Fish Populations in Bendway Weir Fields, Results of the November 1996 Hydroacoustic Surveys Performed on the Middle Mississippi River

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Executive Summary

Hydroacoustic surveys for fish were performed on four bends in the Middle Mississippi River in November 1996. Three of the bends have bendway weir fields installed. The fourth bend is without weirs. This is the third consecutive year surveys have been performed on weir fields in the Middle Mississippi River. This study is consistent with the previous studies showing a continued increased presence of fish in the weir fields compared with the bend without weirs.

Overall numbers of observed fish targets are down compared to the 1994 and 1996 studies. This may be due in part to the higher river stages during the 1996 survey. Densities in the bends with weirs averaged 13 times greater than the bend without weirs. Analysis of fish distribution within the bends with weirs shows a greater use of the weir fields by fish compared with other parts of the channel. While there has been a reduction in the extent of the point bars on the interior of the bends, the overall stage-surface area characteristics of the bends with weirs have not been altered significantly from the stage-surface area relationship of the bend studied without weirs.

The changes in channel morphology concentrate a more diverse bottom structure and hydraulic response within the weir fields than what is typically present in the unaltered bend surveyed. This diverse environment appears to attract an increase in numbers of fish and is likely to attract more diverse species capable of utilizing the altered habitat.

Introduction

The U. S. Army Corps of Engineers, St. Louis District, has been installing bendway weir navigation structures in the Middle Mississippi since 1989. The weirs have a pronounced impact on the river morphology and the hydraulics in the bend. These changes in morphology and hydraulics also affect fish populations. This report evaluates the results of hydroacoustic surveys for fish performed November 4, 5 and 6, 1996, on four bends on the Middle Mississippi River and relates the detected fish to the morphologic characteristics of the bends. The results are also compared to two previous studies prepared by the Corps of Engineers.

Study Area

Four bends on the Middle Mississippi river between river mile (RM) 22 and RM 50 (measured upstream from the confluence with the Ohio River) were used in this study and are shown in Figure 1. Dogtooth Bend, Price Towhead and Cape Bend have weir fields installed, and Goose Island Bend is without weirs. Table 1 lists the study reaches in terms of river mile, number of weirs installed, the approximate bend radius and the average depth through the bend. The bend radius was taken at the channel centerline at the sharpest degree of curvature.

Table1. Bend Characteristics.

Reach Name	River Mile, RM	Number of Weirs	Approximate Bend Radius, m (ft)	Average Depth, m (ft)
Cape Bend	48.6 - 49.7	13	2,350 (7,700)	8.4 (27.6)
Dogtooth Bend	22.4 - 24.2	13	1,450 (4,750)	10.1 (33.1)
Goose Island Bend	33 - 35	None	3,750 (12,300)	4.8 (15.9)
Price Towhead	29.6 - 30.6	9	1,525 (5,000)	9.8 (32.0)

Figure 1. Location Map

The bathymetry of each bend is shown in Figures 2-5. The bend without weirs, Goose Island bend, has the least curvature and smallest average depth. The thalweg (deepest part of the channel) is near the outside of the bend. Dramatic changes in the morphology of a bend have been induced by the construction of bendway weirs. In the bends with weirs, the thalweg has moved out into the center of the channel at the ends of the weirs and deposition has occurred along the outer bank along the weirs. There has also been a reduction in the point bar that was formed on the inside of the bend. Figure 6 is a longitudinal profile through Goose Island bend (without weirs) and Figure 7 is a profile through the weir field in Cape Bend. The natural bend is characterized by relatively gentle changes in grade along the profile while the bend with weirs has a greater variation in depth because of the scour and deposition near the weirs. Given the localized changes in the bends with weirs the overall bend depth versus area relationship appears to be relatively unaffected. Figure 8 shows the depth versus surface area for each bend. The plotted lines are of similar slope, being offset only by depth. Varying depths in the bends are the result of radius of curvature, bed geometry and composition, and other local conditions.

Hydroacoustic Sampling

Sampling was performed using a Biosonics Model DT5000 sounder with a 120-kHz dual beam 8.3 X 17 transducer. Target detection ranged from a depth of 1.5 m to within 0.2 m of the bottom. Latitude and longitude were recorded for each target using Global Positioning System data (GPS) from the on board navigation system. Each bend was surveyed by running transects parallel to flow. Transects ranged in length from 750 m (2460 ft) to 2750 m (9000 ft). Transects were run to cover both the weir fields and the channel outside the weirs. Transect data are shown in Table 2. Cape Bend was surveyed on November 4, Goose Island Bend and Price Towhead were surveyed on November 5, and Dogtooth Bend was surveyed on November 6, 1996. The corresponding river stages at Cape Girardeau (U.S. Geological Survey, provisional data) were 18.82, 19.42 and 18.47 respectively.

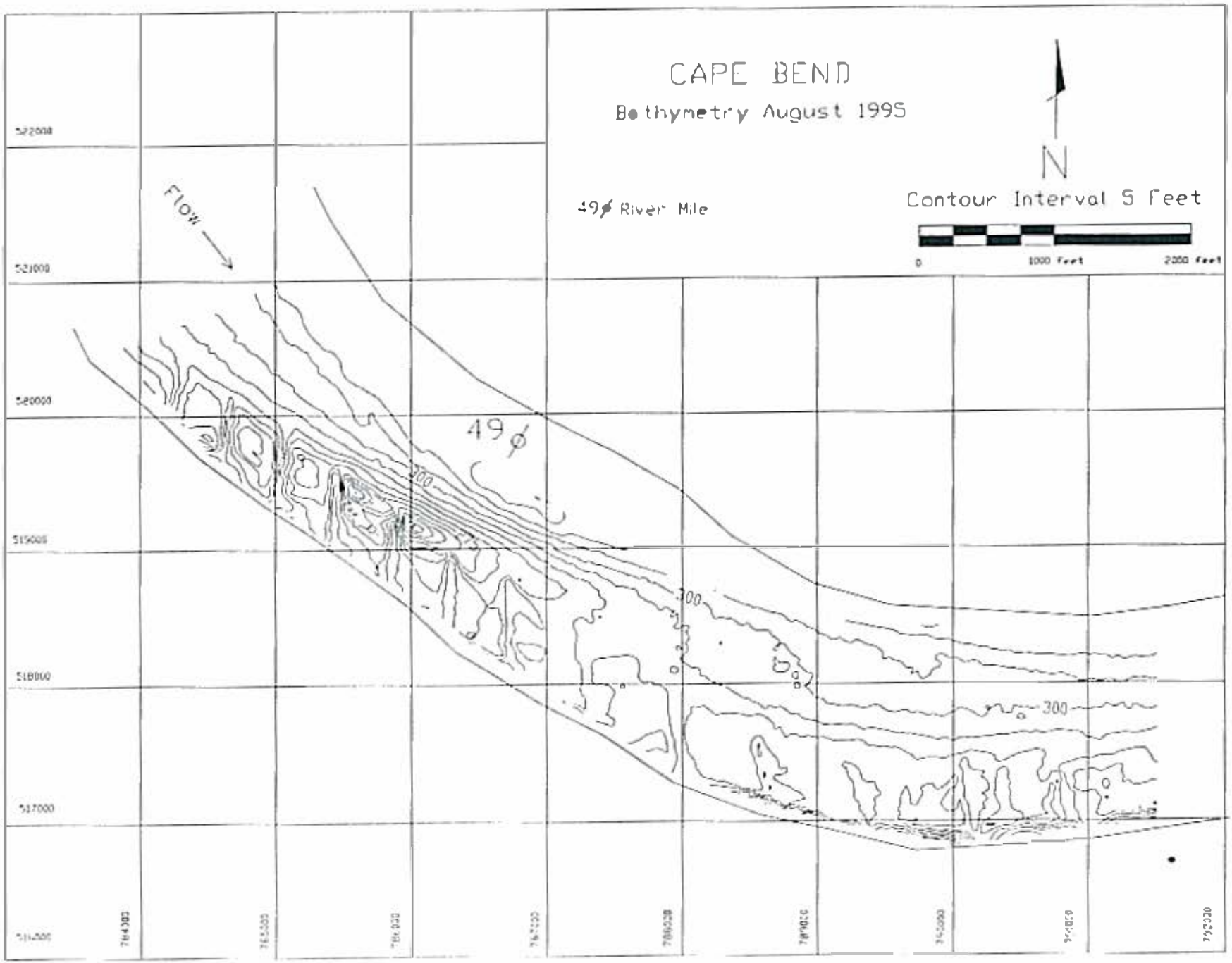

CAPE BEND
Bathymetry August 1995
N
Contour Interval 5 Feet
0
1000 Feet
2000 Feet
49¢ River Mile
Flow
49¢
300
300
300
522000
521000
520000
519000
518000
517000
516000

