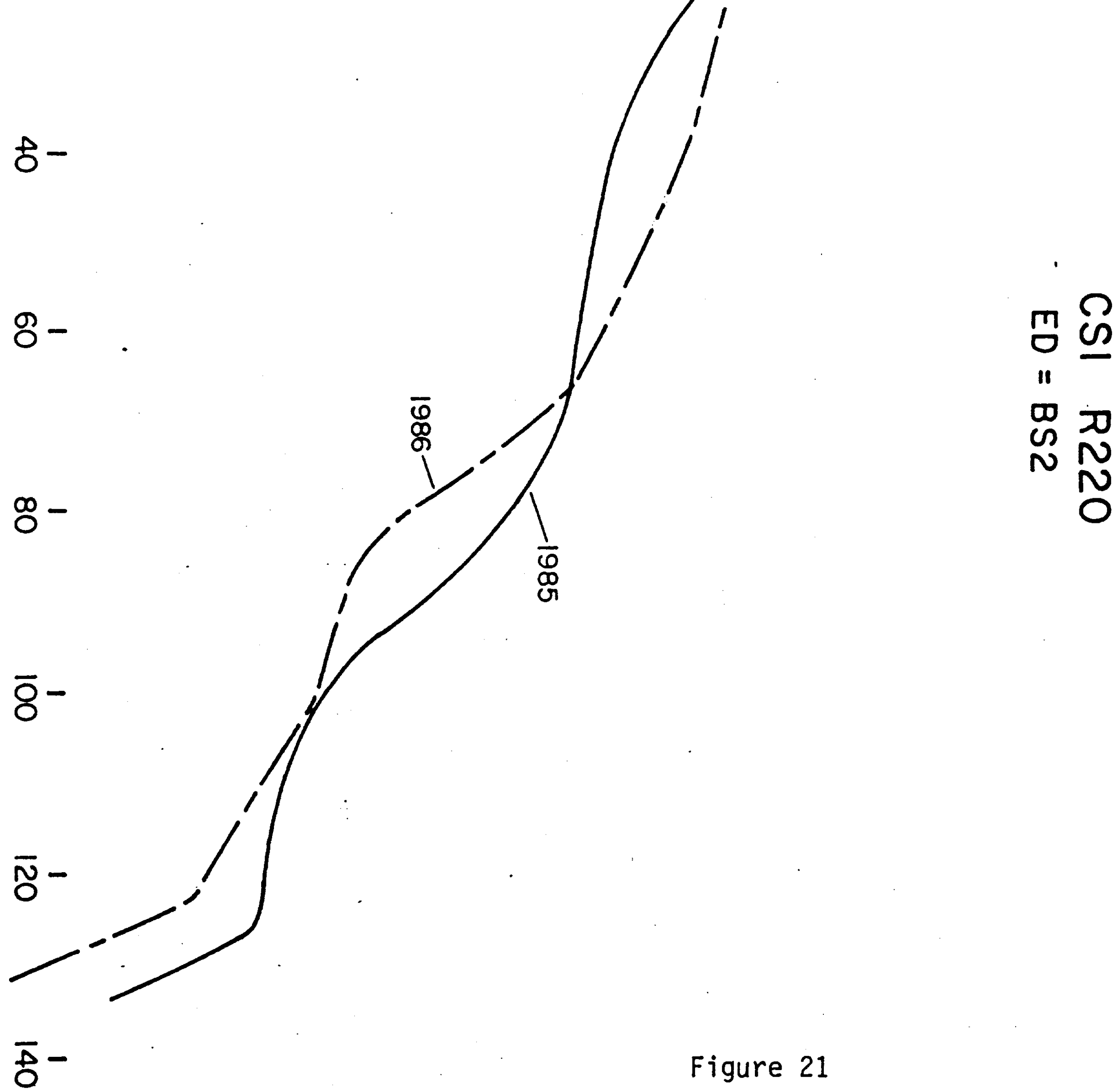


Figure 21

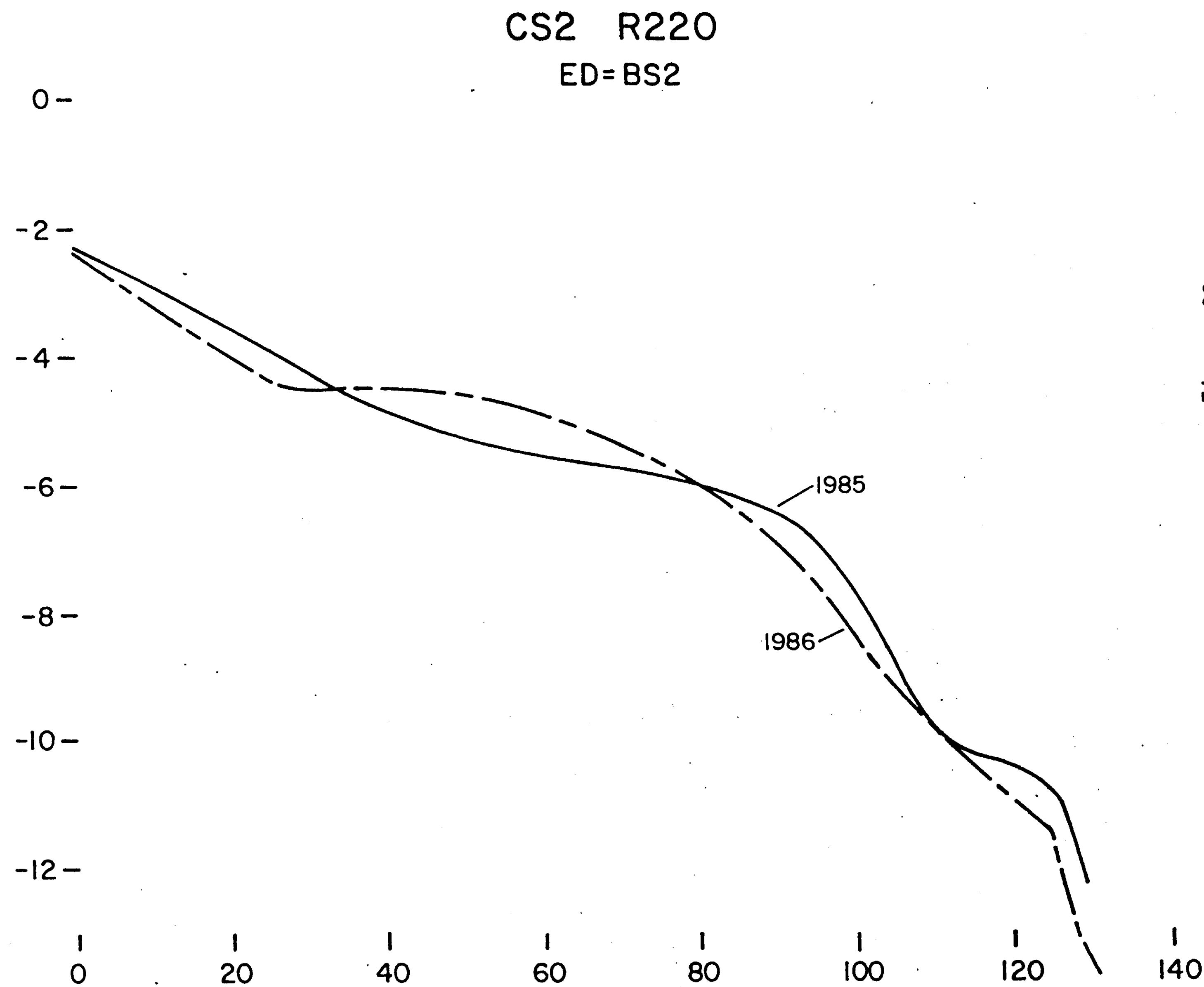


Figure 22

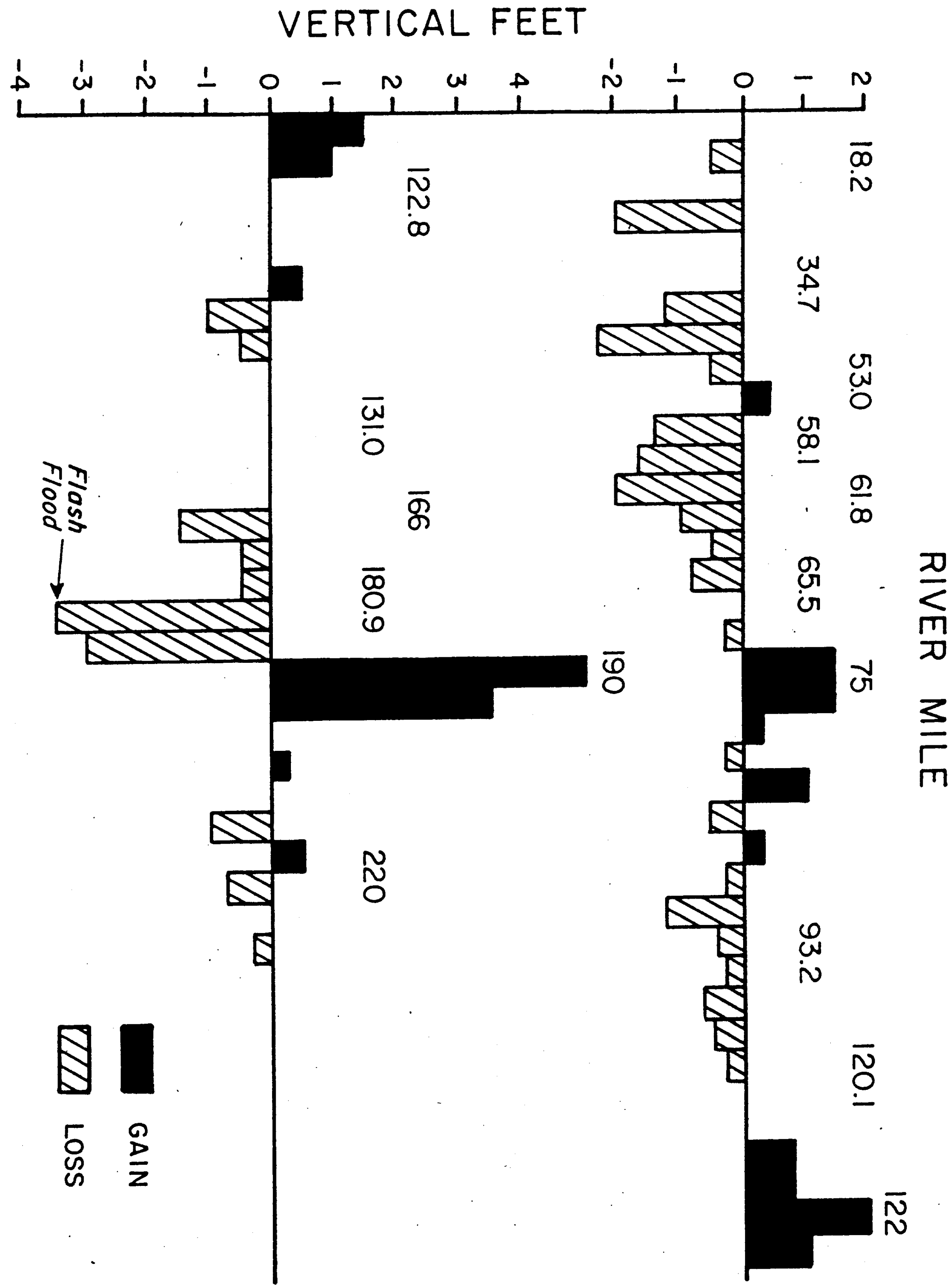

VERTICAL FEET
RIVER MILE
2
1
0
-1
-2
4
3
2
1
0
-1
-2
-3
-4
18.2
34.7
53.0
58.1
61.8
65.5
75
93.2
120.1
122
122.8
131.0
166
180.9
190
220
Flash Flood
GAIN
LOSS

Figure 23

CHAPTER III

FIVE YEAR COMPREHENSIVE STUDY ON BEACH SAND GRAIN SIZE ON THE COLORADO RIVER IN THE GRAND CANYON

Frank B. Lojko

INTRODUCTION

Sand samples were collected from 11 beaches along the Colorado River in the Grand Canyon for a comparative grain size analysis during the following years: 1982, 1983, 1984, 1985 and 1986. 270 samples were collected in this five year study from established beaches as well as from new research sites. The data was analyzed to determine any significant trends in the textural parameters of the beach sands during these years.

This investigation is expected to provide definitive data on the textural parameters of the sand and how they may be affected. In addition, from the grain size analysis it is possible to predict the minimum water current velocity required to initiate transportation and deposition of the beach sand.

METHODS

Six types of sites were sampled in this study:

1. Surface samples collected at previously sampled transect and non-transect sites for the purpose of comparison.
2. Surface samples collected at measured transect sites not previously sampled.
3. Random surface samples collected at high dunes on beaches.

4. Surface samples collected along perpendicular transect which intersect established transect sites.
5. Profile samples collected from eroded and exposed sand banks.
6. Profile samples collected from dug trench sites.

Transect samples were collected at selected points along a tape stretched across the beach. Some of the transects were run perpendicular to established transect sites in order to sample a greater area of the beach. This method of sampling results in a T or a cross-pattern. One or more of the following field techniques were employed to insure continued accuracy in future sand studies: compass bearings, photographs, surveying, mapping and transect measurements of the sample sites.

Sand samples ranging from 38 to 82 grams in weight, were collected in small uniform plastic vials. These samples were sieved through a standard set of 3-inch diameter sieves graduated in 1/2 phi sizes. Each sample was shaken by hand for ten minutes using a clamping device that held two sieve sets together. Each size fraction was weighed, using a Ohaus triple beam balance and/or a portable Ohaus battery operated field balance. The mean phi size and Wentworth Scale rating (very fine, fine, medium, coarse) were determined for each sample site. The samples were saved for future reference and study.

The five years of composite data were entered into a special computer program (Appendix A) which calculates the mean phi size, Moment Measure Statistics, Folk's Statistics, Folk's Textural Description and Inman's Statistics. The results of this analysis are presented in Appendix B.

In the 1982 study, samples were randomly collected at selected sites on established beaches. The high water spill of 1983 caused dramatic changes to the beaches and many of the 1982 sample sites were unable to be collected for comparison. Therefore, new sites were established at these beaches and were consistently sampled.

RESULTS

The sand was found to be generally fine- to medium-grained, moderately sorted, and composed predominantly of quartz. A river current velocity of 22 to 25 cm/sec was calculated (from Hjulstrom's diagram, 1929) to be the minimum velocity required to initiate erosion of any beach sand sampled.

Comparison of samples taken at the beginning of the study to those collected at the end of the study, show that eleven out of the eighteen sites exhibit little or no change in mean grain size (Table 1). Those sites are as follows: Badger (T-3m and T-27m), Shinumo Wash (T-19m), Nautiloid (T-12m), Lower Nankoweap (T-30m), Grapevine (T-30m), Lower Bass (T-4m), Dubendorff (T-27m), Lower National (T-38m) Granite Park (T-6m) and Pumpkin Bowl (T-38m). There are three beaches, (20 Mile T-34m, Forster T-6m and 220 Mile T-20m), which indicate noticeable changes in mean phi size and two beaches which had slight changes in mean phi size (Nevills T-6m and Pumpkin Bowl T-3m). Although fluctuations in grain size occur throughout the five year study, it appears that the mean phi size in a large percentage of the beach sites tended to stabilize close to their original (1982) measured phi size.

There was one sample site (220 Mile T-40m) which showed a significant decrease in grain size between the years 1983/1984 and 1985/1986. It was observed that in the first two years of sampling at this site there was no evidence of riparian vegetation, while in the last two years of sampling, scouring rush (Equisetum hiemale) was present.

CONCLUSION

Data indicates that the majority of the sample sites initially changed in mean phi size, yet the end results of the study showed that the mean phi sizes stabilized close to their original measured phi size. What influence(s) prevailed to cause such changes? The most obvious influence was the high water spill of 1983, which altered temporarily the "normal" velocity and sediment load through the Grand Canyon. With normal flow discharge restored, the sand was equilibrated back to a steady state.

Vegetation may have influenced the beach sand size at 220 Mile (T-40). It seems reasonable to postulate that the growth of scouring rush in the latter part of the study (1985/1986), was effective in trapping the finer-grained sand, thus accounting for the significant decrease in grain size in this beach during these years.

Table 1. Mean phi size of sand samples from selected beaches on the Colorado River (Grand Canyon) from 1982 -1986.

River Mile	Beach	Sample Site	Mean Phi Size 1982	1983	1984	1985	1986
8	Badger	T-3m	1.97	2.06	2.11	1.94	1.91
		T-27m	1.75	1.60	*	1.63	1.84
20	20 Mile	T-34m	2.28	-	2.04	2.09	1.88
29	Shinumo Wash	T-19m	2.16	1.83	1.64	1.79	2.15
34.7	Nautiloid	T-12m	-	2.04	2.12	2.11	1.93
53	Lower Nankoweap	T-30m	2.33	-	2.21	1.96	2.35
75.5	Nevills	T-6m	2.13	-	2.63	1.94	1.80
81.1	Grapevine	T-30m	-	1.61	1.80	-	1.57
108.5	Lower Bass	T-4m	2.54	2.66	2.56	2.17	2.60
122.8	Forster	T-6m	-	1.61	1.83	2.06	-
132	Dubendorff	T-27m	-	1.80	1.6	-	1.95
166.6	Lower National	T-38m	2.58	2.69	2.56	2.20	2.43
208.8	Granite Park	T-6m	-	2.13	2.10	2.27	2.16
213	Pumpkin Bowl	T-3m	-	2.14	1.95	1.70	1.82
		T-38m	-	2.09	-	1.83	2.04
220	220 Mile	T-20m	-	2.57	2.45	2.32	2.17
		T-40	-	1.95	2.13	3.13	3.05

(*) Not listed due to error in data/computer
(-) No samples collected

REFERENCES

Beus, S. S., and Lojko, F. B., 1982. A study of beach and sand grain size in lower Glen Canyon and Grand Canyon. Colorado River Investigation I, Northern Arizona University and Museum of Northern Arizona University, pp. 20-43.

Lojko, F. B., 1983. Shape, composition and charcoal content of Colorado River Beach sands from selected sites in Grand Canyon. Colorado River Investigation II, Northern Arizona University, pp. 23-48.

-------------- 1983. Beach sand grain size on the Colorado River in the Grand Canyon, Colorado River Investigation II, Northern Arizona University, pp. 499-57.

-------------- 1984. Beach sand grain size on the Colorado River in the Grand Canyon. Colorado River Investigation III, Northern Arizona University and Museum of Northern Arizona, pp. 85--93.

-------------- 1986. Beach sand grain size on the Colorado River in the Grand Canyon (abstract). Missouri Academy of Science, p. 34.

Best, D. M., 1982, Program to analyze sieve data, either quarter or half phi (computer program). Northern Arizona University.

APPENDIX A

Reference - Fortran Program


```
C$$$  PROGRAM TO ANALYZE SIEVE DATA, EITHER QUARTER OR HALF PHI
C$$$
C$$$  PROGRAM BASED ON MISSOURI SED PET 1 VERSION 1 OF 1 MAY 1963
C$$$  PROGRAMMED BY W.T.KANE, REPROGRAMMED FOR 7040 BY J.R.RHYNE
C$$$  UNIV OF TENN GEOL 4130 REPROGRAMMED BY WILLIAM FRANK
C$$$  REPROGRAMMED FOR THE IBM/360 BY DON GIDLEY, UNC, MAY 1968
C$$$  GRAPHIC SUPPORT BY TOM HUGGETT, UNC, NOV 1969
C$$$  REVISED AND CORRECTED BY DAVID M. BEST & ED CUSTER, UNC, JULY 1974
C$$$  WRITTEN FOR EITHER QUARTER OR HALF PHI BY DAVID M. BEST, SPRING 1982
C$$$  PROBABILITY PLOT ADAPTED BY D. M. BEST, APR 1984
C$$$
      DIMENSION PHI(2,1000),PCT(300),WT(300),FD(20)
      DIMENSION DIAM(57),CUMPER(57),SAMP(2),IANAL(2)
      COMMON ND
C$$$  SET INPUT AND OUTPUT DEVICE NUMBERS
      IN1=105
      IOUT=108
C$$$  DESIGNATE THE TYPE OF ANALYSIS AS EITHER HALFPHI OR QTRPHI
 5000 READ(IN1,1000,END=999) IANAL
 1000 FORMAT(2A4)
      IF(IANAL(1).EQ.4HHALF) GO TO 401
      IF(IANAL(1).EQ.4HQTRP) GO TO 410
  401  ND=29;LIM1=7;LIM2=8;LIM3=17;LIM4=18;LIM5=25
      LIM6=26;LIM7=ND;XINC=0.50
      GO TO 411
  410  ND=57;LIM1=13;LIM2=14;LIM3=33;LIM4=34;LIM5=49
      LIM6=50;LIM7=ND;XINC=0.25
  411 PHI(1,1)=-4.0
      DO 50 N=2, ND
   50 PHI(1,N)=PHI(1,N-1) +XINC
C$$$
C$$$  IF A PLOT OF A CUMULATIVE CURVE IS DESIRED THEN SET IPLOT=1
C$$$  OTHERWISE NO GRAPH WILL BE RETURNED
C$$$
C$$$  READ IN WEIGHTS FOR EACH PHI SIZE; ALSO TOTAL SAMPLE WEIGHT AND
C$$$  SAMPLE NUMBER (CHARACTER STRING OF LENGTH 8)
C$$$
      IF(IANAL(1).EQ.4HHALF) GO TO 1
      IF(IANAL(1).EQ.4HQTRP) GO TO 2
    2 READ(IN1,101)(WT(N),N=1,ND),TOTWT,SAMP,IPLOT ; GO TO 103
    1 READ(IN1,102)(WT(N),N=1,ND),TOTWT,SAMP,IPLOT
  101 FORMAT(11F7.4/11F7.4/11F7.4/11F7.4/11F7.4/2F7.4,3X,F7.3,2A4,1X,I1)
  102 FORMAT(10F8.4/10F8.4/9F8.4/F8.4,2X,2A4,1X,I1)
  103  WRITE(IOUT,301) SAMP
  301 FORMAT(//17H1SAMPLE NUMBER - ,2A4)
      SUM=0.0
      KNT=0
      KADD=0
      DO 36 N=1, ND
      IF (KNT.EQ.1) GO TO 30
      IF (WT(N).EQ.0.0) KADD=N
      IF (WT(N).NE.0.0) XI=PHI(1,N); KNT=1
   30  SUM=SUM + WT(N)
      SUMWT=SUM
   36 CONTINUE
      PLOST=(TOTWT-SUMWT)*100./TOTWT
      WRITE(IOUT,399) PLOST
[illegible]
```

APPENDIX B

```
SAMPLE NUMBER = 7.8T-3-2 [illegible]
PERCENT LOST= 1.24

CALCULATION OF MOMENT MEASURE STATISTICS.
MEAN =    2.129
VARIANCE =   .35364E+00
STANDARD DEVIATION =    .595
SKEWNESS =  -.608
KURTOSIS =  7.445
THIRD MOMENT = -.25553E+00
FOURTH MOMENT=   .13062E+01

CALCULATION OF FOLK'S STATISTICS.
MZ =   1.974
SORTING =    .347
SKEWNESS =  -.207
KURTOSIS =    .947

FOLK'S TEXTURAL DESCRIPTION.
SAND.
VERY WELL SORTED.
MESOKURTIC.
COARSE SKEWED.

CALCULATION OF INMAN'S STATISTICS.
M PHI =  1.922
SIGMA PHI =    .324
SKEWNESS =  -.480
KG (INMAN)=     .886
ALPHA TWO PHI =    .126
```

(1982)

1982
Badger
7.8
T-3

SAMPLE NUMBER - 7.8T-3-3
PERCENT LOST= .05

CALCULATION OF MOMENT MEASURE STATISTICS.
MEAN = 2.121
VARIANCE = .21204E+00
STANDARD DEVIATION = .460
SKEWNESS = .151
KURTOSIS = -.517
THIRD MOMENT = .29528E-01
FOURTH MOMENT= .11164E+00

CALCULATION OF FOLK'S STATISTICS.
MZ = 2.061
SORTING = .439
SKEWNESS = .105
KURTOSIS = .815

FOLK'S TEXTURAL DESCRIPTION.
SAND.
MODERATELY SORTED.
PLATYKURTIC.
FINE SKEWED.

CALCULATION OF INMAN'S STATISTICS.
M PHI = 2.076
SIGMA PHI = .509
SKEWNESS = .085
KG (INMAN)= .196
ALPHA TWO PHI = .149

Badger
7.8
T-3

PERCENT LOST= 3.34

CALCULATION OF MOMENT MEASURE STATISTICS.
MEAN = 2.249
VARIANCE = .31512E+00
STANDARD DEVIATION = .561
SKEWNESS = .394
KURTOSIS = -.097
THIRD MOMENT = .13925E+00
FOURTH MOMENT= .28826E+00

1984
Badger Rape
7.8

CALCULATION OF FOLK'S STATISTICS.
MZ = 2.111
SORTING = .526
SKEWNESS = .241
KURTOSIS = .732

FOLK'S TEXTURAL DESCRIPTION.
SAND.
MODERATELY SORTED.
PLATYKURTIC.
FINE SKEWED.

T-3

CALCULATION OF INMAN'S STATISTICS.
M PHI = 2.136
SIGMA PHI = .548
SKEWNESS = .132
KG (INMAN)= .518
ALPHA TWO PHI = .532

```
SAMPLE NUMBER - 7.8T03-5
PERCENT LOST= -.02

CALCULATION OF MOMENT MEASURE STATISTICS.
MEAN =   2.056
VARIANCE =   .17484E+00
STANDARD DEVIATION =    .418
SKEWNESS =  -.206
KURTOSIS =  3.470
THIRD MOMENT = -.30079E-01
FOURTH MOMENT=  .19779E+00

CALCULATION OF FOLK'S STATISTICS.
MZ =  1.943
SORTING =   .328
SKEWNESS =  -.191
KURTOSIS =   .868

FOLK'S TEXTURAL DESCRIPTION.
SAND.
VERY WELL SORTED.
PLATYKURTIC.
COARSE SKEWED.

CALCULATION OF INMAN'S STATISTICS.
M PHI =  1.896
SIGMA PHI =   .316
SKEWNESS =  -.444
KG (INMAN)=     .772
ALPHA TWO PHI =    .109
```

1985 ✓
Badger
7.8
T-3

SAMPLE NUMBER 8" Jaagu -T-3--6
PERCENT LOST= .46

CALCULATION OF MOMENT MEASURE STATISTICS.
MEAN = 1.979
VARIANCE = .27023E+00
STANDARD DEVIATION = .520
SKEWNESS = .295
KURTOSIS = .231
THIRD MOMENT = .82648E-01
FOURTH MOMENT= .23597E+00

CALCULATION OF FOLK'S STATISTICS.
MZ = 1.913
SORTING = .504
SKEWNESS = .455
KURTOSIS = 1.106

FOLK'S TEXTURAL DESCRIPTION.
SAND.
MODERATELY SORTED.
MESOKURTIC.
STRONGLY FINE SKEWED.

CALCULATION OF INMAN'S STATISTICS.
M PHI = 2.025
SIGMA PHI = .512
SKEWNESS = .654
KG (INMAN)= .599
ALPHA TWO PHI = .409

/ Ba 7.8

/

SAMPLE NUMBER = SWT-19-2 [illegible]
PERCENT LOST= 1.41 [illegible]

CALCULATION OF MOMENT MEASURE STATISTICS.
MEAN = 2.325
VARIANCE = .42545E+00
STANDARD DEVIATION = .652
SKEWNESS = -.251
KURTOSIS = 2.622
THIRD MOMENT = -.13931E+00
FOURTH MOMENT= .10176E+01

CALCULATION OF FOLK'S STATISTICS.
MZ = 2.162
SORTING = .588
SKEWNESS = .040
KURTOSIS = .925

FOLK'S TEXTURAL DESCRIPTION.
SAND.
MODERATELY SORTED.
MESOKURTIC.
NEAR SYMMETRICAL.

CALCULATION OF INMAN'S STATISTICS.
M PHI = 2.168
SIGMA PHI = .557
SKEWNESS = .031
KG (INMAN)= .836
ALPHA TWO PHI = .090

1982
Shim
29
T-19

SAMPLE NUMBER = 29[illegible]
PERCENT LOST [illegible]

CALCULATION OF MOMENT MEASURE STATISTICS
MEAN = 2.005
VARIANCE = .49734E+00
STANDARD DEVIATION = .705
SKEWNESS = .221
KURTOSIS = -.064
THIRD MOMENT F) .15468E+000
FOURTH MOMENTF .72618E+00

CALCULATION OF FOLK'S STATISTICS
MZ = 1.829
SORTING = .701
SKEWNESS = .323
KURTOSIS = .891

FOLK'S TEXTURAL DESCRIPTION.
SAND.
MODERATELY SORTED.
PLATYKURTIC.
STRONGLY FINE SKEWED.

CALCULATION OF INMAN'S STATISTICS
M PHI = 1.896
SIGMA PHI = .750
SKEWNESS = .269
KG (INMAN)= .435
ALPHA TWO PHI = .540

1983
Shinumo
29
T-19

SAMPLE NUMBER = 29T-29-4
PERCENT LOST= -.99

CALCULATION OF MOMENT MEASURE STATISTICS.
MEAN = 1.781
VARIANCE = .28531E+00
STANDARD DEVIATION = .534
SKEWNESS = .023
KURTOSIS = 3.091
THIRD MOMENT = .69215E-02
FOURTH MOMENT= .49580E+00

1984
Shinumo Wa.
29
T-19

CALCULATION OF FOLK'S STATISTICS.
MZ = 1.636
SORTING = .481
SKEWNESS = .163
KURTOSIS = 3.239

FOLK'S TEXTURAL DESCRIPTION.
SAND.
MODERATELY SORTED.
EXTREMELY LEPTOKURTIC.
FINE SKEWED.

CALCULATION OF INMAN'S STATISTICS.
M PHI = 1.644
SIGMA PHI = .463
SKEWNESS = .049
KG (INMAN)= .780
ALPHA TWO PHI = .494

```
SAMPLE NUMBER = 29T19-5
PERCENT LOST= -1.49

CALCULATION OF MOMENT MEASURE STATISTICS.
MEAN =    1.908
VARIANCE =   .19246E+00
STANDARD DEVIATION =     .439
SKEWNESS =      .375
KURTOSIS =   2.808
THIRD MOMENT =   .63372E-01
FOURTH MOMENT=    .21512E+00

CALCULATION OF FOLK'S STATISTICS.
MZ =   1.789
SORTING =      .391
SKEWNESS =     .373
KURTOSIS =   1.183

FOLK'S TEXTURAL DESCRIPTION.
SAND.
MODERATELY SORTED.
LEPTOKURTIC.
STRONGLY FINE SKEWED.

CALCULATION OF INMAN'S STATISTICS.
M PHI =   1.845
SIGMA PHI =     .324
SKEWNESS =     .517
KG (INMAN)=     1.331
ALPHA TWO PHI =      .535
```

198

Shinn

2-29

T-19

SAMPLE NUMBER 29-T19-6 Shinumo Wash
PERCENT LOST= 2.49

CALCULATION OF MOMENT MEASURE STATISTICS.
MEAN = 2.307
VARIANCE = .28137E+00
STANDARD DEVIATION = .530
SKEWNESS = .226
KURTOSIS = .312
THIRD MOMENT = .67373E-01
FOURTH MOMENT= .26216E+00

CALCULATION OF FOLK'S STATISTICS.
MZ = 2.146
SORTING = .513
SKEWNESS = .150
KURTOSIS = .793

FOLK'S TEXTURAL DESCRIPTION.
SAND.
MODERATELY SORTED.
PLATYKURTIC.
FINE SKEWED.

CALCULATION OF INMAN'S STATISTICS.
M PHI = 2.153
SIGMA PHI = .526
SKEWNESS = .041
KG (INMAN)= .569
ALPHA TWO PHI = .406

198
Shinumo C
29
T-19

CHAPTER IV

SEDIMENTARY STRUCTURES OF BEACHES AND BARS IN THE GRAND CANYON

Cynthia L. Burfield

INTRODUCTION

Eighteen beaches were surveyed between July and August 1986 to determine the types of sedimentary structures formed on river beaches and bars in the Grand Canyon. Recognition of an association of sedimentary structures is useful in determining the transportational and depositional history of the sand deposits. Sedimentological data gathered along this 11 day research trip may serve as a useful tool for studies of beach stability and maintenance.

OBJECTIVES

The purpose of this project is twofold. The first is to determine what sedimentary structures are present on the beaches and bars, and the second is to determine what relationship these sedimentary structures have to depositional processes that operate on the beaches.

METHODS

Materials:
- 2 shovels
- trowel
- 3 cans of clear acrylic spray
- 2 packages cheese cloth
- scissors
- straight pins

1 dozen disposable paint brushes
2 gallons krylon latex acrylic
1 gallon tin can
Brunton compass

Procedure:

1. A trench was dug both parallel and at right angles to the direction of flow of the Colorado River at each site.

2. The selected site was smoothed with a trowel, photographed and sketched.

3. Latex peels were made at a few sites for more detailed observation. The peels were obtained by the following method:

   a. Cheese cloth was cut 20 cm longer than the trench was deep.
   b. The cheese cloth was anchored from above by a rock or wet sand.
   c. The cheese cloth was then flipped back up off the smoothed trench wall.
   d. Clear acrylic spray was applied evenly over the smoothed trench wall.
   e. The cheese cloth was flipped back down and carefully pressed against the sticky clear spray and held fast by straight pins on all edges.
   f. More clear acrylic spray was than applied over the cheese cloth.
   g. Krylon latex was then applied to the cheese cloth with light upward motions and allowed to dry.
   h. A second coat could be applied later that same night.
   i. In the morning the peel was removed and compass orientation was written on the back of the peel.

RESULTS

During the eleven-day river trip, 7 peels and 26 photographs were taken. Sketches were made at 18 sites. Listed below are selected beaches and sedimentary structures observed.

1. Mile 18.2 (Figure 1)
   Trenches no. 1 and 2, climbing ripple laminations.

2. Mile 20.0 (Figure 2)
   Trench no. 1, top 20 cm horizontal laminations, basal 20 cm ripple laminations.
   Trench no. 2, horizontal laminations with heavy mineral laminae 27 cm below the beach surface.
   Trench no. 3, intercalated horizontal laminations and low-angle foreset bedding.

3. Mile 34.7 (Figure 3)
Trench no. 2, intercalated horizontal and ripple laminations.

4. Mile 53.0 (Figure 4,5)
Trench no. 1, low-angle foreset bedding.
Trench no. 2, ripple lamination
Trench no. 3, structureless bedding, horizontal lamination and climbing ripple lamination.

5. Mile 58.1 (Figure 6)
Trench no. 1, fining-upward sequence of coarse-grained low-angle foresets at the base, overlain by finer grained horizontal and ripple laminations.
Trench no. 2, low-angle foreset bedding.

6. Mile 61.8 Little Colorado River (Figure 7)
Trench no. 2, horizontal lamination and low-angle foreset bedding.

7. Mile 75.5 Nevills Rapid (Figure 8)
Trench no. 1, low-angle foreset bedding
Trench no. 2, climbing ripple lamination

8. Mile 81.1 Grapevine (Figure 9)
Trench no. 1, climbing ripple laminations
Trench no. 2, low-angle foreset bedding

9. Mile 93.2 Granite Rapids (Figure 10)
Trench no. 1, ripple lamination, convolute bedding, and some low-angle foreset bedding at the base.
Trench no 2, climbing ripple lamination at the top, low-angle foreset bedding (dipping to the west). No photograph.

10. Mile 122.0 (Figure 11)
Trench no. 1, low-angle foreset bedding and ripple lamination.

11. Mile 131.0 Bedrock (Figure 12)
Trench no. 2, structureless bedding and indistinct horizontal laminations.

12. Mile 132.0 Dubendorff (Figure 13)
Trench no. 1, low-angle foreset bedding.

13. Mile 166.6 Lower National (Figure 14,15)
Trench no. 1, low-angle foreset bedding near the top with graded bedding, ripple lamination at the base.
Trench no. 2, low-angle foreset bedding with some beds dipping slightly to the west.

14. Mile 180.9 Lower Lava Falls (Figure 16,17)
Trench no. 1, ripple laminations intercalated with low-angle foreset bedding.

Trench no. 2, convolute bedding, climbing ripple lamination, and low-angle foreset bedding.

15. Mile 190.2 (Figure 18,19)
Trench no. 1, climbing ripple lamination.
Trench no. 2, convolute bedding

16. Mile 196.0 (Figure 20)
Trench no. 1, ripple lamination, low-angle foreset bedding dipping to the east at 30 degrees.

17. Mile 208.9 (Figure 21)
Trench no. 1, ripple lamination, low-angle foreset bedding dipping to the west at 31 degrees.

18. Mile 220.0 - middle beach (Figures 22)
Trench no. 1, convolute bedding.

INTERPRETATION

The dominant sedimentary structure found on the beaches is ripple lamination. Ripples form by migrating down current with traction transport on their back slope and deposition on their slip slope. "Climbing" ripple stratification occurs where sedimentation is sufficiently rapid so there is deposition on the back slope of the ripple form and suspension fall-out is of prime importance. Subsequently, the ripple marks are built upward in an overlapping series rather than merely migrating forward (McKee, 1965). Almost all ripple structures are formed under tranquil or waning flow conditions.

Horizontal laminations may form either by suspension (under low-flow regime) or by traction transport (under transitional to upper flow regime). Convolute bedding is a type of soft sediment deformation formed from overloading of saturated or moist layered stratum.

Low-angle foreset bedding is found where receding waters deposit sand along a sloping surface, analogous to small-scale delta foresets (McKee, 1965). Structureless bedding forms from rapid sedimentation or physical disruption of the beds.

The diverse orientation of these structures within the beach sands indicate a distinctive multi-directional current system.

CONCLUSIONS

Most beaches along the Colorado River were formed as a response of flow separation in back eddies (Schmidt, 1986). Recirculating currents in these relatively slow-moving eddies deposit sand in areas protected from the main river current. The association of sedimentary structures found within the beaches and bars in this study indicate a fairly low-energy environment, one most likely deposited by periodic inundations of sediment-laden flood waters. In addition, the varied paleocurrent directions support a recirculating pattern with upstream as well as downstream currents.

REFERENCES

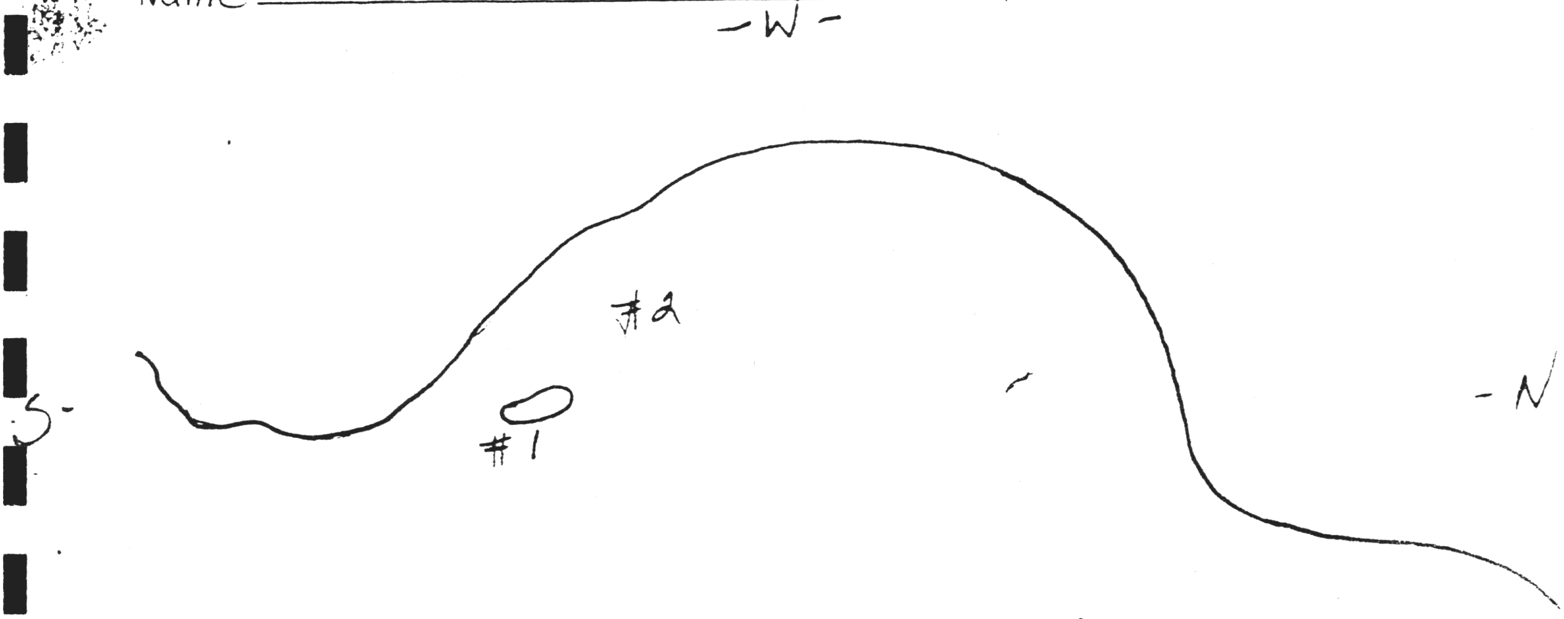
Frazier, D. E. and A. Osanik, 1961. Point-bar deposits, old river locksite, Louisiana. Transaction of the Gulf Coast Association of Geological Societies, v. 11, p. 121-137.

McKee, E. D., 1965, Experiments on ripple lamination. In Middleton, G. V. (ed.), Primary Sedimentary Structures and Their Hydrodynamic Interpretation. Society of Economic Paleontologist and Mineralogists Special Publication, no. 12, Tulsa, Oklahoma, p. 63-83.

Schmidt, J. C., 1986, Location and characteristics of alluvial deposits, Colorado River, Grand Canyon, Arizona. The Geological Society of America. Abstracts with Programs 1986, Rocky Mountain Section, v. 18, p. 410.