Figure 2

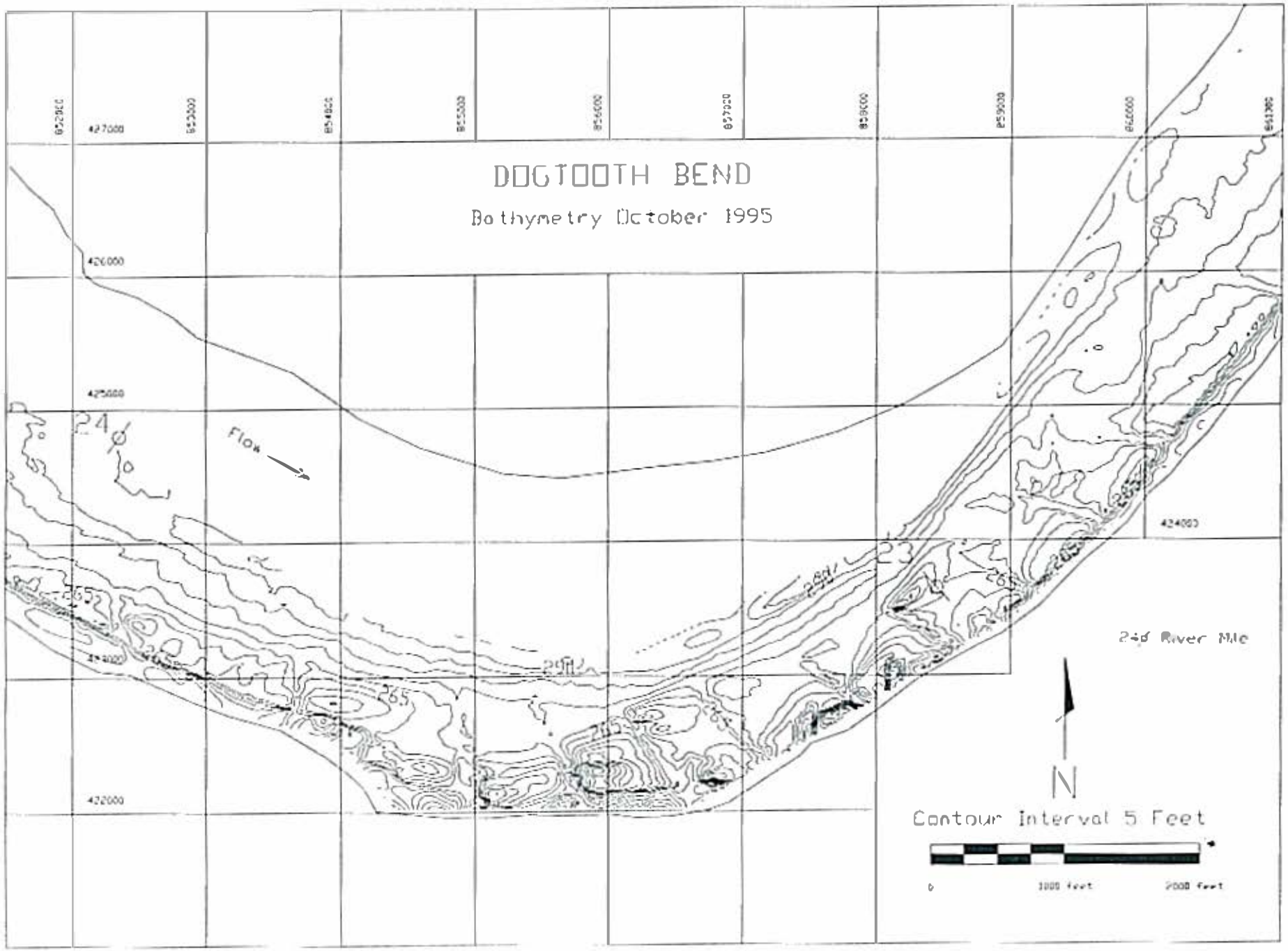

DOGTOOTH BEND
Bathymetry October 1995
Flow
24
25
26
Contour Interval 5 Feet
0
1000 feet
2000 feet

Figure 3

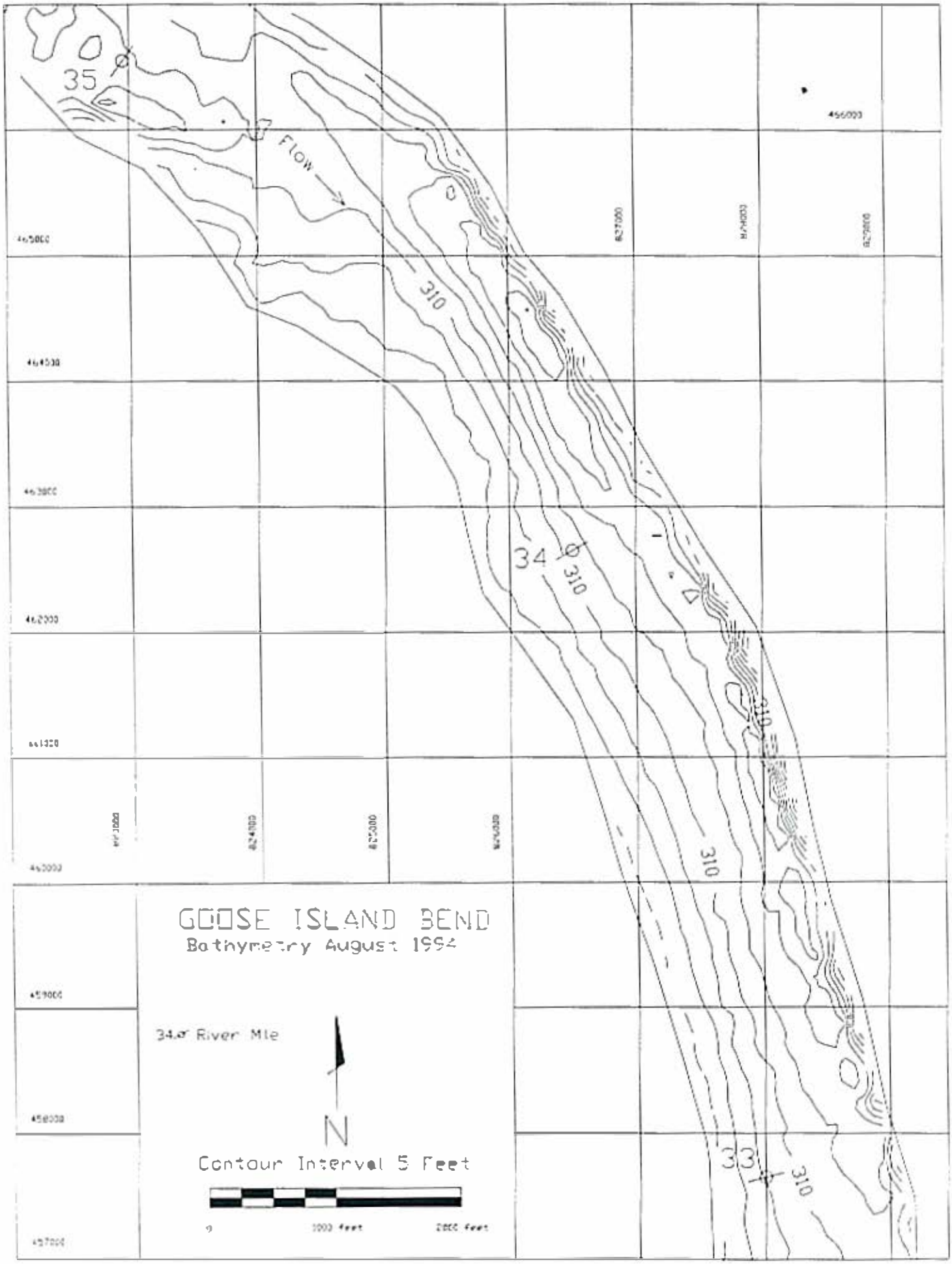

GOOSE ISLAND BEND
Bathymetry August 1994
34.0 River Mile
N
Contour Interval 5 Feet
Flow
35
34
33
310

Figure 4

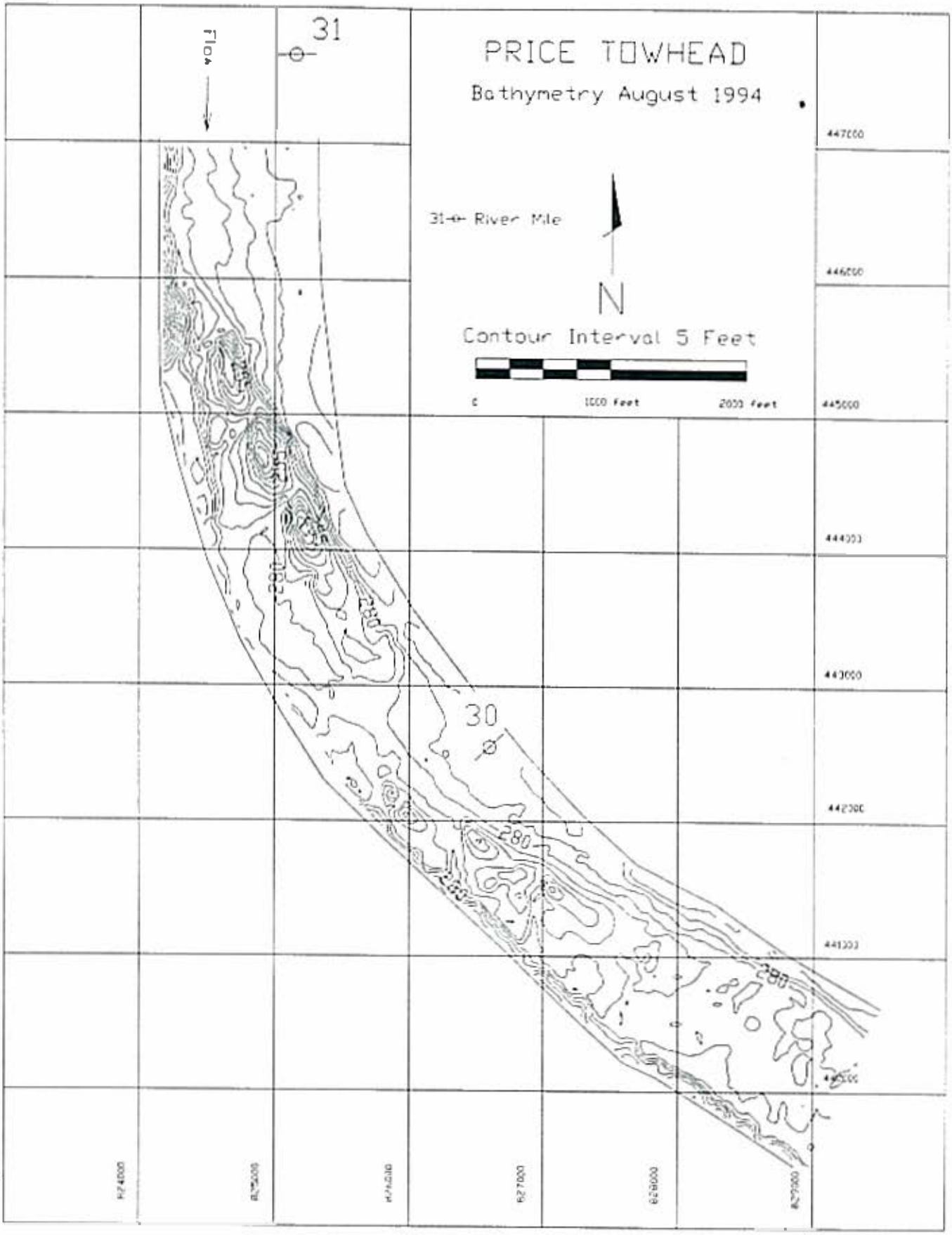

PRICE TOWHEAD
Bathymetry August 1994
31 River Mile
N
Contour Interval 5 Feet
0
1000 Feet
2000 Feet
Flow
31
30
447000
446000
445000
444000
443000
442000
441000
440000
280
280
280
280