Sedimentary Structures on Beaches and Bars

Name ______________________ Mile L 18.0 ____________



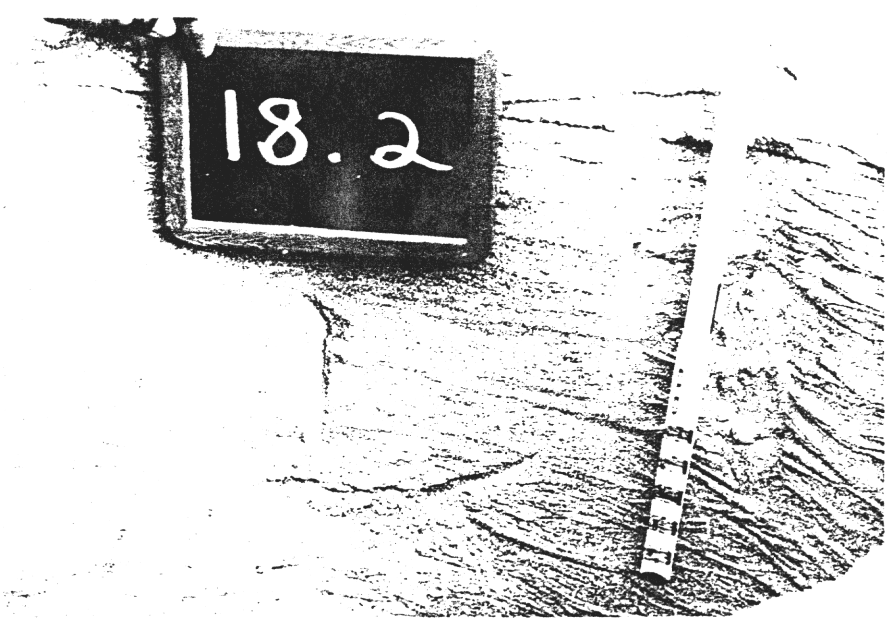
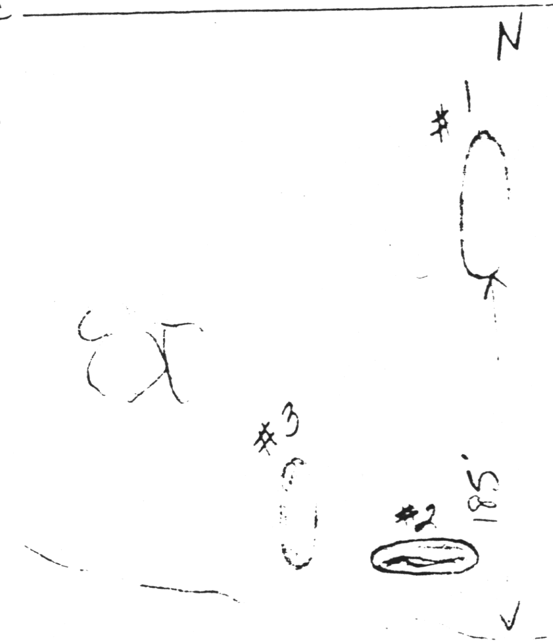
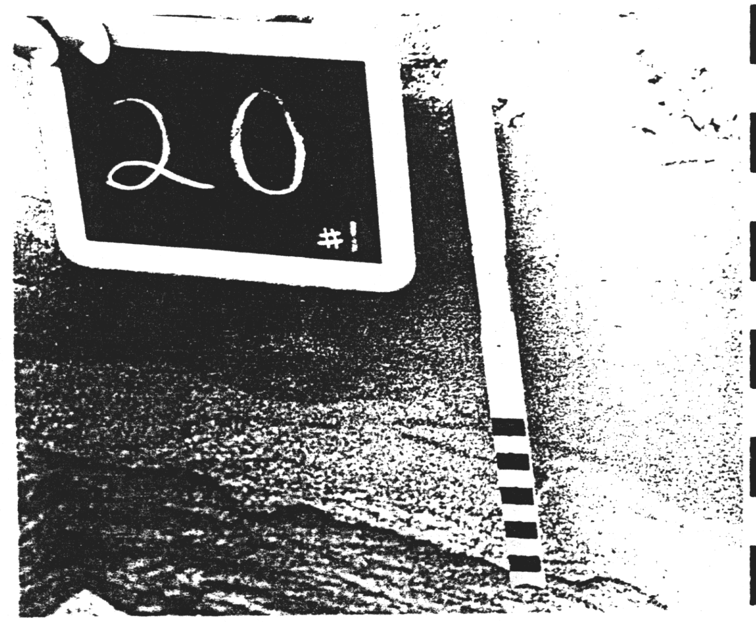


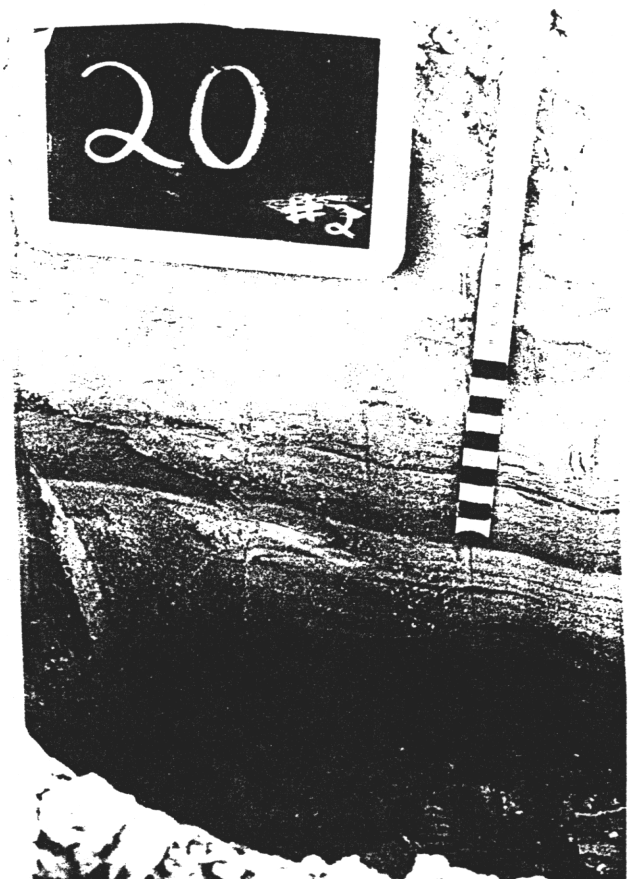
Figure 1.

Sedimentary Structures on Beaches and Bars

Name ______________________ Mile 20.0







— Peel
— Photo

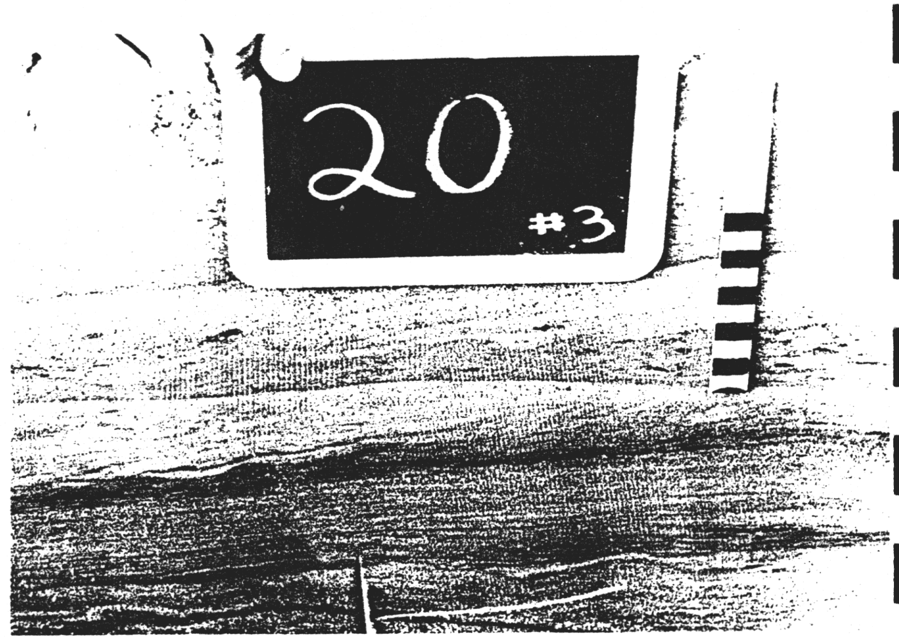


Figure 2

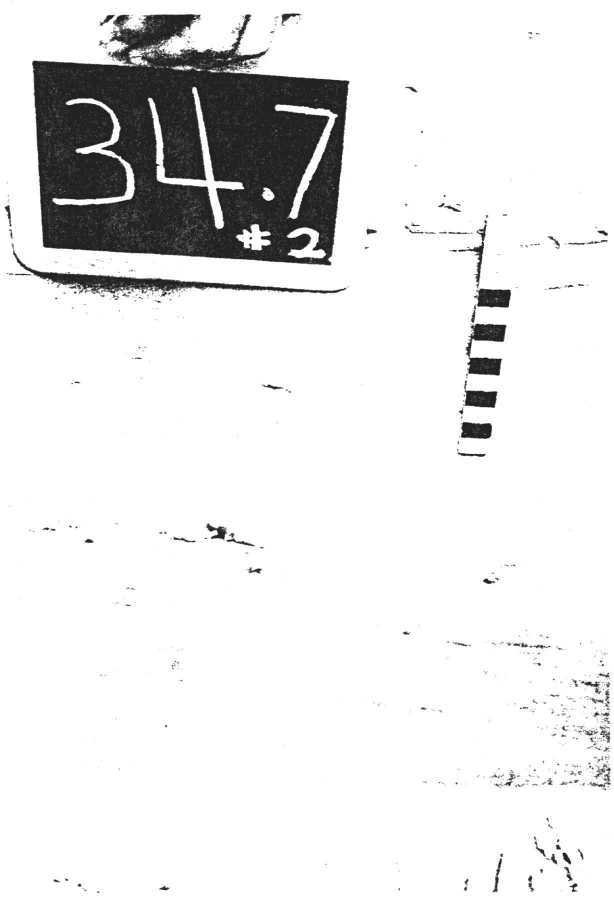
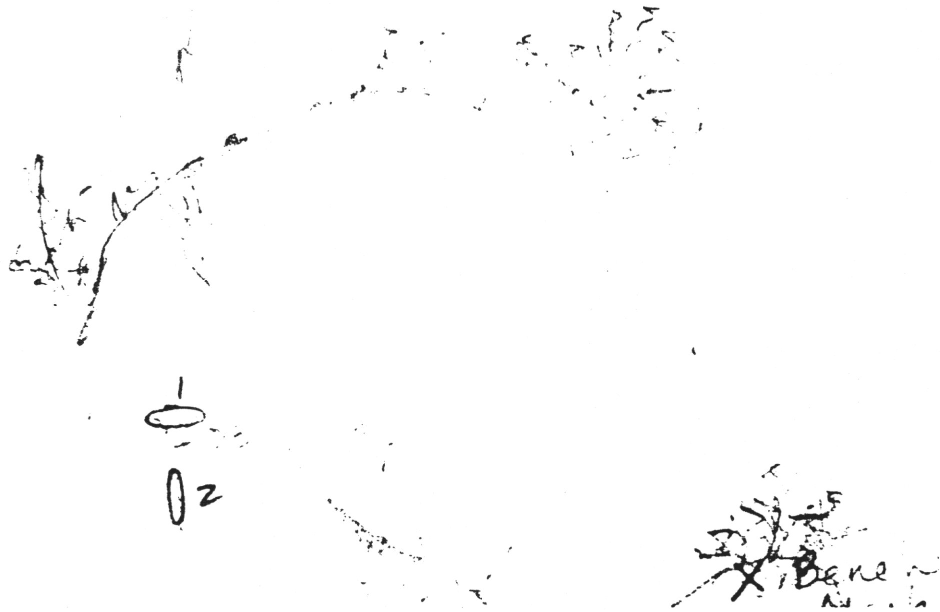


Figure 3

Sedimentary Structures on Beaches and Bars

Name Nankoweap Lower Mile 53

N. 84°E



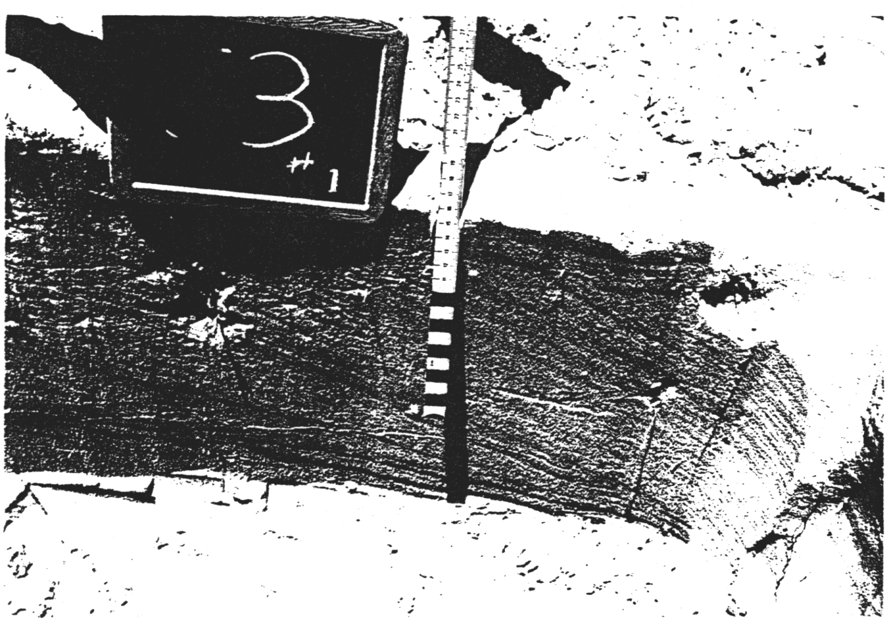
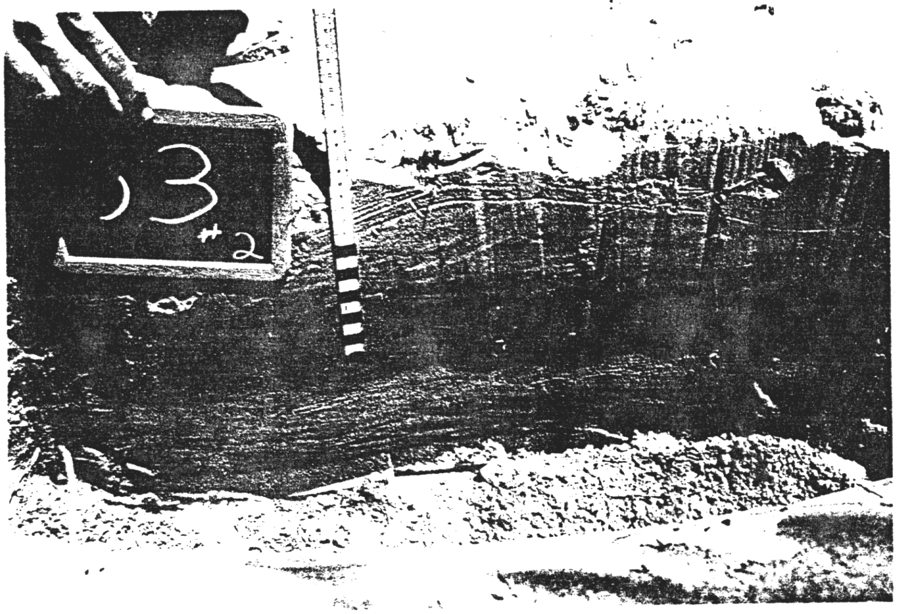


Figure 4.

Mile 53



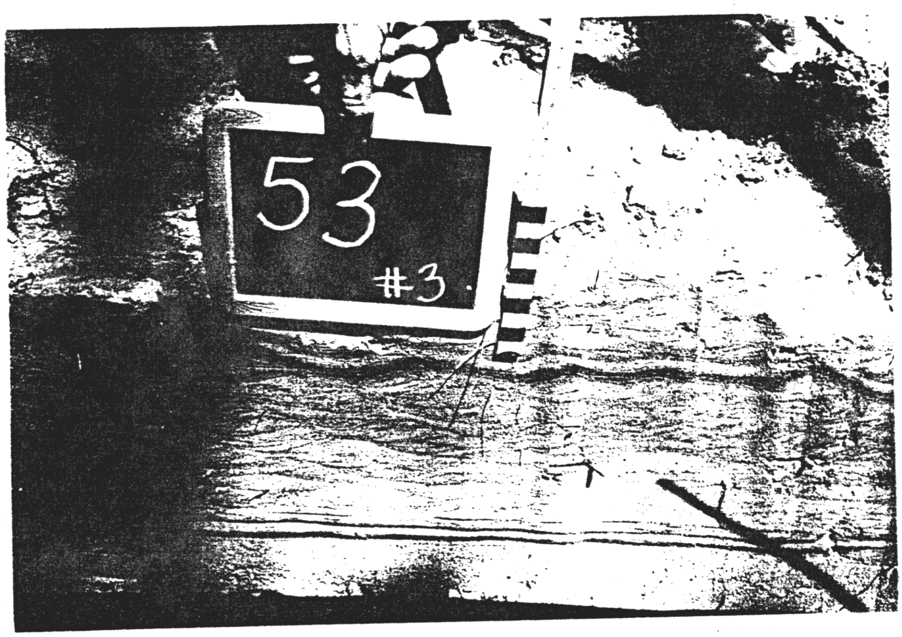
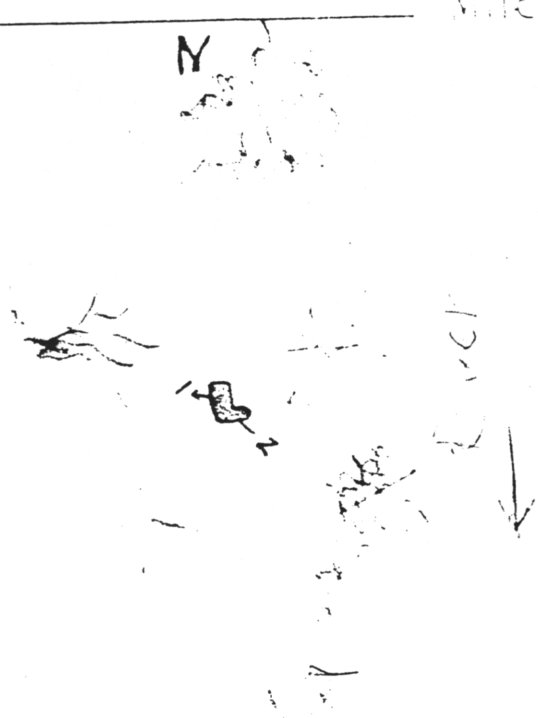


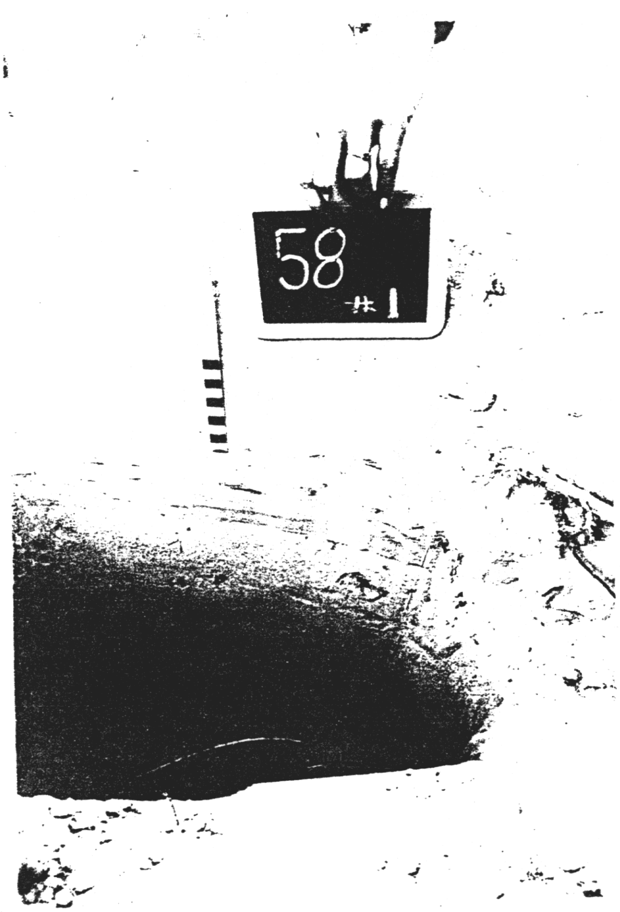
Figure 5.

Sedimentary Structures on Beaches and Bars

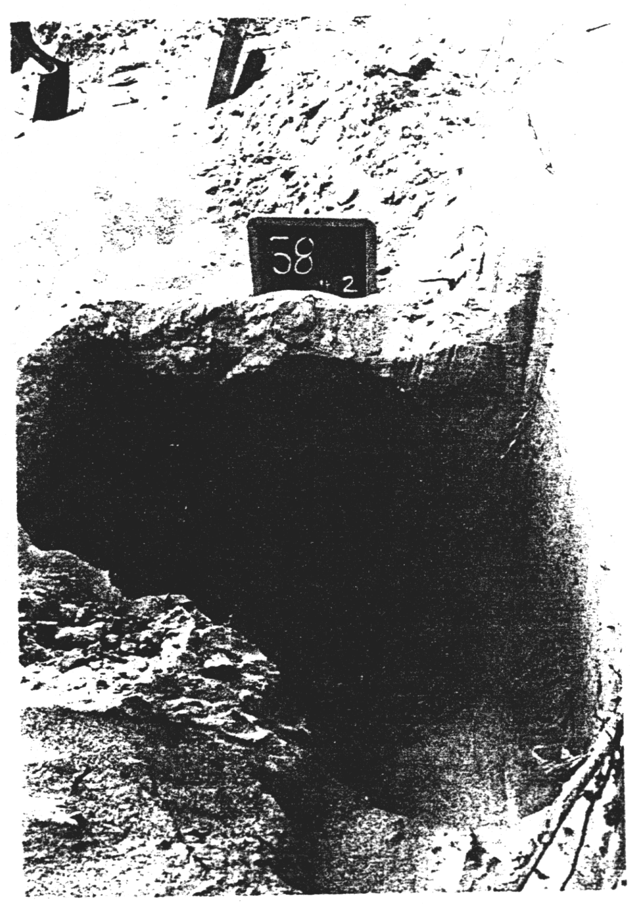
Name Awatubi Mile 58.1



No. 1



No. 2



Sedimentary Structures on Beaches and Bars

Name LCR Mile 61.8

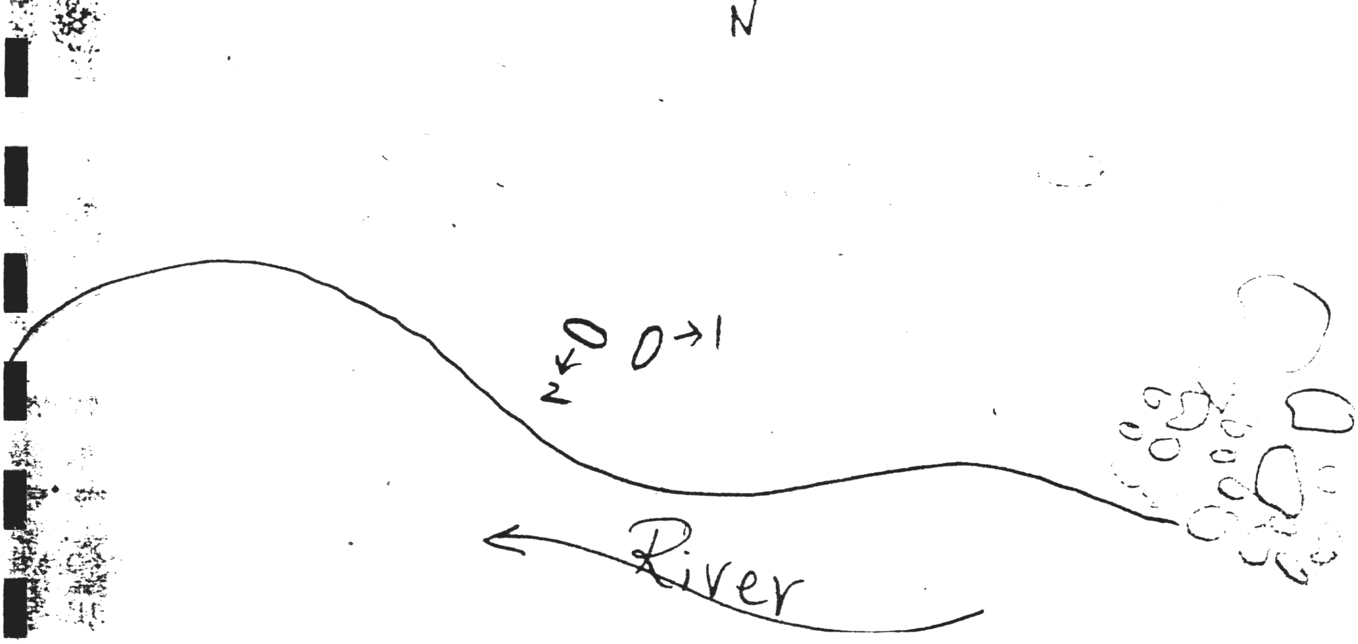
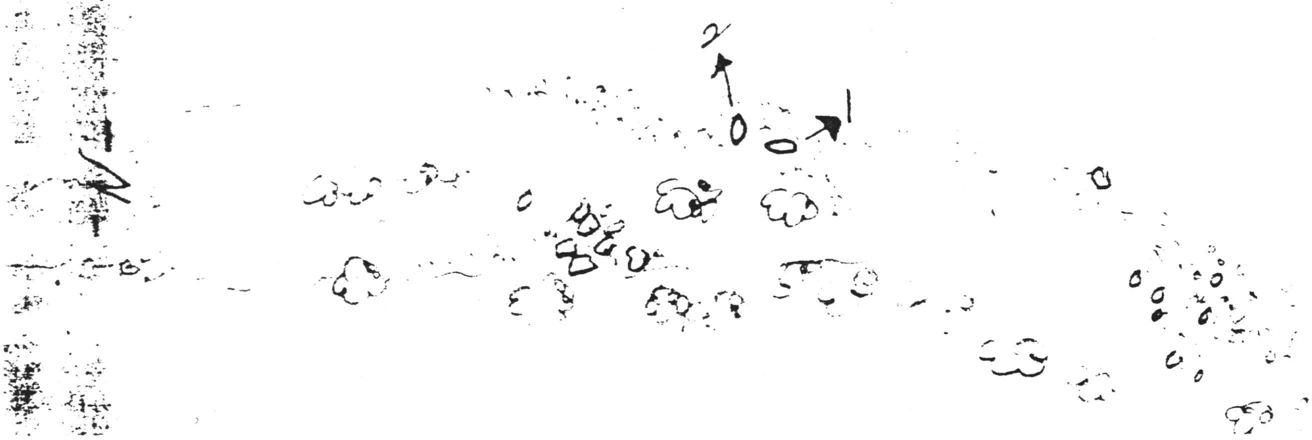


Figure 7

Sedimentary Structures on Beaches and Bars

Name Nevills Pond Mile 75.5



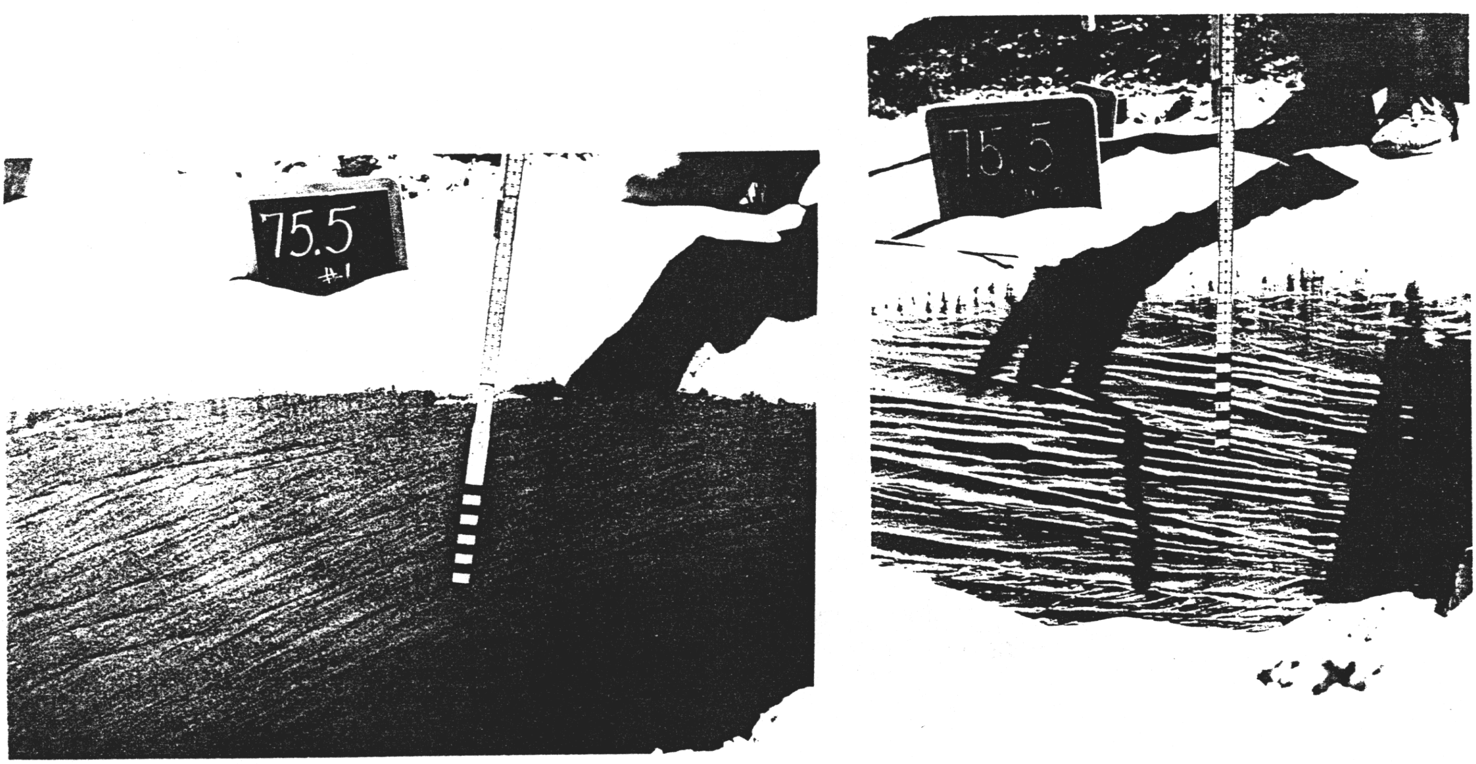
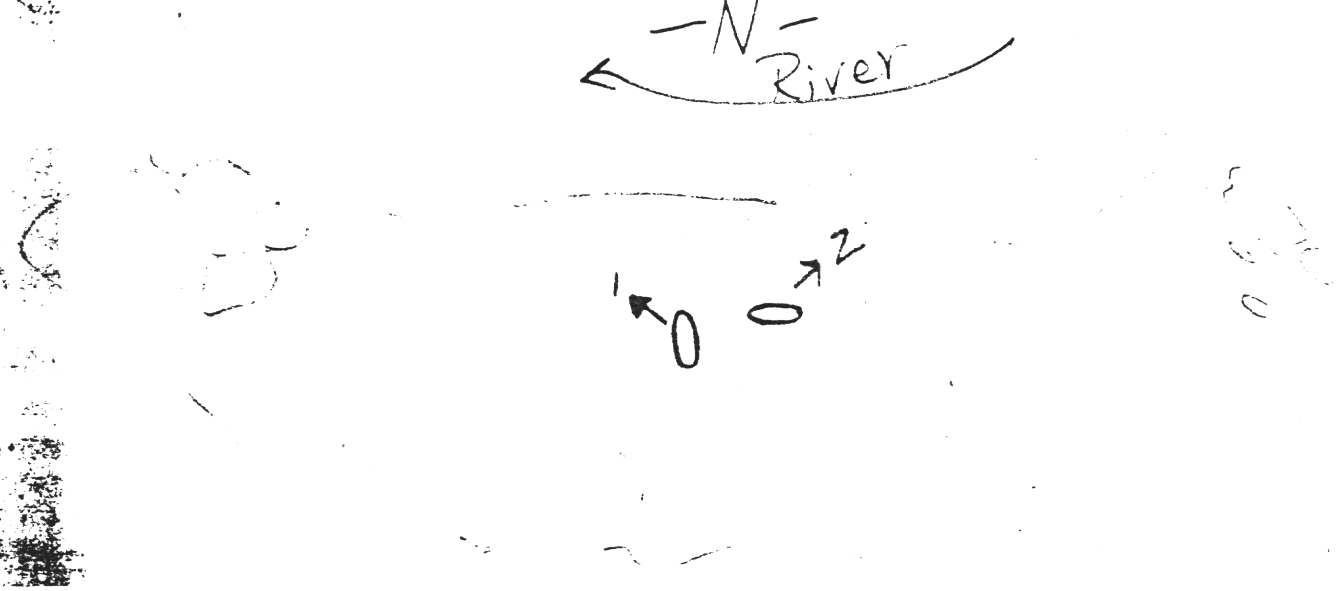


Figure 8.

Sedimentary Structures on Beaches and Bars

Name Grapevine Rapids Mile 81.1



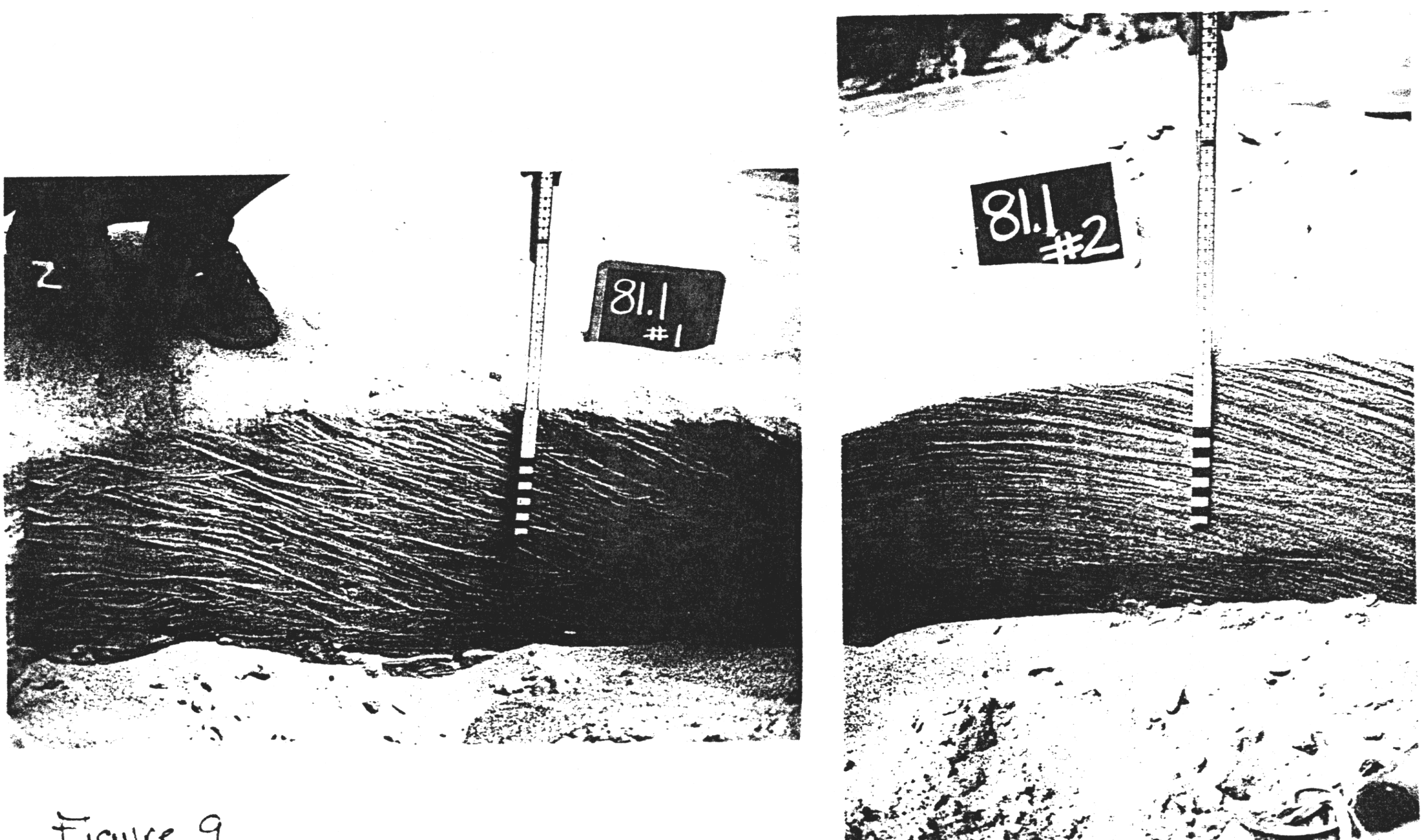
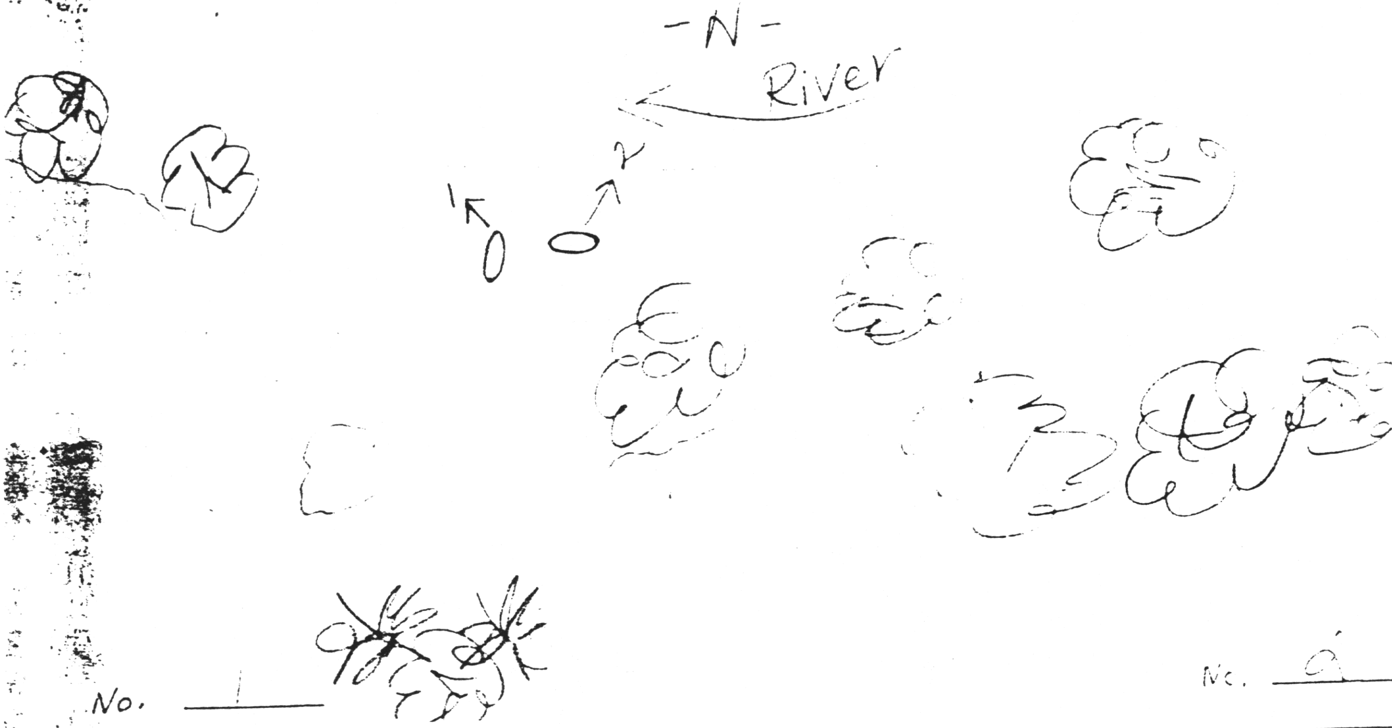


Figure 9

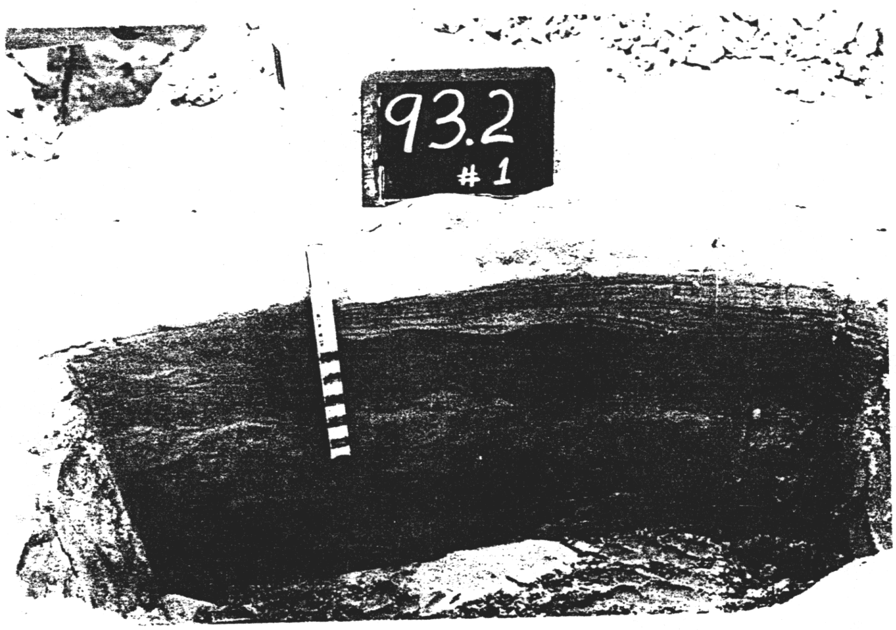
Sedimentary Structures on Beaches and Bars

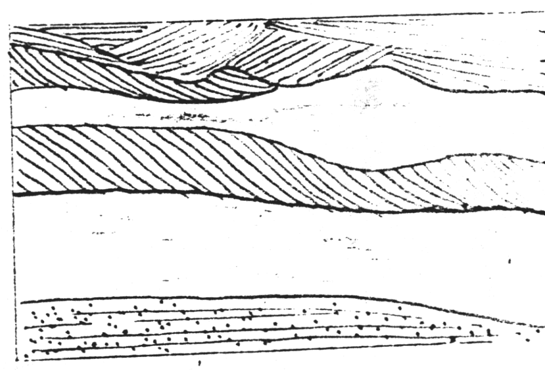
Name .Granite Rapids Mile L93.2



No. 1

No. 2





No.