Figure 5

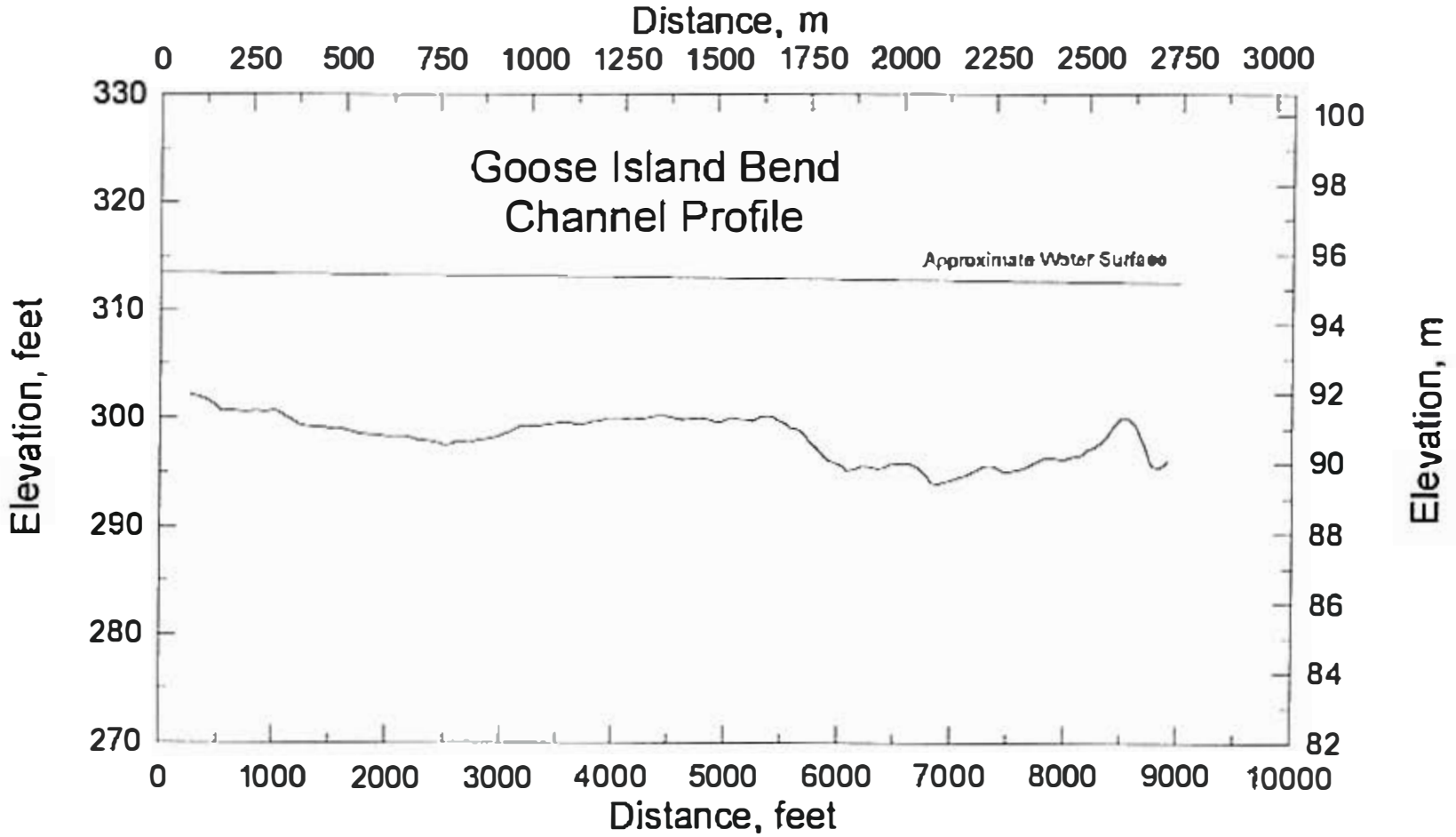


Figure 6. Goose Island Profile

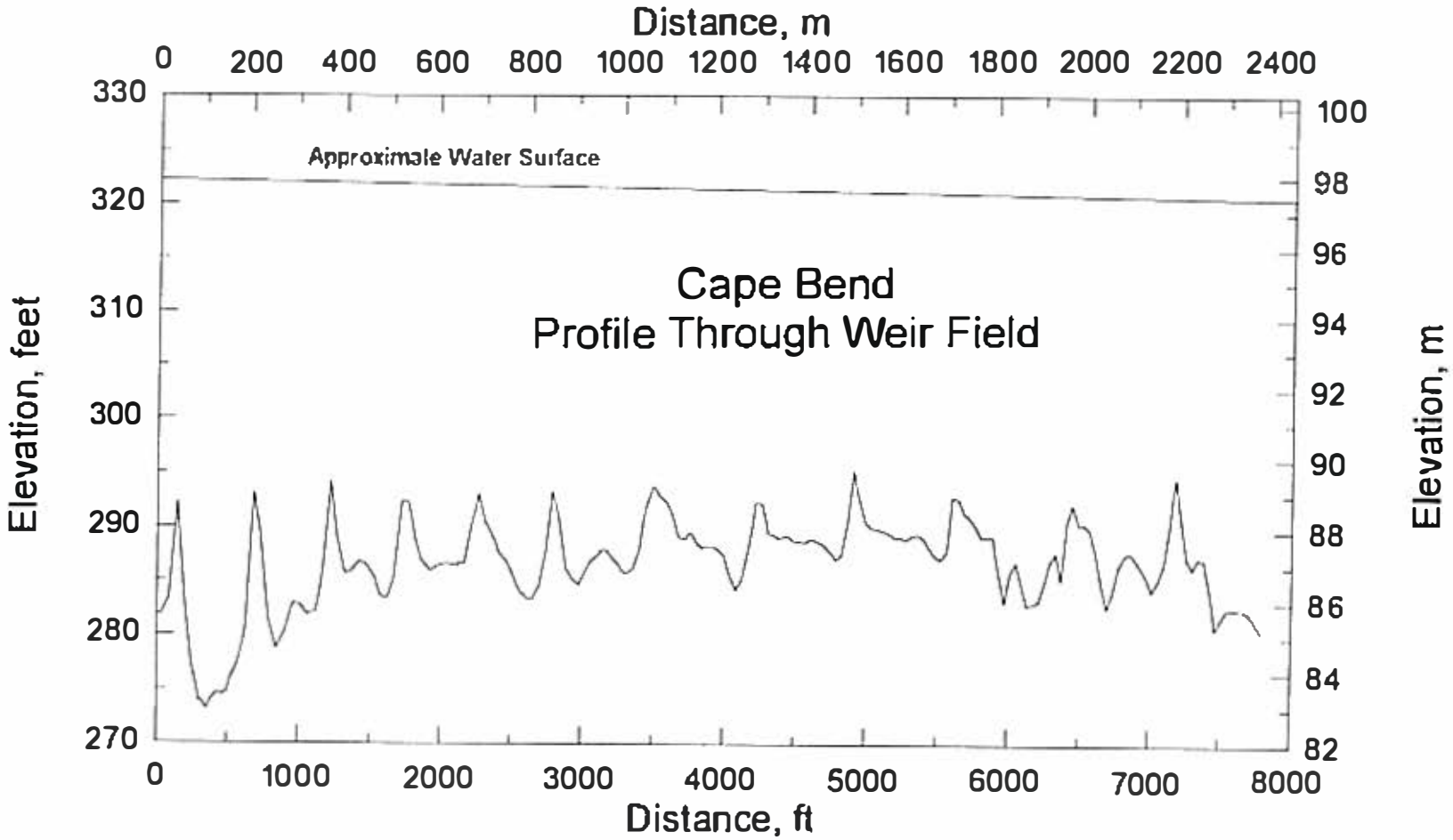


Figure 7. Cape Bend Profile

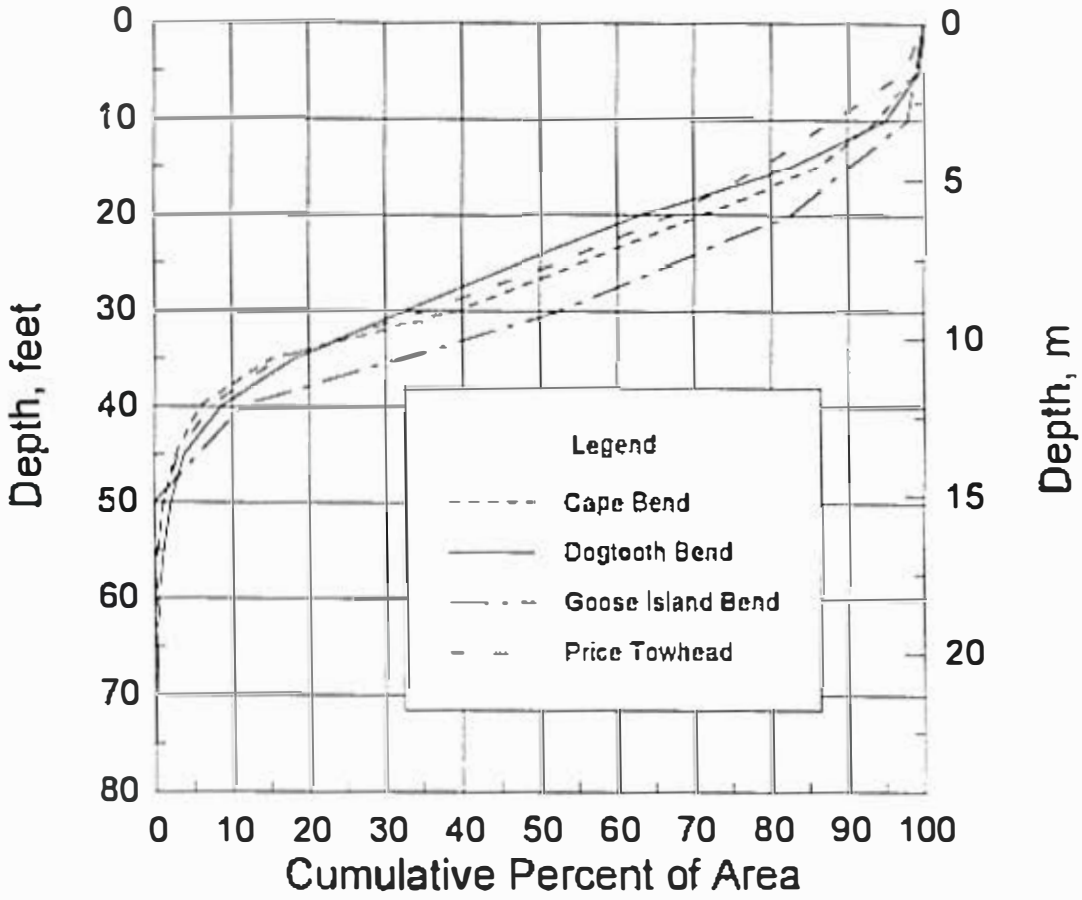


Figure 8. Stage - Area

Table 2. Transect Data.

Reach Name	Number of Transects	Approximate Transect Spacing
Cape Bend	7	50 m (165 ft)
Dogtooth Bend	8	50 m (165 ft)
Goose Island Bend	5	75 m (245 ft)
Price Towhead	6	50 m (165 ft)

A total of 45 echoes were detected for Goose Island Bend. For the bends with weirs, 75, 164 and 149 targets were detected for Cape Bend, Dogtooth Bend and Price Towhead, respectively. Figures 9-12 show the location of the detected targets relative to the weir fields.

Densities were computed based upon the number of targets per volume sampled extrapolated to the total bend volume and expressed at targets per unit area. The resulting densities are shown in Table 3, Mean Fish Density, below and in Figure 13. An analysis of variance shows n greater mean fish density in the bendways with weirs as compared with the bend without weirs ($p = 0.007$). The p-value is a measure of the probability that there is no difference in the mean values compared. A value of p smaller than α (where α =1- the level of significance for the test) indicates a probable difference in mean density. All statistical analyses for this report were performed at a 95% level of significance ($\alpha = 0.05$). Fish density in the bends with weirs averaged 13 times the density of fish in the bend studied without weirs.

Table 3. Mean Fish Density.

Reach Name	Mean Density, fish/ha (fish/ac)
Cape Bend	77 (31)
Dogtooth Bend	140 (57)
Goose Island Bend	9 (4)
Price Towhead	142 (57)

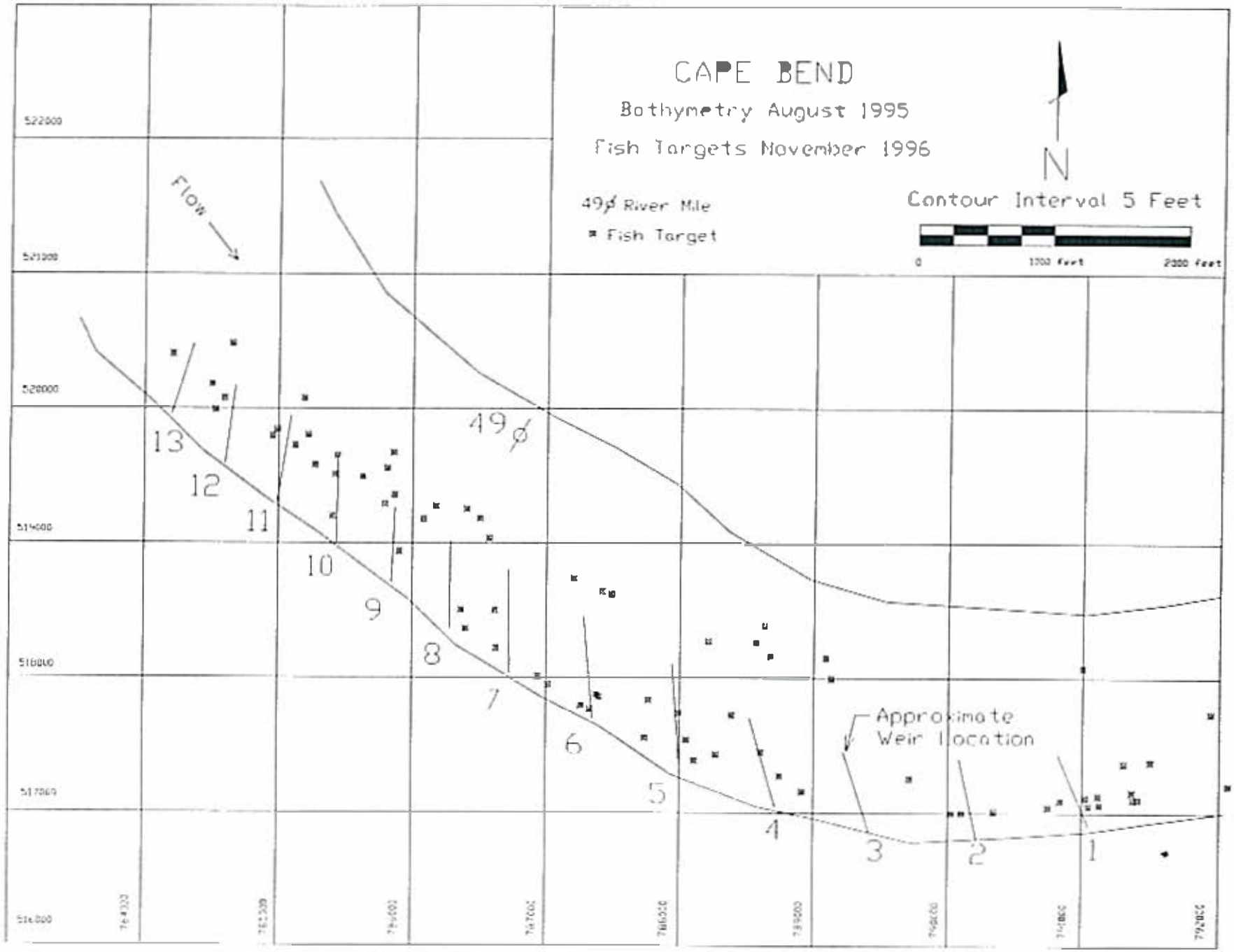

CAPE BEND
Bathymetry August 1995
Fish Targets November 1996
49ø River Mile
Fish Target
N
Contour Interval 5 Feet
0
1700 Feet
3400 Feet
Flow
522000
521200
520000
514000
516000
517000
516000
49ø
13
12
11
10
9
8
7
6
5
4
3
2
1
Approximate
Weir Location

Figure 9

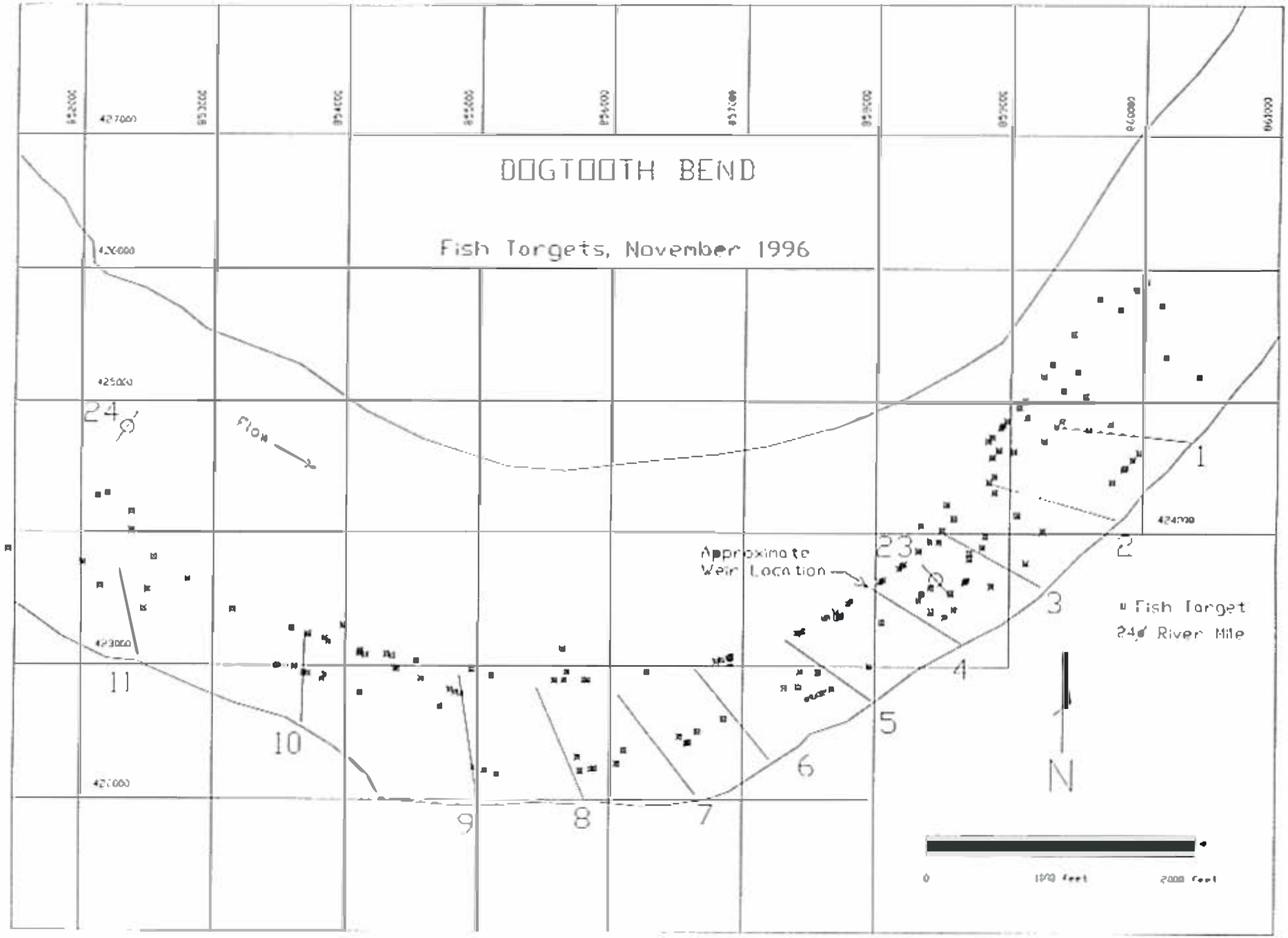

DOGTOOTH BEND
Fish Targets, November 1996
Flow
Approximate
Weir Location
Fish Target
24 River Mile
N
0
1000 feet
2000 feet