Sedimentary Structures on Beaches and Bars

Name ______________________ Mile R 122.0

large sketch of Beach Structure

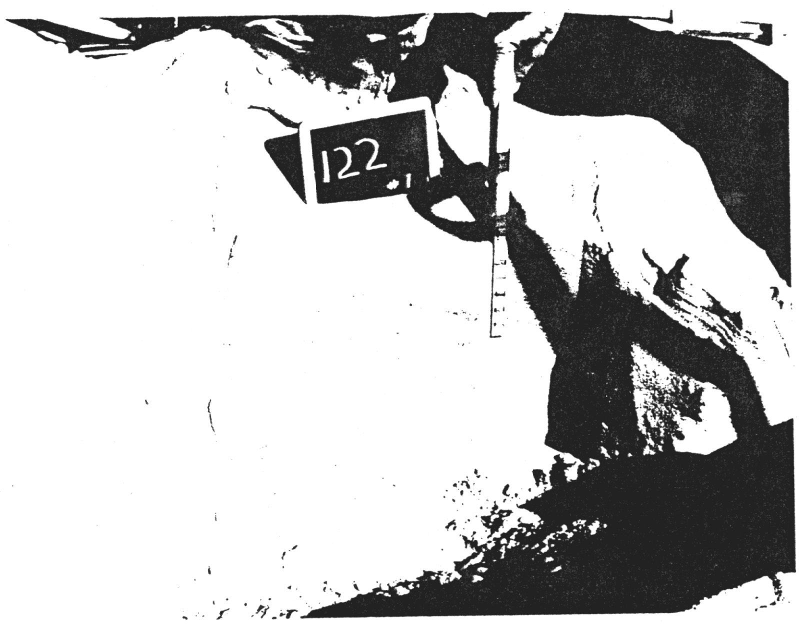
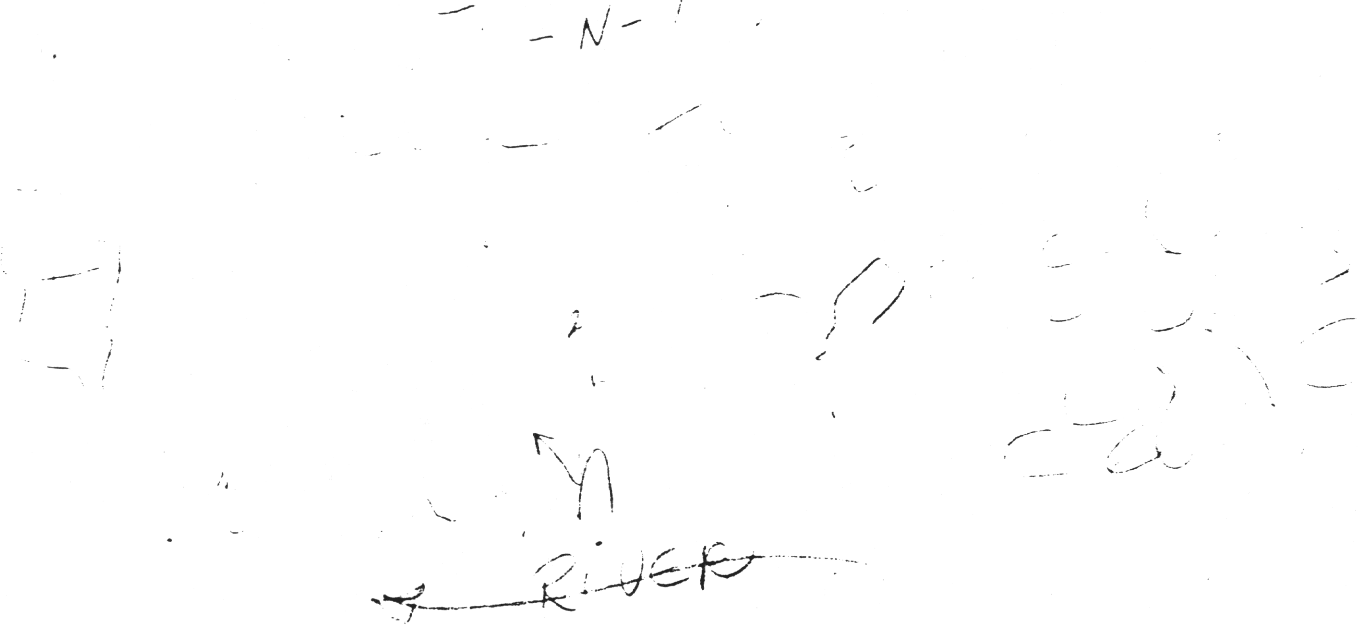


Figure 11

Sedimentary Structures on Beaches and Bars

Name Bedrock Mile 131.0



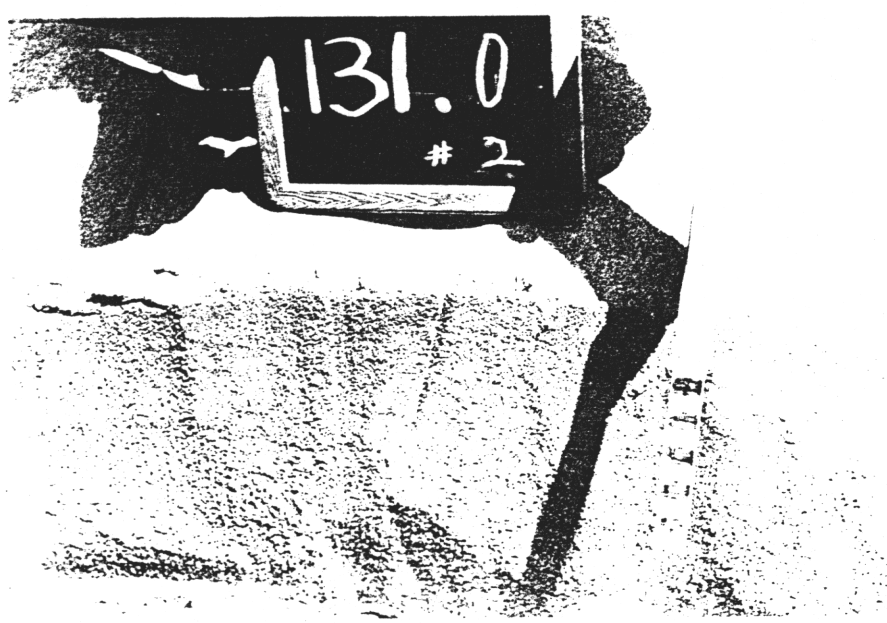
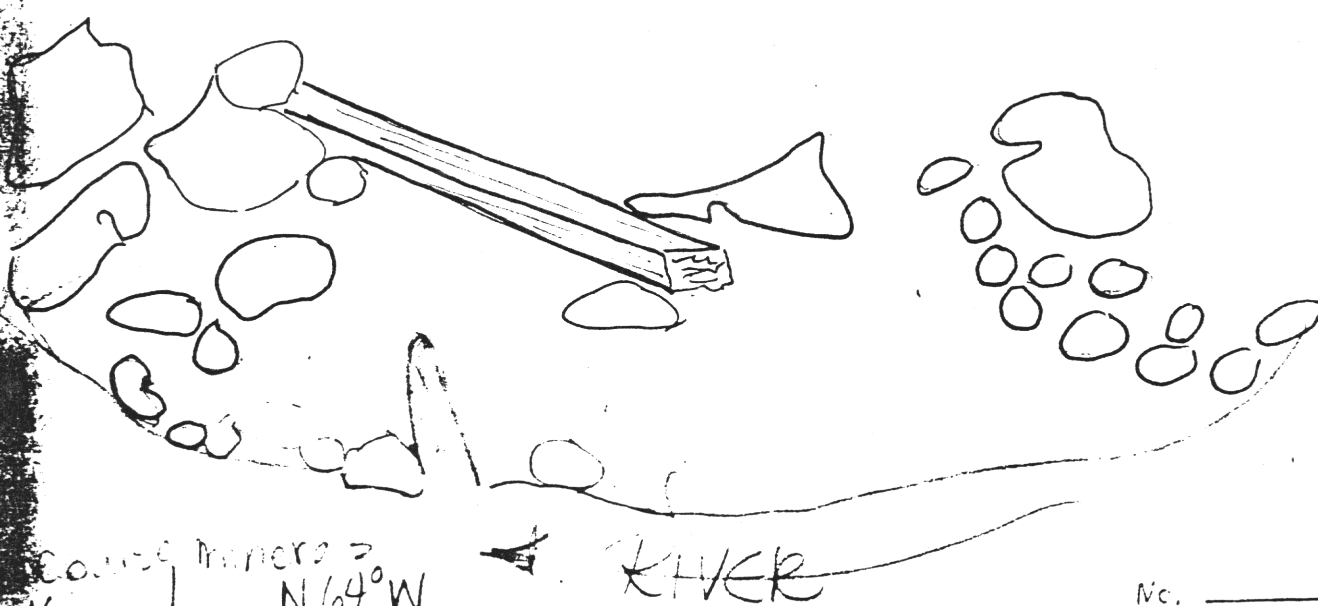


Figure 12.

C Burfield

Sedimentary Structures on Beaches and Bars

Name DUBENDORF Mile R 132.00



[illegible]

No. 1 N 64° W

[illegible] cross bedding

___ Peel

___ Photo

S

No. ______

No. ______

___ Peel

___ Photo

No. ______

Sedimentary Structures on Beaches and Bars

Name Lower National Mile L166.6

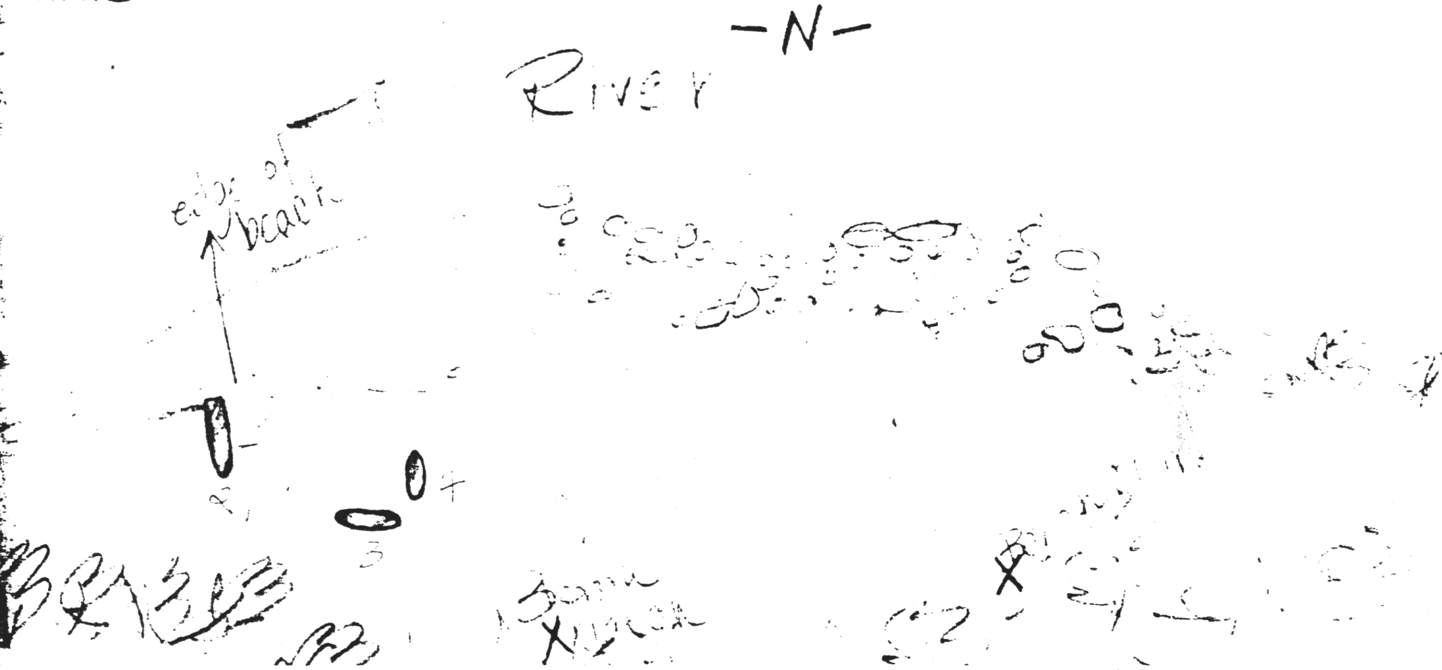


Figure 14.

Lower National, Mile 166.6

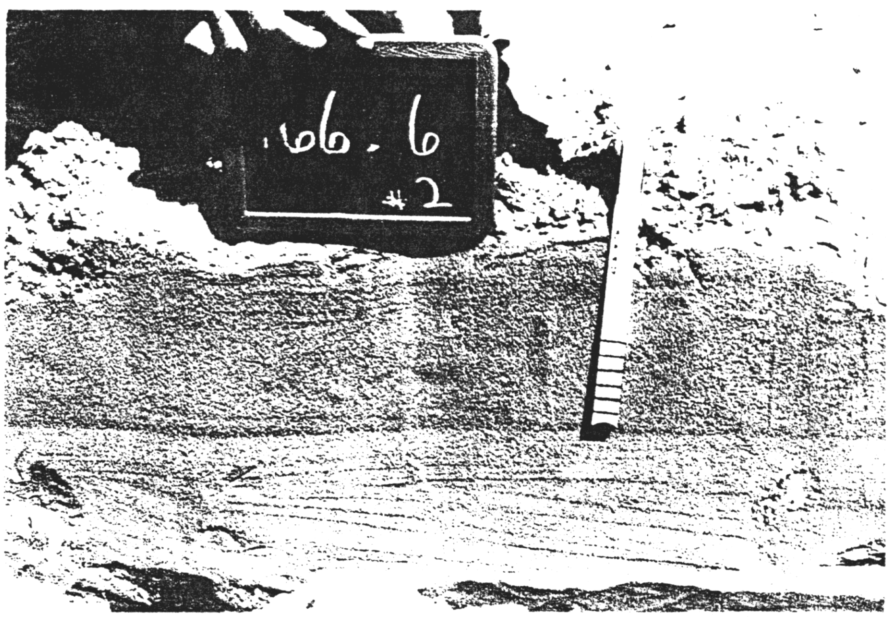
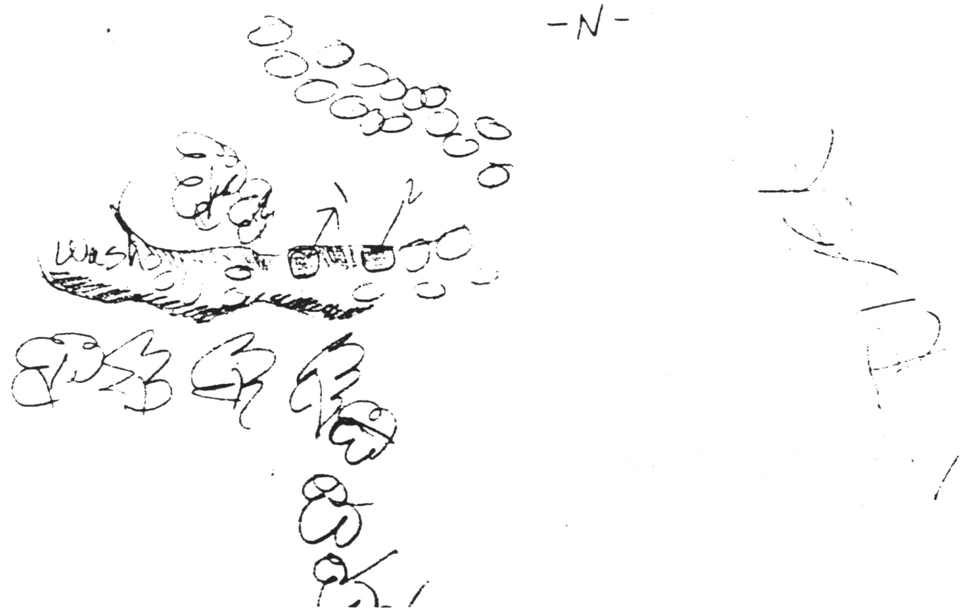


Figure 15

Sedimentary Structures on Beaches and Bars

Name Lower Lava Falls Mile 180.9



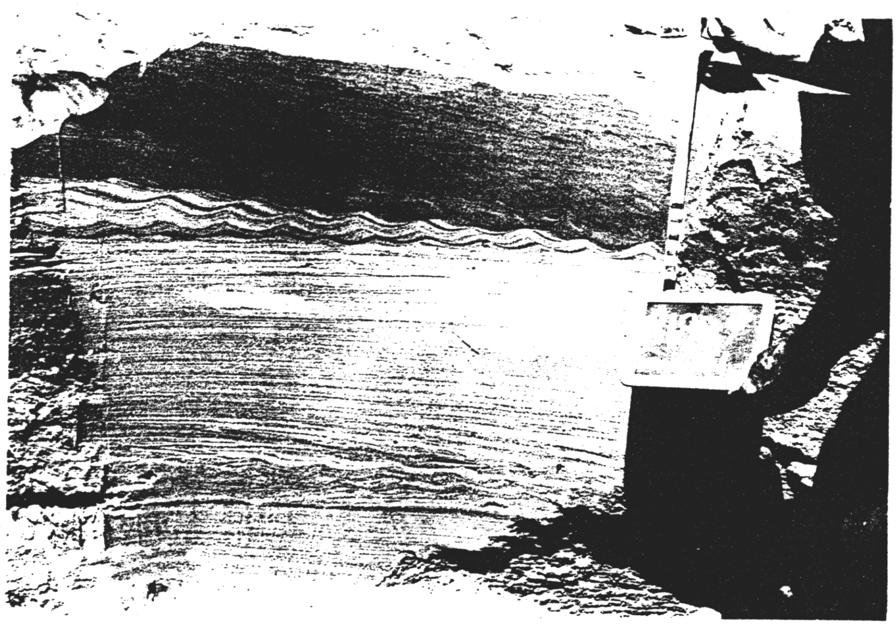


Figure 16.

Lower Lava Falls' Mile 180.9

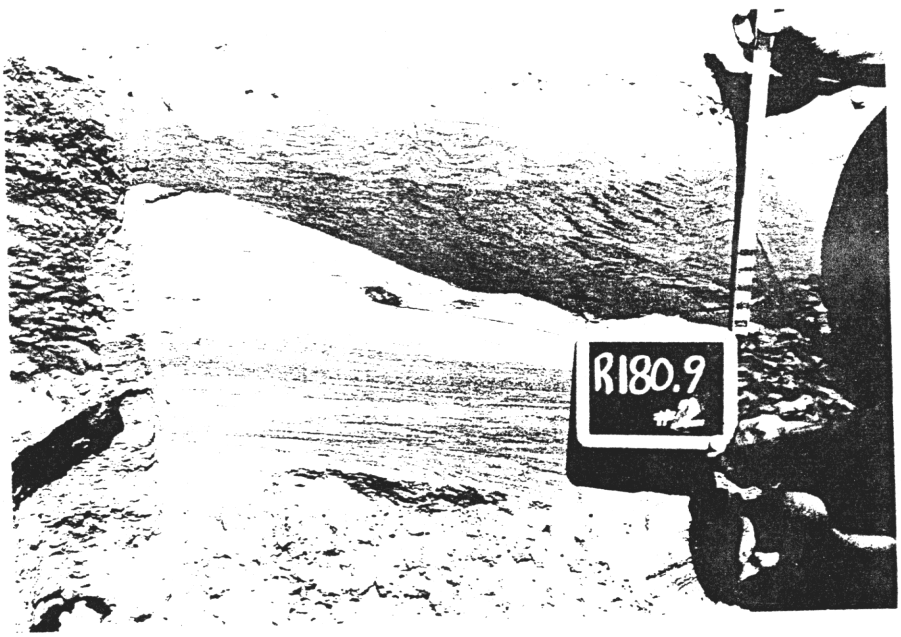
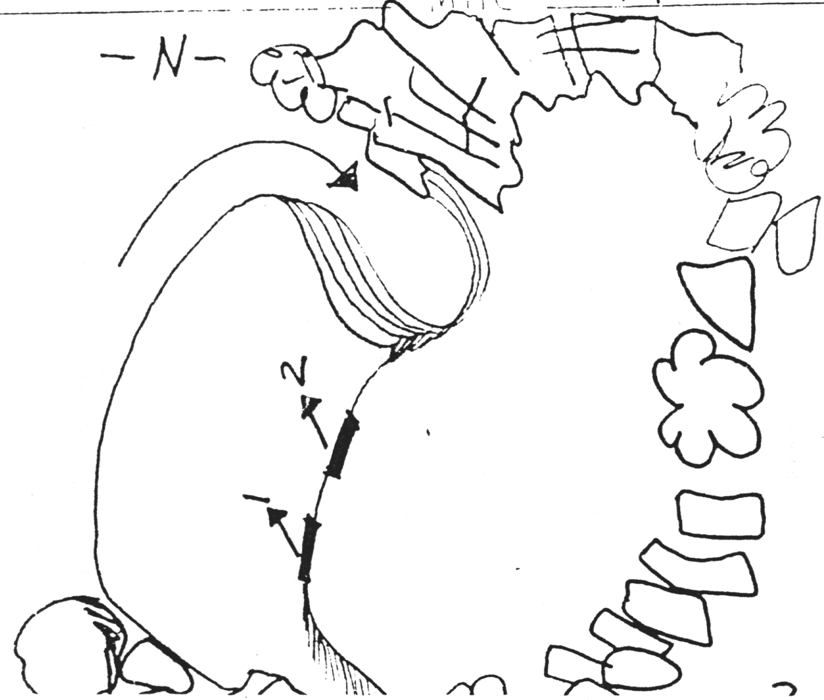


Figure 17

Sedimentary Structures on Beaches and bars

Name ______________________ Mile L190.2



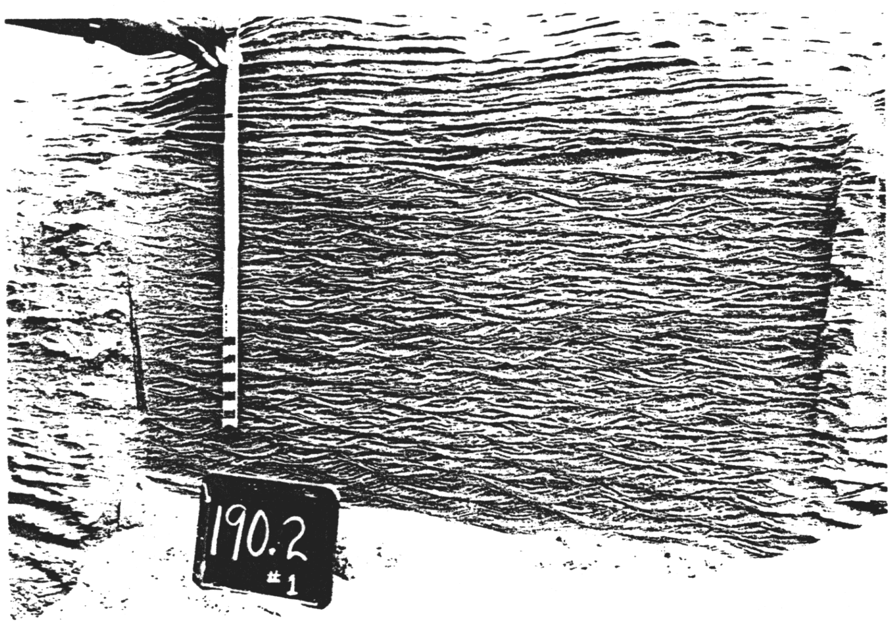


Figure 18

Mile 190.2

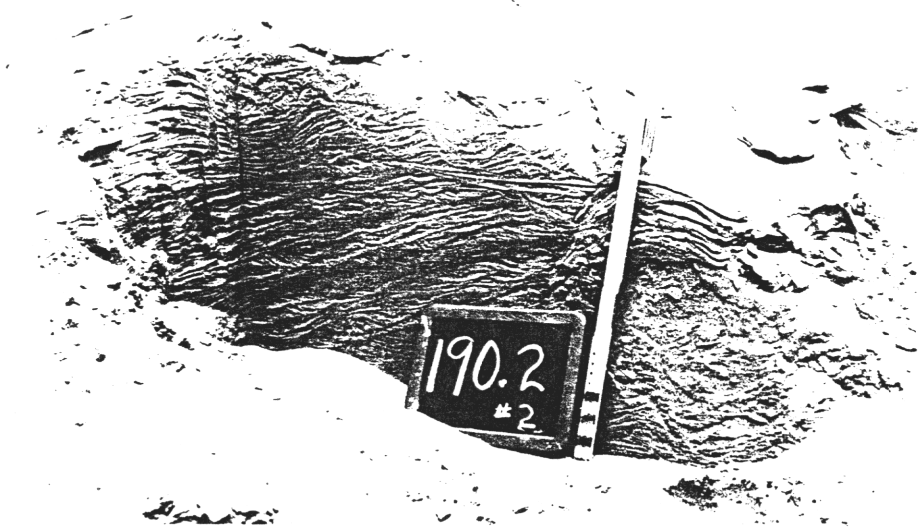
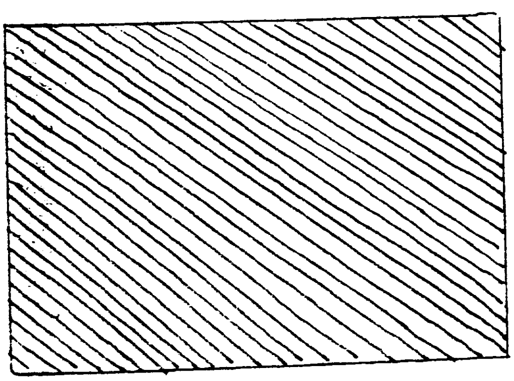


Figure 19

Sedimentary Structures on Beaches and Bars

Name ________________________ Mile L196 ________________

No. #1



X Peel

-N-

___ Photo

No. ______

No. ______

___ Peel

___ Photo

No. ______

Sedimentary Structures on Beaches and Bars

Name GRANITE PARK Mile L208.9

No. 31°

No.

No.

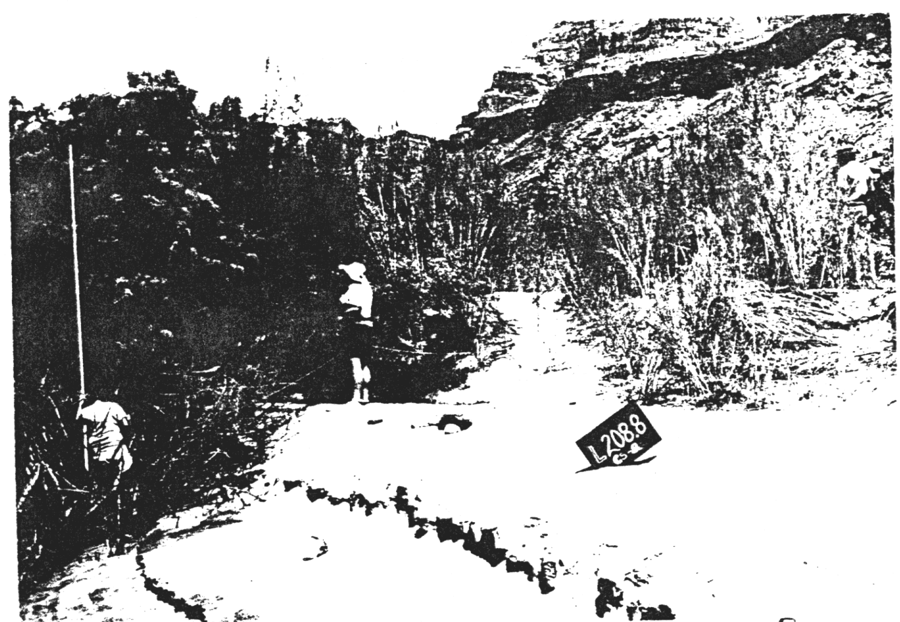
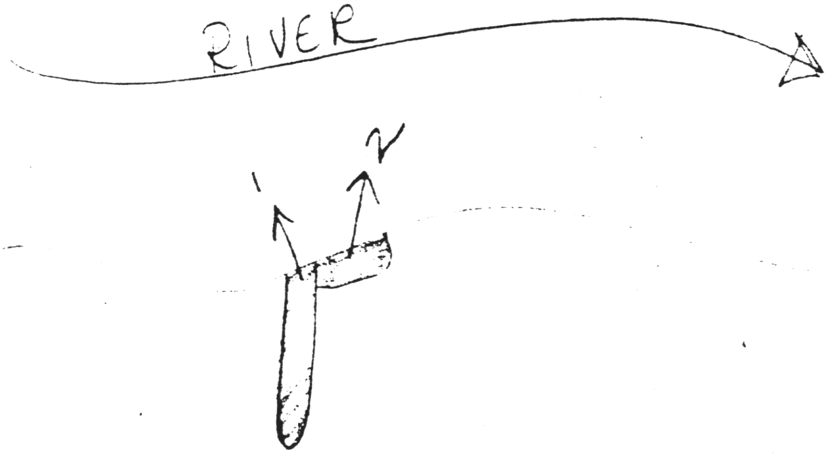


Figure 21

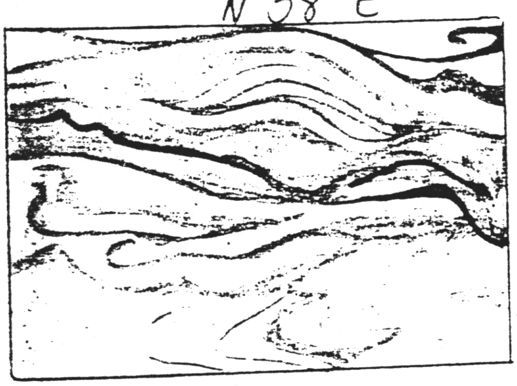
Sedimentary Structures on Beaches and Bars

Name LAST BEACH (Middle Beach) / R220



No. #1

N 58° E



No. ______

peel

photo

Figure 22

CHAPTER V

SECCHI DISC READINGS OF THE COLORADO RIVER, JULY 30 - AUGUST 8 1986

Micheal Stock

INTRODUCTION

The turbidity (or conversely, the clarity) of the Colorado River along its coarse through the national park is important for an understanding of the aquatic food chain. Clear water is conducive to the growth of Cladophera algae, which in turn hosts Gammaris amphipods which are the food source for trout. As Colorado River water is released from Glen Canyon Dam we find it very clear and cold. Various tributaries and side canyons within the park contribute variable amounts of sediment and thus affect the degree of turbidity along the coarse of the river. In this study a quantitative value was placed on the turbidity of the river water at various locations by use of Secchi Disc readings.

PROCEDURE

A 6 inch diameter, black and white disc (Secchi Disc) was lowered into the river water at designated locations. Observation of the disc was made from one meter above the water surface, and the disc was lowered until it was out of sight. The distance at which this occurs is estimated by use of the line which is calibrated in meters and decimeters. The light conditions were also noted.

DATA

Reading site	depth reading (meter)	comments
Lee's Ferry	none	had to construct
Badger	"	a disc since the
18.2 mile	"	original one had
		been forgotten
20 mile	2	sunny
34.7 mile	1.8	shaded
Upper Nankoweap	none	night condtions
61.8 mile (upper)	2.3	sunny
61.8 mile (lower)	0.2	sunny
65.5 mile	0.2	sunny
81.1 mile	0.2	sunny
131 mile	0.3	sunny
132 mile	0.3	sunny
133 mile	0.3	sunny
136 mile	0.35	sunny
146 mile	none	
156.9 mile	none	
166.5 mile (upper)	0.34	sunny
166.5 mile (lower)	0.375	sunny
180.9 mile	0.32	sunny
195 mile	0.38	sunny
220 mile	0.40	shaded, near bank

CONCLUSIONS

The Little Colorado has a dramatic effect on the turbidity of the Colorado River. The clear flowing tributaries, Vasey's Spring, Nankoweap, Bright Angel, Elves Chasm, Tapeats, Deer Creak, Havasu, and National have a minimal clearing effect on the clarity of the river. The combined diluting effects of these flows causes a slight increase in water clarity.

CHAPTER VI

MEASUREMENT OF TOTAL DISSOLVED SOLIDS CONCENTRATION (TDS) IN THE COLORADO RIVER, JULY 29 - AUGUST 7 1986

Micheal Stock

INTRODUCTION

This study was undertaken to determine the amount of dissolved solids (TDS) in the Colorado River along its coarse through the Grand Canyon. The sediment capacity of the river is essential for biologists in understanding the biotic system, for geologists in providing information on river dynamics, and may be important as well by providing more definitive data on beach stability and maintenance.

PROCEDURE

A dissolved solids meter was used to measure the concentration of dissolved solids (TDS) in parts per million in the Colorado River. At each stop along the river water samples were gathered and registered into the meter. The results are listed in the Table 1.

Table 1. Total dissolved solids (TDS) along the Colorado River from Lee's Ferry to Mile 220.

River mile	TDS (ppm)	
Lee's Ferry (mile 0)	550	
8	475	
18.2	495	
20	500	
33.1	500	
34.2 (Vasey's Spring)	280	(meas. of spring water)
34.7	495	
53	530	
58.1	480	
63.5	540	
65.5	490	
75.5	500	
76.5	500	
81.1	510	
93.2	510	
108.5	530	
122.8	530	
131	550	
137	550	
166.5	575	
166.6	525	
180.9	580	
195	595	
208.8	575	
220	605	

CONCLUSIONS

It is difficult to interpret the data since the measurement device does not differentiate between organic and inorganic solids. The data indicate a gradual increase in dissolved solid concentration as the river flows from mile 8 to mile 220. The initial decrease in concentration from 550 ppm to 475 ppm, seen from Lee's Ferry (mile 0) to mile 8, may be due to an extremely high concentration of TDS in the Paria tributary which enters the Colorado at Lee's Ferry.

CHAPTER VII

TEMPERATURE GRADIENTS OF SELECTED BEACHES ALONG THE COLORADO RIVER BETWEEN LEE'S FERRY AND DIAMOND CREEK, AUGUST 1986

Mark Weber

INTRODUCTION

Maximum/minimum temperature readings were taken over a 10 day period from July 20 through August 8 1986, on 9 different beaches along the Colorado River in the Grand Canyon. The study was undertaken by a group of students from Northern Arizona University during overnight campsite stops.

Beach temperatures are an important factor in the ecological system along the Colorado River in the Grand Canyon. Plant distributions and some animal movements, particularly reptilian, are regulated in part by air and surface temperature. It is therefore of interest to gain an understanding of the thermal characteristics of the beaches in this area.

OBJECTIVES

The purpose of this study is to document the variability of temperature along the slope of the beach from the water's edge to the highest point of the beach. In addition, relative humidity and dew point profiles were recorded at each beach. River water temperatures were measured as well.

METHODS

Thermometers were placed on wooden stakes set with screws approximately 4 feet above the surface of the ground. The first stake was placed at the river's edge and successive stakes placed in intervals of 10 meters up the slope of the beach, to the edge of the talus slope. The slope of the beach was determined by eye-height measurements taken with a Brunton compass.

The stations were generally set up before 8:30 in the evening, and were read before 7:30 the next morning. The only exception was the 2 day layover at National Beach where the stakes were in place for over 36 hours. Water temperatures were taken with a lab thermometer at the water's edge each morning.

Eighteen relative humidity and dew point readings were recorded each morning (two at each beach). The first was taken at the river's edge, while the second was taken at the most distant station. The data was collected using wet and dry bulb readings with a sling psychrometer.

RESULTS

The highest temperature recorded was 110 degrees at Mile 220 at station 7, located high on the beach. The lowest temperature was 64 degrees at Upper Nankoweap at station 1, near the edge of the water. The mean high temperature of the entire trip was 93.4 degrees and the low mean temperature fkor the entire trip was 73.3 degrees. Mille 220 beach had the highest mean temperature (102.7 degrees) and Awatubi had the lowest mean temperature (65 degrees.)

Many high temperature were noted away from the talus slope.

(Mile 20 - 93 degrees at station #3/5, Upper Nankoweap - 99 degrees at station #4/8, Awatubi - 106 degrees at station #7/8, Carbon Creek - 99 degrees at station #3/4, and Upper National - 100 degrees at station #1/6). The lowest temperatures were generally recorded at the river's edge, with the exception of National Beach.

The mean difference in temperature from station #1 to the talus slope or last station was 19.7 degrees. Greater differences were noticed in beaches where the tape line exceeded 50 meters.

The relatively humidity and dew points at the river's edge had a mean of 32.6% for the first 5 days of the trip. The relative humidity increased during the last 4 days to a mean of 43%, due to frequent rain storms. At the talus slope, the humidity showed a mean of 24.4% the first 5 days and increased to 47.3% the last 4 days.

The average angle of slope of the 9 beaches is 6.7 degrees. The average difference between the highest point and the lowest point on the eeach is 19.7 degrees.

The water temperature gradually increased with minor fluctuations as the trip progressed. The average mean temperature for the entire trip was 54.6 degrees. fluctuations as the trip progressed. The average mean temperature for the entire trip was 54.6 degrees.

CONCLUSIONS

The high temperature readings noted were due not the the distance from the water or the degree of slope, but to direct exposure to the sun's rays. One example of this would be the reading recorded at National Beach, where the highest reading was at the water's edge, where the thermometer had first exposure to the sun. At many other beaches, the highest reading occurred where the thermometer was in direct sunlight and unaffected by large rocks, trees, and shrubs. At times this occurred at the highest point on the beach. Some high temperature did occur at the talus slope as expected, but only when the rock wall had been exposed nearly all day the the direct rays of the sun.

The lowest temperature readings were directly correlated to the proximity of the water. This was due to the cooling influnces of the water.

The rise in relative humidity in the latter stages of the trip was obviously due to the increased rainfall. There does not seem to be any correlation between the degree of slope of the beach and the temperature. Awatubi beach, for example, has a 6.5 degree beach slope (close to the mean), though the temperature difference across the beach is fairly high (36 degrees).

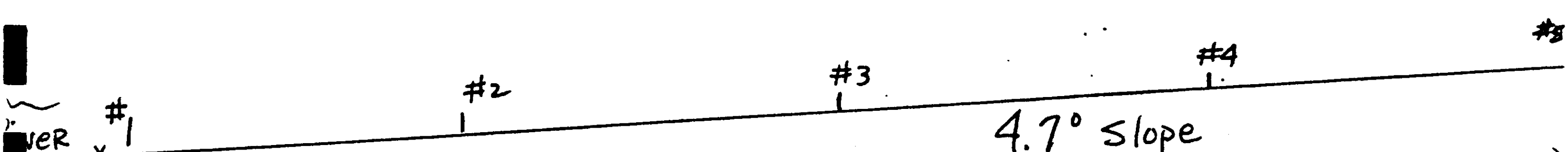
AY 1

MAXIMUM/MINUMUM TEMPERATURE STUDY

Location: Camp | Mile: 20.0 | Set-Up Date: July 29 8:50pm | Reading Date: July 30 6:45am

Station #	Zone	Initial Temp./Time	Maximum Temp./Time	Minimum Temp./Time	Comments
1	4	92° / 8:50p	92° / 6:37a	68 / 6:37a	River Edge Beach Area - Sandy No Rocks / Vegetation
2	4	92° / 8:50p	90 / 6:37a	70 / 6:37a	Sandy Beach Gravel Fan 8.0 M to Right
3	4	92° / 8:50p	93 / 6:37a	73 / 6:37a	Sandy Beach Gravel Fan to Right No Vegetation
4	3	92° / 8:50p	91 / 6:38a	73 / 6:38a	Sandy Beach Gravel Fan to Right Some sm. shrubs surrounding
5	3/2	92° / 8:50p	88 / 6:38a	74 / 6:38a	Under Sheer Rock wall face Large Acacia Nearby Sandy Beach (Talus)
6					Note: Large Stand of Tamarix to Left
7					
8					
AVERAGE		92° / 8:50p	90.8° / 6:38a	71.6° / 6:38	WATER TEMP.: 51.8° F

BEACH PROFILE:
(Stations 10 Meters apart)



Relative Humidity: 48% Time: 8:44p Location: Station 1 Wet = 60 (15.5°C)
Dew Point: 17°C Dry = 73 (22.78°C)

Relative Humidity: 28% Time: 8:44p Location: Station 5 Wet = 61 (16.1°C)
Dew Point: 20°C Dry = 82 (27.8°C)

ay 2

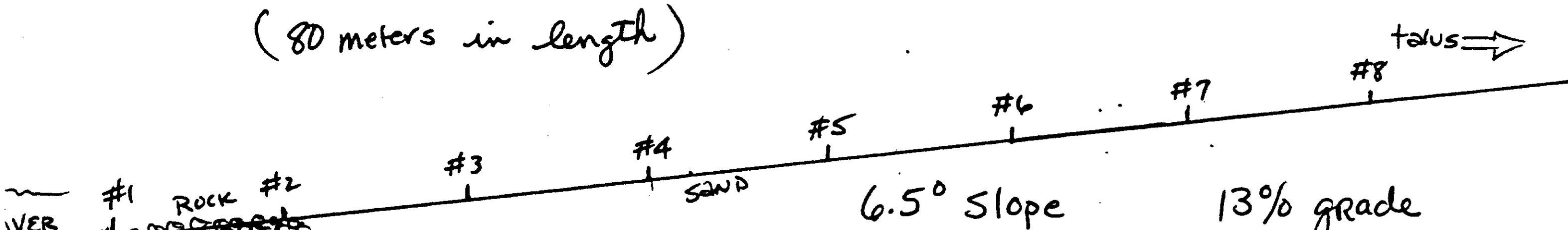
MAXIMUM/MINUMUM TEMPERATURE STUDY

Location: Upper Nankoweap   Mile: 52.0   Set-Up Date: July 30
Reading Date: July 31

Station #	Zone	Initial Temp./Time	Maximum Temp./Time	Minimum Temp./Time	Comments
1	4	80° / 8:00p	92° / 8:32a	64° / 8:32a	River Edge - Slope very Rocky & steep - many sm. Rocks
2	4	80° / 8:00p	94° / 8:32a	65° / 8:32a	Midde of Gravel Fan - sm. Tamarix saplings
3	4	80° / 8:00p	97° / 8:32a	66° / 8:32a	- Sandy Flat Surface - sm. tamarix saplings
4	3	80° / 8:00p	99° / 8:32a	66° / 8:32a	- Rocky incline - @ foot of sandy incline
5	3/2	80° / 8:00p	90° / 8:33a	64° / 8:33a	- Sandy, brushy incline - v. large dead stump in front of #5 marker
6	2	80° / 8:00p	93° / 8:33a	66° / 8:33a	- Sandy area in grassy incline. Near trail - brushy veg. to left
7	2	80° / 8:00p	92° / 8:34a	66° / 8:34a	- sandy, grassy area - some dead stumps
8	2/1	80° / 8:00p	96° / 8:34a	66° / 8:34a	- sandy, grassey area - sm. brush everywhere - station near lg. thorny bush
AVERAGE		80°/8:00p	94°/8:33a	65°/8:33a	WATER TEMP.: 50°F

BEACH PROFILE:

(80 meters in length)



Relative Humidity: 39%   Time: 8:15p   Location: Station 1   D = 26.7°C
Dew Point: 17.5°C   W = 17.2°C

Relative Humidity: 24%   Time: 8:15p   Location: Station 8   D = 28.9°C
Dew Point: 19°C   W = 16.1°C

Camp area bordered by very large gravel fan to the left

13

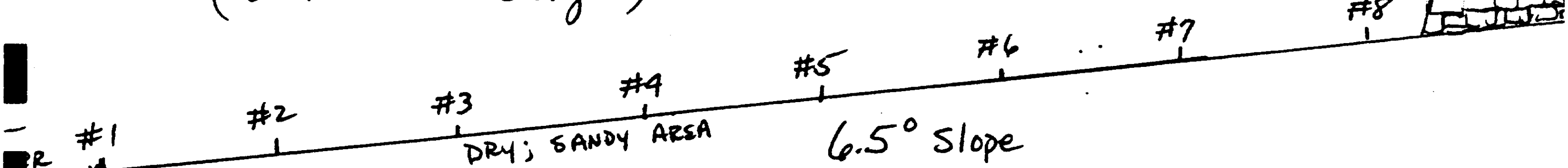
MAXIMUM/MINUMUM TEMPERATURE STUDY

Location: Awatubi	Mile: 58.1	Set-Up Date: July 31 Reading Date: Aug 1

Station #	Zone	Initial Temp./Time	Maximum Temp./Time	Minimum Temp./Time	Comments
1	4	65° / 4:45p	98° / 7:02a	60° / 7:02a	-River Edge -large Willow tree to left - Sandy
2	4	65° / 4:45p	101° / 7:02a	64° / 7:02a	- sandy, grassy slope - many willow saplings
3	4	65° / 4:45p	101° / 7:02a	64° / 7:02a	- sandy grassy slope - sm. incline
4	3	65° / 4:45p	102° / 7:02a	64° / 7:02a	- sandy - some willow saplings
5	3	65° / 4:45p	101° / 7:03a	66° / 7:03a	- dry, sandy slope
6	3/2	65° / 4:45p	100° / 7:03a	66° / 7:03a	- dry, sandy, grassy
7	2	65° / 4:45p	106° / 7:03a	66° / 7:03a	- dry, sandy, grassy
8	2/1	65° / 4:45p	102° / 7:04a	70° / 7:04a	- talus slope - in front of small rock face
AVERAGE		65° / 4:45p	101.3° / 7:03a	65° / 7:03a	WATER TEMP.: 50°

BEACH PROFILE:

(80 meters in length)



Relative Humidity: 24% Dew Point: 22.5°C	Time: 5:04p	Location: Station 1	D = 35.6°C W = 20.0°C
Relative Humidity: 10% Dew Point: 21°C	Time: 5:04p	Location: Station 8	D = 37.8°C W = 18.3°C

AY 4

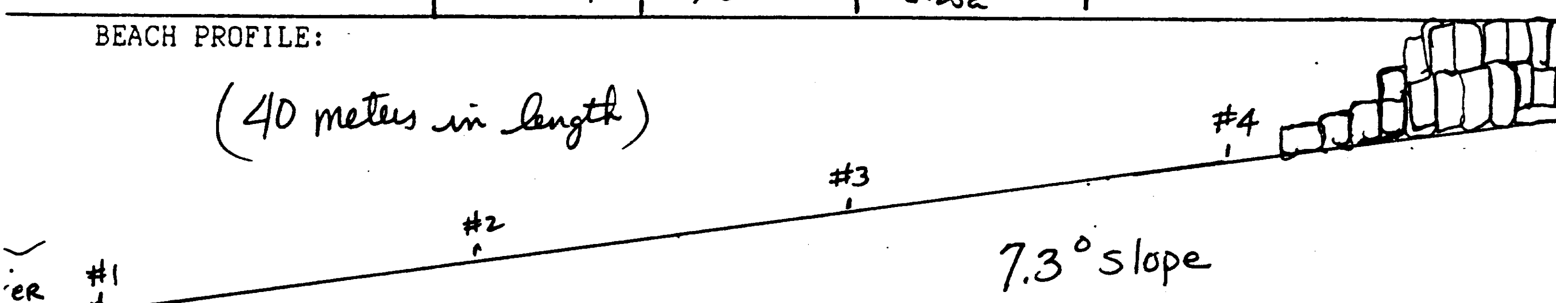
MAXIMUM/MINUMUM TEMPERATURE STUDY

Location: Carbon Creek | Mile: 63.5 | Set-Up Date: Aug 1 | Reading Date: Aug 2

Station #	Zone	Initial Temp./Time	Maximum Temp./Time	Minimum Temp./Time	Comments
1	4	65° / 2:10p	97° / 6:25a	81° / 6:25a	- River Edge - Near gravel base - much tree cover behind
2	4	65° / 2:10p	98° / 6:25a	84° / 6:25a	- sandy - Rocks to Right - large Tamarix to left
3	3	65° / 2:10p	99° / 6:25a	84° / 6:25a	- sandy - gravel fan to Right - inclined
4	3/2	65° / 2:10p	90° / 6:25a	80° / 6:25a	- Base of talus - very large mesquite tree behind (providing shade)
5					
6					
7					
8					
AVERAGE		65° / 2:10p	96° / 6:25a	82° / 6:25a	WATER TEMP.: 57°

BEACH PROFILE:

(40 meters in length)



Relative Humidity: 17% | Time: 2:30p | Location: Station 1 | W = 18.3°C
Dew Point: 21°C | | | D = 35°C

Relative Humidity: 27% | Time: 2:30p | Location: Station 4 | W = 18.9°C
Dew Point: 22°C | | | D = 32.2°C

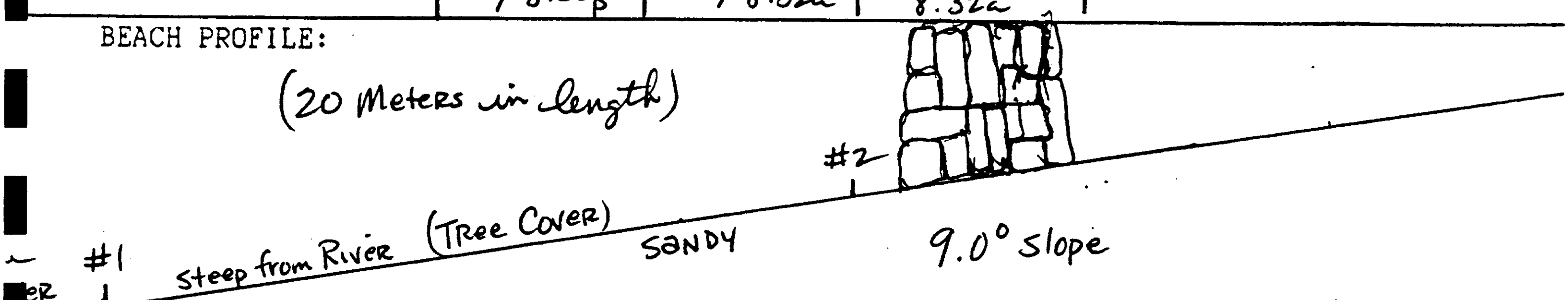
y #5

MAXIMUM/MINUMUM TEMPERATURE STUDY

Location: Camp (unscheduled) Mile: 92.1 Set-Up Date: Aug 2 8:50pm
Reading Date: Aug 3

Station #	Zone	Initial Temp./Time	Maximum Temp./Time	Minimum Temp./Time	Comments
1	4	94° / 8:50p	103.° / 8:30a	82° / 8:30a	- Very steep sloping beach - much tree & shrub cover
2	4/3	94° / 8:50p	92° / 8:32a	82° / 8:32a	- Talus slope beneath sheer rock wall
3					
4					
5					
6					
7					
8					
AVERAGE		94° / 8:50p	97.5° / 8:32a	82° / 8:32a	WATER TEMP.: 55°

BEACH PROFILE:



Relative Humidity: 35% Time: 8:02a Location: Station 1 W= 20.5°C
Dew Point: 24°C D= 31.7°C

Relative Humidity: 33% Time: 8:04a Location: Station 2 W= 21.1°C
Dew Point: 24°C D= 33.3°C

AY 6

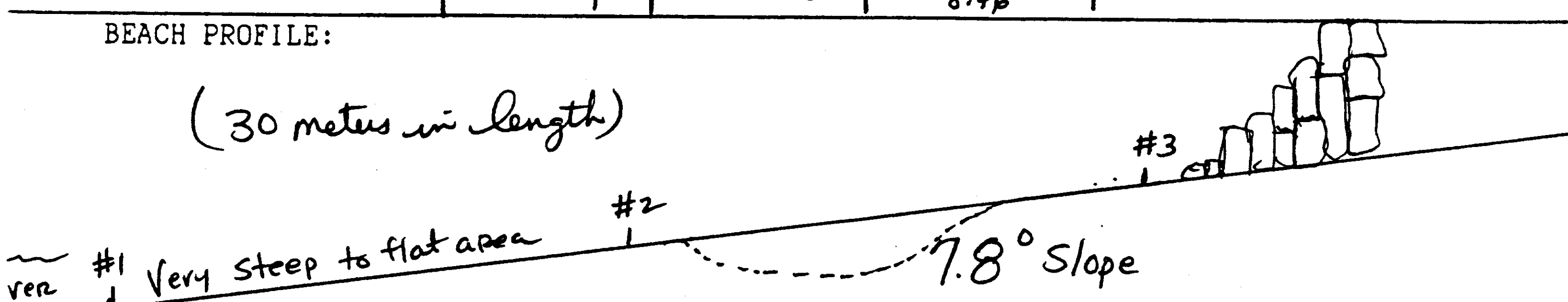
MAXIMUM/MINUMUM TEMPERATURE STUDY

Location: Camp Mile: 122.0 Set-Up Date: AUG 3 Reading Date: AUG 4

Station #	Zone	Initial Temp./Time	Maximum Temp./Time	Minimum Temp./Time	Comments
1	4	80° / 8:03p	84° / 8:46a	70° / 8:46a	- Sandy - very steep incline to flat area - tree cover to left
2	4	80° / 8:03p	91° / 8:46a	72° / 8:46a	- sandy beach - large depression to rear w/ wet sand
3	4/3	80° / 8:03p	93° / 8:46a	73° / 8:46a	- talus slope - Rock face
4					
5					
6					
7					
8					
AVERAGE		80°/8:03p	89°/8:46a	71.7°/8:46	WATER TEMP.: 55°

BEACH PROFILE:

(30 meters in length)



Relative Humidity: 72% Time: 8:26p Location: Station 1 D = 72 (22.2°C)
Dew Point: 19°C W = 66 (18.9°C)

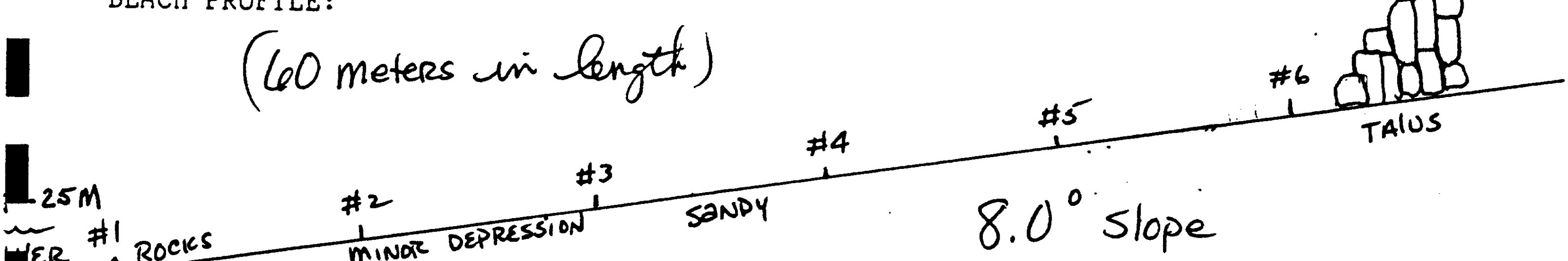
Relative Humidity: 56% Time: 8:27p Location: Station 3 D = 74 (23.3°C)
Dew Point: 18°C W = 63 (17.2°C)

MAXIMUM/MINUMUM TEMPERATURE STUDY

Location: Upper National | Mile: 166.5 | Set-Up Date: Aug 4 | Reading Date: Aug 5

Station #	Zone	Initial Temp./Time	Maximum Temp./Time	Minimum Temp./Time	Comments
1	4	80° / 8:02p	100° / 6:30a	77° / 11:00a	- Sandy stream channel - Water Receded during the night .25 meters - original River Edge
2	4	80° / 8:02p	99° / 6:30a	78° / 11:01a	- sandy stream channel - minor depression - sm. Rocks
3	4/3	80° / 8:02p	~~87°~~ 99° / 6:30a	78° / 11:01a	- sandy incline - no Rocks
4	3	80° / 8:02p	99° / 6:31a	81° / 11:01a	- sandy incline - no Rocks
5	3	80° / 8:02p	80° / 6:31a	80° / 11:02a	- sandy, grassy - no Rocks
6	2	80° / 8:02p	81° / 6:31a	79° / 11:03a	- talus slope - lg. desert broom to left
7					
8					
AVERAGE		80° / 8:02p	93° / 6:30a	79° / 11:02a	WATER TEMP.: 57°

BEACH PROFILE:



Relative Humidity: 29% | Time: 10:55a | Location: Station 1 | W= 69 (20.5°C)
Dew Point: 23.5°C | | | D=93 (33.9°C)

Relative Humidity: 35% | Time: 10:55a | Location: Station 6 | W= 68 (20.0°C)
Dew Point: 22°C | | | D = 88 (31.1°C)

Note: - Stations #5 & #6 in shade due to ROCK WALL UNTIL APPROXIMATELY 11:30am.
- stations #1 & #2 in SUN at 9:00am
- station #1 left @ water edge in evening was approximately .25M from water @ 8:00

(Layover)

MAXIMUM/MINUMUM TEMPERATURE STUDY

Location: Upper National   Mile: 166.5   Set-Up Date: AUG 5
Reading Date: AUG 6

Station #	Zone	Initial Temp./Time	Maximum Temp./Time	Minimum Temp./Time	Comments
1	4	79° / 6:39p	88° / 7:04a	71° / 7:04a	(see day 7)
2	4	79° / 6:39p	88° / 7:04a	70° / 7:04a	
3	4/3	79° / 6:39p	73° / 7:04a	70° / 7:04a	
4	3	79° / 6:39p	84° / 7:05a	68° / 7:05a	
5	3	79° / 6:39p	80° / 7:05a	68° / 7:05a	
6	2	79° / 6:39p	77° / 7:05a	68° / 7:05a	
7					
8					
AVERAGE		79° / 6:39p	81.6° / 7:04a	69.2° / 7:04a	WATER TEMP.: 57°

BEACH PROFILE:

(see DAY 7)

Relative Humidity: Time: 7:20a   Location: Station 1   W=
Dew Point: D=

Relative Humidity: Time: 7:20a   Location: Station 6   W=
Dew Point: D=

Note: Much Rain the previous day; sand was very wet

49

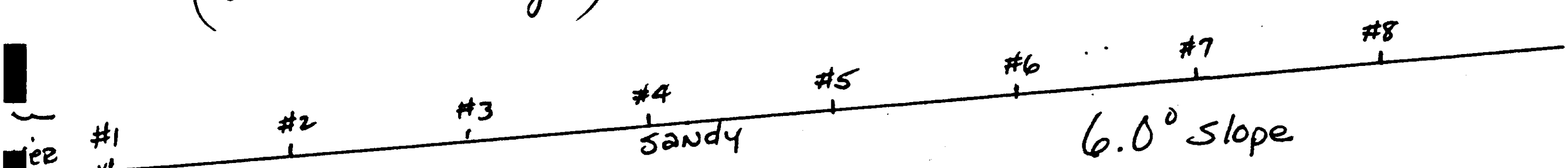
MAXIMUM/MINUMUM TEMPERATURE STUDY

Location: Camp | Mile: 196 | Set-Up Date: AUG 6 | Reading Date: AUG 7

Station #	Zone	Initial Temp./Time	Maximum Temp./Time	Minimum Temp./Time	Comments
1	4	84° / 7:15p	85° / 6:55a	69° / 6:55a	- sandy beach - many dispersed Rocks
2	4	84° / 7:15p	86° / 6:55a	69° / 6:55a	- sandy beach - some lg. Rocks
3	4/3	84° / 7:15p	92° / 6:55a	70° / 6:55a	- sandy beach - inclined
4	3	84° / 7:15p	86° / 6:56a	72° / 6:56a	- sandy beach - some plant saplings
5	3	84° / 7:15p	86° / 6:56a	72° / 6:56a	- sandy beach - some beach grasses
6	3/2	84° / 7:15p	88° / 6:56a	70° / 6:56a	- sandy beach - some Rocks & grasses
7	2	84° / 7:15p	86° / 6:57a	72° / 6:57a	- sandy beach - Zone 2 vegetation
8	2/1	84° / 7:15p	96° / 6:57a	82° / 6:57a	- talus slope - lg. tree to left
AVERAGE		84°/7:15p	88.1/6:57a	72°/6:57a	WATER TEMP.: 55°

BEACH PROFILE:

(80 meters in length)



Relative Humidity: 55% Time: 7:05a Location: Station #1 D= 29°C
Dew Point: 25°C W= 23°C

Relative Humidity: 51% Time: 7:05a Location: Station #8 D= 31°C
Dew Point: 25°C W= 23°C

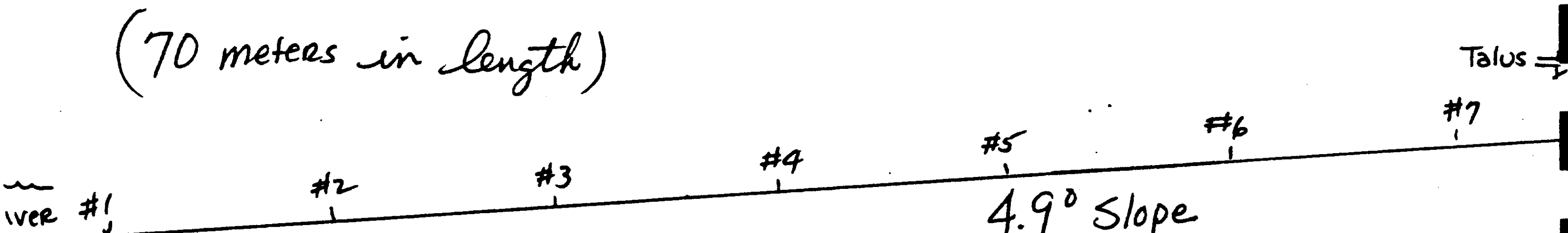
MAXIMUM/MINUMUM TEMPERATURE STUDY

Location: Camp   Mile: 220   : Set-Up Date: AUG 7
Reading Date: AUG 8

Station #	Zone	Initial Temp./Time	Maximum Temp./Time	Minimum Temp./Time	Comments
1	4	85° / 7:10p	100° / 7:22a	74° / 7:22a	-River Edge (water Rose 5 m during night) -sandy
2	4	85° / 7:10p	102° / 7:22a	80° / 7:22a	- sandy, grassy - med. tamarix near
3	4/3	85° / 7:10p	104° / 7:23a	81° / 7:23a	-sandy, grassy - sm. tamarix near
4	3	85° / 7:10p	104° / 7:23a	81° / 7:23a	- sandy, grassy
5	3	85° / 7:10p	98° / 7:23a	81° / 7:23a	-sandy, grassy - beach inclined
6	3	85° / 7:10p	101° / 7:24a	81° / 7:24a	- sandy; much grassy plants - some large rocks
7	2	85° / 7:10p	110° / 7:24a	81° / 7:25a	-sandy - many shrubs - some rocks
8	2/1				
AVERAGE		85° / 7:10p	102.7° / 7:23a	79.9° / 7:23a	WATER TEMP.: 58°

BEACH PROFILE:

(70 meters in length)



Relative Humidity: Time: 7:30a   Location: Station #1   W =
Dew Point: D =

Relative Humidity: Time: 7:30a   Location: Station # 7   W =
Dew Point: D =

CHAPTER VIII

A STUDY OF CURRENT VELOCITIES WITHIN EDDIES AND LOW-FLOW AREAS ASSOCIATED WITH MAJOR BEACHES ALONG THE COLORADO RIVER

Mark Weber

INTRODUCTION

Current velocity readings were measured along seven beaches of the Colorado River in Grand Canyon National Park during a eleven day river trip in July and August 1986. The direction of the current system as well as the orientation of ripple marks observed along the water's edge were noted. This report is based on data collected in the 75-mile reach immediately below Lee's Ferry, to where the turbidity of the river makes it impossible to observe the ripples marks beneath the surface of the water. Integration of this analysis with photographic, topographic and sedimentological data may permit an estimation of the effect of river velocity on the erosion of established beaches in the future.

PROCEDURE

A hydrological flow meter was used to measure the speed of the current. It consists of a long metal rod approximately 6.0 feet in length with a rotating blade on the bottom to measure the movement of the water, and a listening headset on the top to count the blade rotation. The blade was placed approximately one foot beneath the surface of the water. When possible the strongest current was measured within safety limitations. As the blade rotates during each revolution, an audible "click" or "scratch" can be heard through the headset. The conversion of audible clicks into feet per second was done using the following formulas:

LESS THAN 40 REVOLUTIONS: revolutions divided by time in seconds (X 2.18) + 0.02 = feet per second

MORE THAN 40 REVOLUTIONS: revolutions divided by time in seconds (X2.17) + 0.03 = feet per second

Example: 25 revolutions (""clicks") = 25/60= (0.417)(2.18) + 0.02 = 0.928 feet per second

Careful notes were taken by a second observer as to the direction of the current. Two good indicators of flow direction are the orientation of sand ripples and floating Cladophora algae. When neither of these were visible, a floating bob was used to determine the direction of flow.

Collection of data started at the highest point of the beach, with each subsequent reading approximately 10 - 15 meters downstream. Plan view sketches of the study area along with current velocity values and ripple orientations are presented in Appendix A. The local water currents near the beach are represented in blue, the ripple patterns in orange, and the main current direction of the river in purple.

OBSERVATIONS

Badger Rapid - 7.8 mile: Adjacent to a large boulder fan (3.14) no sandy deposits observed. Just downriver a sizable back eddy occurs (.674 fps). A small back eddy (0.965 fps) occurs around an isolated rock, with some ripple marks on the lower end of the eddy parallel to the beach. Another back eddy (0.783 fps) around a second rock contains large ripple marks.

18.2 Mile: Sand stripped away adjacent to rocks (3.36 fps). Current decreased at mouth of dry wash (0.238 fps). A fairly substantial back eddy was evident (0.565 fps) with associated ripple marks. Two large boulders in the river showed increased currents (0.856 fps). Ripple marks seen in front of the boulders. Back eddy through the rocks at (0.636 fps), no ripple marks seen.

Middle Nankoweap - 52.5 mile: No sand deposits seen adjacent to boulder fan (2.38 fps). Just downstream a massive back eddy exsists covering the entire inlet, with decrease in flow at the very bottom of the inlet (0.420 fps). A major increase was then noted from (1.29 fps) to (2.56 fps). At this point the back eddy and the main current merge (0.710 fps) into the main current. Another major current over shallow submerged rocks also feeds the main channel at this point (1.11 and 2.20 fps).

Lower Nankoweap - 53.0 mile: No sand deposits adjacent to boulder fan upstream (1.36 fps). The large back eddy downstream continues along a natural mud-silt shelf. No sand, but a silty, muddy sediment covered the bottom in this area, along with many exposed tree branches. Some minor ripples were seen at the upper end of the back eddy (0.165 fps).

Awatubi - 58.1 mile: The whole current is a large back eddy. The current is somewhat slow (0.492 fps) to moderate (0.928 fps). Many well-defined ripple marks can be seen in this area measuring approximately 0.30 cm apart and 2-3 centimeters in height.

Lower Little Colorado - 61.8 mile: Current flows in the direction of the river except for a well-developed back eddy at the right (1.22 fps). Numerous ripple marks are seen in this area, ranging approximately 17 cm apart and 1-2 cm in height. Many similar dry ripple marks are also noted along the beach with the same dimensions, parallel to the water's edge.

Nevills's Rapid - 75.5 mile: Current is running in an unusual manner perpendicular to the beach (0.529 and 0.274 fps). At the middle of the beach the current back eddies and speeds up (0.383 and 0.747 fps).

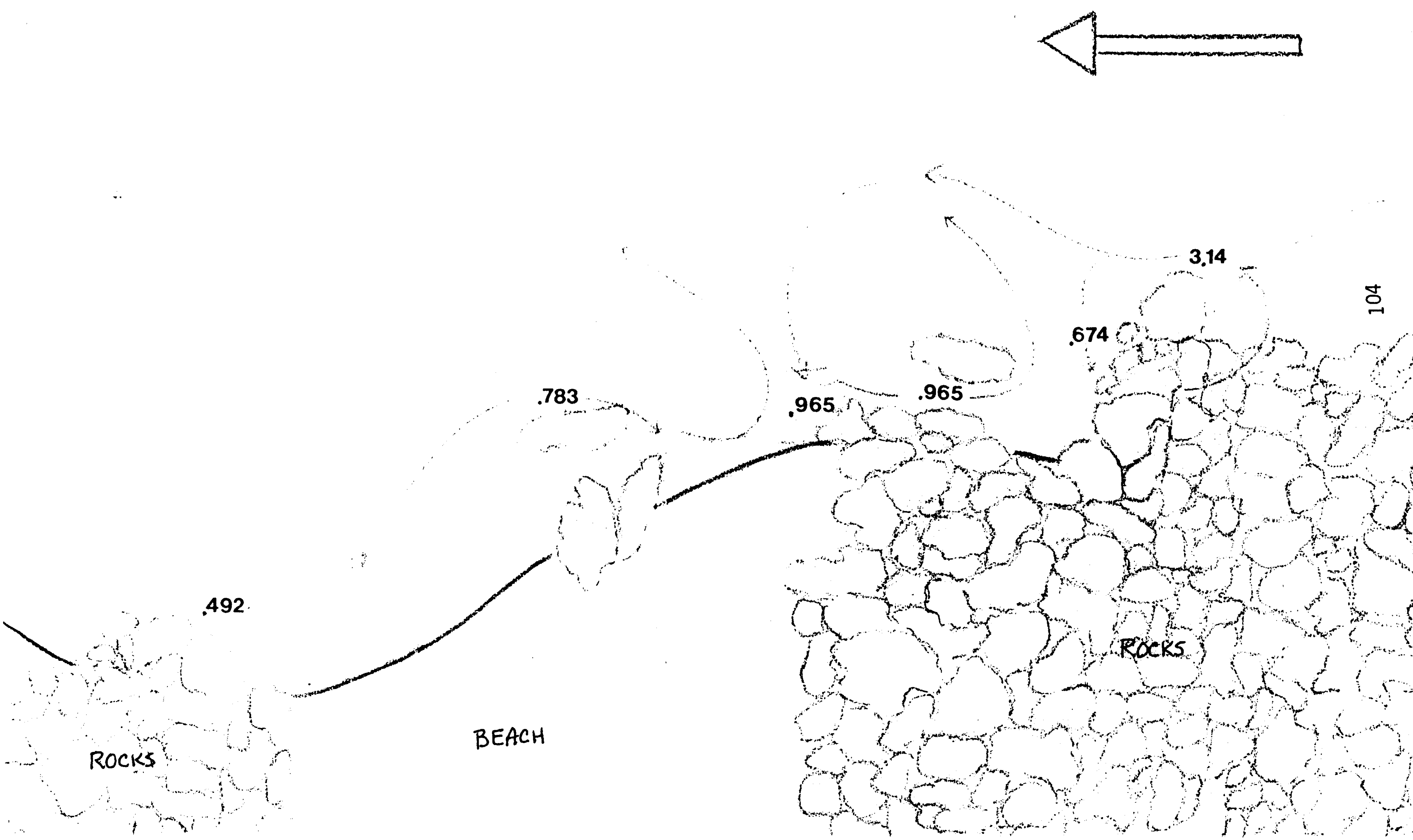
CONCLUSIONS

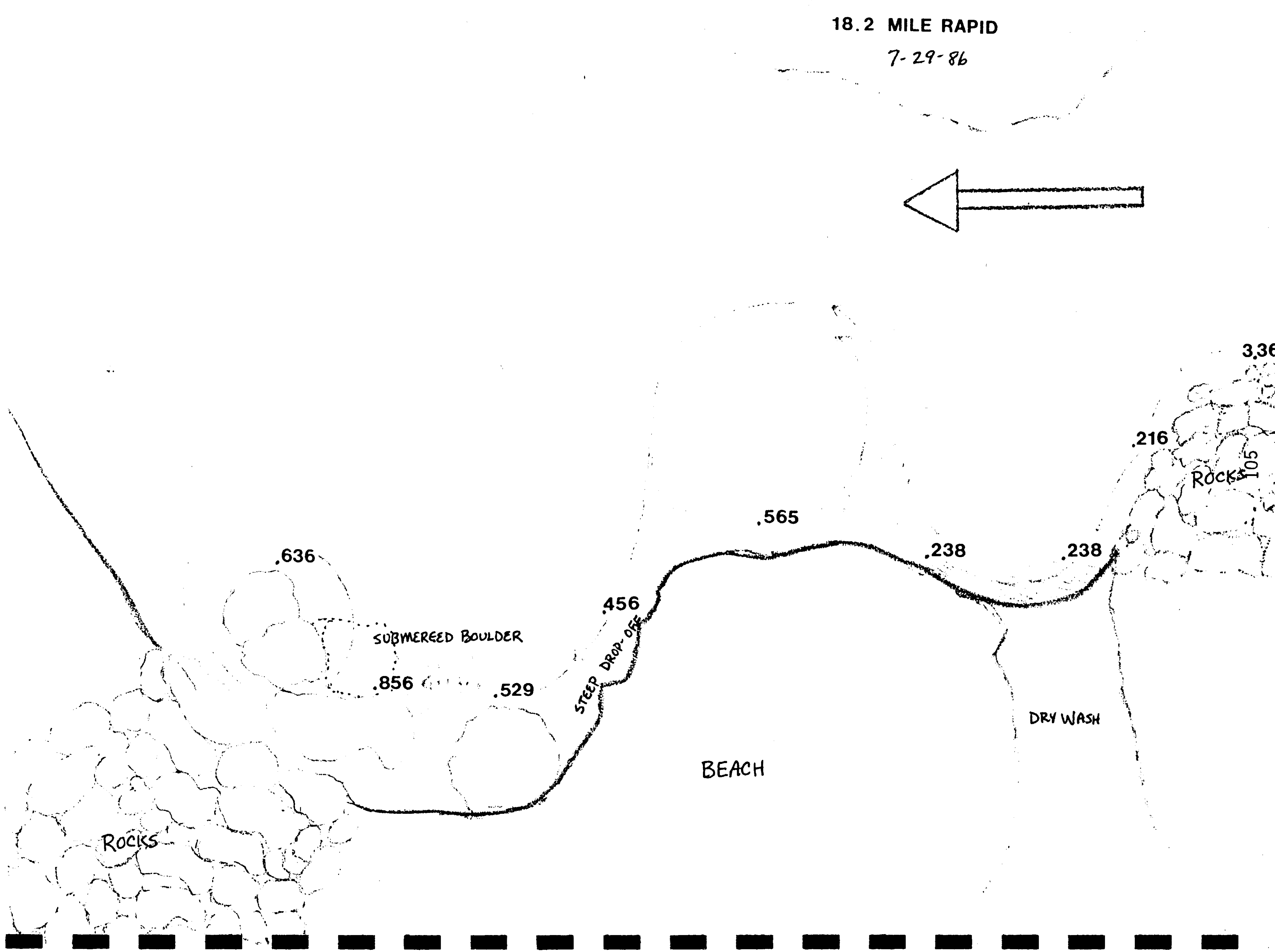
Velocity within the eddies varies greatly; from .056 to about 1.22 fps. There is a general absence of sandy deposits where the water velocity exceeds approximately 1.50 fps. This generally occurs around the large gravel fan deposits that border the eddies. Although the current directions within the eddies are extremely variable, the predominate flow direction appears to be upstream.

APPENDIX A

BADGER RAPID 7.8

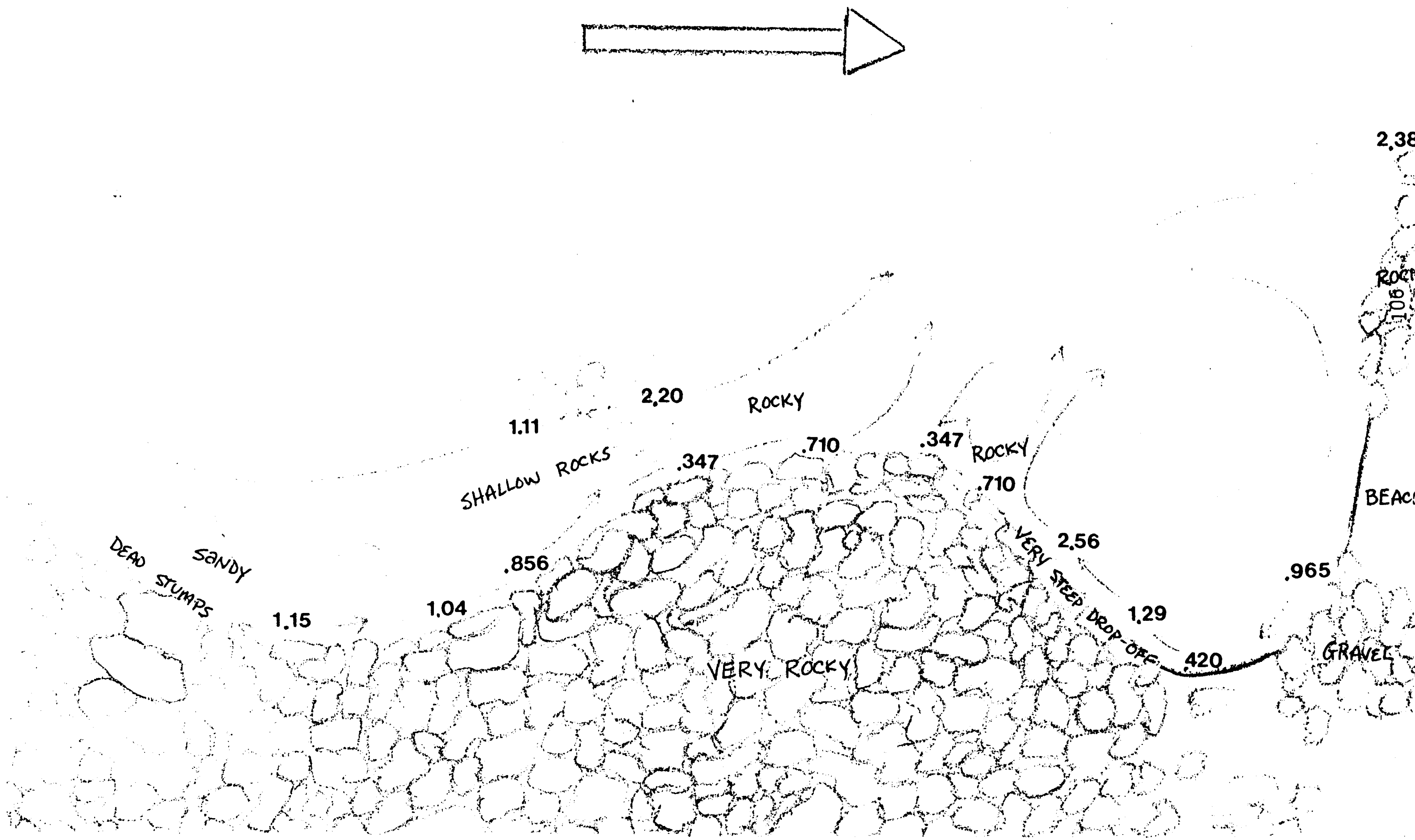
7-29-86




18.2 MILE RAPID
7-29-86
.636
SUBMERGED BOULDER
.856
.529
.456
STEEP DROP-OFF
.565
.238
.238
.216
3,36
ROCKS
ROCKS
BEACH
DRY WASH

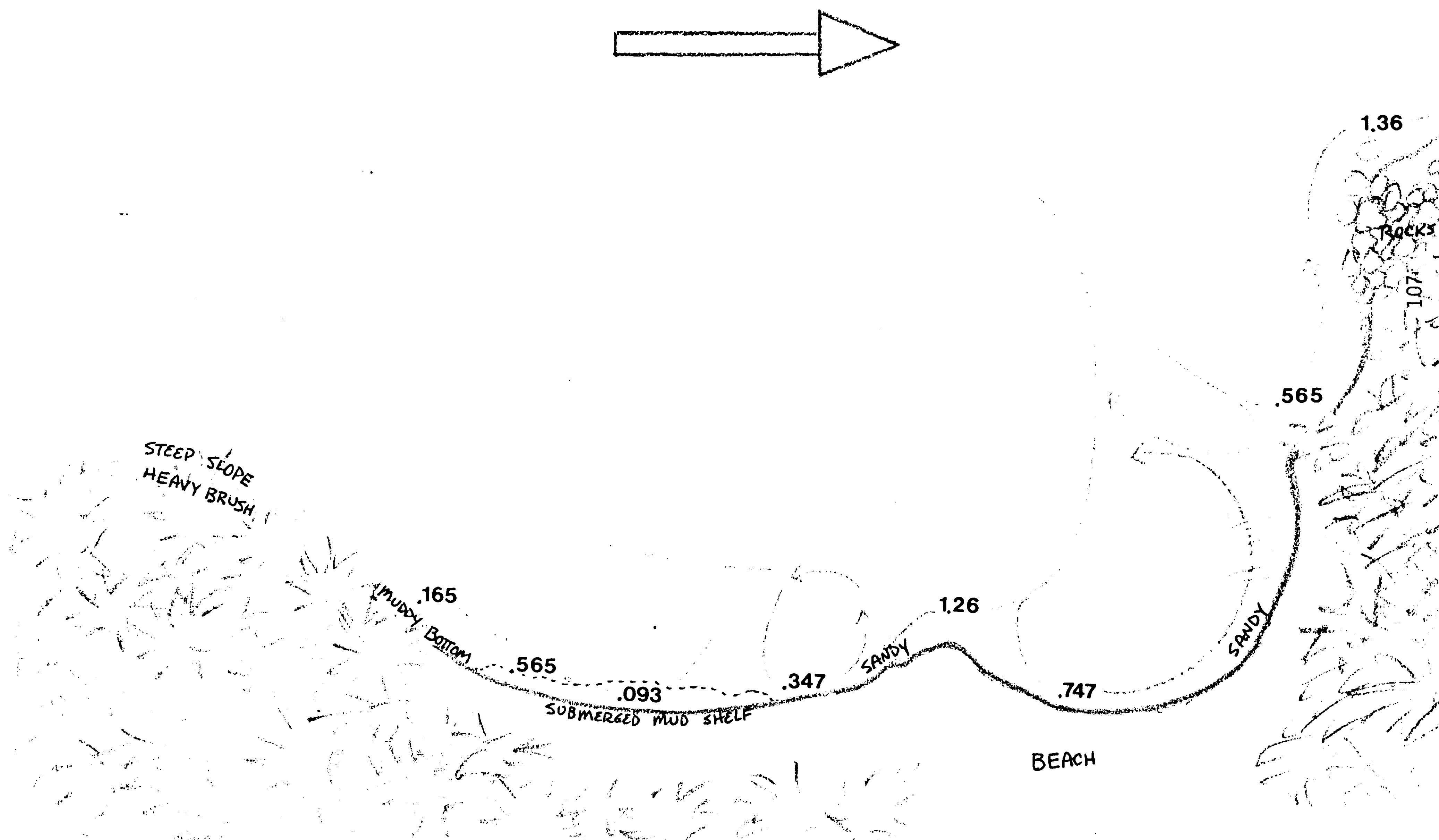
MIDDLE NANKOWEAP 52.5

7-31-86



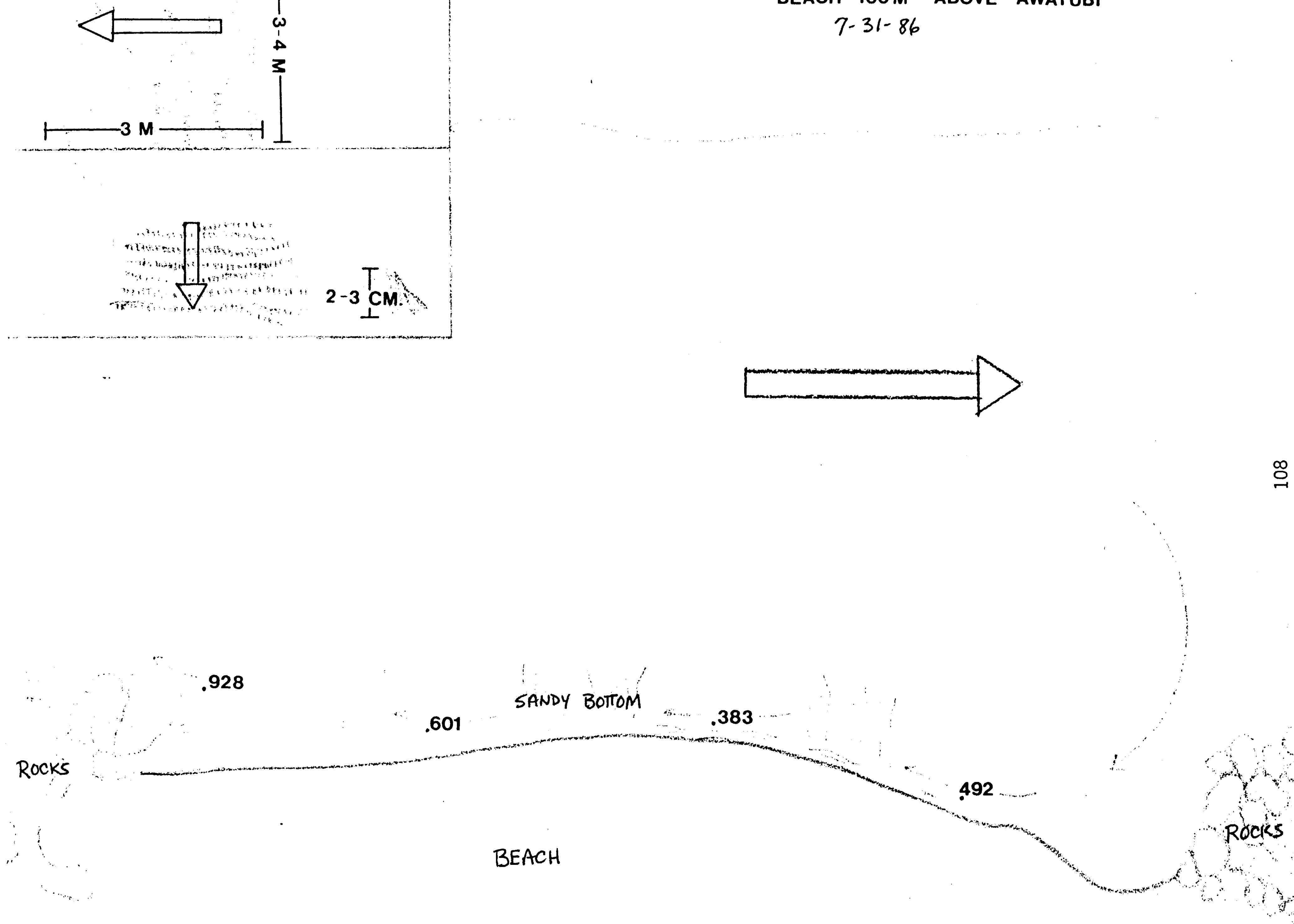
LOWER NANKOWEAP 53.0

7-31-86

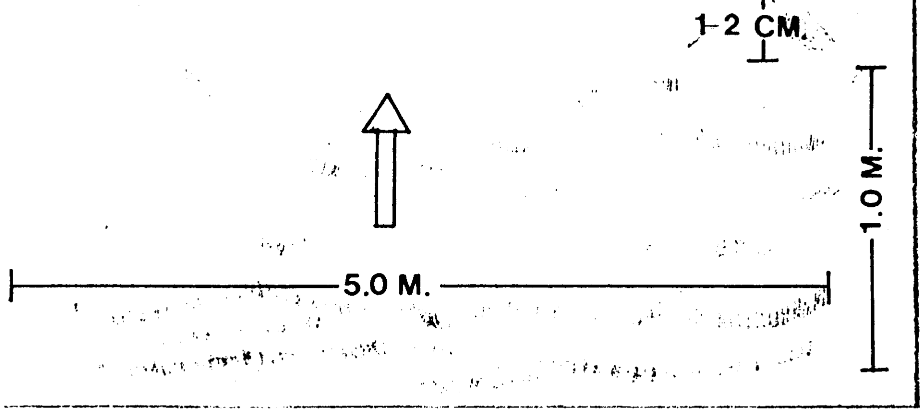


BEACH 100M ABOVE AWATUBI

7-31-86

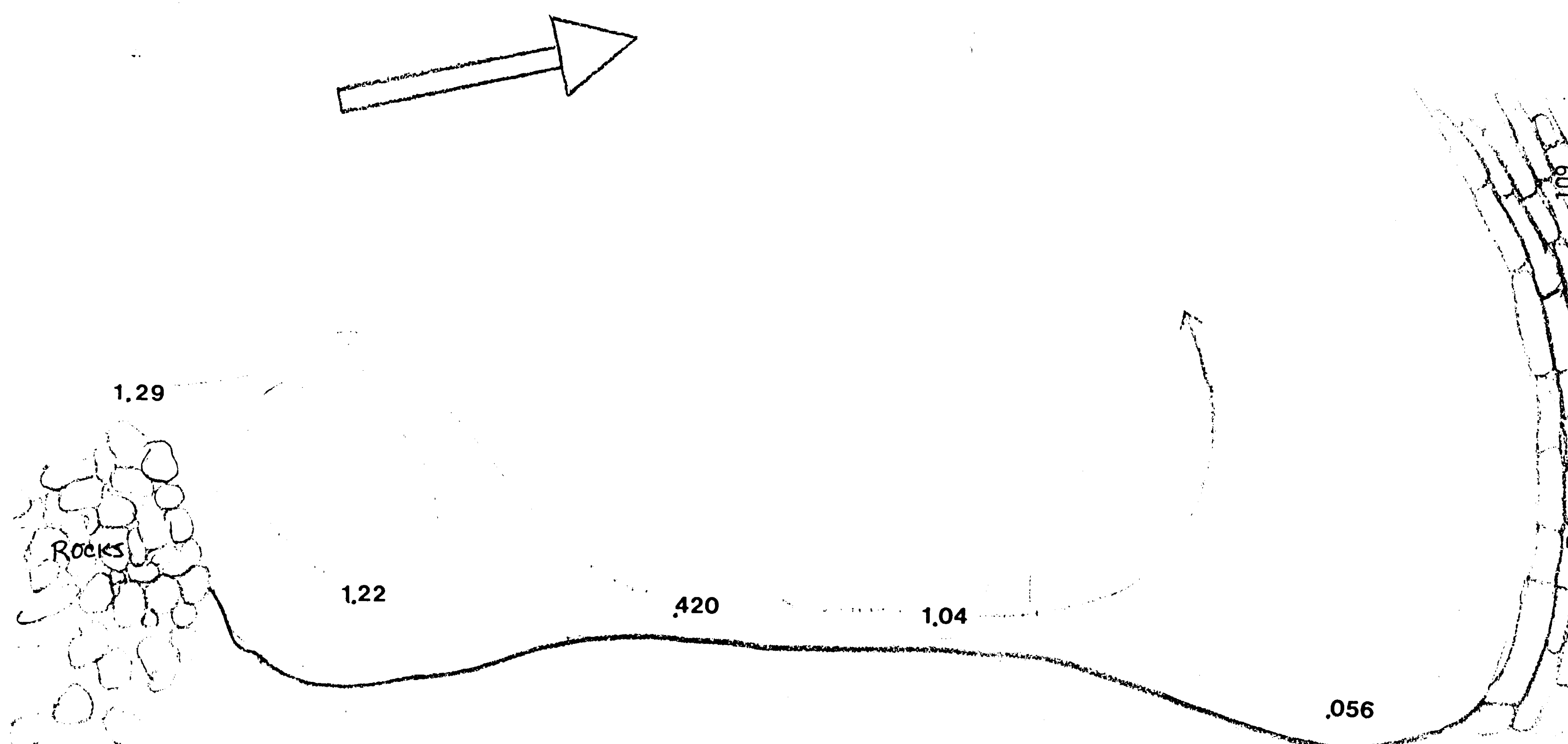


RIPPLE MARKS IN DRY SAND 61.8



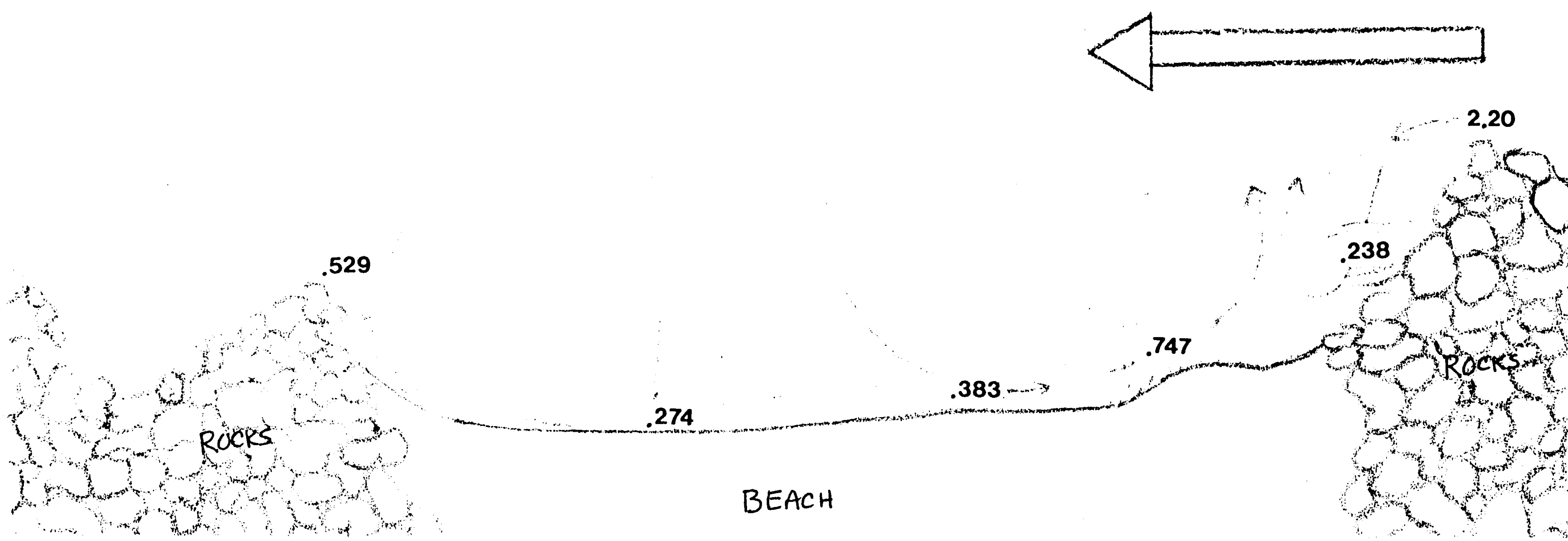
LOW. L.C.R. OPPOSITE BANK 61.8

8-1-86



NEVILL'S RAPID 75.5

8-2-86



CHAPTER IX

RIVER EXPEDITION REPORT: SOCIOLOGICAL DATA
SUMMER, 1986

Jim Novak

INTRODUCTION

This sociological report presents data on the frequency of human and aircraft contacts during an eleven day river trip on the Colorado River through the Grand Canyon. Contacts include commercial and private raft trips as well as aircraft sightings. The results of this survey will be useful in determining if the frequency of these sightings affect the natural setting and wilderness experience of recreationists in the Grand Canyon. The research party consisted of thirty-three people using four motor-powered boats. The personnel included: twenty-one students, two faculty members from Northern Arizona University, one photographer and eight boat crew members.