Figure 10

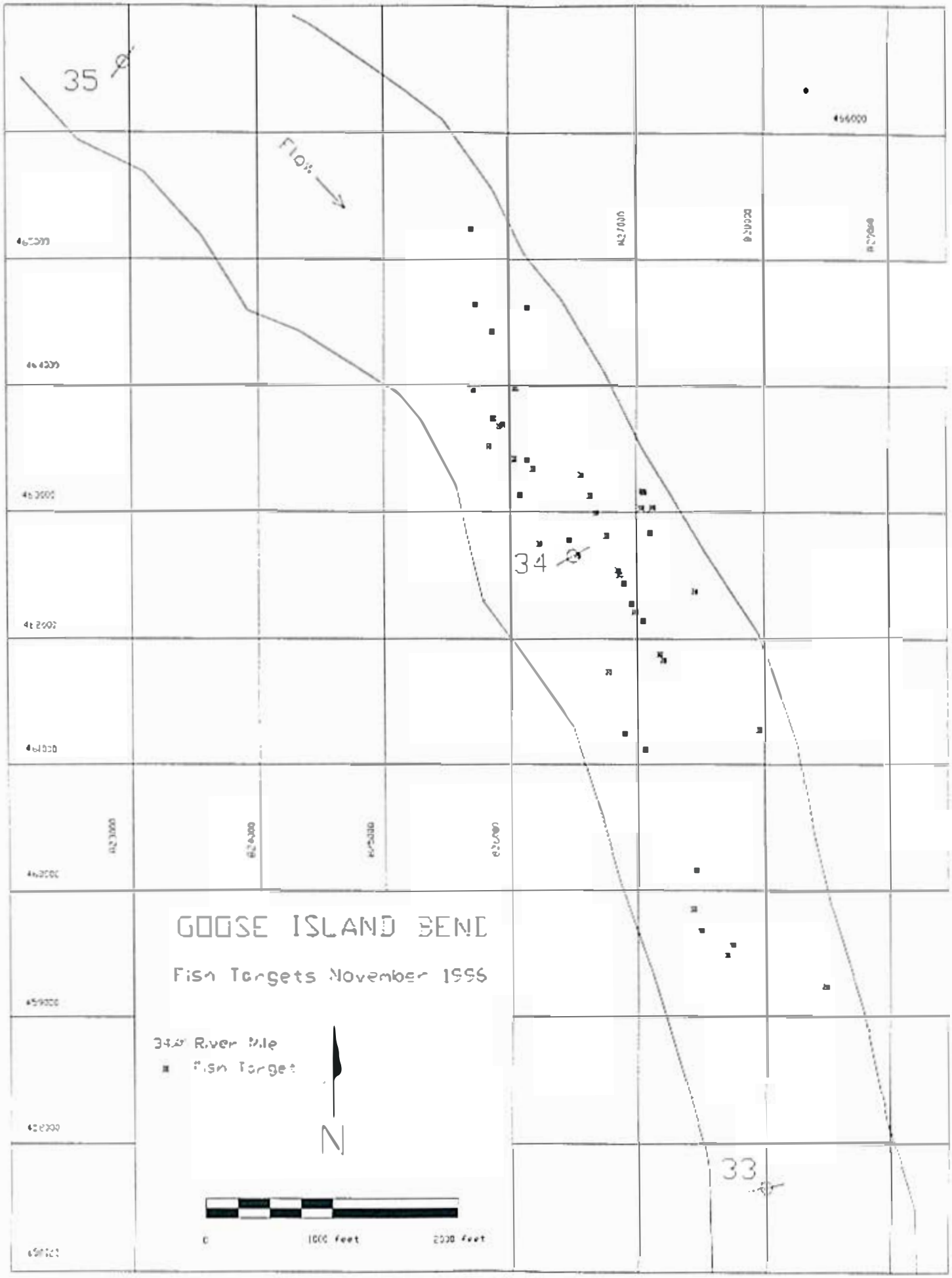

35
Flow
34
33
GOOSE ISLAND BEND
Fish Targets November 1996
River Mile
Fish Target
N
0
1000 feet
2000 feet

Figure 1:

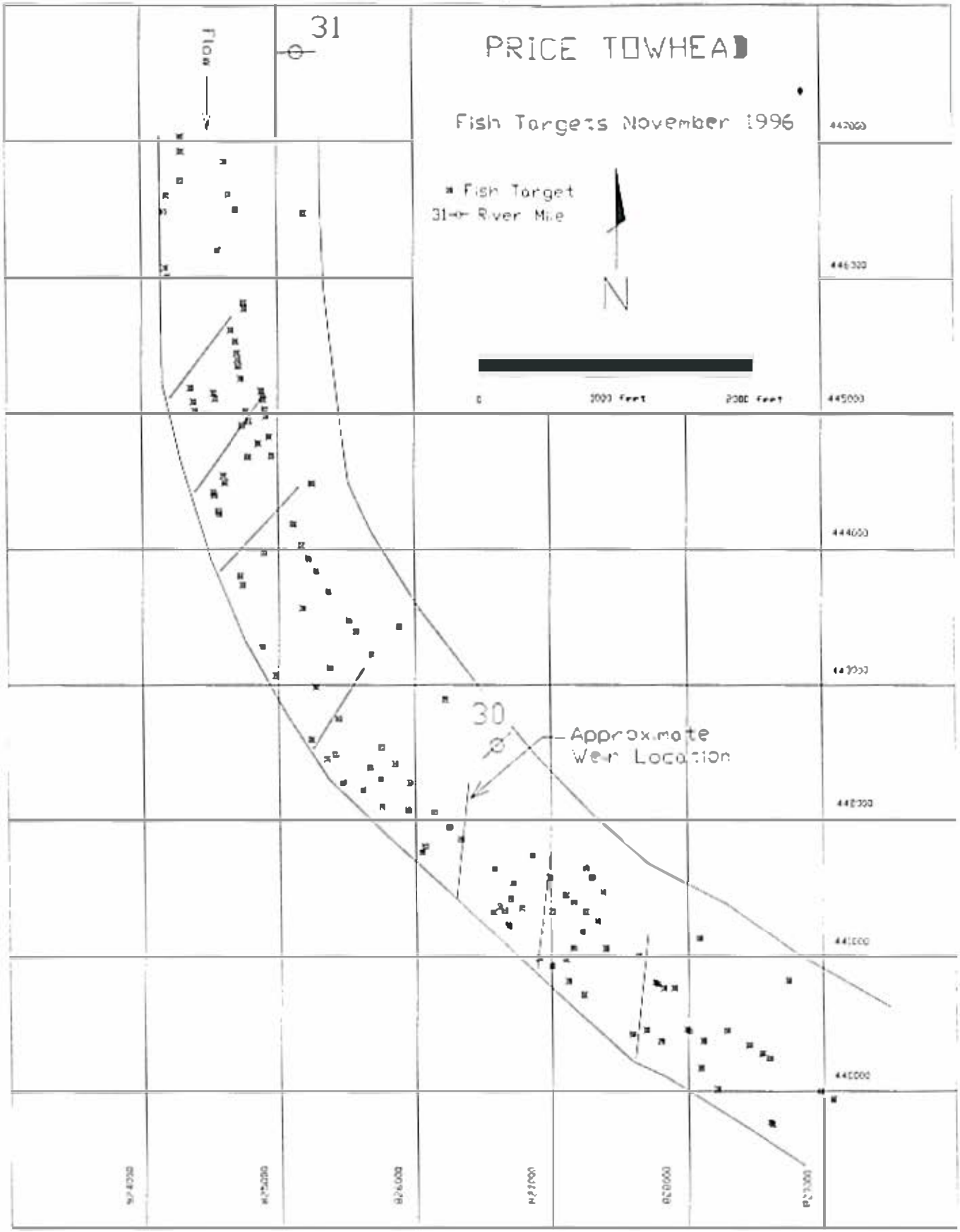

PRICE TOWHEAD
Fish Targets November 1996
* Fish Target
31-er River Mile
N
0
2000 Feet
31
30
Approximate
Weir Location

Figure 12

In the bends with weirs, the densities were computed for the area within the weir field (the region between the outside shore line and the ends of the weirs) and for the area outside the weir fields. The computed densities are given in the Table 4, Weir Field Densities.

Table 4. Weir Field Densities.

Reach Name	Mean Density, in weir field fish/ha (fish/ac)	Mean Density, outside of weir field fish/ha (fish/ac)
Cape Bend	85 (34)	70 (29)
Dogtooth Bend	146 (59)	139 (56)
Goose Island Bend	9 (4)*	9 (4)
Price Towhead	158 (64)	117 (47)

* Computed using an assumed section of channel that would include weirs if constructed.

An analysis of variance comparing the mean densities inside and outside of the weir fields shows no statistically significant difference in densities ($p=0.76$). Further analysis was conducted to determine if there were preferential locations within the weir field. Areas upstream and downstream of the weirs, shown in Figure 14, were analyzed and densities computed. There was no significant difference in mean densities based on upstream or downstream locations within the weir fields.

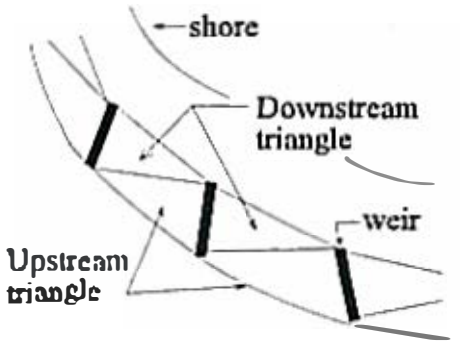


Figure 14. Upstream and Downstream Area Configurations.

Size Distribution

Echoes were detected from -54 decibels (dB) to -19.2 dB. This acoustic size was translated to fish length with Love's (1971) dorsal aspect equation.

$$TS = 19.1 \log(Length) + 0.91 \log(Frequency) - 23.9$$

The minimum sized used in this study was -48 dB, approximately 62 mm. The maximum length of a detected target was 2062 mm. The average length of the detected targets was 147 mm (143 mm if the 2062 mm target is treated as an outlier). The size distribution of fish targets in each bend is shown in Figure 15. The average length of fish detected in the weir fields was 144 mm. Fish targets outside of the weir field averaged 140 mm in length. For $\alpha = 0.05$, an analysis of variance yielded a p-value of 0.83 indicated no statistically significance in mean length. No pattern of location versus size could be determined from the data. Figure 16 shows target depth versus target size. The depth of fish targets in the weir field was compared to depth of targets out of the weir field and no statistically significant difference in mean depth was found, p-value = 0.06 for $\alpha = 0.05$.