SCHEDULE

A total of fifty-eight stops were made on this eleven day river trip. Forty-four stops were for beach research, six stops were for attraction points, three for scouting rapids, one for repairs, and two for take0outs. The expedition had one lay-over stop for two nights at National Canyon for a full day of research. The stops are identified in Table 1.

CONTACTS

Contacts with other raft trips on the river totaled fifty-one. Sixteen of these were with private groups; thirty-five were commercial groups. The majority of the commercial groups were motor-powered trips. Most of the contacts were shore to river due to the many beach stops necessary for research. The largest number of contacts occurred on day seven where fourteen contacts were made over 44.6 river miles. Daily group contacts are presented in Table 2.

AIRCRAFT

To be recorded, aircraft had to be both seen and heard. High altitude commercial airliners and military aircraft were not counted. Since the observer traveled fairly quickly downstream by motor-powered raft, it is probable that some planes were missed. The largest number of sightings were recorded on days six through nine, through the Inner Gorge section of the Grand Canyon. The daily aircraft sightings are presented in Table 3.

CAMPSITES

We camped alone the first nine nights of the river trip. The last two nights our campsite was in view of one other group.

AVERAGES

The average daily group contacts and aircraft sightings are presented in Table 4. Group contacts averaged 4.7 per day, and aircraft encounters averaged 16.9 per day.

DATA SUMMARY

Mileage (M), human contact (C), and aircraft sightings (A) are presented for each trip day for the years 1982 through 1986 in Table 5.

Table 1. Trip schedule: July 29 - August 8 1986

Stop Number	Location	River Mile	Arrive Time	Arrive Day	Depart Time	Depart Day	Reason For Stop
0	Lees Ferry	0	---	---	13:20	1	Start
1	Badger Rapid	8	14:55	1	17:30	1	BR,L
2	16.5 Mile	16.5	18:45	1	19:15	1	BR
3	18.2 Mile	18.2	17:20	1	19:20	1	BR
4	20 Mile	20.0	19:40	1	10:15	2	BR,C
5	22.5 Mile	22.5	10:33	2	11:10	2	BR
6	Indian Dick	23.0	11:00	2	11:20	2	BR
7	Shinumo Wash	29.0	12:12	2	13:30	2	BR
8	Vasey's Paradise	31.7	13:00	2	13:18	2	AP
9	Redwall Cavern	33.1	13:30	2	15:25	2	AP,L
10	Nautiloid	34.7	15:50	2	18:17	2	BR
11	39 Mile	39.0	19:08	2	19:21	2	BR
12	Anazazi Bridge	43.5	17:30	2	18:30	2	BR
13	Middle Nankoweap	52.5	19:40	2	12:25	3	BR
14	Lower Nankoweap	52.6	12:30	3	15:00	3	BR,L
15	Awatubi	58.1	16:15	3	10:15	4	BR,C
16	Lower Little Colorado River	61.8	10:45	4	11:55	4	BR
17	Carbon Creek	63.5	12:15	4	9:15	5	BR,L,C
18	Lava Canyon	65.5	14:33	5	16:15	5	BR
19	Nevills Rapid	75.5	10:31	5	12:10	5	BR
20	Hance Rapid	76.5	12:15	5	12:50	5	BR
21	Grapevine	81.1	13:40	5	15:25	5	BR
22	Phantom Ranch	87.5	16:04	5	17:21	5	AP,P
23	92.1 Mile	92.1	18:15	5	9:25	6	C
24	Granite Rapid	93.2	9:34	6	11:00	6	BR
25	94 Mile	94.0	11:25	6	11:45	6	TO
26	95.2 Mile	95.2	12:05	6	12:35	6	Repairs
27	Crystal Rapid	98.2	13:00	6	13:30	6	Rapids
28	Lower Bass Camp	108.5	15:00	6	16:05	6	BR,L
29	115.5 Mile	115.5	17:20	6	17:35	6	BR
30	Elves Chasm	116.5	17:40	6	17:55	6	AP
31	Blacktail	120.1	18:03	6	19:30	6	BR
32	122 Mile	122.0	18:30	6	9:25	7	BR,C
33	Forster	122.8	9:13	7	10:15	7	BR
34	125.5 Mile	125.5	10:30	7	10:50	7	BR
35	Bedrock	131.0	10:45	7	12:15	7	BR
36	131.4 Mile	131.4	11:30	7	12:00	7	BR
37	Dubendorff	132.0	11:45	7	12:45	7	BR
38	Christmas Tree Cave	135.0	13:14	7	13:30	7	AP

Table 1 (continued)

Stop Number	Location	River Mile	Arrive Time –	Day	Depart Time –	Day	Reason For Stop
39	Deer Creek	136.0	13:24	7	13:45	7	BR
40	Deer Creek Falls	136.0	13:45	7	14:15	7	AP
41	Pancho's Kitchen	137.0	14:30	7	15:40	7	L
42	138.5 Mile	138.5	16:10	7	16:20	7	BR
43	National Canyon	166.6	19:13	7	10:40	9	BR Layover
44	Stairway	171.0	11:36	9	12:22	9	BR
45	Upper Lava Falls	179.0	13:40	9	14:05	9	Rapid
46	Lower Lava Falls	180.0	13:45	9	14:20	9	BR
47	180.9 Mile	180.9	13:55	9	15:55	9	BR, L
48	186 Mile	186.0	16:35	9	16:55	9	BR
49	190.2 Mile	190.2	17:15	9	18:00	9	BR
50	192.2 Mile	192.0	17:17	9	17:55	9	BR
51	196.5 Mile	196.5	18:20	9	9:25	10	BR, C
52	Parashant	198.5	9:32	10	10:20	10	BR
53	207 Mile	207.0	11:32	10	12:05	10	BR
54	Granite Park	208.8	11:30	10	14:50	10	BR, L
55	Pumpkin Bowl	213.0	15:30	10	16:05	10	BR
56	214 Mile	214.0	17:02	10	17:12	10	BR
57	220 Mile	220.0	17:15	10	7:40	11	BR, C
58	Diamond Creek	225.0	8:30	11	9:30	11	TO

BR = Beach Research
L = Lunch
AP = Attraction Point
C = Camp
TO = Take-out

Table 2. Group Contacts.

Day	Miles Covered	River Mile	River-River P	River-River C	River-Shore P	River-Shore C	Shore-River P	Shore-River C	Shore-Shore P	Shore-Shore C	Total P	Total C	Total T
1	20.0	0-20.0	0	0	0	1	0	1	0	1	0	3	3
2	32.5	20.0-52.5	0	0	0	3	0	2	0	0	0	5	5
3	5.6	52.5-58.1	0	0	0	0	0	6	0	0	0	6	6
4	5.4	58.1-63.5	1	0	0	0	2	2	0	0	3	2	5
5	28.6	63.5-92.1	0	2	0	2	1	3	0	0	1	7	8
6	29.9	92.1-122.0	1	0	0	2	0	0	0	0	1	2	3
7	44.6	122.0-166.6	4	1	2	3	4	0	0	0	10	4	14
8	0.0	at 166.6	0	0	0	0	1	0	0	2	1	2	3
9	29.9	166.6-196.5	0	1	0	0	0	0	0	0	0	1	1
10	23.5	196.5-220.0	0	0	0	1	0	2	0	0	0	3	3
11	5.0	220.0-225.0	0	0	0	0	0	0	0	0	0	0	0
	Total		6	4	2	12	8	16	0	3	16	35	39

P = Private
C = Commercial
T = Total

Table 3. Aircraft encounters.

Day	Miles Covered	River Mile	Single Engine	Multi-Engine	Helicopter	Total
1	20.0	0-20.0	0	1	0	1
2	32.5	20.0-52.5	1	3	0	4
3	5.6	52.5-58.1	1	1	0	2
4	5.4	58.1-63.5	3	6	1	10
5	28.6	63.5-92.1	5	7	3	15
6	29.9	92.1-122.0	6	23	16	45
7	44.6	122.0-166.6	2	22	1	25
8	0.0	at 166.6	0	33	0	33
9	29.9	166.6-196.5	2	31	0	33
10	23.5	196.5-220.0	1	17	0	18
11	5.0	220.0-225.5	0	0	0	0
		Totals	21	144	21	186

Table 4. Average group and aircraft encounters.

1. Group contacts per day.

River-River			River-Shore			Shore-River			Shore-Shore			Total		
P	C	T	P	C	T	P	C	T	P	C	T	P	C	T
0.5	0.4	1.0	0.18	1.09	1.2	0.7	1.4	2.1	0.0	0.2	0.2	1.3	3.0	4.5

2. Aircraft encounters per day.

Single Engine	Multi-engine	Helicopter	Total
1.9	13.0	1.9	16.8

Table 5. Summary data for each trip day for years 1982-1986.

Day	1982 M	1982 C	1982 A	1983 M	1983 C	1983 A	1984 M	1984 C	1984 A	1985 M	1985 C	1985 A	1986 M	1986 C	1986 A
1	19.0	2	7	20.0	4	0	24.0	4	1	19.8	3	0	20.0	3	1
2	15.0	6	3	32.2	3	3	29.0	6	4	38.4	4	5	32.5	5	4
3	24.5	2	2	0.0	0	8	7.5	3	4	0.0	3	11	5.6	6	2
4	26.0	3	4	19.8	3	4	15.0	5	4	35.3	3	12	5.4	5	10
5	27.5	3	13	21.4	6	17	21.0	3	12	28.4	1	14	28.6	8	15
6	0.0	4	8	29.4	2	31	25.5	3	38	15.0	3	8	29.9	3	45
7	13.0	3	7	0.0	3	38	0.0	3	29	29.6	5	5	44.6	14	25
8	17.5	1	4	43.2	14	7	44.0	4	8	0.0	7	18	0.0	3	18
9	16.0	8	5	42.4	2	28	0.0	4	10	27.4	2	16	29.9	1	18
10	28.5	2	5	16.1	1	2	42.8	9	10	26.0	1	6	23.5	3	18
11	26.0	3	3	-----------			55.0	2	2	5.5	0	1	5.0	0	0

CHAPTER X

HUMAN IMPACT ON THE BEACHES OF THE COLORADO RIVER

Sharon Staats, Tom Staats, Anne Kalinowski,
Linda Fuller, and Lillian Shellinger

INTRODUCTION

Within the past 20 years two major and distinctly interrelated natural resource management problems have arisen along the river corridor of the Colorado River in Grand Canyon National Park. Specifically, the problems relate to: 1) the extensive environmental changes that have taken place in the hydrological characteristics of the river as a result of Glen Canyon Dam, and 2) the dramatic increase in recreational use of the systems by river runners.

Although located 15 miles upstream of the national park boundary, Glen Canyon Dam changed the very nature of the Colorado River in Grand Canyon almost as soon as construction began in the mid 1950s. Post-dam changes in water flow, temperature, and sediment discharge have all combined, often synergistically, to alter the Grand Canyon river ecosystem. On one side of Glen Canyon Dam, the wildly variable and raging Colorado River has been buried beneath the deep waters of Lake Powell; on the other side, the river we still call the Colorado is now released through turbines and gates as a predictable, computer-regulated, icy cold, sediment-free, and partially tamed river. To further complicate the matter, the "new" dam-controlled Colorado River in Grand Canyon has recently proven to be one of the most popular white-water recreation areas in the world, with a strict National Park Service permit system regulating and allocating both private and commercial use of the 225 miles of Colorado River from Lees Ferry to Diamond Creek (NPS 1981). The high waters and ensuing floods of 1983 unexpectedly disrupted the stabilizing patterns of water flow established during the past 20 years.

Given the above considerations, the present challenges to developing an adequate system for resources management along the river corridor of Grand Canyon National Park include: a) determining the eventual ecological "steady state" of the dam-altered river in terms of sediment erosion and deposition, vegetation and animal community composition, and overall ecosystem stability; b) determining and evaluating the impacts of river recreationists on the changing aquatic and terrestrial systems; and c) mitigating such recreational impacts to the extent that natural park values are not compromised.

As mandated by "The Planning Process of the National Park Service" in 1975, a Colorado River Management Plan (NPS 1981) was drafted to guide short- and long-term management of the riverine and riparian areas of Grand Canyon National Park. Subsequently, a monitoring program was initiated to analyze and quantify human impacts and to determine how changes in management policies influence present resource trends. This monitoring program was designed to gather baseline data and show the impact (adverse and otherwise) of visitor numbers and use patterns on the riparian environment.

Heavy recreational use in other parks has caused changes in plant species composition and vegetation density and diversity (Burden and Randerson 1972; Whitson 1974; Dolan et al. 1974; Bates 1935; Dotzenko et al. 1967; LaPage 1967; Liddle 1975; Greig-Smith 1975; Young and Gilmore 1976). Preliminary data from Grand Canyon (Carothers and Aitchison 1976) indicated that similar changes or impacts were taking place on the principal 100 plus campsites (Borden 1976) of the river corridor. All of these campsites are on alluvial terraces (sand and silt/sand composition) that were deposited during pre-dam flood discharges. In the 20 years prior to 1983, vegetation previously scoured from the beaches on an annual basis proliferated, while human related debris incorporated into beach sands during normal camping activities accumulated. With no natural purging of recreation related debris (organic as well as inorganic) there existed the potential for popular beaches to fill "cat box style" with any number of forms of human waste products. Additional problems of a similar vein have recently been observed in backcountry campsites where recreational use is clearly in excess of the natural purging capacity of the system.

In an effort to clean up the beaches, the Colorado River Management Plan requires that all wood and charcoal carried into the Canyon by river recreationists be burned in fire pans and the ashes be carried out. Gas stoves are now required for most cooking purposes. Regulations also require all river users to haul out solid human wastes.

The 1983 floods cleaned the beaches, resorted the sand, and gave the system a fresh start. Along with this cleansing, new beaches formed and others disappeared. The 1983 study established important baseline data for future investigations. These data are the control for this study.

Early in 1976, approximately 25 Colorado River campsites in Grand Canyon were selected for the purpose of monitoring levels of recreational impact (see Carothers 1977). In 1980-81, nine additional beaches in the 15 miles of Glen Canyon below Glen Canyon Dam were evaluated for levels of human impact (Carothers et al. 1981). Since 1976, the original Grand Canyon sites have been monitored and re-evaluated several times (Carothers and Johnson 1980). In 1982, human impact data for 35 beach sites in Glen and Grand Canyons were presented and compared with the results of previous sampling efforts.

In 1983, human impact data for 22 Grand Canyon beach sites, including 17 of the beaches evaluated in 1982 and five new beaches, were compared to the 1982 data. Eleven of the original beaches were no longer comparable in 1983 and were dropped from the study. In 1984, two previously studied beaches were not included; however, seven new beaches were added.

OBJECTIVES

The objectives of this 1986 study are 1) to collect data on the degree of sand discoloration and the incidence of charcoal and human litter present on Colorado River beaches in the Grand Canyon, and 2) to compare those data with the findings from similar studies conducted in 1983, 1984, and 1985 to determine the human impact on the beaches in the two years following the flood. It was hypothesized that human use in these years had resulted in a significant increase in sand discoloration, and in charcoal and litter on the beaches.

METHODS

1. A 40 meter transect line was run through the principal use area of the beach along the same line established in previous years. If the beach was had been so altered by the river as to change patterns of use, a new transect line was established and documented.

2. Black and white photographs of the transect, including the metric tape and river mile marker, were taken from each direction. The river mile number was written on a chalkboard and positioned in the sand for inclusion in the photograph.

3. Ten $1m^2$ plots were laid out equidistant from each other in an alternating pattern along the transect line.

4. Each m^2 plot was inspected, and pieces of charcoal of 1 cm or over and all pieces of human litter found in the plot were counted and recorded. A dry sand sample from the surface of each plot was collected in a whirl pack. If damp sand was unavoidable, it was collected anyway to be dried out later. Each sample was labeled with the beach name, the river mile, and the plot number.

5. Sand samples were also collected at the sand/water interface and from the terrace above the beach.

6. Each sand sample was sifted through a 150 micron stainless

steel mesh apparatus until the amount of sifted material completely covered the bottom.

7. A piece of No. 7 course grade filter paper was placed in the lid, hatched side up, and the sifted material shaken against the filter paper 75 times.

8. The filter paper was removed and stored in a labelled petri dish.

9. When all of the samples from a transect were shaken, the discoloration on the filter paper was evaluated with a Colorguard II Reflectometer and recorded on a data sheet.

10. The Colorguard II Reflectometer is an instrument operating with an optical system, photocell amplifier, digital readout and portable power system, and is used to make reflective measurements. Hence, with a digital readout display, reflected light can be measured from any source. The reflectometer was used to obtain reflective values from the filter paper discs which were discolored with filtrate from the sand samples. The reflectometer was standardized prior to each series of readings against a white standard and a grey standard to calibrate the instrument.

11. Means and standard deviations of the reflectometer readings from the ten transect samples were calculated for each beach. These were then tabulated with the 1982, 1983, 1984, and 1985 data. A small sample t test for level of significance was

calculated for the differences between the 1984 and 1985 data, between the 1983 and 1985 data, between 1984 and 1986, and between 1985 and 1986 data.

RESULTS

Twenty-seven beaches were sampled in 1986. The levels of sand discoloration as measured by reflectometer reading are presented in Table 1. For purposes of comparison, these data are presented with equivalent figures from 1983, 1984, and 1985. The differences in sand discoloration between 1984 and 1986 are as follows: five beaches showed a significant increase in discoloration, two showed a significant decrease in discoloration, and 15 showed no significant difference in discoloration. Due to lack of data from 1984, five beaches tested in 1986 could not be compared. The differences in sand discoloration between 1985 and 1986 are as follows: seven beaches showed a significant increase in sand discoloration and eighteen beaches showed no significant difference. Two beaches in 1986 could not be compared due to lack of data in 1985. Of the twenty-five beaches that were tested in both 1984 and 1985, the differences in sand discoloration are as follows: six beaches showed a significant increase in discoloration, five showed a significant decrease in discoloration, and fourteen showed no significant difference in discoloration. Four beaches could not be compared in 1985 due to lack of data form 1984. Of the 21 beaches that were tested in both 1983 (the year the flood cleansed the beaches) and 1985, eleven showed a significant increase in sand discoloration, one showed a significant decrease in discoloration, and nine showed no significant difference in discoloration. The results of a "t" test for level of significance of differences in sand discoloration are presented in Table 3 for 1984 and 1986, Table 4 for 1985 and 1986, Table 5 for 1984 and 1985, and Table 6 for 1983 and 1985.

Charcoal and human debris accumulations are presented in Table 2. The differences in charcoal level between 1986 and 1985 are as follows: thirteen beaches showed an increase, four beaches showed a decrease, and eight beaches showed no change. There was little difference in the levels of charcoal found between 1984 and 1985. Of the 26 beaches for which there were comparative data, eight showed a slight increase, eight showed a decrease, and ten showed no change. The difference between 1983 and 1985 was more significant. Out of 21 beaches sampled both years, nine showed an increase, only one showed a decrease, and 11 showed no change.

Between 1985 and 1986, the amounts of human litter found on the beaches increased on eleven beaches, decreased on three beaches while ten beaches showed no significant change. Between 1984 and 1985, the amounts of human litter found changed in the following ways: five beaches showed an increase, 11 beaches showed a decrease, and ten beaches showed no change. Between 1983 and 1985, six beaches showed an increase, four showed a decrease, and 11 showed no change.

CONCLUSIONS

The Colorado River beaches in 1986 appear to have suffered a deterioration in cleanliness compared to the previous years.

Between 1986 and 1985, six out of twenty-five beaches showed an increase in sand discoloration while the remainder remained unchanged. No beaches showed a decrease. Compared to the 1984 study, five showed an increase in sand discoloration, while two showed a decrease and fourteen had no change. Between 1984 and 1985, the beaches did not appear to have suffered appreciable degradation. Six of twenty-five beaches did show increased sand discoloration; however, five showed a decrease and 14 remained unchanged. The same number of beaches showed an increase in charcoal contamination as showed a decrease. A similar number showed no significant change.

In terms of human litter found, eleven beaches showed an increase from 1986 to 1985, while only three beaches decreased. In the 1985 study, the beaches appeared to improve overall. More than twice as many beaches showed a decrease (11) in incidence of human litter as showed an increase (5). The levels of charcoal and litter were small for both years. The mean value of charcoal contamination for all beaches in 1984 was .27 cm/m^2; the mean value in 1985 was .29 cm/m^2, and in 1986 the mean value was 0.6 cm/m^T2^T. The mean value of human litter in 1984 was .19 pieces per m^2; the mean value in 1985 was .09 pieces per m^2, and in 1986 the mean value was 0.2 pieces per m^T2^T.

This 1986 study indicates that the beaches have shown a significant increase in contamination in comparison to previous years. While the 1985 data show that little overall beach degradation has occurred since the 1984 study, if compared to data collected in 1983, they do show an overall deterioration since that time.

The results of this study support the initial hypothesis that Grand Canyon camping beaches have deteriorated since the 1983 flood scoured them clean. This is attributed to human use.

Table 1. Results of sand discoloration analysis of beach campsites in Grand Canyon, 1983-1986 (means only).

Site no.	Campsite Name	River Mile	Sand Discoloration (Standard Deviation) 1983 (S.D.)	1984 (S.D.)	1985 (S.D.)	1986 (S.D.)
1	Badger Rapid	8.0	71.65 (1.65)	69.69 (2.52)	70.55 (1.82)	59.65 (5.59)
2	20 Mile	20.0	66.74 (3.53)	68.78 (3.14)	64.29 (3.07)	67.47 (4.54)
3	Shinumo Wash	29.0	70.01 (3.00)	69.10 (3.16)	68.62 (3.03)	68.24 (5.14)
4	Anasazi Bridge	43.5	73.28 (1.24)	70.55 (1.83)	71.13 (1.80)	71.61 (1.79)
5	Lower Nankoweap	53.0	73.21 (2.33)	64.91 (3.16)	69.33 (2.66)	66.67 (3.51)
6	Awatubi	58.1	72.40 (1.34)	64.48 (5.73)	66.97 (3.31)	64.96 (4.21)
7	Lava Canyon (Chuar)	65.5	70.66 (0.83)	65.91 (4.05)	68.56 (3.81)	67.24 (2.87)
8	Unkar (gone)	72.2	68.93 (2.67)	67.70 (2.28)		
9	Nevills Rapid	75.5	72.00 (1.91)	66.80 (4.87)	72.21 (1.35)	70.94 (2.98)
10	Hance Rapid	76.5		66.87 (5.14)	63.82 (2.92)	65.00 (4.12)
11	Grapevine	81:1	71.91 (1.43)	67.62 (2.18)	67.39 (2.95)	69.38 (3.95)
12	Granite Rapid	93.2	68.20 (2.49)	68.48 (3.28)	62.35 (3.50)	68.55 (2.06)
13	Lower Bass Camp	108.5	66.53 (2.39)	63.38 (5.69)	64.46 (1.69)	67.87 (3.71)
14	114 Mile	114.0		69.22 (2.06)	63.77 (2.39)	71.44 (2.30)
15	122 Mile	122.0		71.16 (2.15)	68.55 (2.65)	71.44 (2.30)
16	Forster	122.8	70.04 (3.05)	68.65 (5.16)	69.74 (0.74)	73.27 (1.93)
17	Bedrock	131.0		70.54 (3.40)	68.20 (2.02)	71.50 (1.64)
18	Dubendorff	132.0	69.12 (3.36)	70.22 (2.51)	69.63 (2.35)	69.62 (1.76)
19	Deer Creek	136.0	67.82 (2.03)		65.46 (1.38)	66.68 (2.16)
20	Pancho's Kitchen	137.0	65.91 (3.11)	65.90 (3.79)	67.20 (3.81)	69.43 (3.04)
21	Upper National Canyon	166.5	71.22 (0.96)	68.95 (3.00)	73.31 (0.98)	beach gone
22	Lower National Canyon	166.6	69.39 (2.73)	63.59 (3.00)	67.10 (2.42)	69.23 (1.66)

Table 1. (continued)

Site no.	Campsite Name	River Mile	Sand Discoloration (Standard Deviation) 1983	(S.D.)	1984	(S.D.)	1985	(S.D.)	1986	(S.D.)
23	Upper Lava Falls	179.0	69.39	(2.60)			67.74	(1.65)	67.63	(2.92)
24	186 Mile	186.0			72.06	(1.50)	70.95	(2.18)	69.54	(1.23)
25	Parashant	198.5			63.94	(4.77)	68.39	(2.68)	beach gone	
26	Indian Canyon	207.0							71.09	(1.52)
27	Granite Park	208.8	69.70	(3.78)	68.93	(2.17)	69.88	(2.13)	69.97	(2.48)
28	Pumpkin Bowl	213.0	73.66	(0.94)	70.83	(1.75)	68.63	(2.41)	69.54	(1.81)
29	Trail Canyon	219.0			72.18	(1.45)	68.78	(3.38)	beach gone	
30	220 Mile	220.0	67.50	(2.61)	67.71	( )	66.93	(2.28)	68.67	(1.74)

Table 2. Results of charcoal and human litter accumulations analysis of beach campsites in Grand Canyon 1983-1986 (means only).

Beach No.	Campsite Name	River Mile	Charcoal cm/m2				Human Litter m2			
			1983	1984	1985	1986	1983	1984	1985	1986
1	Badger Rapid	8.0	0.8	2.5	0.2		0.1	0.2	0.0	0.3
2	20 Mile	20.0	0.1	0.0	0.3		0.0	0.0	0.2	0.0
3	Shinumo Wash	29.0	0.0	0.0	0.0		0.0	0.1	1.0	0.1
4	Anasazi Bridge	43.5	0.0	0.0	0.0		0.0	0.0	0.0	0.0
5	Lower Nankoweap	53.0	0.0	0.2	0.6		0.0	0.4	0.0	0.0
6	Awatubi	58.1	0.0	0.0	0.0		0.0	0.0	0.3	0.1
7	Lava Canyon (Chuar)	65.5	0.1	1.6	1.3		0.0	0.3	0.0	0.2
8	Unkar	72.2	0.0	0.2			0.0	0.1		
9	Nevills Rapid	75.5	0.0	0.3	0.0		0.0	0.0	0.0	0.0
10	Hance Rapid	76.5		0.2	0.9			0.0	0.0	0.0
11	Grapevine	81.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0
12	Granite Rapid	93.2	0.0	0.0	0.0		0.1	0.0	0.0	0.4
13	Lower Bass Camp	108.5	0.0	1.5	0.4		0.1	2.2	0.0	0.5
14	114 Mile	114.0		0.2	0.0			0.1	0.0	0.5
15	122 Mile	122.0		0.0	0.0			0.3	0.2	0.1
16	Forster	122.8	0.0	0.0	0.0		0.0	0.0	0.0	0.0
17	Bedrock	131.0		0.0	0.3			0.1	0.0	0.1
18	Dubendorff	132.0	0.0	0.0	0.5		0.0	0.0	0.0	0.0
19	Deer Creek	136.0	0.2		2.0		0.1		0.0	0.6
20	Pancho's Kitchen	137.0	0.0	0.0	0.1		0.0	0.4	0.1	0.8
21	Upper National Canyon	166.5	0.0	0.0	0.0		0.0	0.2	0.2	
22	Lower National Canyon	166.6	0.0	0.0	0.0		0.0	0.0	0.2	0.7

Table XV-2 continued.

Beach No.	Campsite Name	River Mile	Charcoal cm/m2 1983	1984	1985	1986	Human Litter m2 1983	1984	1985	1986
23	Lower Lava Falls	179.0	0.3		0.7		0.0		0.0	0.9
24	186 Mile	186.0		0.2	0.6			0.0	0.0	0.0
25	Parashant	198.5		0.0	0.0			0.2	0.3	
26	Indian Camp	207.0				0.0				0.0
27	Granite Park	208.8	0.0	0.1	0.0		0.0	0.1	0.0	0.1
28	Pumpkin Bowl	213.0	0.0	0.0	0.2		0.0	0.1	0.0	0.0
29	Trail Canyon	219.0		0.1	0.0			0.0	0.0	
30	220 Mile	220.0	0.0	0.4	0.0		0.0	0.2	0.0	0.0

Table 3. t test for level of significance of differences between 1984 and 1986 sand discoloration measurements for Grand Canyon beaches.

Campsite Number	Campsite Name	t Value	t test	Significant Difference?
1	Badger Creek	t= 5.175	5.175<2.101	Yes
2	20 Mile	t= 0.749	0.749<2.101	No
3	Shinumo Wash	t= 0.450	0.450<2.101	No
4	Anasazi Bridge	t= 1.309	1.309<2.101	No
5	Lower Nankoweap	t= 0.557	0.557<2.101	No
6	Awatubi	t= 0.213	0.213<2.101	No
7	Lava Canyon (Chuar)	t= 0.847	0.847<2.101	No
8	Unkar	the beach is gone		
9	Nevills Rapid	t= 2.287	2.287<2.101	Yes
10	Hance Rapid	t= 0.899	0.899<2.101	No
11	Grapevine	t= 1.230	1.230<2.101	No
12	Granite Rapid	t= 0.057	0.057<2.101	No
13	Lower Bass Camp	t= 2.088	2.088<2.101	No
14	114 Mile	t= 2.265	2.265<2.101	Yes
15	122 Mile	t= 0.255	0.255<2.101	No
16	Forster	t= 2.655	2.655<2.101	Yes
17	Bedrock	t= 0.807	0.807<2.101	No
18	Dubendorff	t= 0.619	0.619<2.101	No
19	Deer Creek	t= no data		
20	Pancho's Kitchen	t= 2.292	2.292<2.101	Yes
21	National Canyon (Upper)	the beach is gone		
22	National Canyon (Lower)	t= 5.222	5.222<2.101	Yes
23	Lower Lava Falls	t= no data		
24	186 Mile	t= 4.131	4.131<2.101	Yes
25	Parashant	the beach is gone		
26	Indian Camp	t= no data, new beach		
27	Granite Park	t= 1.000	1.000<2.101	No
28	Pumpkin Bowl	t= 1.613	1.613<2.101	No
29	Trail Canyon	the beach is gone		
30	220 Mile	t= no data		

Table 4. t test for level of significance of differences between 1985 and 1986 sand discoloration measurements for Grand Canyon beaches.

Campsite Number	Campsite Name	t Value	t test	Significant Difference?
1	Badger Creek	t= 1.856	1.856<2.101	No
2	20 Mile	t= 1.838	1.838<2.101	No
3	Shinumo Wash	t= 0.201	0.201<2.101	No
4	Anasazi Bridge	t= 0.600	0.600<2.101	No
5	Lower Nankoweap	t= 1.914	1.914<2.101	No
6	Awatubi	t= 1.189	1.189<2.101	No
7	Lava Canyon (Chuar)	t= 0.579	0.579<2.101	No
8	Unkar	the beach is gone		
9	Nevills Rapid	t= 1.223	1.223<2.101	No
10	Hance Rapid	t= 0.738	0.738<2.101	No
11	Grapevine	t= 1.276	1.276<2.101	No
12	Granite Rapid	t= 4.844	4.844<2.101	Yes
13	Lower Bass Camp	t= 2.643	2.643<2.101	Yes
14	114 Mile	t= 7.304	7.304<2.101	Yes
15	122 Mile	t= 2.388	2.388<2.101	Yes
16	Forster	t= 5.385	5.385<2.101	Yes
17	Bedrock	t= 4.024	4.024<2.101	Yes
18	Dubendorff	t= 0.011	0.011<2.101	No
19	Deer Creek	t= 1.506	1.506<2.101	No
20	Pancho's Kitchen	t= 1.448	1.448<2.101	No
21	Upper National Canyon	the beach is gone		
22	Lower National Canyon	t= 2.290	2.290<2.101	Yes
23	Lower Lava Falls	t= 0.104	0.104<2.101	No
24	186 Mile	t= 1.785	1.785<2.101	No
25	Parashant	the beach is gone		
26	Indian Camp	no data, new beach		
27	Granite Park	t= 0.087	0.087<2.101	No
28	Pumpkin Bowl	t= 0.958	0.958<2.101	No
29	Trail Canyon	the beach is gone		
30	220 Mile	t= 1.912	1.192<2.101	No

Table 5. t test for level of significance of differences between 1984 and 1985 sand discoloration measurements for Grand Canyon beaches.

Campsite Number	Campsite Name	t Value	t test	Significant Difference?
1	Badger Creek	t= 2.210	1.210<2.101	No
2	20 Mile	t= 4.180	4.180>2.101	Yes
3	Shinumo Wash	t= 0.440	0.440<2.101	No
4	Anasazi Bridge	t= 0.900	0.900<2.101	No
5	Lower Nankoweap	t= 4.700	4.700>2.101	Yes
6	Awatubi	t= 0.970	0.970<2.101	No
7	Lava Canyon (Chuar 3)	t= 1.910	1.910<2.101	No
8	Unkar	the beach is gone		
9	Nevills Rapid	t= 4.290	4.290>2.101	Yes
10	Hance Rapid	t= 2.060	2.060<2.101	No
11	Grapevine	t= 0.250	0.250<2.101	No
12	Granite Rapid (Granite 4)	t= 5.120	5.120>2.101	Yes
13	Lower Bass Camp	t= 0.730	0.730<2.101	No
14	114 Mile	t= 5.350	5.350>2.101	Yes
15	122 Mile	t= 3.640	3.640>2.101	Yes
16	Forster	t= 0.910	0.910<2.101	No
17	Bedrock	t= 1.620	1.620<2.101	No
18	Dubendorff	t= 0.510	0.510<2.101	No
19	Deer Creek	no data for 1984		
20	Pancho's Kitchen	t= 0.720	0.720<2.101	No
21	National Canyon (Upper)	t= 5.530	5.530>2.101	Yes
22	National Canyon (Lower)	t= 2.780	2.780>2.101	Yes
23	Upper Lava Falls	no data for 1984		
24	186 Mile	t= 1.680	1.680<2.101	No
25	Parashant	t= 3.250	3.250>2.101	Yes
26	Granite Park	t= 1.250	1.250<2.101	No
27	Pumpkin Bowl	t= 7.780	7.780>2.101	Yes
28	Trail Canyon	t= 3.730	3.730>2.101	Yes
29	220 Mile	no data for 1984		

Table 6. t test for level of significance of differences between 1983 and 1985 sand discoloration measurements for Grand Canyon beaches.

Campsite Number	Campsite Name	t Value	t test	Significant Difference?
1	Badger Creek	t= 1.798	1.798<2.101	No
2	20 Mile	t= 2.170	2.170>2.101	Yes
3	Shinumo Wash	t= 1.840	1.840<2.101	No
4	Anasazi Bridge	t= 3.920	3.920>2.101	Yes
5	Lower Nankoweap	t= 4.390	4.390>2.101	Yes
6	Awatubi	t= 4.680	4.680>2.101	Yes
7	Lava Canyon (Chuar 3)	t= 2.150	2.150>2.101	Yes
8	Unkar	the beach is gone		
9	Nevills Rapid	t= 0.360	0.360<2.101	No
10	Hance Rapid	t= 2.060	2.060<2.101	No
11	Grapevine	t= 5.510	5.510>2.101	Yes
12	Granite Rapid (Granite 4)	t= 5.450	5.450>2.101	Yes
13	Lower Bass Camp	t= 2.710	2.710>2.101	Yes
14	114 Mile	no data for 1983		
15	122 Mile	no data for 1983		
16	Forster	t= 0.380	0.380<2.101	No
17	Bedrock	no data for 1983		
18	Dubendorff	t= 0.360	0.360<2.101	No
19	Deer Creek	t= 3.860	3.860>2.101	Yes
20	Pancho's Kitchen	t= 0.790	0.790<2.101	No
21	National Canyon (Upper)	t= 2.140	2.140>2.101	Yes
22	National Canyon (Lower)	t= 1.920	1.920<2.101	No
23	Upper Lava Falls	t= 2.140	2.140>2.101	Yes
24	186 Mile	no data for 1983		
25	Parashant	no data for 1983		
26	Granite Park	t= 0.610	0.610<2.101	No
27	Pumpkin Bowl	t= 7.780	7.780>2.101	Yes
28	Trail Canyon	no data for 1983		
29	220 Mile	t= 0.660	0.660<2.101	No

References

Aitchison, S. W., S. W. Carothers, and R. R. Johnson. 1979. Natural resources, white water recreation, and river management alternatives on the Colorado River, Grand Canyon National Park, Arizona. In Proceedings of the First Conference on Scientific Research in the National Parks, 1976. U. S. National Park Service, Washington, D.C., p.253-259.

Carothers, S. W. and R. R. Johnson. 1980. Recreational impacts on Colorado River beaches in Glen Canyon, Arizona. Environmental management, 8(4):353-358.

Carothers, S. W. and R. R. Johnson. 1984. Status of the Colorado River ecosystem in Grand Canyon National Park and Glen Canyon National Recreation Area. Manuscript. p.139-160.

Dolan, R. and others. 1977. Man's impact on the Colorado River. The National Parks and Conservation Magazine, 53(3):13-16.

Grand Canyon National Park. 1975. Proposed master plan, Grand Canyon Complex, Arizona. Final environmental statement, p.90-100.

Grand Canyon National Park. 1979. Proposed development concept plan, Grand Canyon Village, Grand Canyon National Park. Final environmental statement, p.78-80.

Grand Canyon National Park. 1981. Proposed Colorado River management plan. Final environmental statement, p.1-17, C-1, and C-2.

U. S. Code of Federal Regulations. 1984. Title 36--Parks, Forests and Public Property. Parts 1-199, p.49-50.

CHAPTER XI

FURTHER INVESTIGATIONS ON *Pogonomyrmex sp.* ANTS ON COLORADO RIVER BEACHES IN GRAND CANYON NATIONAL PARK

Chris Pike and Steve Ward

INTRODUCTION

This work is a continuation of studies done by Northern Arizona University Colorado River Investigations in 1982, 1983, 1984 and 1985. The Red Harvester Ant *Pogonomyrmex sp.* was studied on 34 beach sites along the Colorado River during July and August in 1986. An effort was made to correlate ant densities to the degree of human use of the beaches, and to doccument the foraging habits of the Harvester ant.

The Harvestor ant is of concern on the beaches of the Colorado River because they have the ability to inflict a painful sting. The sting is from injection of formic acid under the skin. The sting is similar to that of a honey bee in terms of the degree of pain suffered. Multiple stings are common and cause differing amounts of pain depending on individual reactions to the ant venom. The workers are 5.0 to 6.5 mm in length, and have have well developed mandibles which can also inflict painful bites, or combinations of bites and stings.

OBJECTIVE

This study is a continuation of efforts to test the hypothesis that Harvester ants densities along Colorado River beaches in Grand Canyon are higher in areas of heavy human use. The control used for this study is two beaches which have little or no camping activity on them. At mile 213.5, a density of 0.23 ant hives per 100m^2, and at mile 214.5 a density of 0.13 ants per 100m^2 were determined. Assuming that our non-human impacted beaches are typical, it would then be expected that an ant hive density of greater than 0.18 hives per 100m^2 is being influenced by extraneous factors. These extraneous factors can be from human activity or specific characteristics of the individual beaches.

Our basic hypothesis is that given easy access to a human supplied source of food, ant hive density will increase. We are also attempting to establish that there is a trend for ant hive densities to return to the density levels prior to the 1983 high waters. The 1983 high water level scoured out most of the ant populations up to and including the old high water lines.

METHODS

Thirty four beaches with varying levels of human use were surveyed. Every ant hive was plotted on a freehand drawing of the beaches to determine the preferred habitat of the harvester ants. There were 18 ant food surveys done to establish the types of foods being taken into the hives by the foraging ants. Our food survey data was taken from what appeared to be well established hives both near the common kitchen areas and far enough away from the kitchen areas to be out of range. It was observed on several occasions that foraging ants have a range of up to 60 m. No ants were observed ranging from their hives greater than that distance. To determine beach size the average length and width of the beach was paced off and recorded.

Temperatures of the soil at 2.5" and 7" were recorded and ambient air temperatures were always measured as close to the food study hive as possible and in a shaded area. Relative humidities were determined with a sling psychrometer. The time of day was also recorded. Typical specimens of ants and their food sources were collected and preserved in isopropyl alcohol. We relied on the professional boatmen's experience in designating beaches either high, medium, low or no human use levels.

Food items foraged by the ants were classified into five categories: seeds, plant parts, insect parts, human food particles and lumped sand grains. The lumped sand grains were either grease laden or moisture saturated.

Ant hives were discovered by transecting the length of the beaches at approximately 10 m intervals from the river's edge up to and approximately 10 m beyond the old high water line. Using two people for these methods allows for completion of a typical beach survey in 20 minutes. A food survey takes an additional 15 minutes (see typical beach maps).

RESULTS

Figure 1 is a typical beach drawing used to locate ant hills. Figure 2 is a representation of how we identified these ants as P. californicus.

Table 1 sums up all observations on individual beaches. It seems to show that ant hive densities increase as you go down river. Also, smaller beaches have more hives per square meter than larger beaches.

Tables 2 and 3 show that ant hives were destroyed in 1983 by the flood and now seem to be returning to pre-flood level. No apparent correlation between human use and number of hives was found.

Food charts 1-18 show type of food. They seem to show that ants are very opportunistic in that they utilize the most available food source. This usually was black flies and seeds. Food from human sources was used when available. Table 4 shows 1985, 1986 food data. The black fly population is strong throughout the study area as seen from individual data. Greater than 90% of all insect parts taken by the ants were the non-biting black flies of the family Simuliidae.

The Harvester ants not only fed on dead flies foraged at the water's edge, but were also observed attacking live, resting flies. Often, we found flies concentrated in depressions in the sand by the wind. These depressions in the sand were caused by both footprints and wind ripples. The ants took advantage of this concentrated food source. We also observed whiptail and spiny lizards utilizing the flies in the same fashion.

An unusual observation we encountered with the black flies was the fact that we watched ants remove black flies from the hives after the rains the night before. The ants were apparently drying the flies on the perimeter of their mounds in the sun. Thousands of flies were piled around the mounds. By mid-morning the ants were observed checking several individual flies with their mouth parts and antennae prior to selecting a fly to return to the hive. The fly specimens we collected from the mound perimeters were found to float in alcohol, whereas, the normally foraged flies would sink.

CONCLUSIONS

Harvest ant densities are increasing. The increase in density does not seem to correlate to the degree of human beach use. Blacktail and Bedrock are medium- to low-use beaches, but have the largest number of hives per 100 square meters. We think the size of beach is a more important factor. Another factor is food source. Our highest density beach (at Mile 122), had a large eddy and the ants were concentrated near back of eddy where black flies were prevelent.

An interesting observation was that we found black flies placed around the hive mound perimeter in the sun. These flies floated in alcohol instead of sinking, indicating that the ants were probably drying their food to prevent fungus growth. If the ants have the ability to control the hive humidity within certain ranges, it may be important for further study. "During excessively wet weather, if the seeds get wet, they are taken out, allowed to dry and returned to storage" (Wheeler, p. 47).

Black flies, the major food supply for the Harvester Ant, must have running water to complete their larval life stage. The larvae live in clear, rapidly flowing streams with high oxygen content. The larvae are filter feeders that attach themselves to rocks. They feed on diatoms and bacteria (Milne, pp. 647-648). It has been observed that the fly populations have drastically increased since the dam was constructed. The habitat utilized by the fly has been improved to better fit their needs. Since the primary food source of the harvester ant is insect parts (up to 39% of total food supply), it seems logical to assume that the greater the black fly population the greater the ant density.

Suggested Future Methods

Durable maps should be made from air photos of each beach containing pertinant information (i.e. beach size, ant density, human use). Have tables for RH that goes well above 40 C. Try to find humidity in nest, maybe with an electric probe. Carry extra thermometers.

A typical beach showing the four vegetation zones and probable ant hive locations

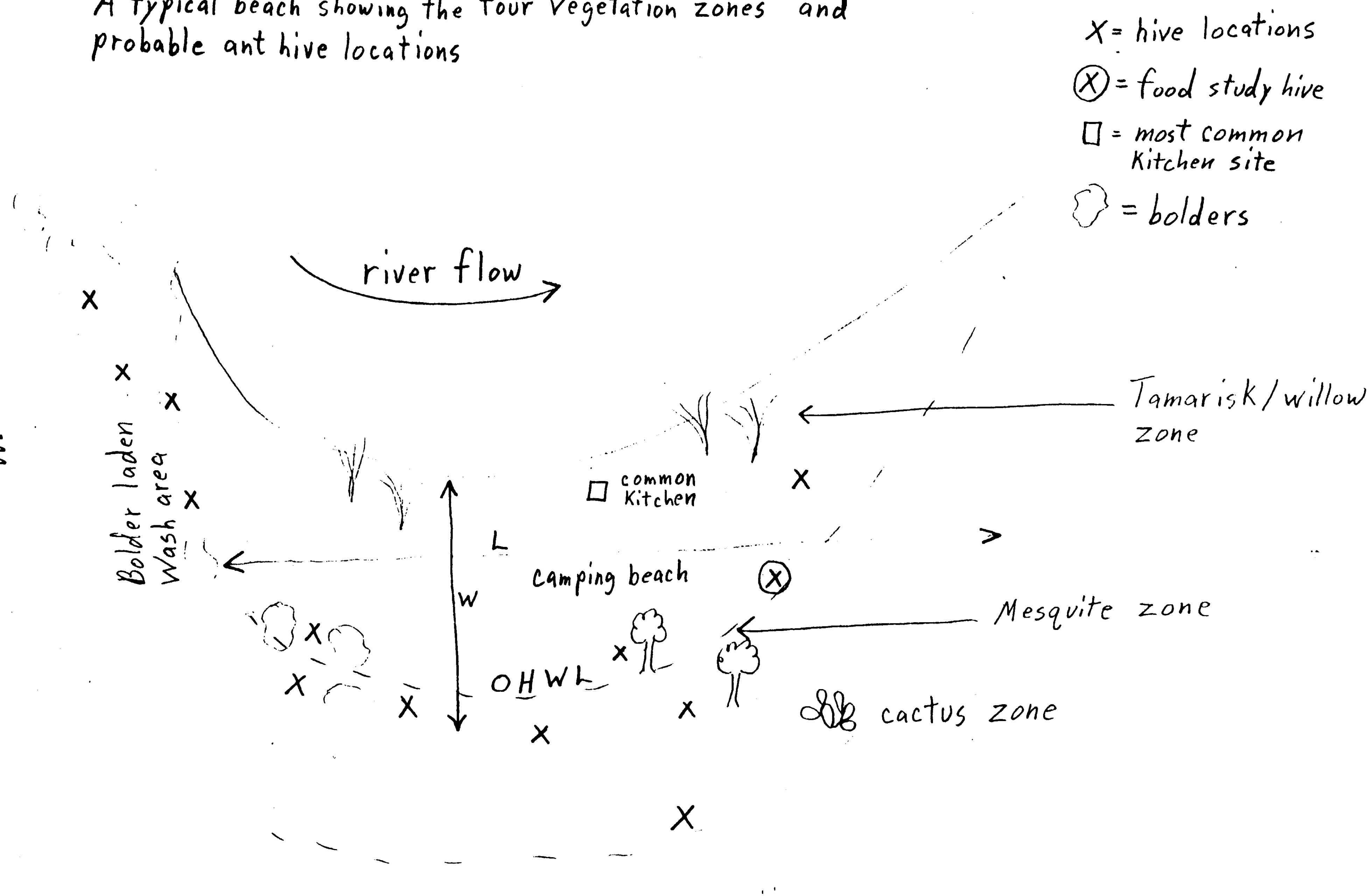
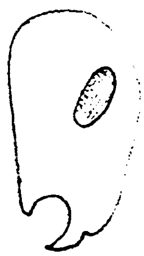


Figure 1.

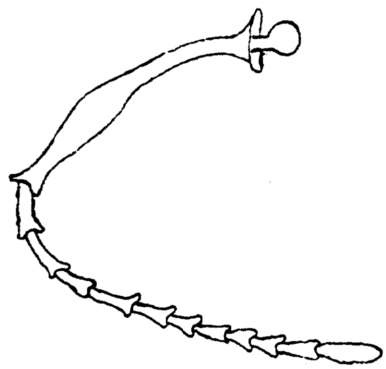
Observed Characteristics of the red harvester ants collected along the Colorado River beaches used to classify the ants as <u>Pogonomyrmex californicus</u>.

1. Entire body concolorous, light ferrugineous red.
2. Average body length of 7.5 mm.
3. Dorsal view of petiole and postpetiole of worker.

4. Right lateral view of head contour of worker.



5. Right lateral view of antenna showing basal scape.



6. Lateral view of thorax, petiole, and postpetiole.

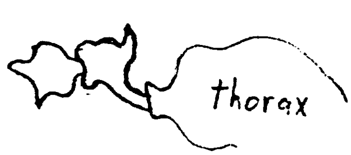


Figure 2.

Table 1. Ant data for individual beaches.

Beach	Badger	20	23.25	Shinumo Wash	Tatahatso	Nanokoweap
Mile	8	20	23.25	29	36	52.5
# of Hives	4	4	5	1	6	7
Vegetation Zone	2/3	2/3	2/3	2/3	2/3	2/3
Human Use Low, Medium, High	H	H	L	L	L	H
Density/100 m	.09	.37	.73	.06	.86	.09
Soil Temperature (C) at 2 in.	--	25	28.8	39.4	41.1	26.6
Soil Temperature (C) at __ in.	--	--	--	--	--	28
Ambient Temperature (C)	41	24	34	33	36	34
Wet Bulb (C)	--	--	--	--	18.8	18.3
Dry Bulb (C)	--	--	--	--	38.8	35
% Relative Humidity	--	--	--	--	21	17
Time at Beach	5:00-5:10	9:00-9:45	10:30-11:00	12:36-1:11	5:35-6:07	11:27-11:54
Size m	4269	1075	684	1153	693	7520
Food Count	NO	NO	YES	YES	YES(2)	NO

Table 1. Ant data for individual beaches (continued)

Beach	Nankoweap	Awaitubi	LCR	Carbon Creek	Nevills	Hance
Mile	53	58.1	61.8	63.5	75.7	76.5
# of Hives	1	9	1	8	17	2
Vegetation Zone	2/3	2/3	2/3	2/3	2/3	2/3
Human Use Low, Medium, High	H	H	L	H	M	H
Density/100 m	.02	.12	.041	.92	.14	.17
Soil Temperature (C) at 2 in.	30.5	46.6	37.2	24.4	43.8	37.7
Soil Temperature (C) at __ in.	26	39	30	37	34	31
Ambient Temperature (C)	37	39	41	43	37	46
Wet Bulb (C)	18.3	17.7	20	20	21	--
Dry Bulb (C)	35.5	30	37.7	37.7	37.7	--
% Relative Humidity	17	25	16	16	18	--
Time at Beach	12:39-1:20	9:40-9:59 5:24-5:55	11:25-1:49	4:09-4:47	10:42-11:30	12:15-12:25
Size m	4284	7552	2400	864	11682	1166
Food Count	NO	YES(2)	YES	YES	NO	NO

Table 1. Ant data for individual beaches (continued).

Beach	Grapevine Creek	Granite Rapids	Bass	Blacktail	122 Mile	Furster
Mile	81.1	93.2	108.5	120.1	122	122.8
# of Hives	3	7	15	8	14	12
Vegetation Zone	1	2/3	2/3	2/3	2/3	2/3
Human Use Low, Medium, High	H	H	H	M	M	M
Density/100 m	.2	.29	.81	1.2	.33	.30
Soil Temperature (C) at 2 in.	40.5	36.1	40	38.8	31.1	--
Soil Temperature (C) at __ in.	47	32	32	40	32	35
Ambient Temperature (C)	39	31	42	37	28	--
Wet Bulb (C)	20	21.1	22.2	20	18.3	--
Dry Bulb (C)	37.7	33.3	40.5	37.7	28.8	--
% Relative Humidity	18	37	10	17	32	--
Time at Beach	2:30-3:12	9:38-10:31	3:01-3:33	6:27-6:41	8:01-9:06	9:33-9:57
Size m	1500	1241	1845	660	4264	4025
Food Count	NO	NO	NO	YES	YES	NO

Table 1. Ant data for individual beaches (continued).

Beach	Granite Park	Unused Beach	Unused Beach	220
Mile	208.9	213.5	214.5	220
# of Hives	24	4	7	12
Vegetation Zone	2/3	2/3	2/3	2/3
Human Use Low, Medium, High	H	L	L	H
Density/100 m	.5	.23	.13	.51
Soil Temperature (C) at 2 in.	35.5	40	33.3	30.5
Soil Temperature (C) at __ in.	32	39	47	32
Ambient Temperature (C)	41	47	44	29
Wet Bulb (C)	22.7	22.2	21.6	20
Dry Bulb (C)	39.4	40.5	43.3	27.7
% Relative Humidity	22	18	10	48
Time at Beach	11:41-12:02	3:51-4:21	4:58-5:40	7:14-7:45
Size m	4800	1775	1540	--
Food Count	NO	YES	YES	NO

Table 1. Ant data for individual beaches (continued)

Beach	Upper Lava	Lower Lava	181	192	196 Creek	Parashont
Mile	179	180.9	181	192	196	198.5
# of Hives	4	3	5	5	6	5
Vegetation Zone	4?	2/3	2/3	2/3	2/3	2/3
Human Use Low, Medium, High	H	H	M	L	L	L
Density/100 m	.57	.05	.09	.23	.73	.13
Soil Temperature (C) at 2 in.	--	40	--	37.7	28.8	28.8
Soil Temperature (C) at __ in.	--	34	--	36	29	30
Ambient Temperature (C)	38	41	41	36	29	36
Wet Bulb (C)	--	23.8	--	21.1	21.1	21.1
Dry Bulb (C)	--	40.5	--	36.6	27.7	33.3
% Relative Humidity	--	25	--	21	58	33
Time at Beach	1:35-1:50	2:19-2:48	2:55-3:09	5:41-6:10	8:40-9:06	9:50-10:19
Size m	702	3472	5428	2147	817	3906
Food Count	NO	NO	NO	YES	YES	YES

Table 1. Ant data for individual beaches (continued).

Beach	125.5	Bedrock	Dubenhoff	138.5	Lower National	Cove
Mile	125.5	131	132	138.5	166	174.5
# of Hives	0	3	3	6	7	12
Vegetation Zone	?	2	2/3	2/3	2/3	2/3
Human Use Low, Medium, High	L	L	M	L	H	M
Density/100 m	0	1.6	.27	.51	.06	.26
Soil Temperature (C) at 2 in.	--	26.6	--	--	33	37.7
Soil Temperature (C) at __ in.	--	--	--	--	35	31
Ambient Temperature (C)	38	38	98F	45	33	31
Wet Bulb (C)	--	--	20.5	--	20	21.6
Dry Bulb (C)	--	--	36.6	--	31	32.2
% Relative Humidity	--	--	2	--	31	32
Time at Beach	10:33-10:47	11:35-12:02	12:24-12:39	4:04-4:26	10:17-10:52	11:31-12:07
Size m	2250	192	1092	1170	12446	4640
Food Count	NO	NO	NO	NO	YES(2)	YES

Table 2. A List of Sample Sites, Harvester Ant Density and the Relative Frequency of Human Recreational Use of the Sites for 1982, 1984, 1985, 1986 (1983 no data).

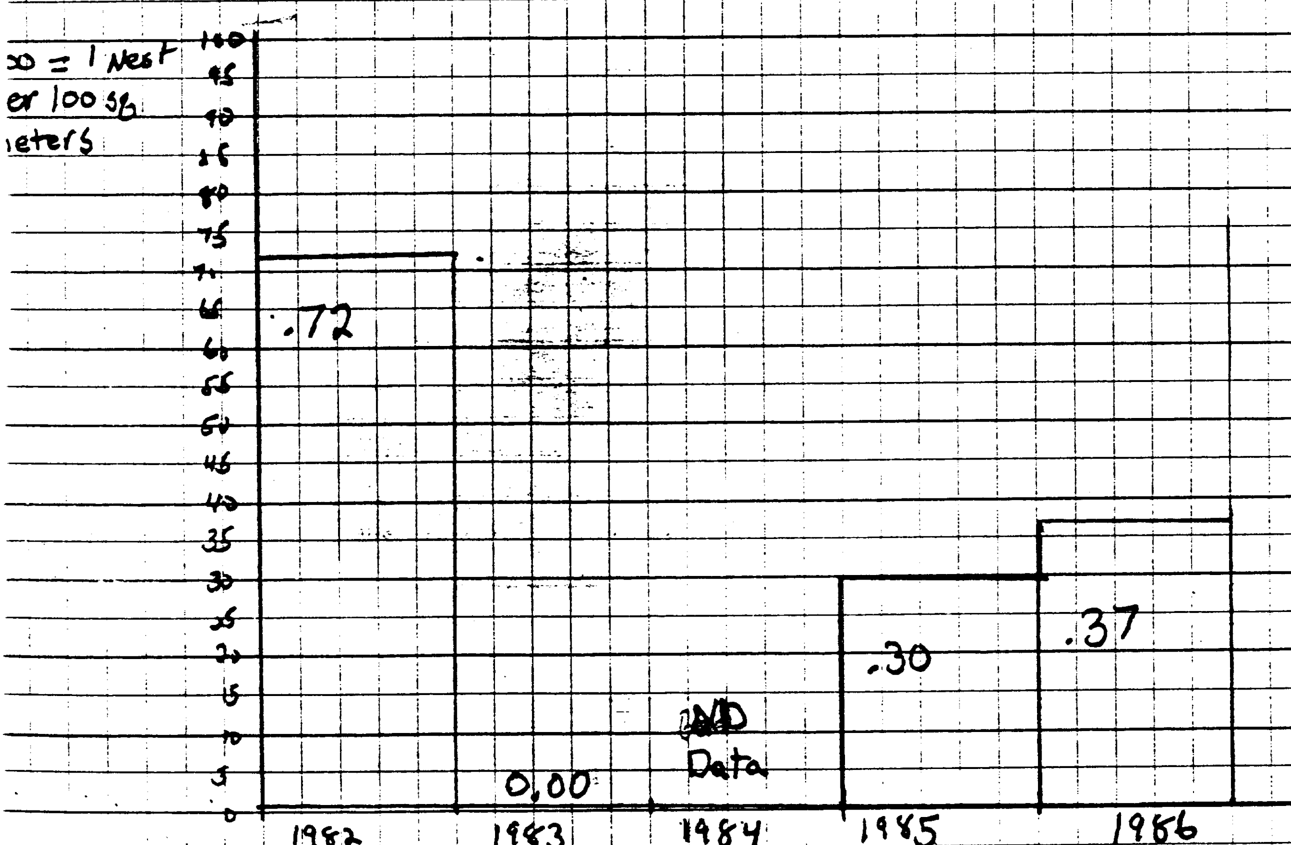
River Mile	Beach	1982	1984	1985	1986	Human Use in 1986 or last year stopped
8	Badger	----	0.00	----	.09	H
20		----	----	.07	.37	H
23.25		----	----	----	.73	L
29	Shinumo Wash	-----	----	----	.06	L
34.7	Nautiloid	----	0.00	.126	----	H
36	Tatahatso	----	----	----	.86	L
43.5	Anasazi Bridge	0.00	0.00	.223	----	H
47		1.40	----	----	----	H
53	Lower Nankoweep	1.10	0.00	----	.09	H
58.1	Awatubi	----	0.00	.256	.12	H
60.5	Upper LCR	----	0.00	----	----	L
61.8	Lower LCR	----	----	----	.041	L
63.5	Carbon Creek	----	----	----	.92	H
65.5	Chuar Canyon	----	0.00	.67	----	H
72.2	Unkar	----	0.00	----	----	L
75.5	Nevills Rapid	.56	0.00	.093	.14	M
76.5	Hance	----	----	.323	.17	H
81.1	Grapevine	----	0.00	.293	.2	H
87	Cremation	----	----	.513	----	H
93.2	Granite Rapids	.56	----	----	.29	H
108.5	Lower Bass	0.00	0.00	.55	.81	H
120.1	Blacktail	.49	0.00	.31	1.2	M
122	122 Mile Creek	----	----	.413	.33	M
122.8	Foster	----	0.00	----	.30	M

Table 2. (continued)

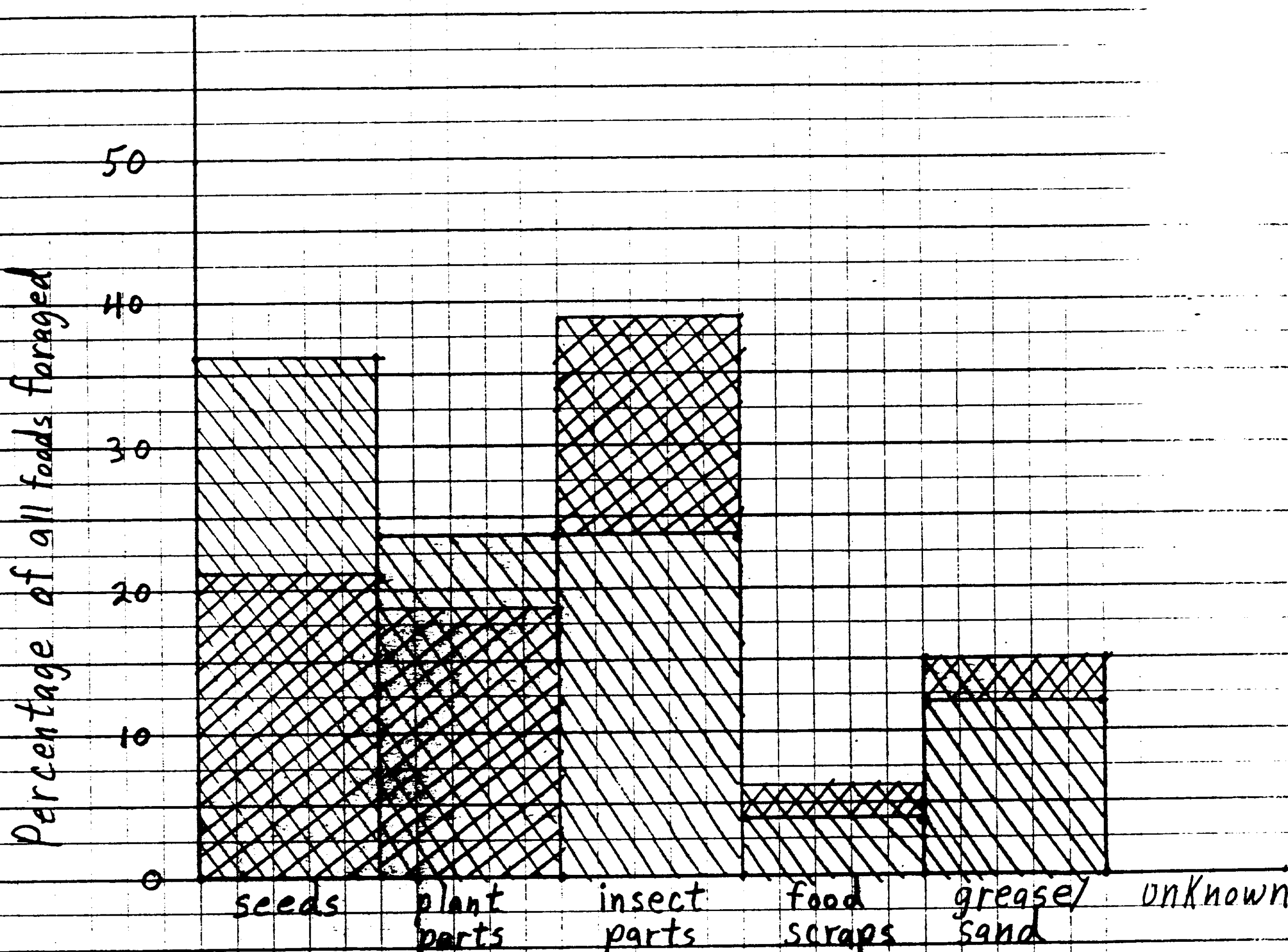
River Mile	Beach	1982	1984	1985	1986	Human Use in 1986 or last year stopped
125.5		----	0.00	----	0.00	L
131	Bedrock	----	0.00	----	1.6	L
132	Dubendorff	0.00	----	----	.27	M
136		2.5	----	----	----	H
138.5		----	----	----	.51	L
166	Lower National	.77	----	.04	.06	H
179	Prospect Canyon	0.00	----	----	----	?
179	Upper Lava	----	0.00	----	.57	H
180.9	Lower Lava	----	0.00	.03	.05	H
181		----	----	----	.09	M
190.2	190 Mile Beach	----	----	.04	----	M
192		----	----	----	.23	L
194	194 Mile Beach	----	----	.146	----	M
196	Creek	----	----	----	.73	L
198.6	Parashont	2.30	----	----	.13	L
208.9	Granite Park	.67	0.00	.7	.5	L
213.5	Unused Beach	----	----	----	.23	None
214.5	Unused Beach	----	----	----	.13	None
219	Trail Canyon	.50	.17	.18	----	L
220		----	0.00	.77	.51	H

TABLE 3

Average Density of nests per 100 sq m on Colorado River for years 1982, 1983, 1984, 1985, 1986



Summary of total food items foraged by the harvester ants from mile 23.25 to mile 214.5. A sample size of 1782 food items were observed for 1986. The 1985 data is from a sample size of 339 total food items.



	seeds	plant parts	insect parts	food scraps	grease/sand	unknown
1986	21%	19%	39%	6%	15%	0%
1985	36%	24%	24%	4%	12%	0%

* L FOOD CHART

each 23.25 | mile 23.26 | time 11:05 - 11:16

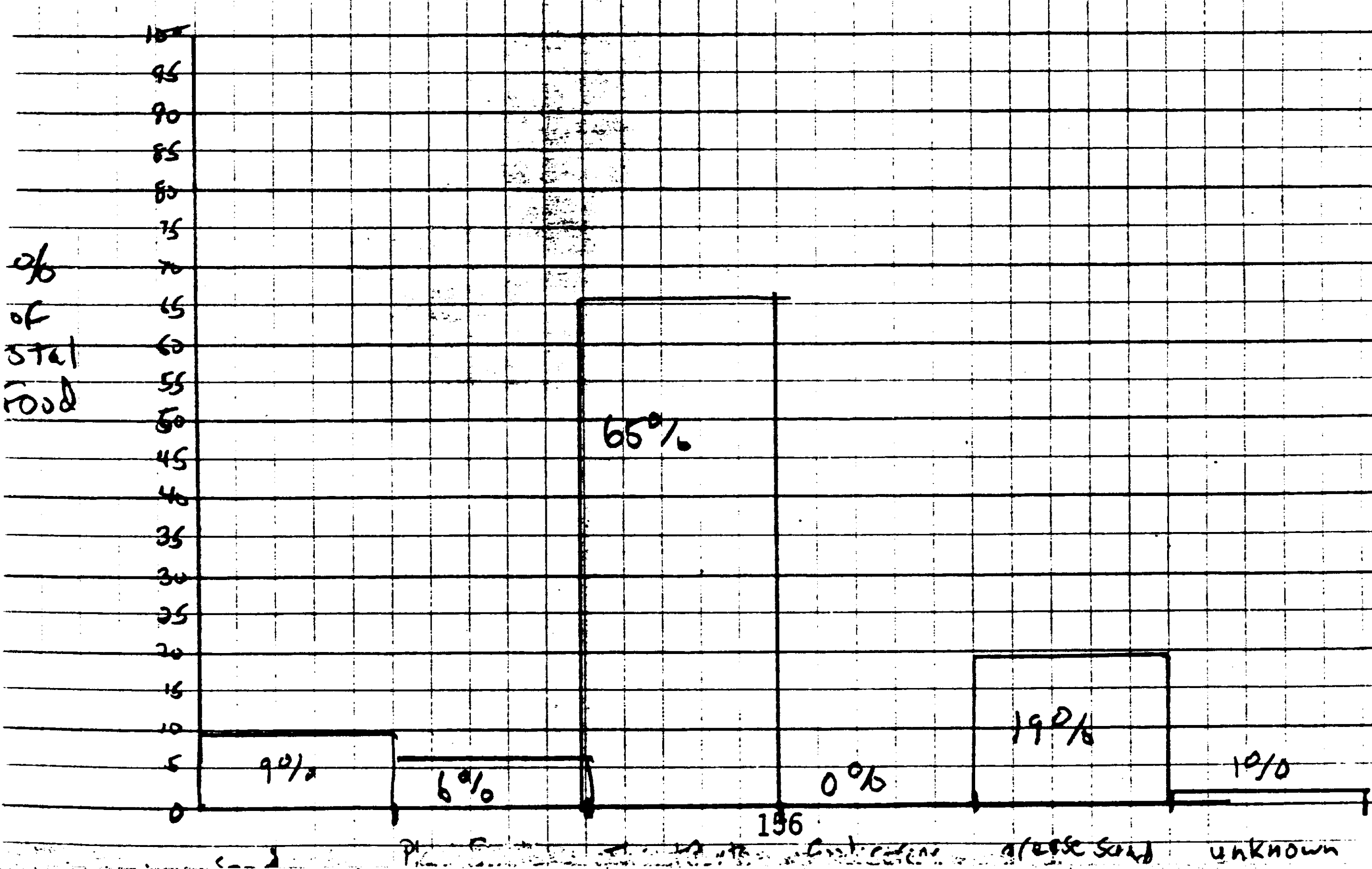
egetation 3 | Distance to campsite 20 m

38° c

soil: 2½ in ~~28~~.8° c

human use m

Beach size 664 m



#2

each Shinomo mile 29 time 1:00-1:11

getation 3 Distance to campsite 12 m

33°C

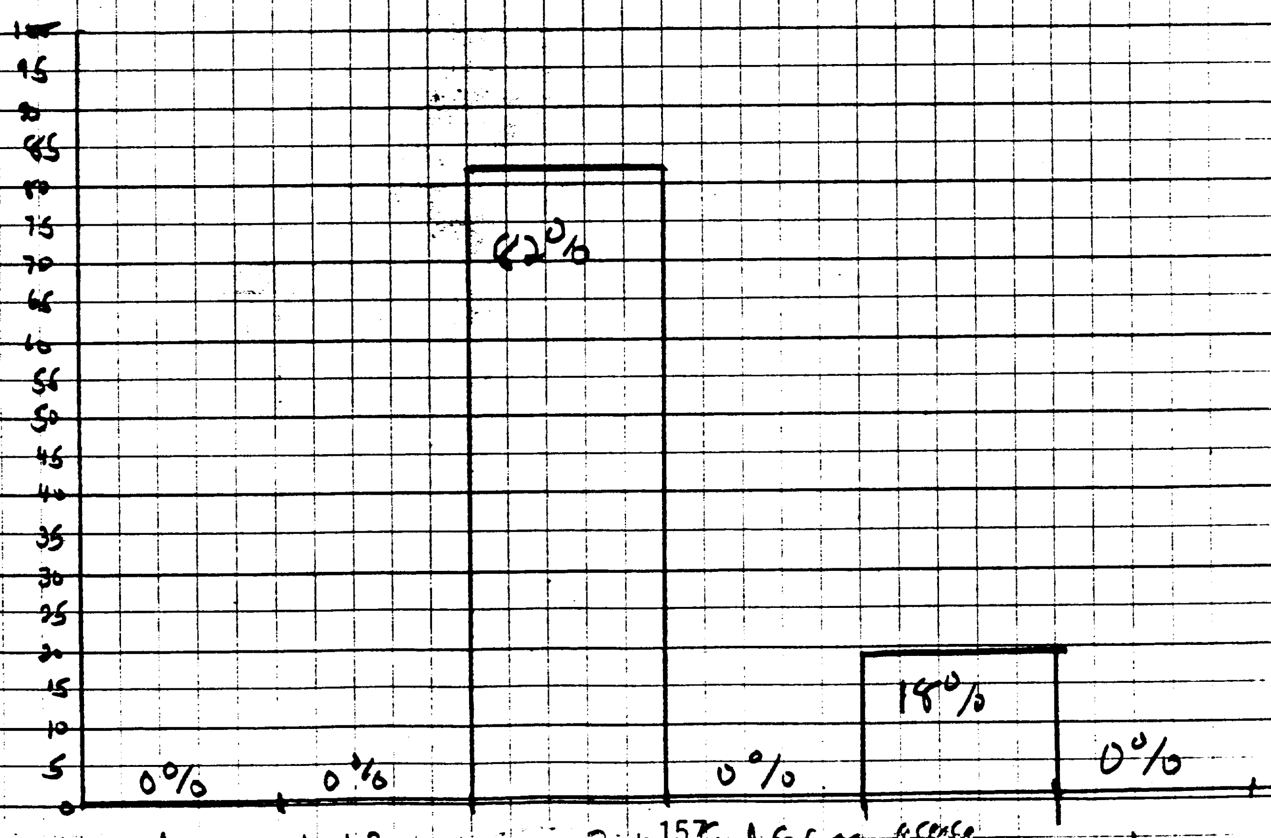
oil 2½in 39.4°C

Insect Parts mostly Ants + Ant Eggs

man use m

each size 1653 m

% of total od



F.3

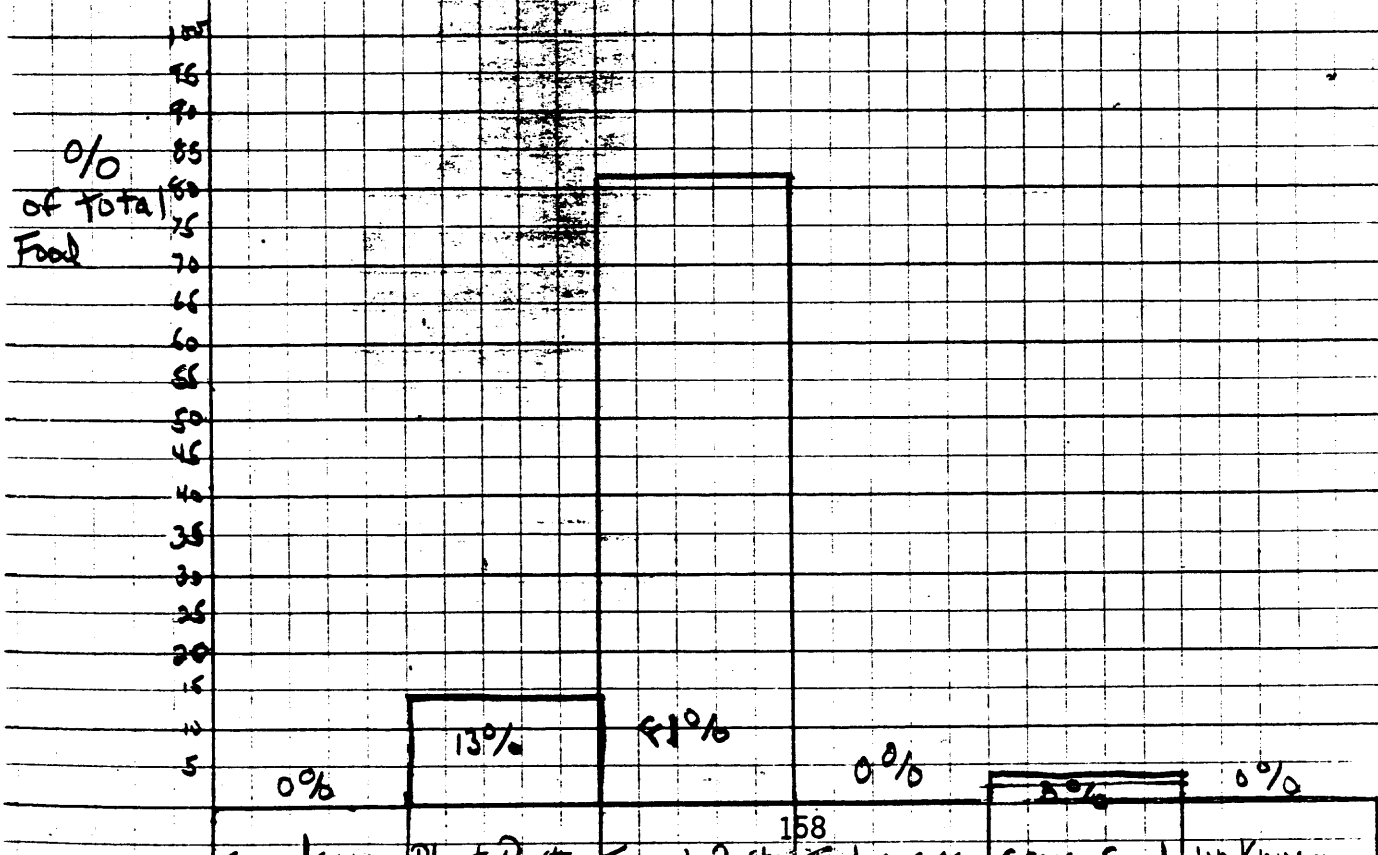
Beach Tatahatso mile 36 Time 5:35 – 5:46

Vegetation 2 Distance to campsite 25m

36°C 37°C Dry 18°C wet RH = 21%

Soil 2½ in 38°C

Beach size 693



#4

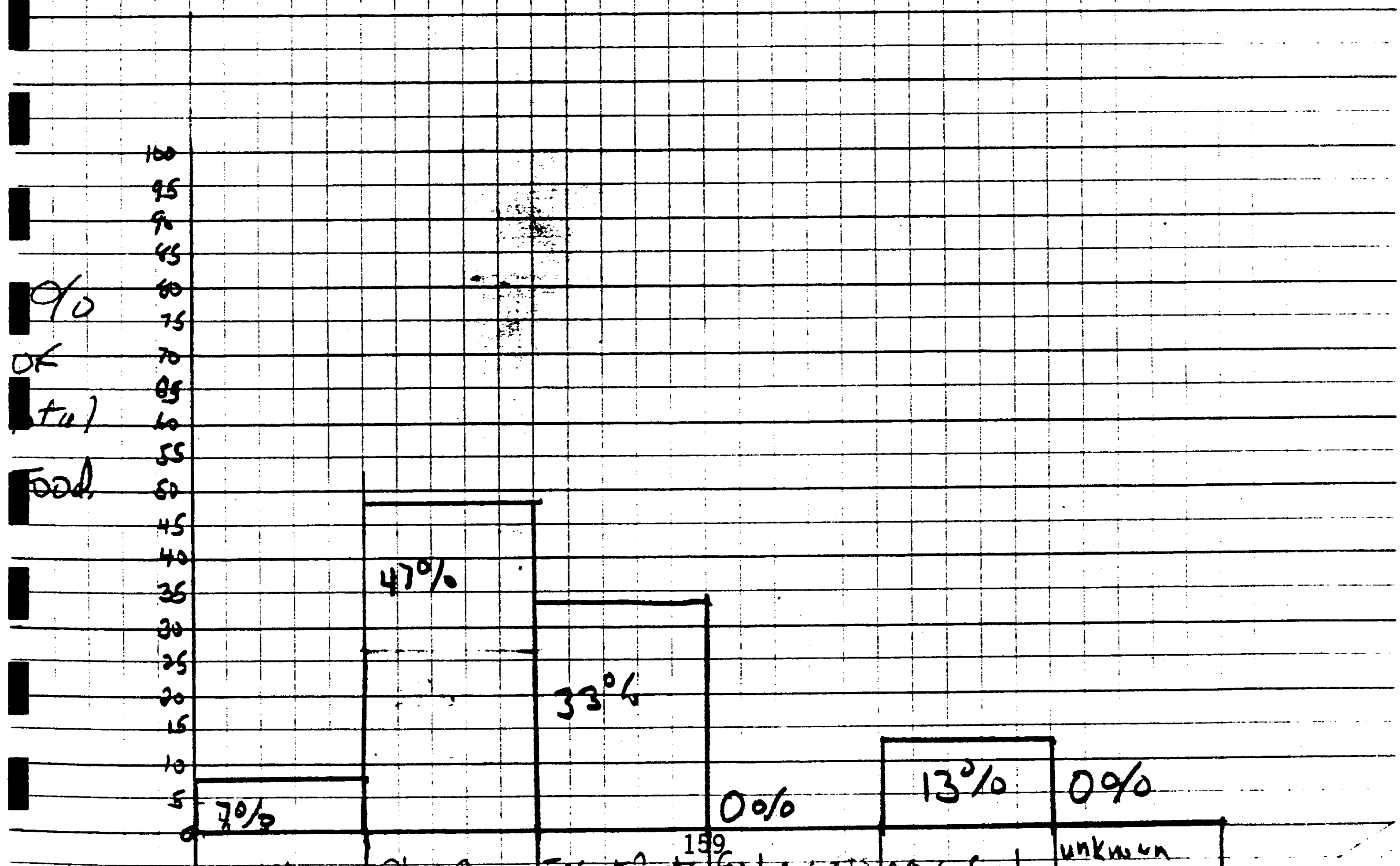
each tatahatsu mile 36 time 6:00 - 6:07

getation 2 Distance to campsite 60m

33°C 34°C Dry 18°C wet RH= 19%

il 2½in 106°F

Beach size 693 m Same as #3



5

each Awatubi mile 58.1 time 5:06 - 5:17

egetation 2, 3 Distance to campsite 50m

39°C observed ants traviling 30 m to catch

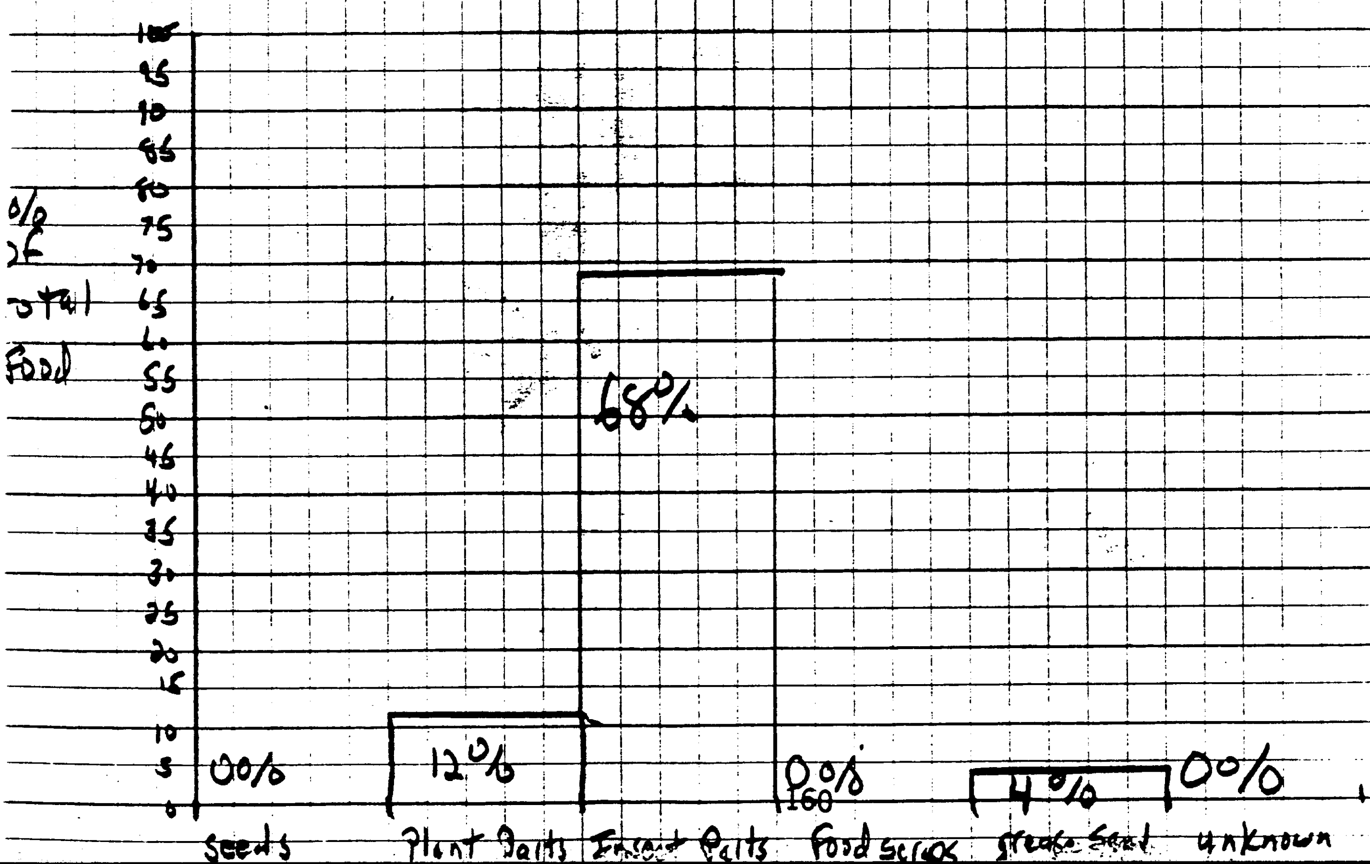
oil at 2½in = 46.6°C Live and dead diptera flies at H_2O Edge