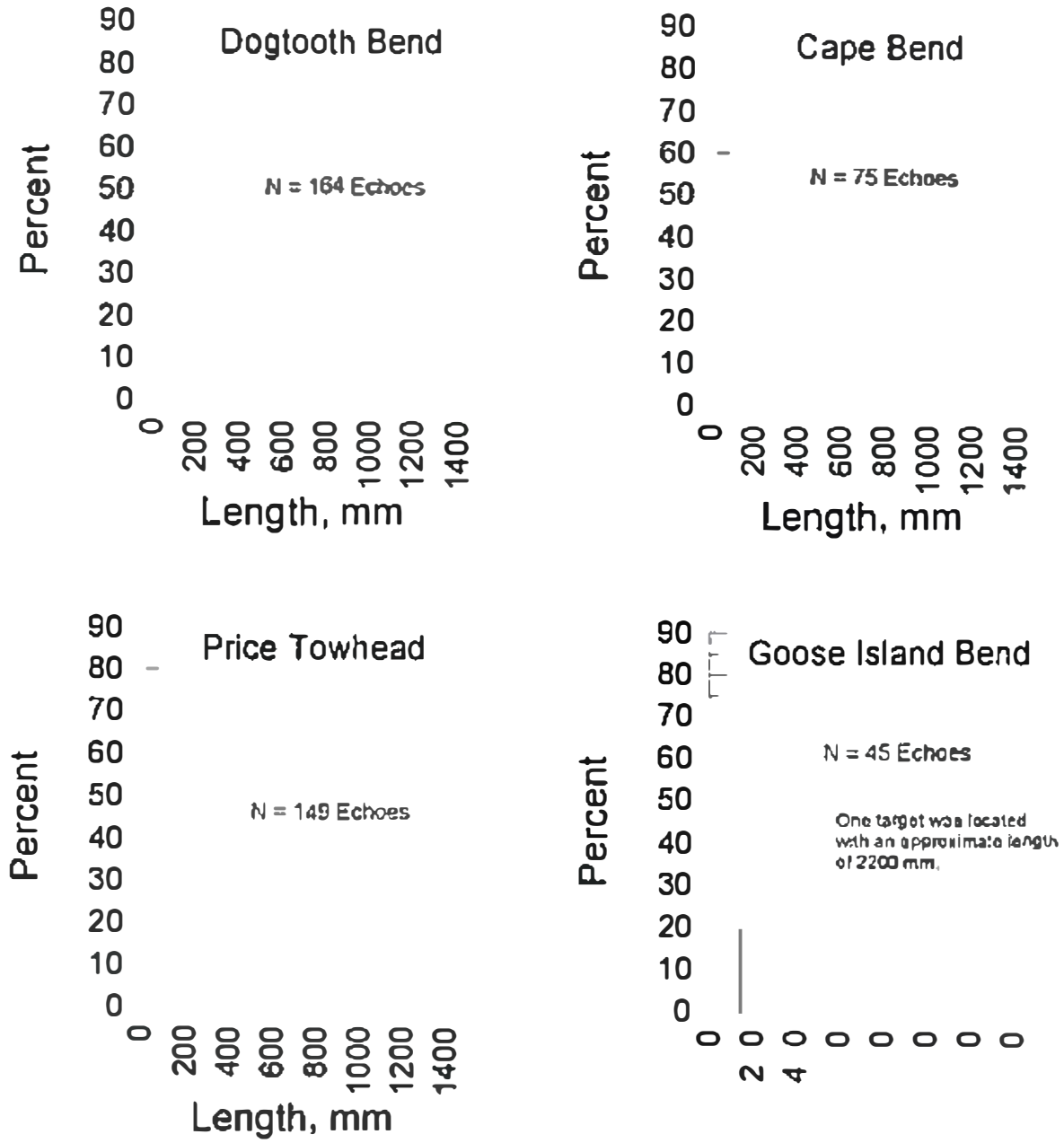


Figure 15. Fish Frequency

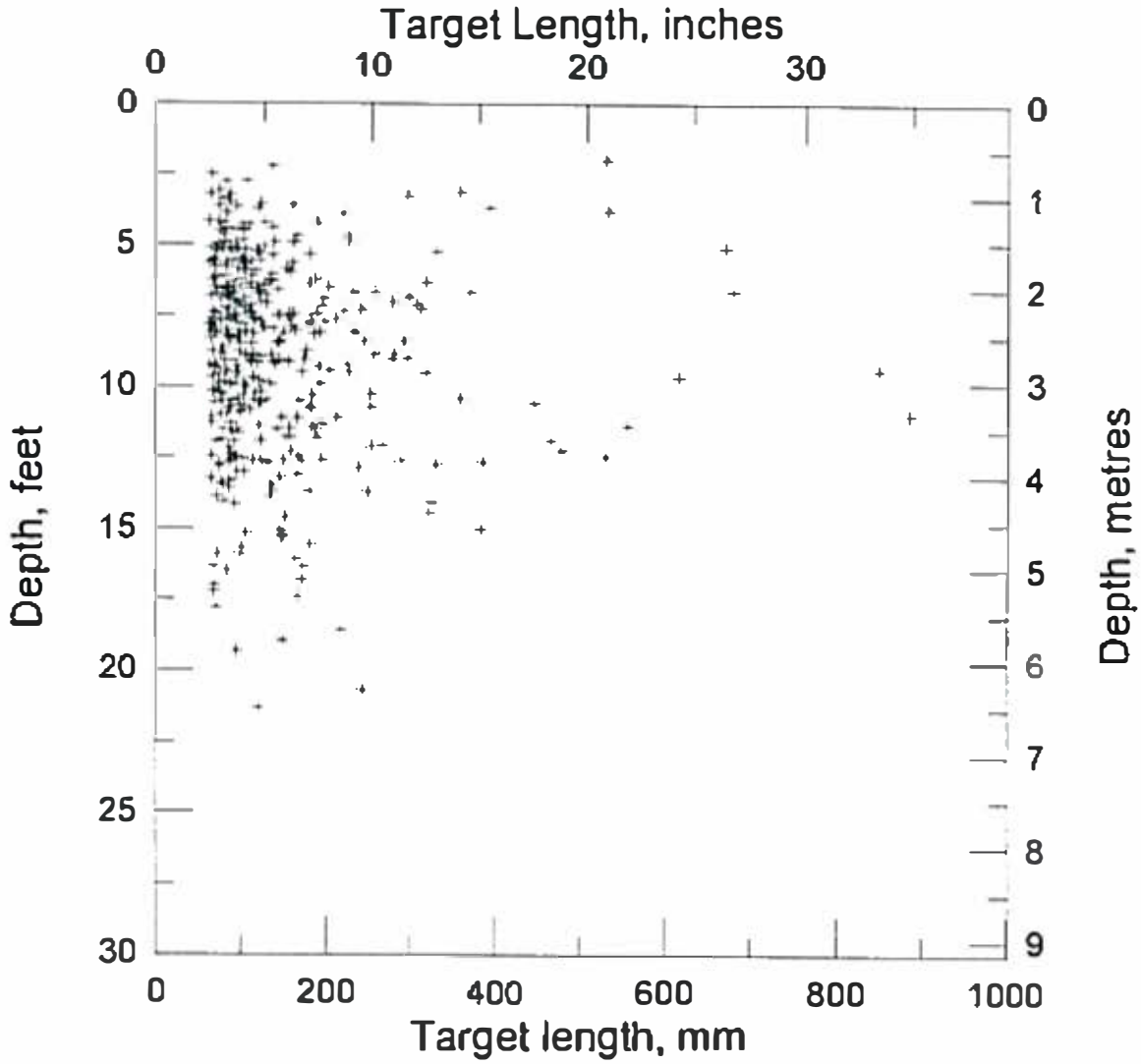


Figure 16. Target Size vs. Depth

Distribution Across the Channel

Figure 17 shows the distribution of fish across the channel as measured from the outside of the bend. In the bends with weirs, the largest number of targets occurred near the ends of the weirs, 200 m-300 m from shore. These areas typically have the greatest diversity in morphology and hydraulics. In Goose Island Bend, the majority of targets were located in the same range (200 m-400 m) across the section.

Comparison to Previous Studies

Previous investigations prepared by the Corps of Engineers show an increased presence of fish in bends with weirs compared with bends without weirs. The results of these previous investigations are given in the following reports:

Four Mississippi River, R. L. Kasul and J. A Baker, Environmental Laboratory, U.S.A.E. Waterways Experiment Station, May 12, 1995.

of September Hydroacoustic

Mississippi (RM2-50),

Laboratory, U.S.A.E. Waterways Experiment Station, May 28, 1996.

Table 5 compares the mean density from the three studies. All three studies show an increase in fish density in bends with weirs as compared to bends without weirs. The overall number of targets detected in 1996 was significantly lower than in the previous two years. The river stage was approximately three feet higher in 1996 than in 1994 or 1995. This may have had an impact on the number of fish detected.