Dry 38.8 wet 18.8 RH ≈ 9%

oil at 7in 39°C

Human use H

Beach Size 7552 m



#6

each Awaitubi mile 58.1 time 9:40 - 9:5

getation 2/3 Distance to campsite 27m

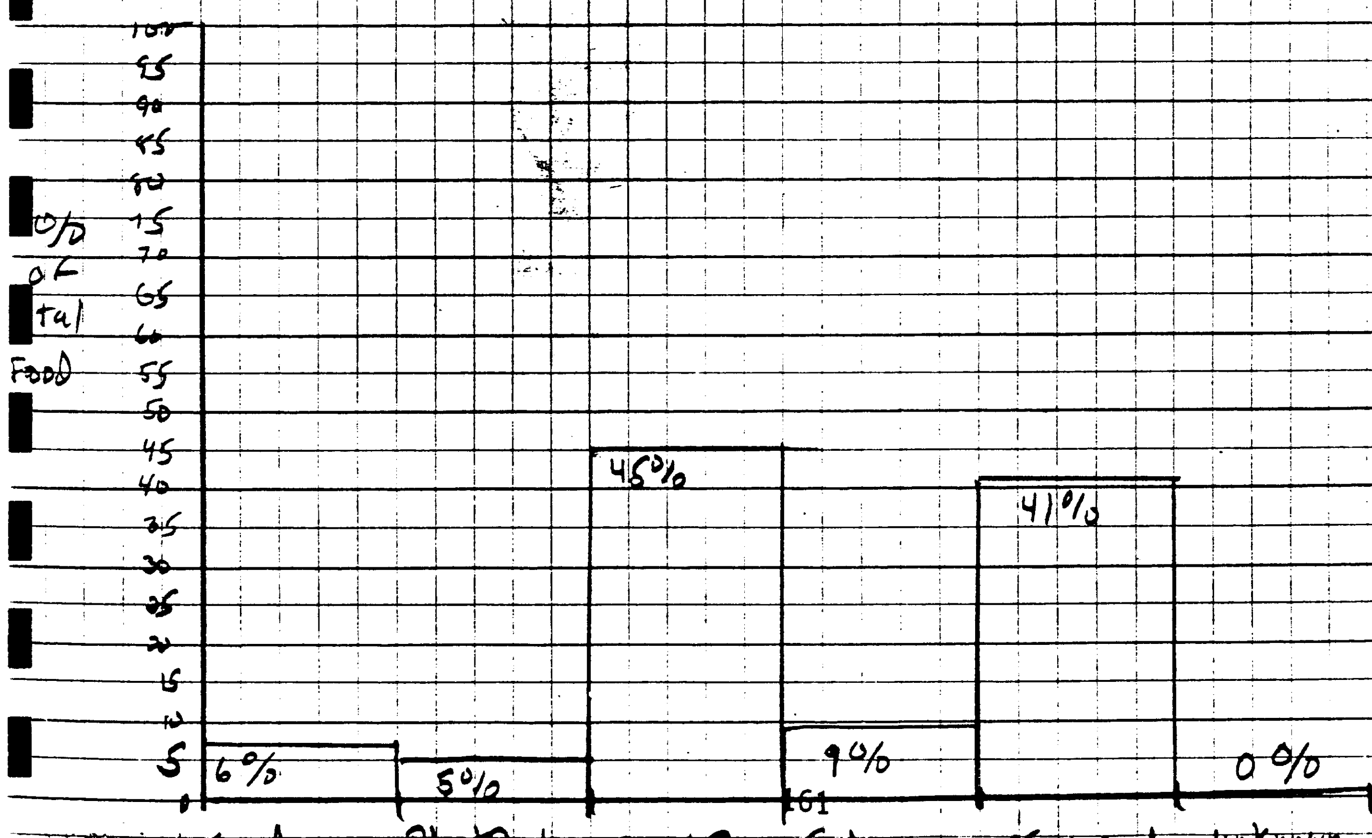
35° °C Dry 30°C wet 17.7°C = RH ≃ 25

s.l 2½ 33.3°, C

oil 7in 30°C

Human use H

Beach size 7552 same as #5



#7

Beach Lower Little Colorado mile 61.8 Time 11:37 - 11:49

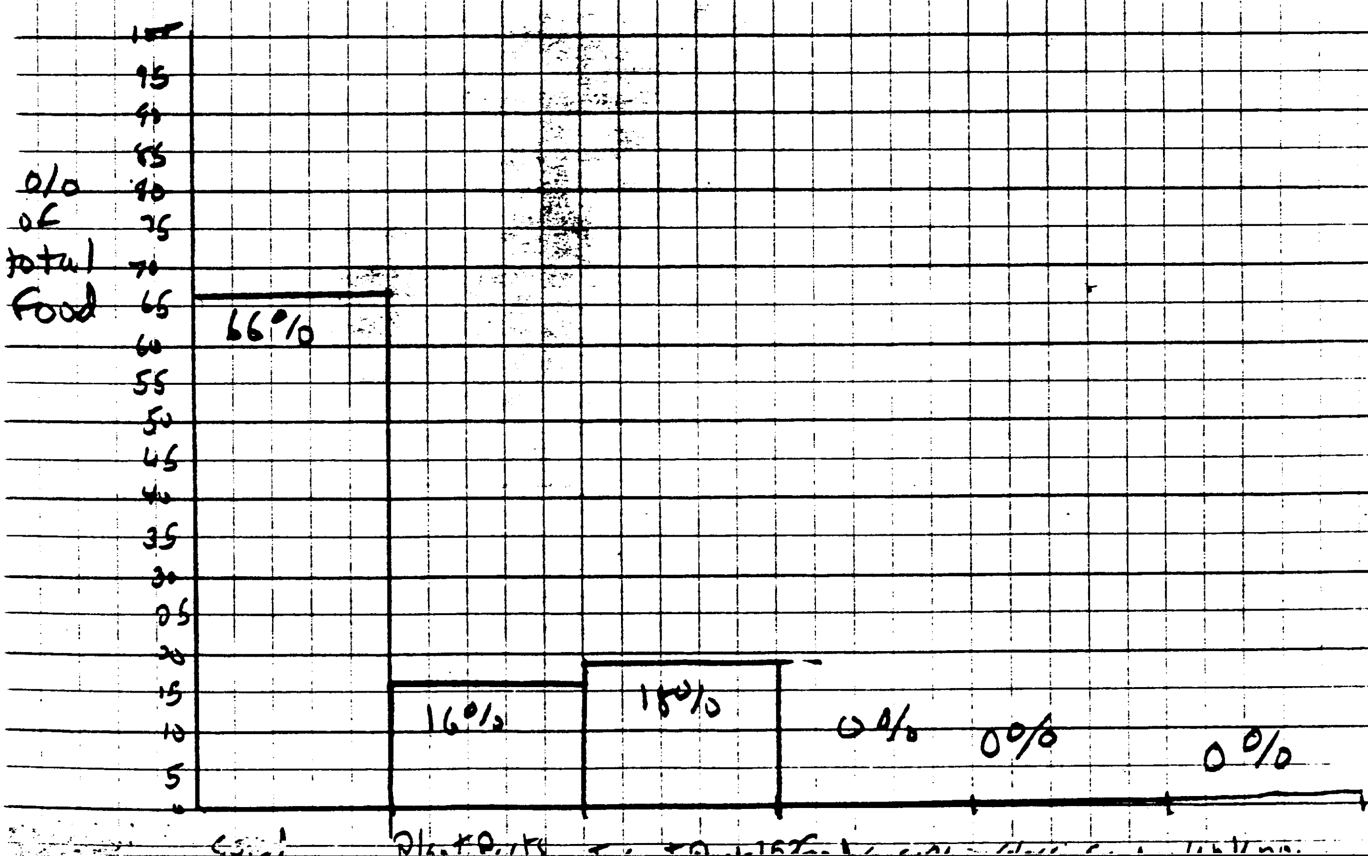
Vegetation 2/3 Distance 40 m

Soil 2½ in = 37.2° Wet 20°c Dry 37.7°c RH ≈ 16%

Soil 7 in = 30°c Ants mostly clearing Nest

Human use L

Beach Size 2400 m



#8

Beach Carbon creek — mile 63.5 — Time 4:37 4:47

Vegetation 2/3 — Distance to campsite 25m

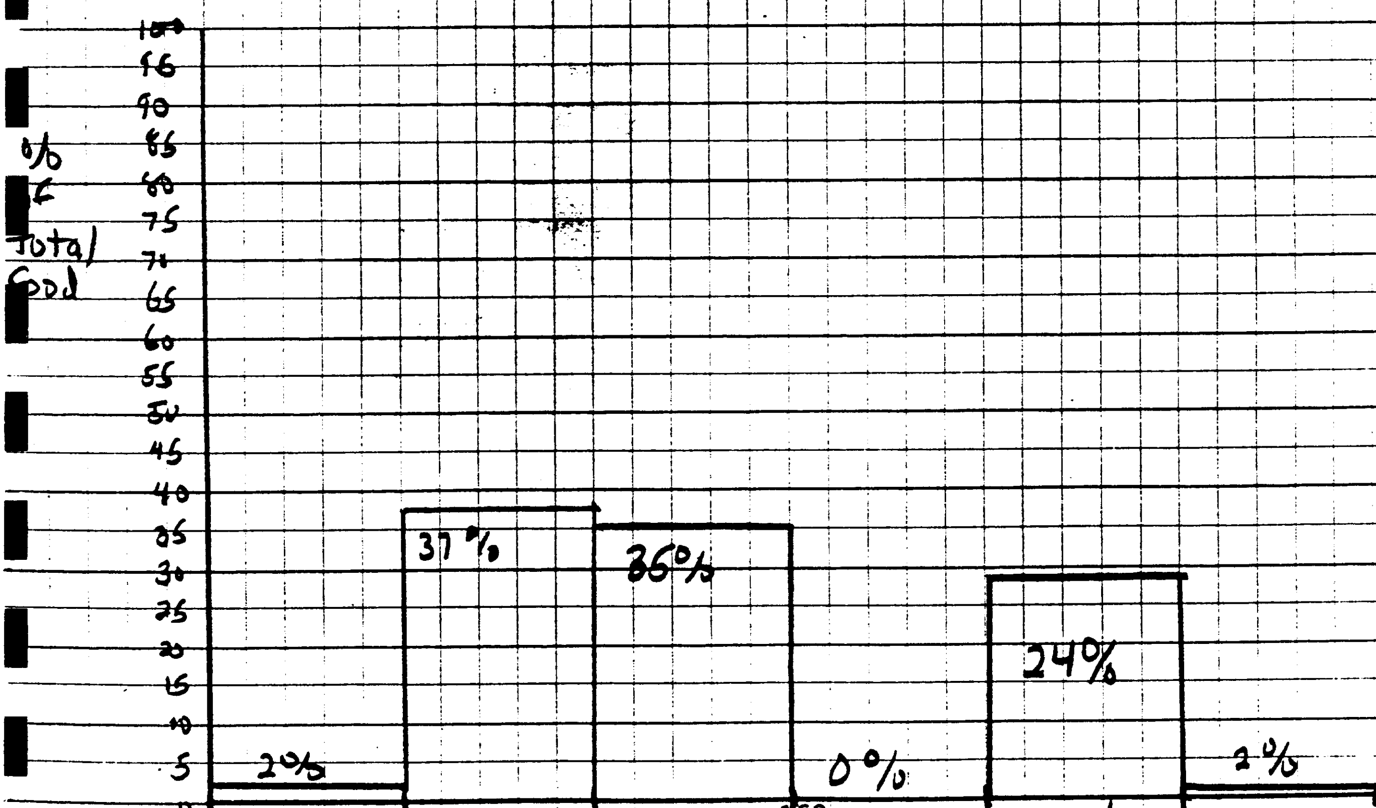
43° C — Wet 20°c Dry 37.7 RH = 16%

2½ 24° (in shade) — other Hive Ants went to our lunch spot.

In Soil 37°C — Saw Q outside Nest

Human use H

Beach Size 864 m



#9

Beach Black tail   Mile 120.1   Time 6:27 - 6:41

Vegetation 2/3   Distance to composite 9m

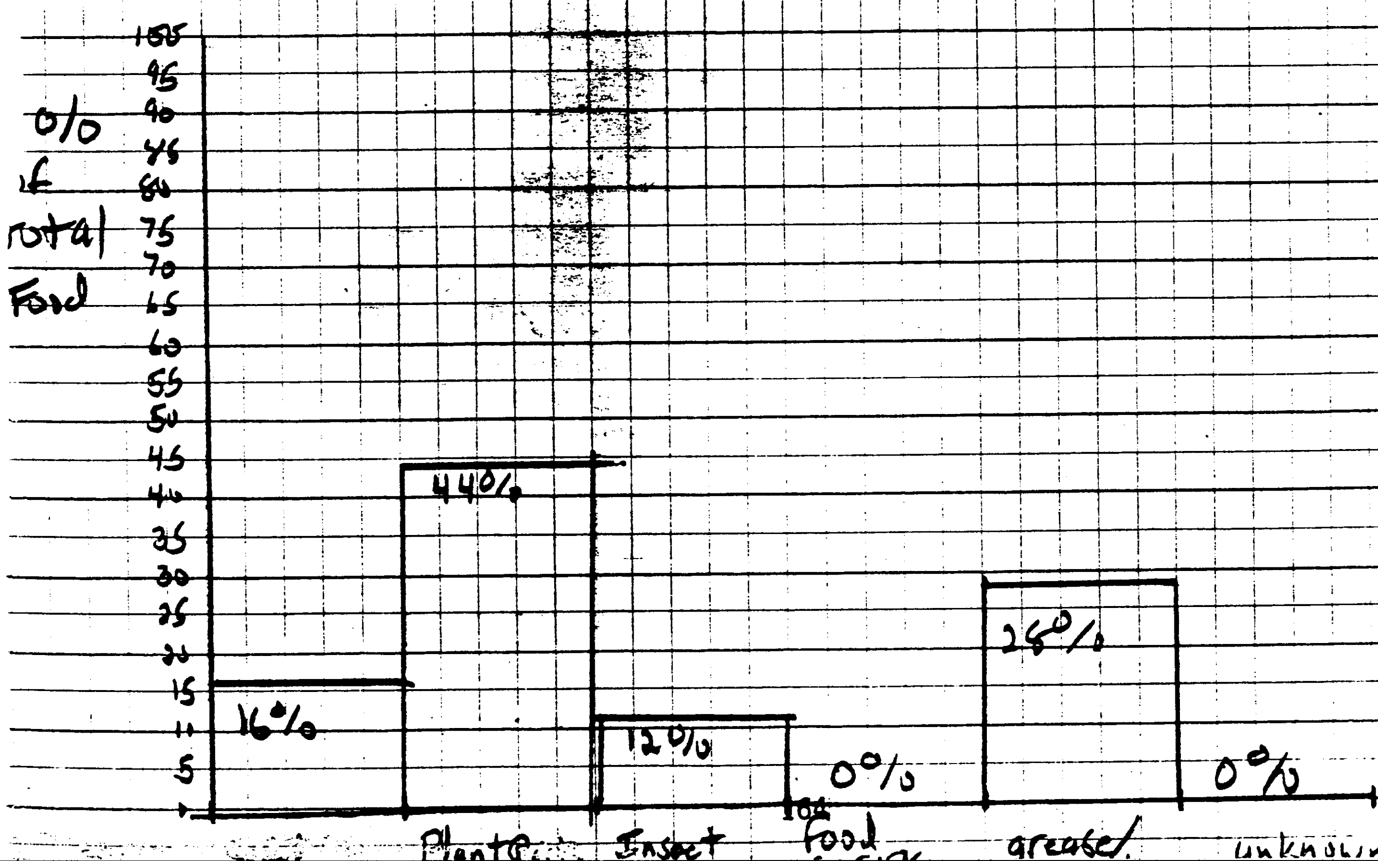
37°c   Wet 20.0°c   Dry 37.7°C   RH ≈ 17%

Soil 2 1/2 in 38.8°C

Soil 7 in 40°C

Human use H

Beach Size 660



#10

each 122 mile 122 time 8:56 - 9:06

getation 1 Distance to composite 20 m

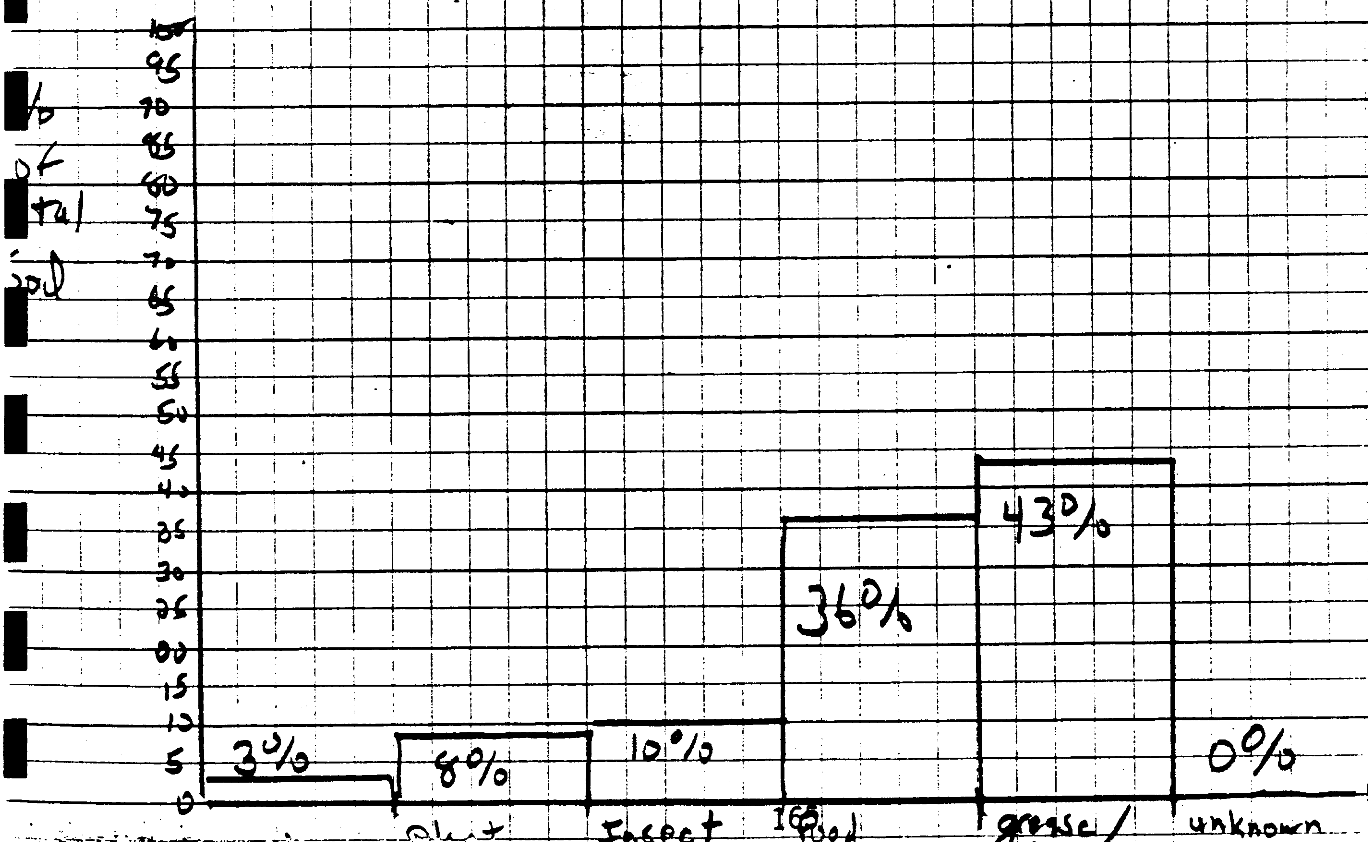
28°C Dry 28.8' Wet 18.3 RH = 32%

oil at 2½ in 31.1°C Large Beach upriver at Eddy Hives

oil at 7 in 32°C feeding on Plants + insects

uman use H

Beach Size 4264 □m



Lower National — mile 166.6 — time 11:04 - 11:14

vegetation 2! — Distance to campsite 30 m

35°C — Dry 34°C — wet 20°C — RH ≈ 23%

Soil at 2in 33.3°C

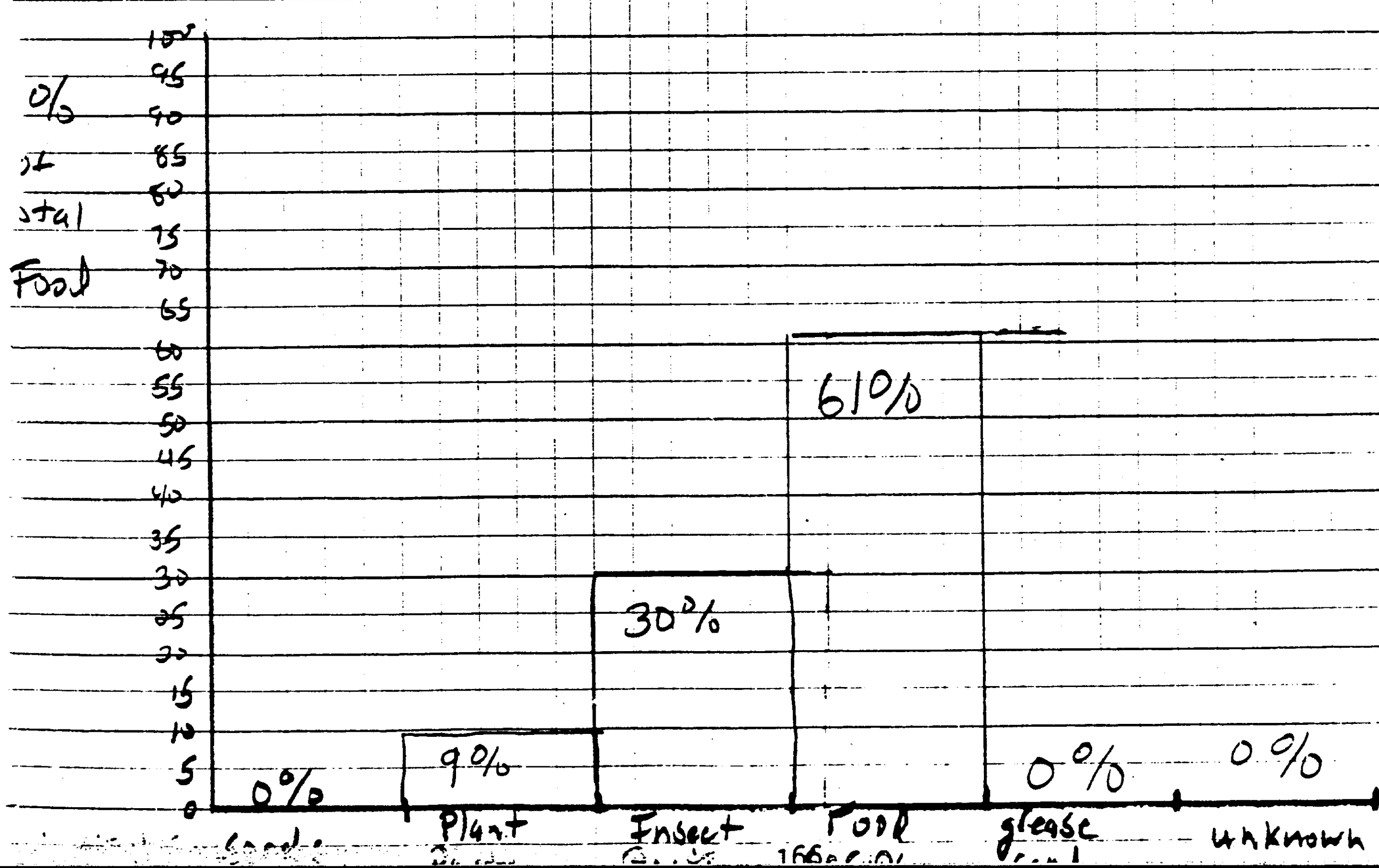
Soil at 7in 30°C

Small Red ants very numerous (sampled) and very well defined trails

H_2O level changed from 10 - 5 cmf

Human use 1+

Beach Size 12446 Same as #14



#13

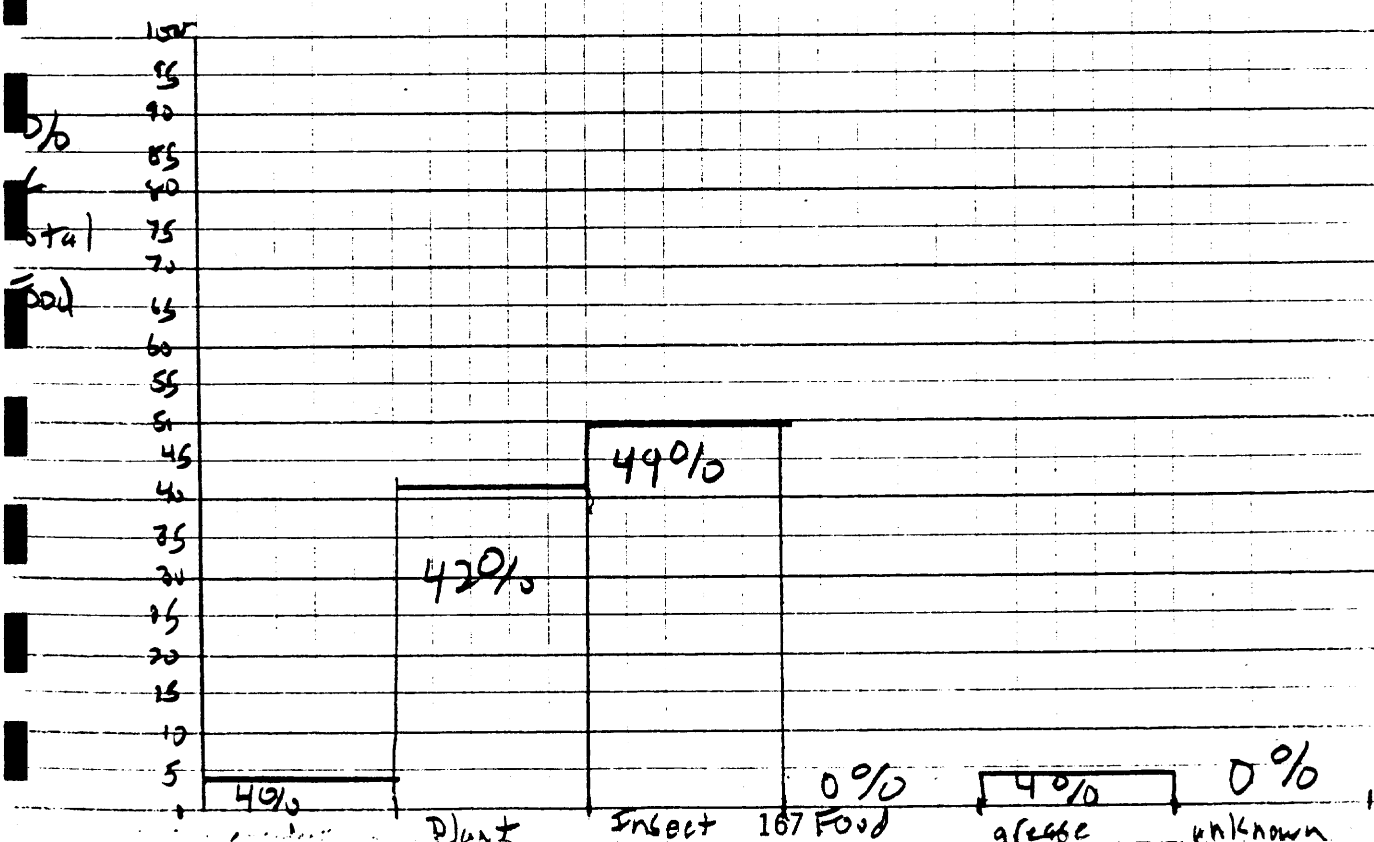
National mile 166.6 time 11:23 - 11:35

Vegetation wash Distance to campsite 254 m

36°C

Human use H

Beach Size 12446 same as #13



13

Beach Cove
mile 174.5
time 11:37 - 12:07

Vegetation 33
Distance to campsite 31m

31°C
wet 21.6°C Dry 32.2°C RH ≈ 32%

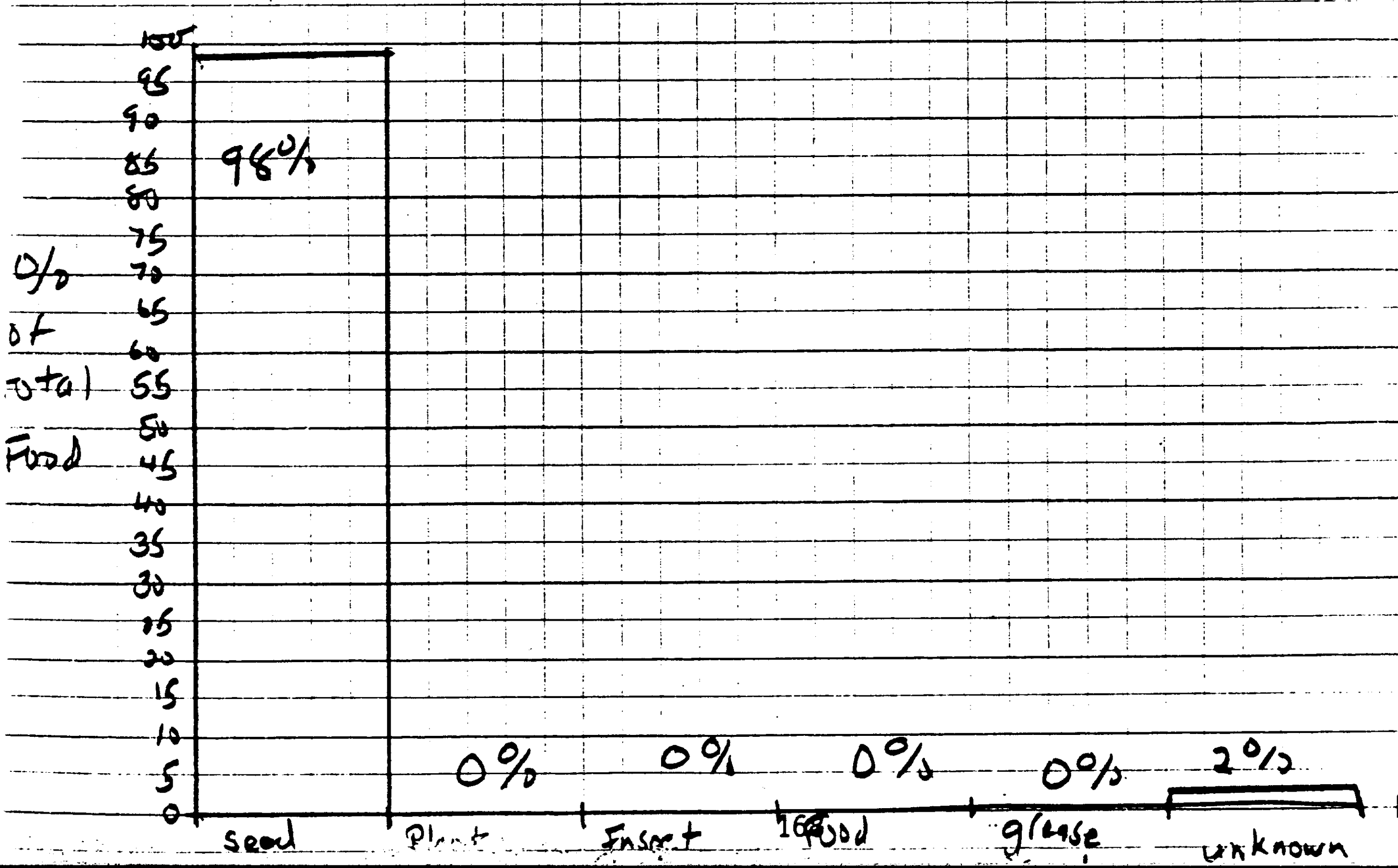
soil at 2½in 37.7°C
Rain Night before (Knocked of seeds?)

soil at 7in 30°C
Small Red Ants Nest also seen

All Nests Have Dead Ants on mounds

Human use m

Beach size 4640



#14

Beach 192 | mile 192 | time 5:41 - 6:10

getation 2/3 | Distance to campsite 20 m

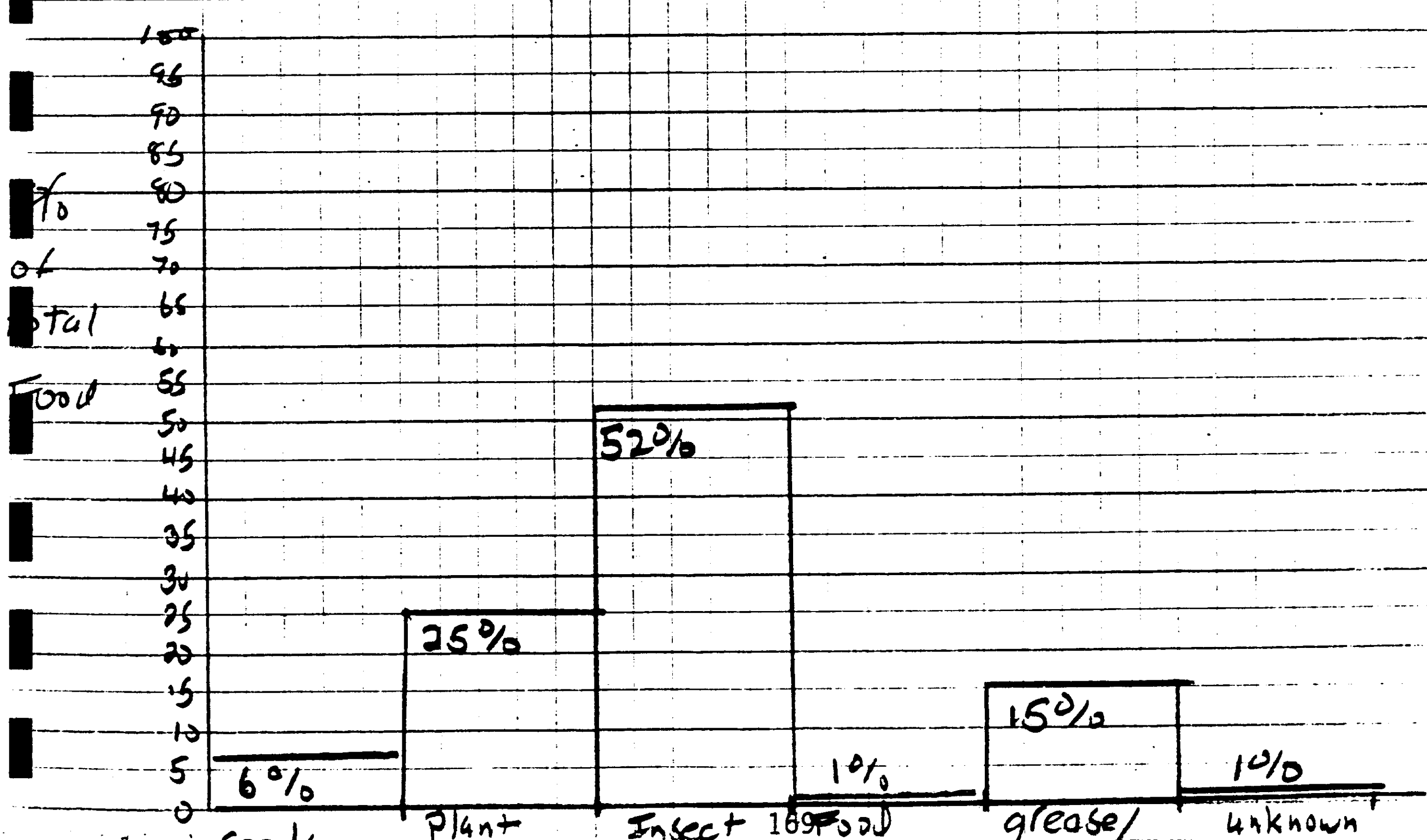
36°c | Dry 36.6°c wet 21.1°c RH ≈ 21%

oil at 2½ 327°c | Ants Eating Black flys and Plants

oil at 7in 36°c

Human use L

Beach Size 2147



#15

196 creek mile 196 time 9:06 - 9:27

egetation 3 Distance to camp site 18m

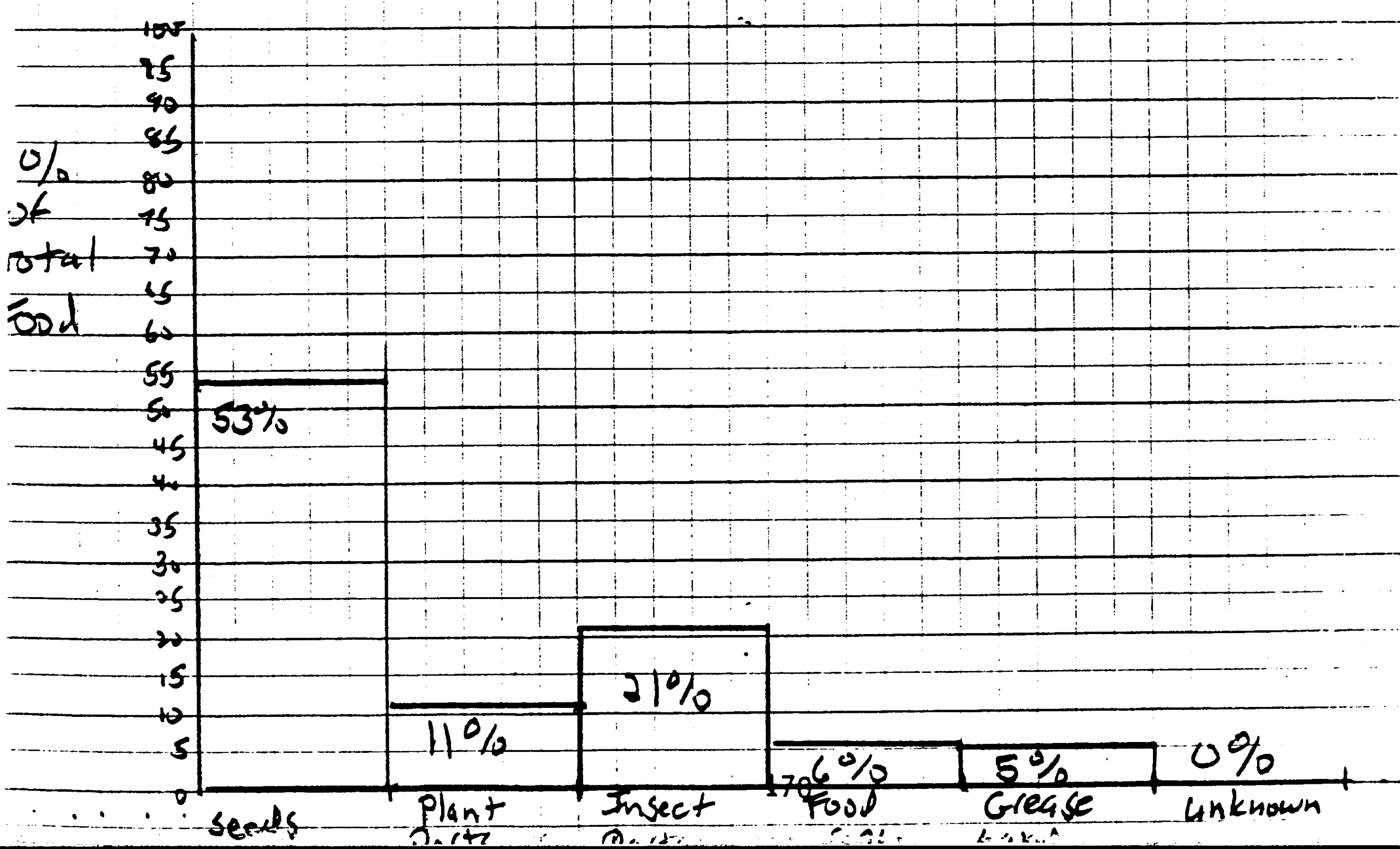
29°C wet 21.1 Dry 27.7 RH ≈ 58%

il at 2½ in 26.8°C Lots of Black flys on Nest

oil at 7in 29°C

Human use L

each Size 817 □m



#16

arashant mile 198.5 10:08 - 10:19

36°c Distance to campsite 33m

Wet 21.1°C Dry 33.3°C RH = 33%

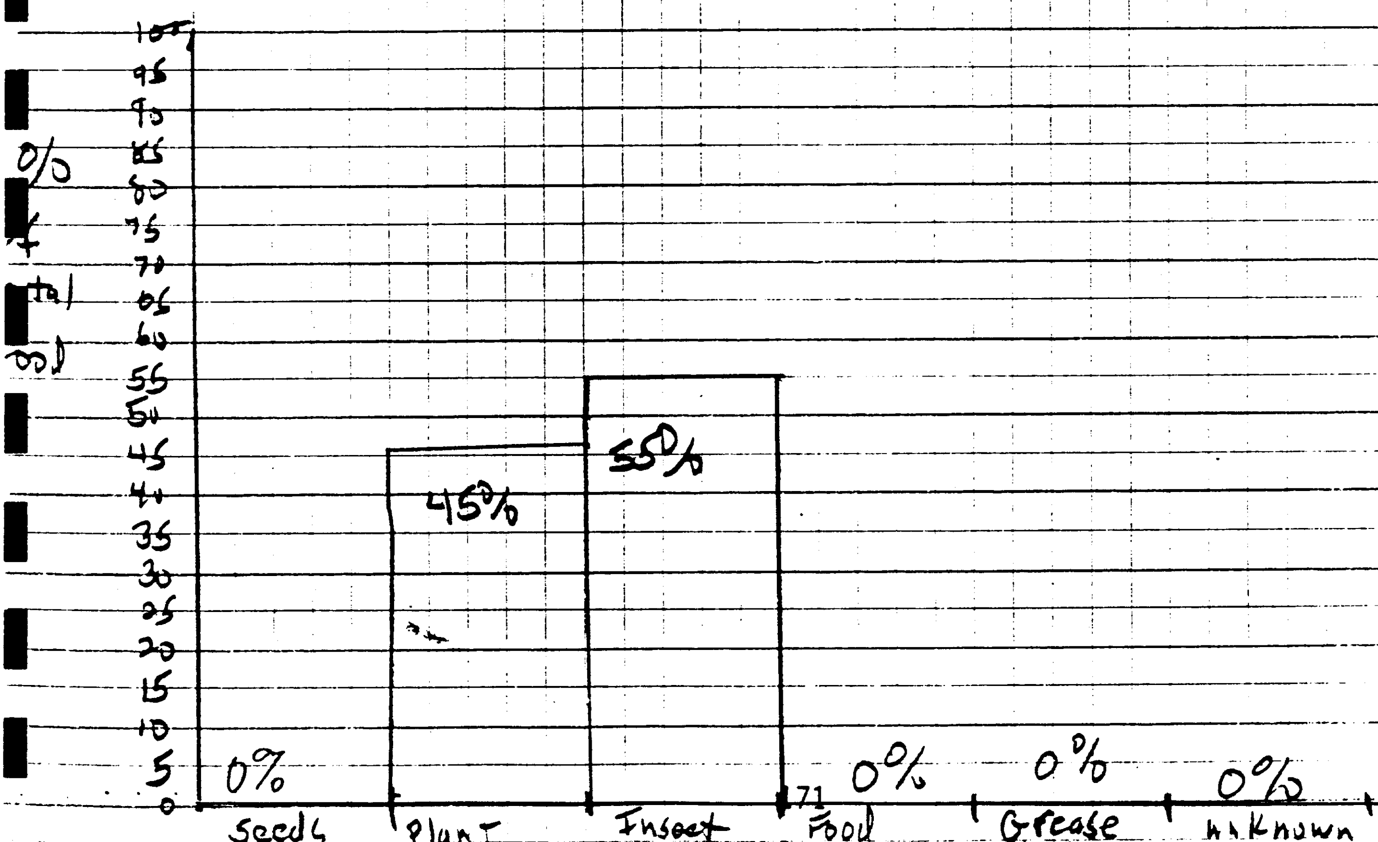
oil at 2½in 28.8°c

il at 7in. 30°c

Human use ?

Beach Size 3906

Observed flies outside of nest
Ants Selectively took from pile and
droped down nest. Also flies brought
out we felt they were drying their
food source for rain night before
So it didn't mold.
All nest on beach have dead flies
flys brought to nest from piles Not
Beach.



#17

Beach unused below Pumkin 213.5 mile time 4:10 - 4:21

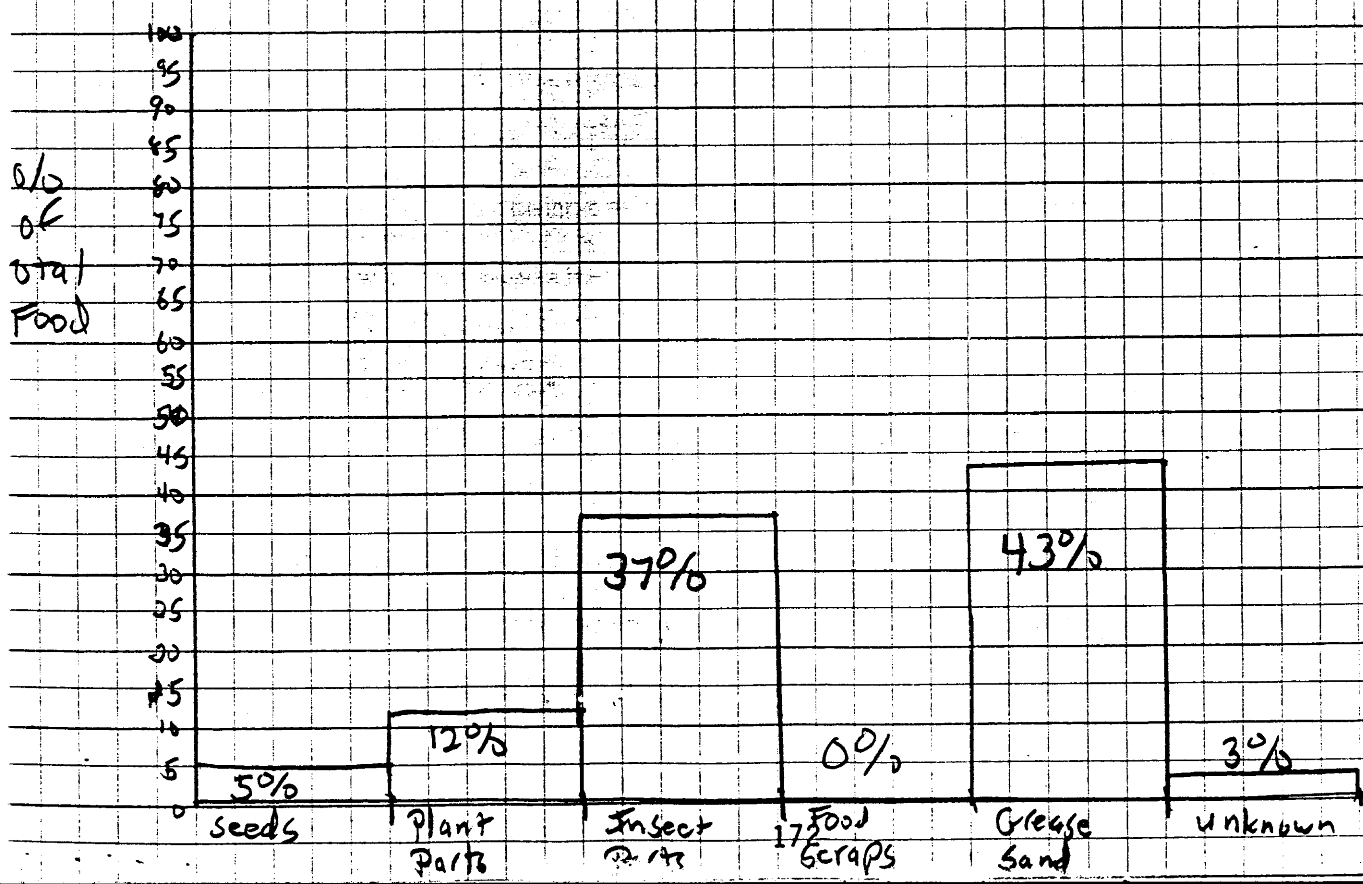
Vegetation 2 No Campsite Wet 22.2 Dry 40.5 RH = 18%

47°C

No camping so wet sand must be for H_2O. We saw ants collect sand from Beach

Human use L

Beach size 1775



#18

each 214.5 mile 214.5 Time 5:10 - 515

40°C Not camped at

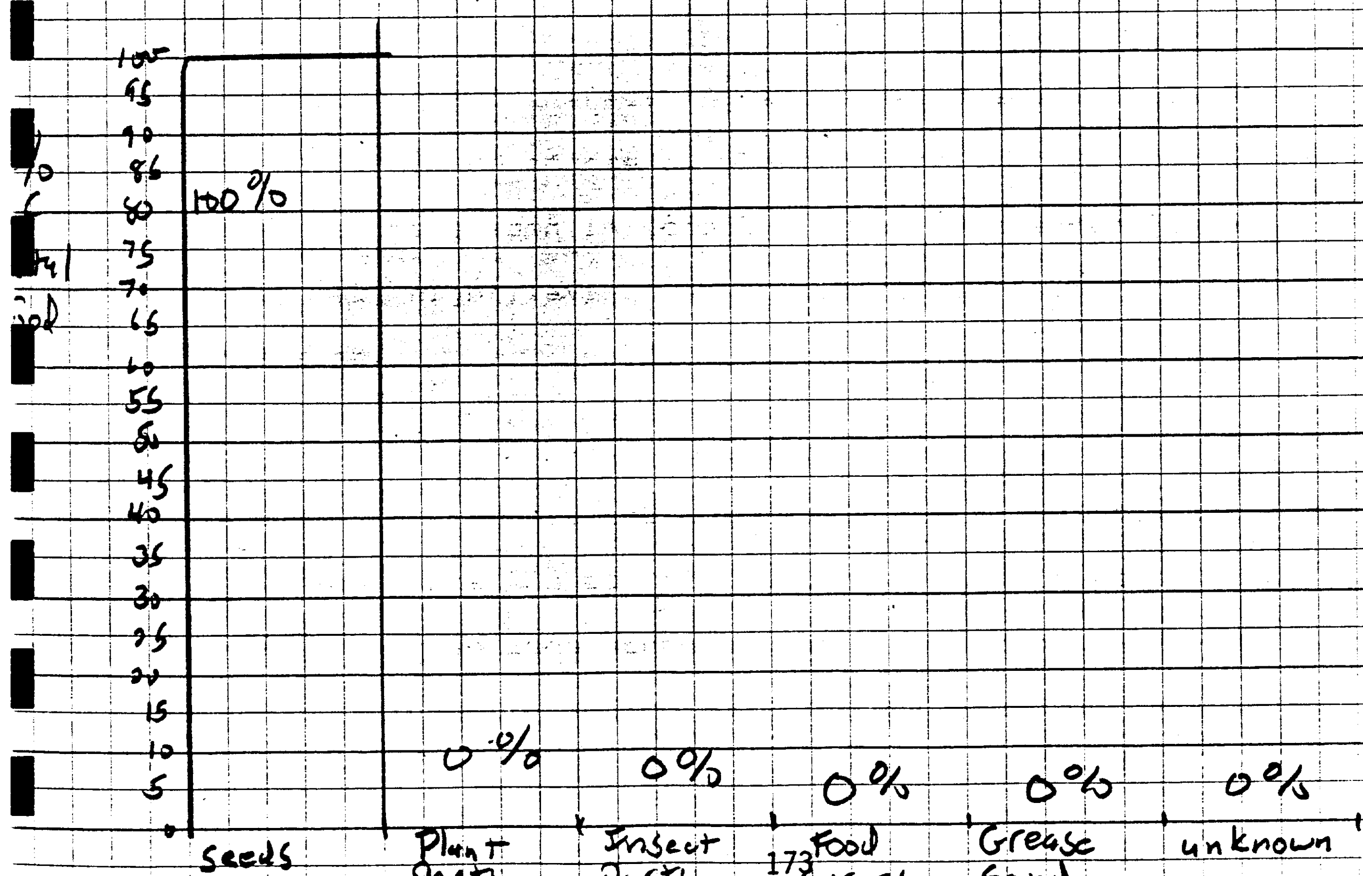
oil 2½in 33.3°C Wet 21.6 Dry 43.3 RH ≈ 10%

oil 7in 41°C Seeds were Burmuda grass

sand still wet from rains 3 in then dry again at 10 in.

uman use L

each size 1540



173

References

Borror, D.J. and R.E. White. 1970. Field Guide to the Insects. Houghton Mifflin Co., Boston.

Byars, B. 1983. "Further investigations on *Pogonomyrmex* ants on Colorado River beaches in Grand Canyon". IN Colorado Investigations II, edited by S.S. Beus and S.W. Carothers. Northern Arizona University Manuscript Report. Submitted to Grand Canyon National Park, pp. 133-142.

Cole, A.C. 1968. *Pogonomyrmex* Harvester Ants. University of Tennessee Press, Knoxville.

Milne, L. and M. Milne. 1980. The Audubon Society Field Guide to North American Insects and Spiders. Alfred A. Knopf, New York.

Petersen K. 1982. Interactions of harvester ant (*Pogonomyrmex*) and river recreationists. IN Colorado River Investigations I, edited by S.S. Beus and S.W. Carothers. Northern Arizona University Manuscript Report. Submitted to Grand Canyon National Park, pp. 133-147.

Thomas, S. and D. Lindquist. 1985. "Further investigations on *Pogonomyrmex* ants on Colorado River beaches in Grand Canyon". IN Colorado Investigations IV, edited by Dorothy A. House. Northern Arizona University Manuscript Report. Submitted to Grand Canyon National Park, pp. 205-214.

Wheeler, G.C. and J. Wheeler. 1973. Ants of Deep Canyon. The Regents of the University of California.

Wynne, W. 1984. "Further Investigations on *Pogonomyrmex* ants on Colorado beaches in Grand Canyon". IN Colorado River Investigations III, edited by S.S. Beus and S.W. Carothers. Northern Arizona University Manuscript Report. Submitted to Grand Canyon National Park, pp. 108-111.

CHAPTER XII

REPTILE STUDY - 1986

Patricia Garges, Jean M. Schwarz, Shirley Bonner
and Doug Adams

INTRODUCTION

The data gathered in this project attempts to quantify the preferred reptile habitat and density in the Colorado River's riparian zones. In the Grand Canyon, four distinct environmental zones may be observed (Figure 1). Zone I is the environmental desert zone furthest from the river and uninfluenced by it. Zone II marks the old high water flood line (OHWL). It is a stable community of woody vegetation such as acacia and mesquite. During the flooding of the Colorado River in 1983, this OHWL was replenished. Zone III, below Zone II, is an unstable vegetative zone due to human impact. This beach area is primarily used for camping. Zone IV, the new riparian zone, consists mainly of the exotic tamarisk species as well as the native arrowweed and willow. The proliferation of this type of vegetation is a direct result of controlled river flows from Glen Canyon Dam. It was thought that the tamarisks or salt cedar species, in the new high water line (NHWL), is of little or no value to most native wildlife. However, recent findings indicate this NHWL zone to be not only richly inhabited by reptiles, but possibly the preferred habitat.

OBJECTIVES

The objectives of this project are as follows:

1) to compare the densities of reptiles in all four zones with particular emphasis between Zone II, the OHWL, and Zone III, the NHWL zone.

2) to determine the types of vegetation most inhabited by reptiles, particularly in Zone II and Zone IV.

3) to determine a correlation between temperature and reptile density.

The initial hypotheses is that of all the species of vegetation in the riparian zones of the Colorado River corridor, the tamarisk (salt cedar) is utilized to a far greater extent than other trees and shrub species. In addition, the vegetative zone most closely associated with the river (Zone IV-NHWL) has the greatest density of reptiles.

METHODS

This project attempts to sample all four zones at as many beaches as possible. The most critical factors are as follows:

1) For this study two observers are consistently used in each zone.

2) Keep accurate records of the species observed.

3) Keep an accurate time of the length of observation - the data are computed on the number of lizards seen per minute.

4) Keep an accurate record of the vegetation associated with each reptile observation.

5) Sample the habitats in a consistent manner throughout the river trip.

6) Keep an accurate ambient temperature in each observed zone.

Data sheets are provided to facilitate the gathering of information (Figure 2). On each data sheet the following information is included: 1) observer; 2) date; 3) ambient temperature (this is the air temperature starting the sample period); 4) the beach name and/or river mile; 5) the time the observation period starts and ends, as the evaluation results are based on the number of individual reptiles observed per minute.

Materials Used:

1) clipboards for observers
2) data sheets
3) watch(es)
4) pencils - no ink
5) 2 thermometers

Observers are familiar with the species of lizards and plants listed on the data sheets. If a reptile is not identified, it is marked unknown in the space provided on the data sheet.

Plant species associated with the sightings are indicated. The consistency with which the observer moves through a specific vegetative zone is very important in comparing the study team's data sheets. Each observation is a minimum of 10 minutes and not more than 40 minutes. Although the 4 zones are not always present at each beach, attempts to sample as many habitats as possible are made when available.

RESULTS

Table 1 and Figures 3, 4, and 5 represent the results of reptile usage in the various species of vegetation, and those found on rocks and sand. Of all individuals observed, 35% were found in tamarisks as compared with 7% and 4% of all individuals found in acacia and mesquite, respectively. It is significant to note that 35% of the total individuals observed were found on rocks.

Figures 6 and 7, and Table 2, represent the results of the reptile densities. Total number of reptiles seen in all four zones are 398 individuals in 1,044 minutes. In Zone I, 71 minutes were spent observing 13 individuals for an individual total of 0.18 per minute. In Zone II, 459 minutes were spent observing 88 individuals for an individual total of 0.19 per minute. In Zone III, 27 minutes were spent observing 22 individuals, for an individual total of 0.81 per minute. In Zone IV, 487 minutes were spent observing 275 individuals, for an individual total of 0.56 per minute.

Figure 8 shows the effect of temperature on numbers of reptiles sighted per minute. It is observed that as the temperature increased in Zone IV, a greater number of reptiles were sighted per minute. It appears that the opposite is true in Zone II.

A total of 5 snakes, 4 rattlesnakes and 1 bullsnake were observed during the course of the river trip. Without exception these snakes were seen in Zone IV. Two of the rattlesnakes were observed at night laying in wet sand under tamarisks near the river's edge.

CONCLUSIONS

Zone IV represents the Colorado River's new high water mark. Zone II represents the old high water mark. It is obvious that the new riparian zone accounts for a disproportionately higher number of reptiles than Zone II. We can safely say that Zone IV, a zone created by the effects of Glen Canyon Dam, is providing habitat for a considerable number of native reptile species. It appears that as a result of Glen Canyon Dam, the reptile density has doubled. It seems apparent that up to 50% of observed reptiles are there because of the NHWL habitat. However a corresponding loss of vegetation in Zone II results from lack of water. In the case of the Western Whiptail, individuals per minute sighted in Zone IV was five times higher than in Zone II. Overall, the number of individuals per minute found in Zone IV was almost three times the number found per minute in Zone II.

A pattern emerged which shows a relationship between reptiles observed per minute and temperature. The number of reptiles per minute was generally greater with increasing temperatures in Zone IV. This was not the case in Zone II. Zone II showed a decrease in reptiles as temperatures increased.

It appears to us that reptiles in Zone IV could remain active during higher temperatures because of the dense shade created by the tamarisk thickets. Zone II offers relatively less shade for its inhabitants. It appears that at some crucial temperature, reptile activity decreases in Zone II. Further investigation is needed in order to determine what this temperature might be. One beach would have to be selected which could be measured throughout the day. Using one beach instead of many would eliminate some of the variables, such as differing amounts of shade available from beach to beach.

It was also observed that the fringe areas of tamarisk thickets were much more productive than the middle of the tamarisk thicket. Our observations indicate that thin bands of tamarisk are more productive per given area than are thick bands of tamarisk. Further study would be necessary to substantiate this observation and determine what thickness of tamarisk growth is optimum.

One question arose from this study as to whether or not the density of reptiles in the Zone I area just above Zone II is as high as in a comparable distance from the river. It would be interesting to look into this question further.

Next year we recommend that ground temperature also be taken. It appears to us that ground temperature is as at least as important as ambient temperature in determining reptile habitat. Also, some notation on the data collecting forms indicating whether the reptile was located in the shade or sun may provide useful information. We observed that reptiles were often not far from the shade line.

Figure 1

Pre-dam

ZONE 1--Typical Vegetation (Desert), Uninfluenced by River Regime (Stable Community)

ZONE 2--High Flood Zone Woody Vegetation <u>Prosopis</u>, <u>Acacia</u>, <u>Cercis</u>, <u>Celtis</u> (Stable Community)

ZONE 3--Ephemeral Plant Zone, Periodically Scoured (Unstable Community)

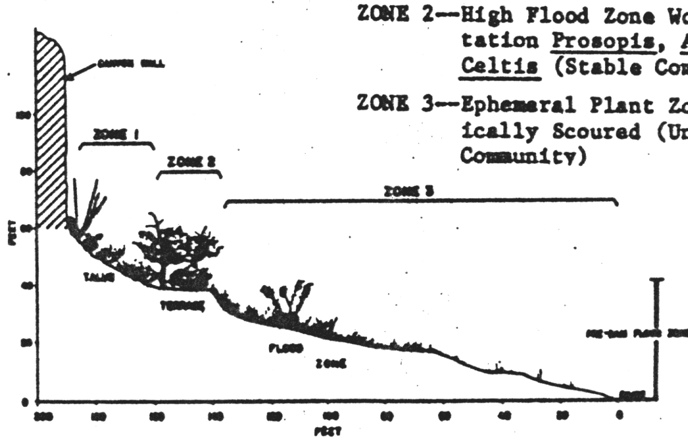


Figure 12A. A profile of the vegetative zones of the Colorado River floodplain in the Grand Canyon prior to the construction of Glen Canyon Dam. After Carothers et al. 1979.

ZONE 1--Typical Vegetation (Desert) Uninfluenced by River Regime (Stable Community)

ZONE 2--High Flood Zone Woody Vegetation <u>Prosopis</u>, <u>Acacia</u>, <u>Cercis</u>, <u>Celtis</u> (Stable Community)

ZONE 3--Zone of Short Lived Invasion Species <u>Alhagi</u>, <u>Salsola</u>, <u>Descurainia</u>, <u>Bromus</u>, <u>Festuca</u> (Unstable Community)

ZONE 4--New Riparian Zone - <u>Tamarix</u>, <u>Salix</u>, <u>Pluchea</u>, <u>Baccharis</u> (Rapid Proliferation)

Post-dam

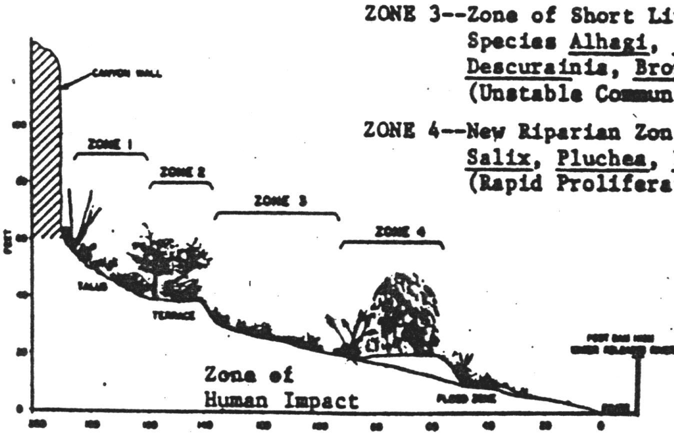


Figure 12B. A profile of the vegetative zones of the Colorado River floodplain in the Grand Canyon 13 years after the impoundment of Colorado River waters by Glen Canyon Dam. After Carothers et al. 1979.

Figure 2

REPTILE PROJECT DATA SHEET - AUGUST 1986

OBSERVER________________ BEACH NAME (RIVER MILE)_______________

DATE____________ TIME START________TIME STOP_______

AMBIENT TEMPERATURE___________ LAPSED TIME_________

VEGETATION ZONE				SPECIES REPTILE								SPECIES VEGETATION							
1	2	3	4	1	2	3	4	5	6	7		1	2	3	4	5	6	7	8

Total Number
Percent
TOTAL INDIVIDUALS PER MINUTE __________

KEY TO ZONES
1 - desert vegetation
2 - Old High Water Line
3 - Zone of Human Impact
4 - New High Water Line

KEY TO REPTILES
1 - side blotched lizard
2 - desert spiny lizard
3 - western whiptail
4 - tree lizard
5 - __________
6 - __________
7 - __________

KEY TO VEGETATION
1. tamarisk
2. seep willow
3. willow
4. arrowweed
5. mesquite
6. acacia
7. desert scrub
8. __________

Table 1. Number and percentage of reptiles by zones found in different vegetative types.

	Zone I		Zone II		Zone III		Zone IV		All Zones	
	Number Observed	%	Number Observed	%	Number Observed	%	Number Observed	%	Number Observed	%
Tamarisk	0	0	5	6	0	0	133	48.4	138	34.7
Desert Broom	0	0	4	5	0	0	6	2.2	10	2.5
Seep Willow	0	0	0	0	0	0	1	.4	1	.3
Willow	0	0	0	0	0	0	23	804	23	5.8
Arrow Weed	0	0	0	0	0	0	6	2.2	6	1.5
Beach Grass	0	0	2	2	0	0	7	2.5	9	2.3
Acacia	0	0	26	30	0	0	0	0	26	6.5
Mesquite	0	0	17	19	0	0	0	0	17	4.3
Desert Scrub	0	0	3	3	0	0	0	0	3	.8
Prickly Pear	3	23	0	0	0	0	0	0	3	.8
Rock	10	77	28	32	21	95	79	28.7	138	34.7
Sand	0	0	3	3	1	5	20	7.3	24	6.0
Total	13	100	88	100	22	100	275	100	398	100

Figure 3

Use of Vegetation Species by Reptiles, Colorado River
Rocks and Sand

All Zones
by percentage

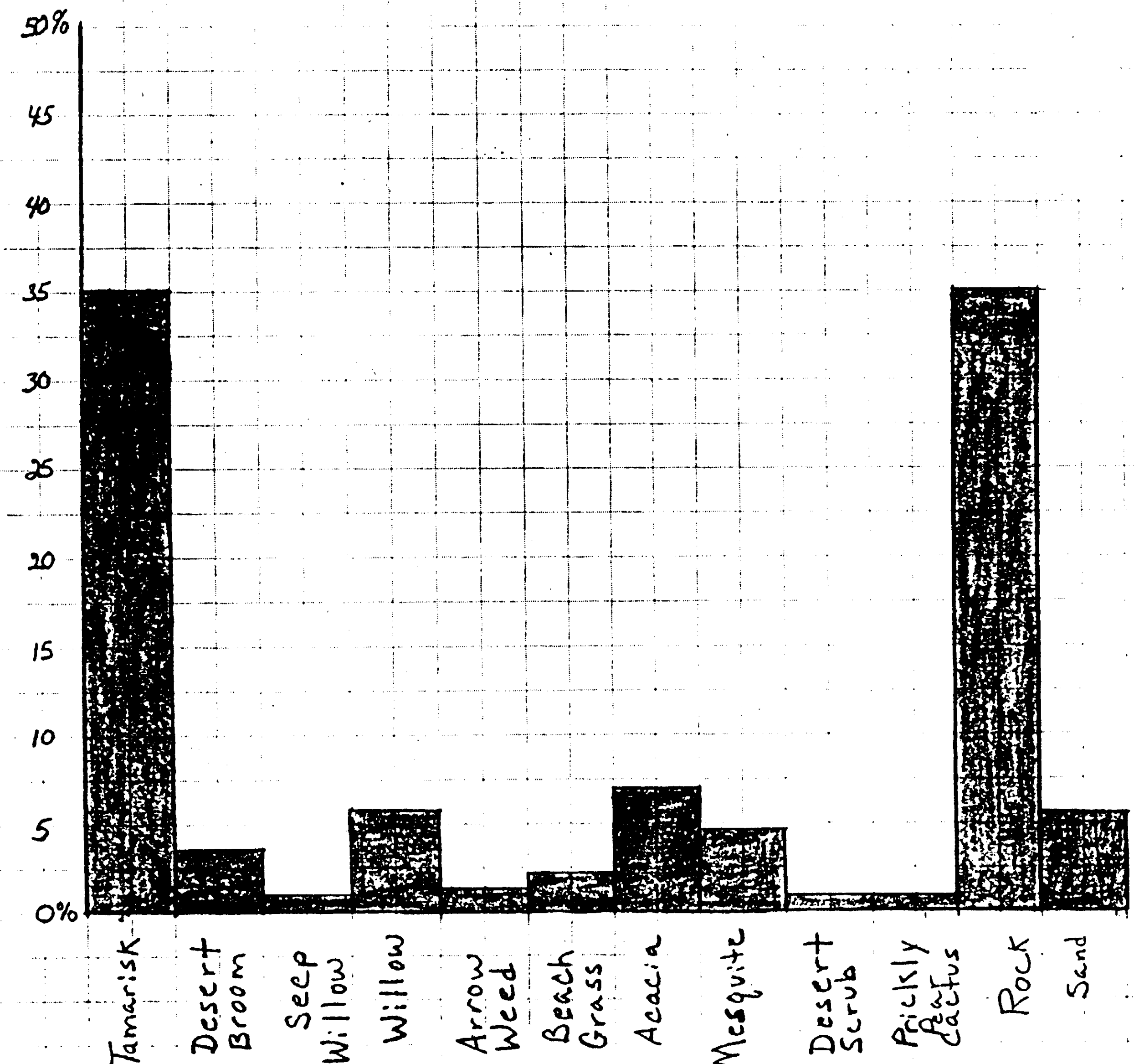


Figure 4

Use of Vegetation Rocks and Sand Species by Reptiles, Colorado River

Zone 2

by percentage

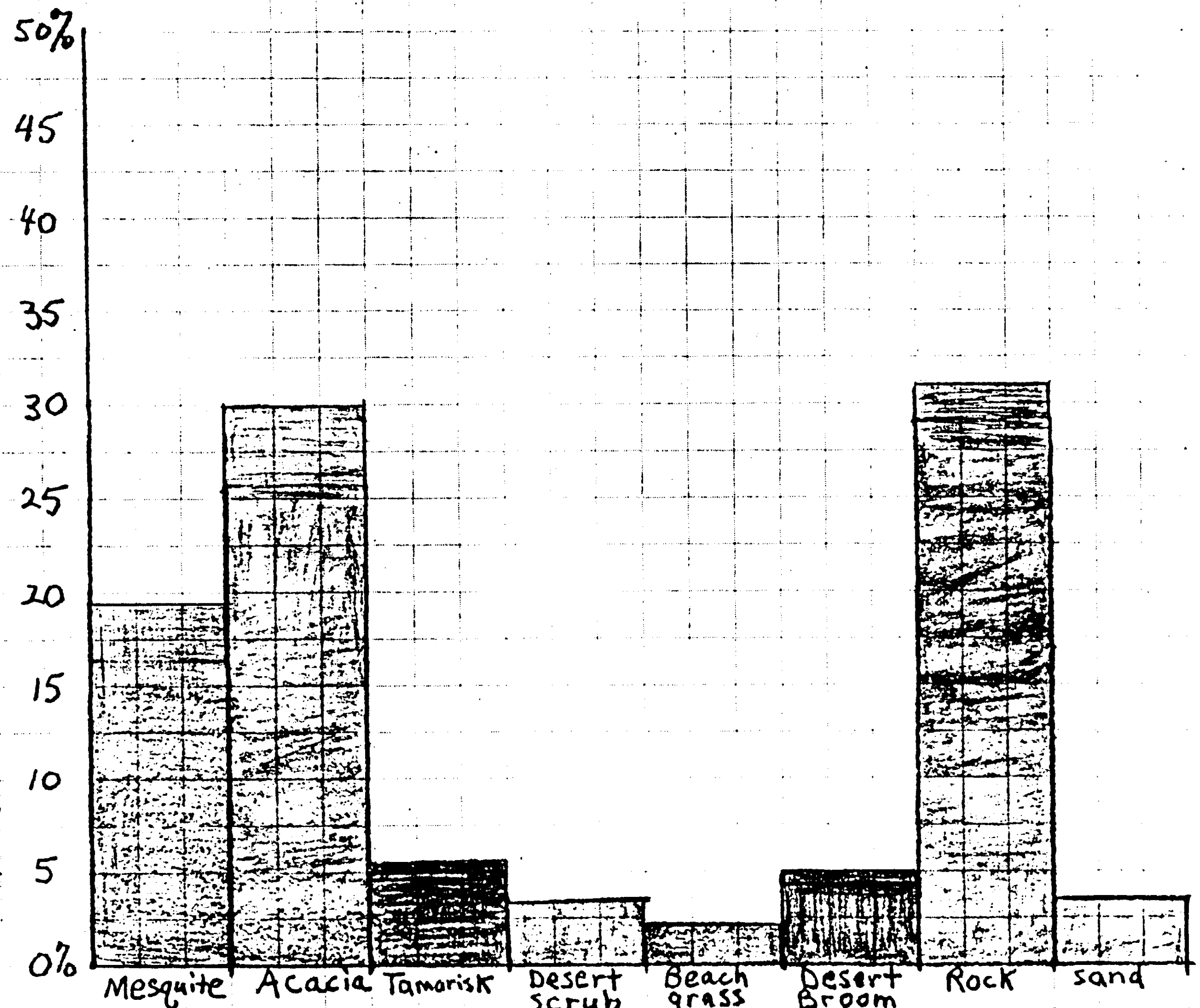
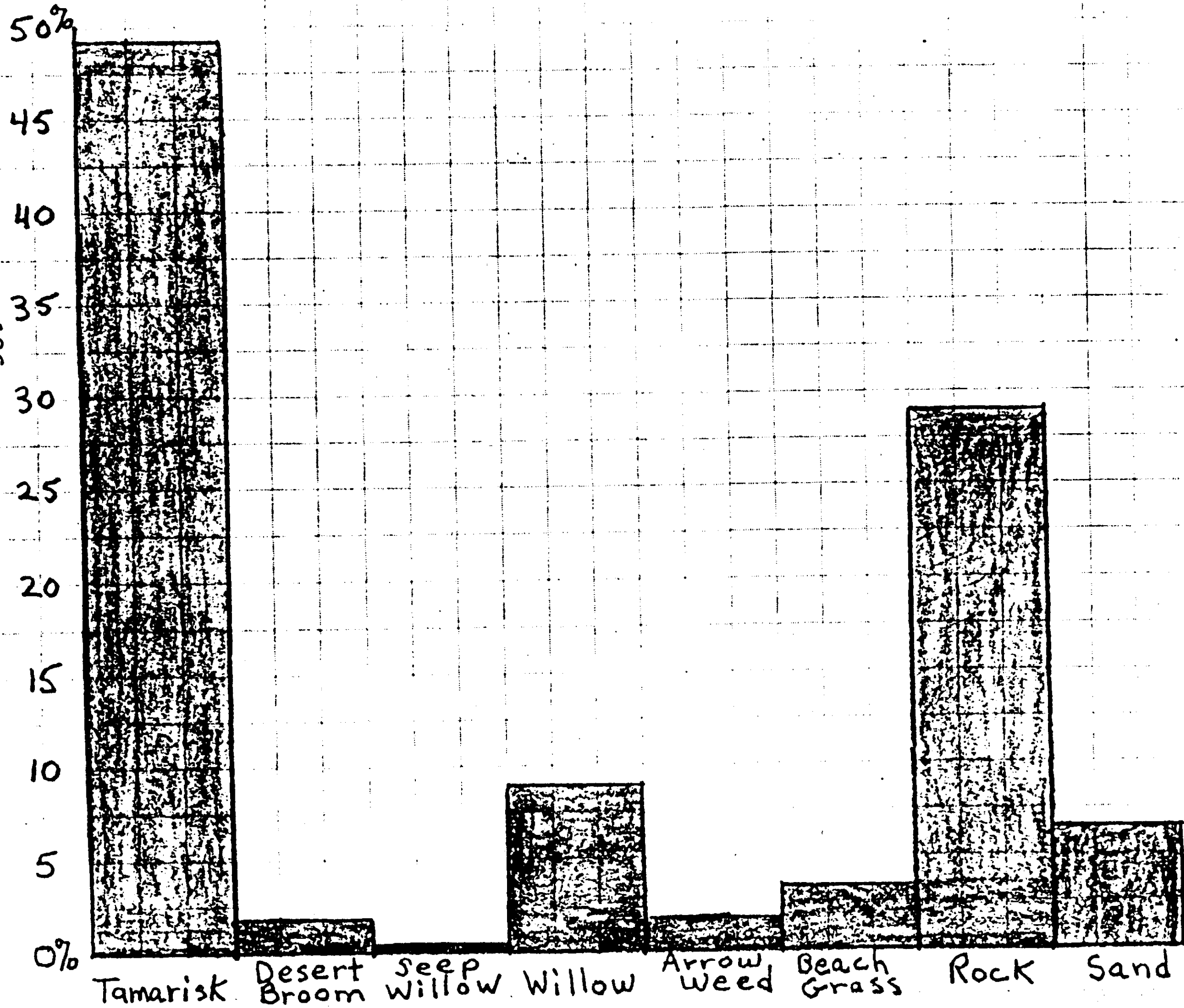


Figure 5

Use of Vegetation Species by Reptiles, Colorado River
Rocks and Sand

Zone 4
by percentage



Figure

Table 2. Number of individuals per minute of reptile types found in each zone.

	Zone I		Zone II		Zone III		Zone IV	
	Number of Individ.	Individ/ Minute	Number of Individ.	Individ/ Minute	Number of Individ.	Individ/ Minute	Number of Individ.	Individ/ Minute
Side-Blotched	7	.10	29	.06	0	.00	81	.17
Desert Spiny	1	.01	11	.02	2	.07	40	.08
Western Whiptail	0	.00	12	.03	2	.07	75	.15
Tree	5	.07	31	.07	18	.67	63	.13
Others	0	.00	5	.01	0	.00	16	.03
Total	13	.18	88	.19	22	.81	275	.56
Observation Time/Zone (minutes)		71		459		27		487

Figure 6

Relative Density of Reptiles (Individuals per Minute) In Two Zones

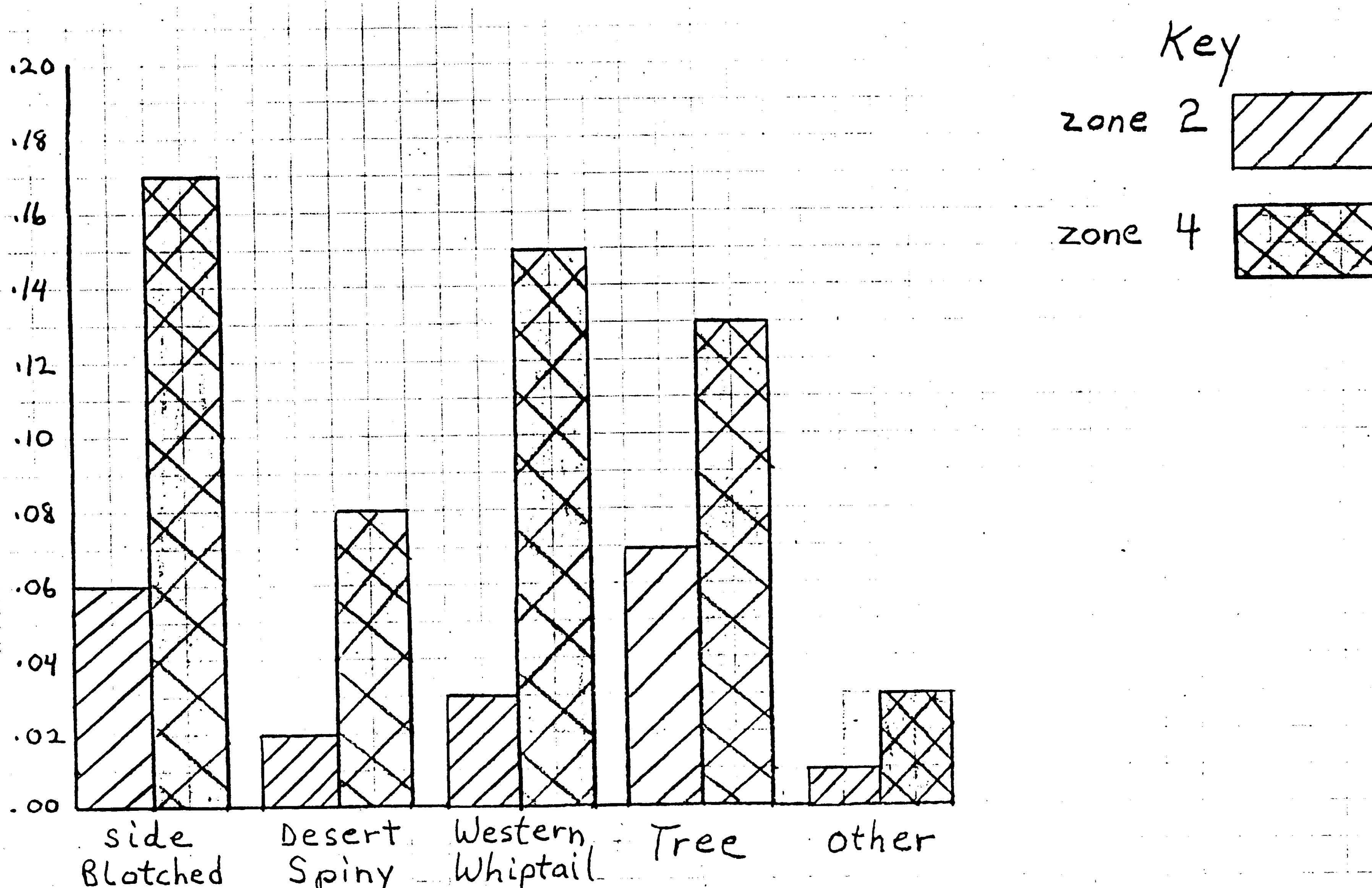


Figure 7

Relative Density of Reptiles (Individuals per Minute)
In ~~All~~ Zones 2 & 4

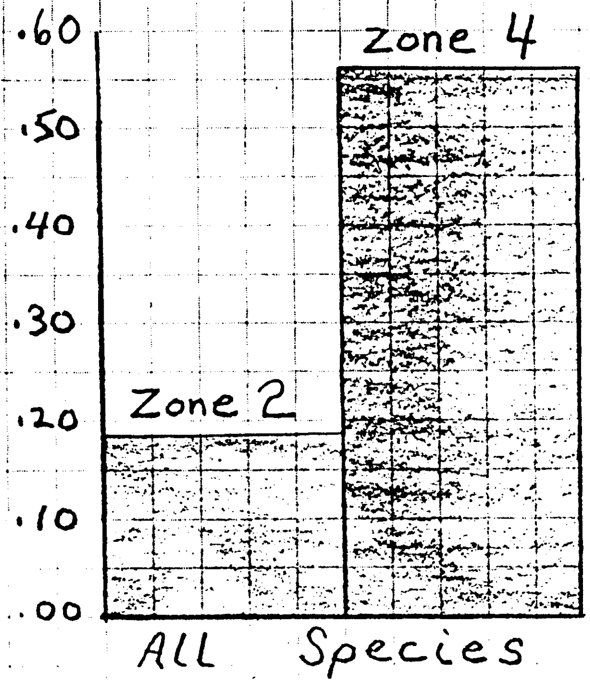
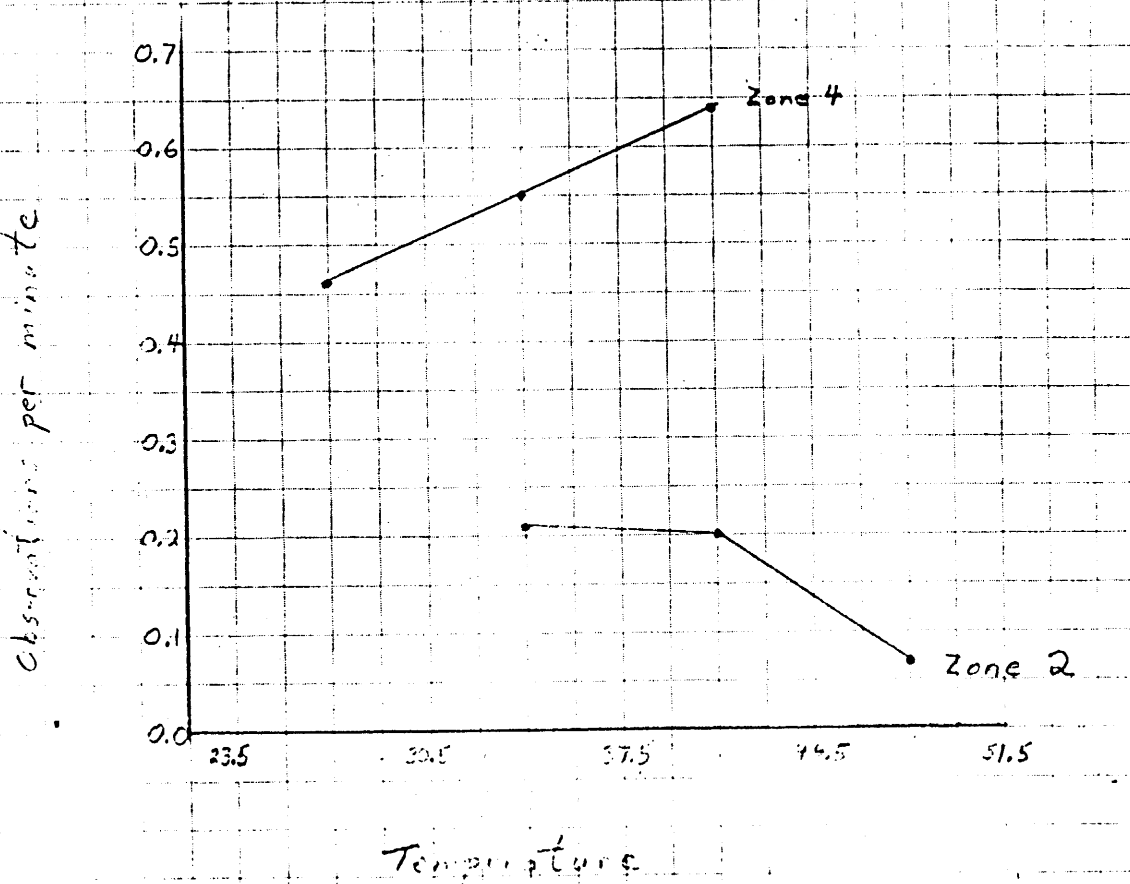


Figure 8

Observations per minute in zones 2 and 4 as a function of temperature.



Freq.	Observations per minute Zone 2	Observations per minute Zone 4
24 – 30	—	.46 (2)
30 – 37	.21 (3)	.55 (3)
37 – 44	.20 (14)	.64 (14)
44 – 51	.07 (2)	—

( ) - [illegible]