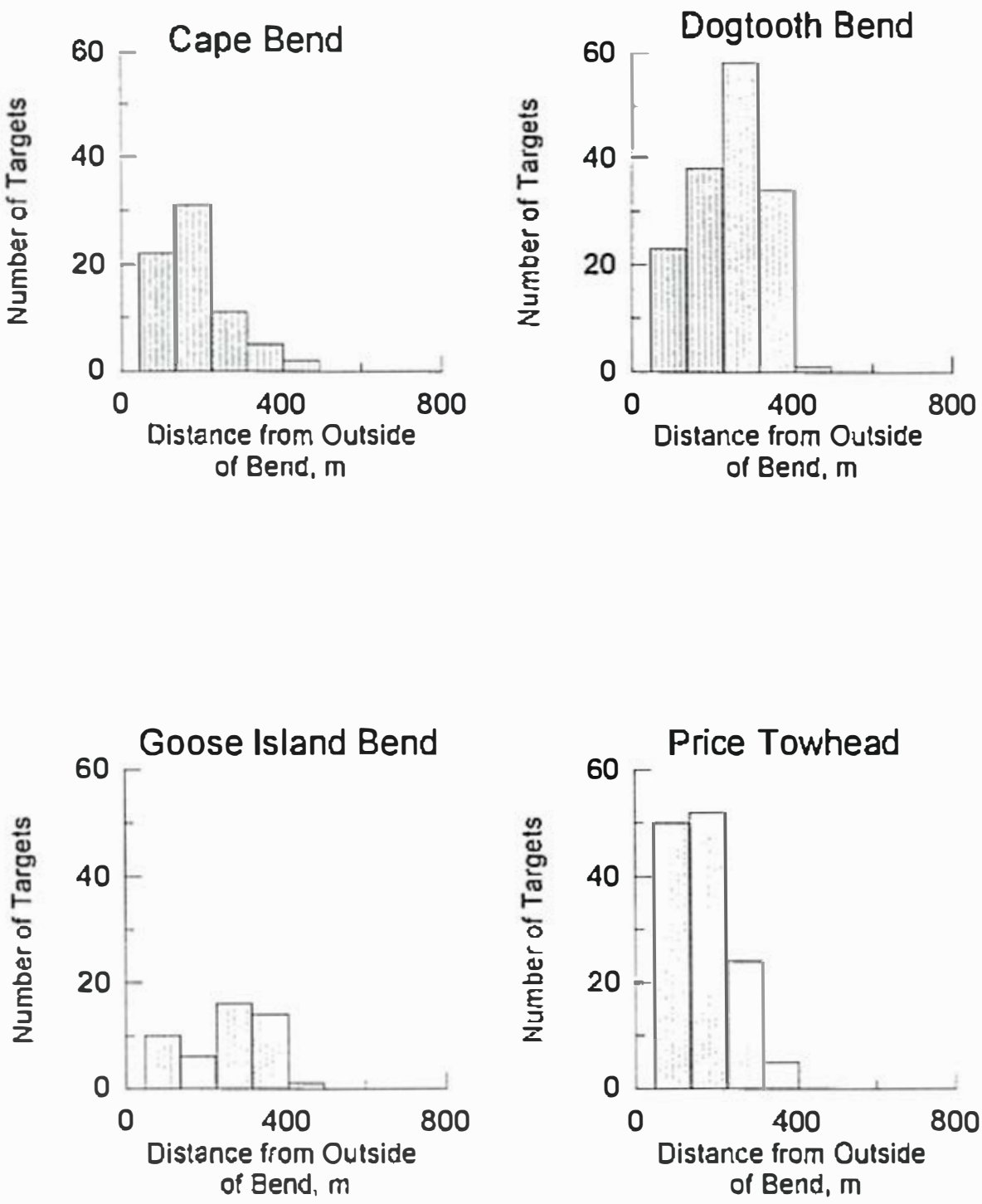


Figure 17. Fish Distribution Across the Channel

Table 5. Comparison of 1994, 1995 and 1996 Densities.

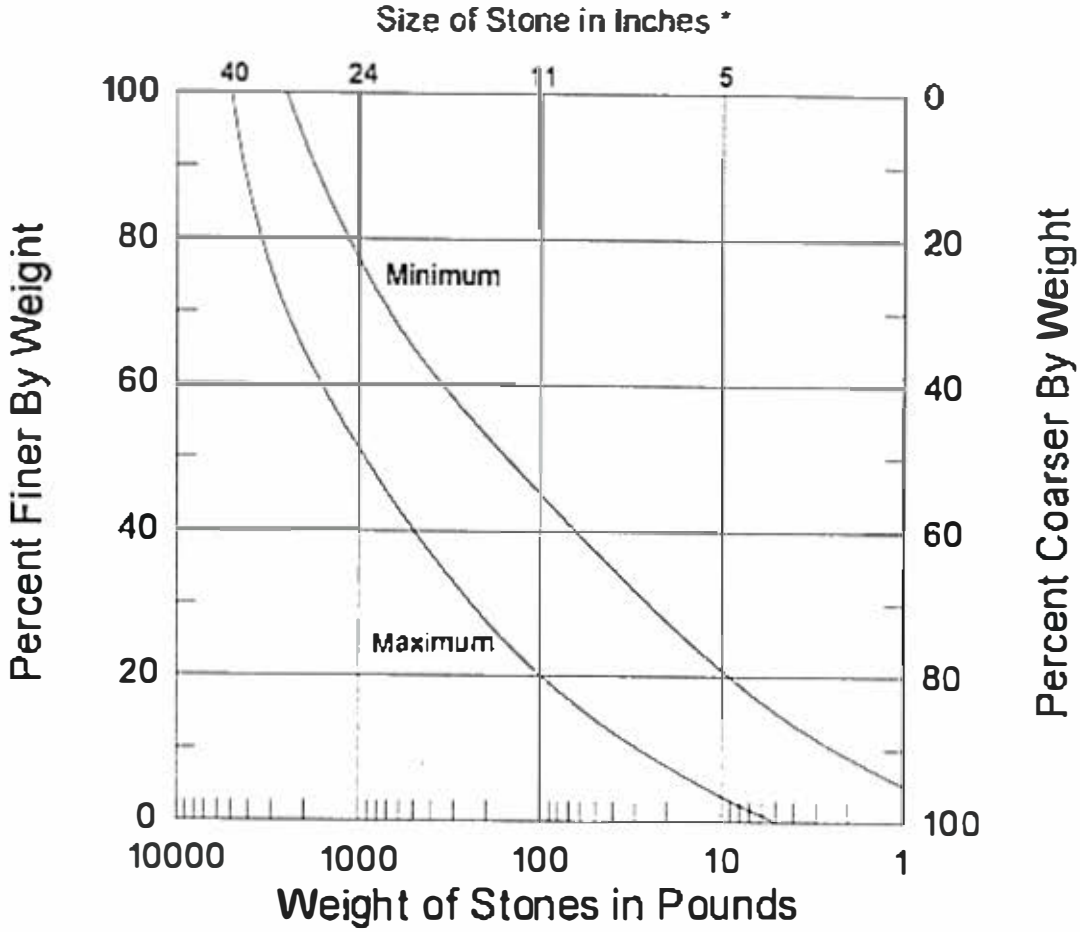
Reach Name	Mean Density, fish/ha (fish/acre)		
	1994	1995	1996
Cape Bend	351 (142)*	951 (385)	77 (31)
Dogtooth Bend	825 (334)	2346 (950)	140 (57)
Goose Island Bend	not sampled	not sampled	9 (4)
Price Towhead	577 (234)	743 (301)	142 (57)

* Did not have weirs in place.

Average fish size (147 mm) in this study is larger than the 1995 study (110mm). The 1994 survey used a larger threshold size than 1995 or 1996 and had a higher average length, possibly due to the exclusion of smaller targets. There were fewer large fish (greater than 800 mm) detected in the 1996 study than in the previous studies. This study does not support the 1994 findings that suggest larger fish prefer the weir fields.

Weir Construction

Construction of bendway weirs add relief to the bottom structure and increase the channel bottom surface area available as shelter for fish and other organisms. Rock fill varies in stone size from 250 mm to 1100 mm. The gradation of the typical stone used in the construction of bendway weirs is shown in Figure 18. The placement of weirs adds less than 1% of channel bottom surface area to a bend (assuming a uniform surface), however the gradation of stone used in the construction of the weirs adds approximately 36% addition surface area over the horizontal length of bend affected by the weir placement (assuming a typical channel bottom of sand and gravel). This estimate of additional channel bottom surface area neglects any pore spaces available between stones.



* Assuming specific graivity = 2.65 and stone shape midway between a sphere and a cube.

Figure 18. Stone Gradation

Summary

The bottom structure and hydraulic environment in bends with weirs is more diverse than in unaltered bends. The increased presence of fish targets in bends with weirs suggests that a favorable habitat has been constructed and is being utilized by fish populations. Fish density in bends with weirs averaged 13 times the density of fish in the bend studied without weirs. There appears to be no correlation between detected fish size and horizontal or vertical location within the bends.

With the increased diversity in habitat in the bendway weir fields, it is likely that not only are more fish utilizing the weir fields, but more variation in species is likely to find suitable habitat in the weir fields.