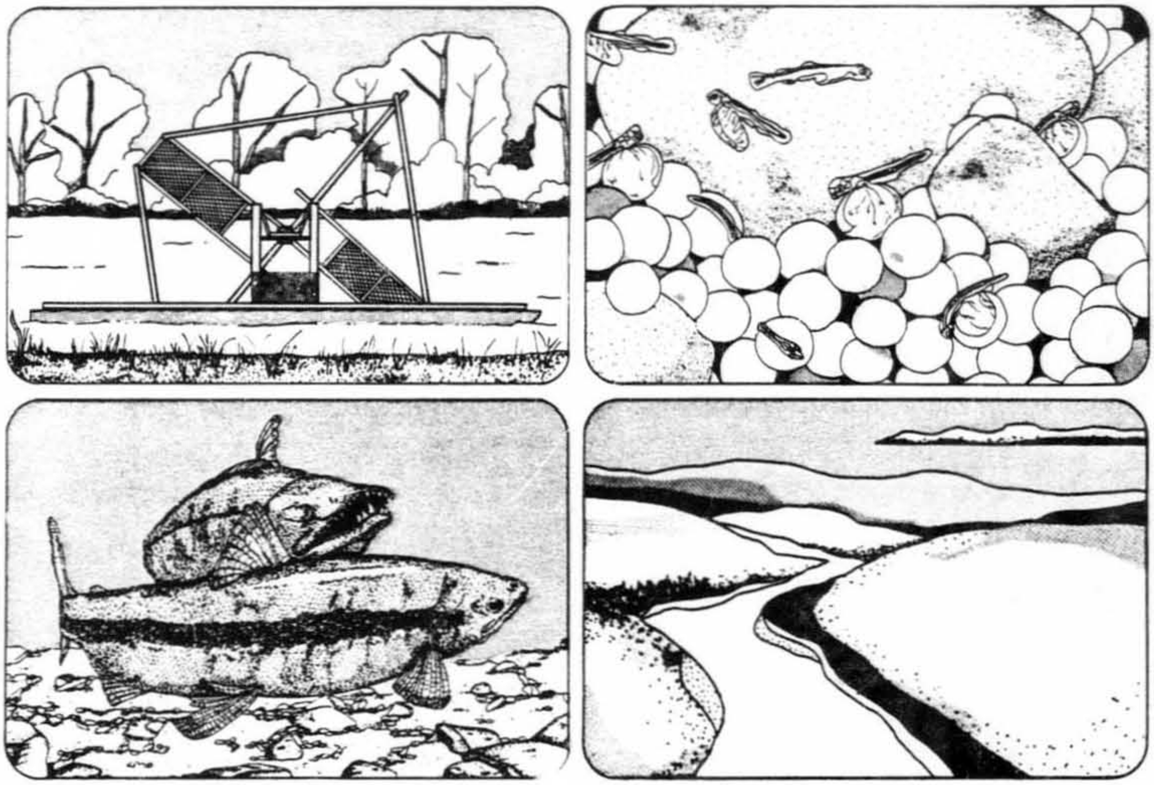

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ALASKA DEPARTMENT OF FISH AND GAME
SUSITNA HYDRO AQUATIC STUDIES

REPORT NO. 3 PART II, Chapter 6, Appendices

AQUATIC HABITAT AND INSTREAM FLOW INVESTIGATIONS (MAY-OCTOBER 1983)

ALASKA DEPARTMENT OF FISH AND GAME
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AQUATIC HABITAT AND INSTREAM FLOW INVESTIGATIONS (MAY-OCTOBER 1983)

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May 10, 1984

APPENDIX 6-A

Passage Reach Cross Section Data Tables

Table 6-A-1. Passage reach cross section data table, Slough 9 - Passage Reach I, September 29, 1983. Mainstem discharge = 9,080 cfs.

Point	Distance Between Points (ft)	Depth (ft)	Point	Distance Between Points (ft)	Depth (ft)
				1.0	
1 (LWE)		0.0	18		0.3
	1.0			1.0	
2		0.23	19		0.4
	1.0			1.0	
3		0.1	20		0.5
	1.0			1.0	
4		0.2	21		0.6
	1.0			1.0	
5		0.44	22		0.4
	1.0			1.0	
6		0.5	23		0.8
	1.0			1.0	
7		0.5	24		0.9
	1.0			1.0	
8		0.4	25		0.7
	1.0			1.0	
9		0.4	26		0.6
	1.0			1.0	
10		0.3	27		0.7
	1.0			1.0	
11		0.4	28		0.7
	1.0			1.0	
12		0.5	29		0.6
	1.0			1.0	
13		0.3	30		0.5
	1.0			1.0	
14		0.3	31		0.5
	1.0			1.0	
15		0.2	32		0.3
	1.0			1.0	
16		0.3	33 (RWE)		0.0
	1.0				
17		0.4			

Table 6-A-2. Passage reach cross section data table, Slough 9 - Passage Reach II, September 29, 1983. Mainstem discharge = 9,080 cfs.

Point	Distance Between Points (ft)	Depth (ft)	Point	Distance Between Points (ft)	Depth (ft)
				1.0	
1 (LWE)		0.0	13		0.6
	1.0			1.0	
2		0.1	14		0.6
	1.0			1.0	
3		0.1	15		0.6
	1.0			1.0	
4		0.2	16		0.6
	1.0			1.0	
5		0.1	17		0.5
	1.0			1.0	
6		0.2	18		0.5
	1.0			1.0	
7		0.3	19		0.5
	1.0			1.0	
8		0.4	20		0.5
	1.0			1.0	
9		0.5	21		0.6
	1.0			1.0	
10		0.5	22		0.5
	1.0			1.0	
11		0.5	23		0.2
	1.0			1.0	
12		0.6	24 (RWE)		0.0

6-A-2

6-A-3

Table 6-A-3. Passage reach cross section data table, Slough 9 - Passage Reach III (TR4) August 25, 1982. Mainstem discharge 13,400 cfs.

Point	Distance Between Points (ft)	Depth (ft)
1 (LWE)		0.0
	1.0	
2		0.1
	2.0	
3		0.1
	2.0	
4		0.1
	2.0	
5		0.2
	2.0	
6		0.3
	2.0	
7		0.1
	2.0	
8		0.2
	1.5	
9 (RWE)		0.0
	15.5	
10 (LWE)		0.0
	1.0	
11		0.1
	2.0	
12		0.1
	2.0	
13		0.2
	2.0	
14		0.1
	2.0	
15		0.1
	2.0	
16		0.1
	2.0	
17		0.1
	2.0	
18		0.2
	2.0	
19		0.2
	2.0	
20		0.2
	2.0	
21		0.2
	2.0	
22		0.25
	2.0	
23		0.2
	2.0	
24		0.1
	2.0	
25		0.1
	2.0	
26		0.1
	2.0	
27		0.1
	2.0	
28		0.1
	2.0	
29		0.1
	2.0	
30		0.1
	2.0	
31		0.1
	2.0	
32		0.1
	2.0	
33 (RWE)		0.0

Table 6-A-4. Passage reach cross section data table, Slough 20 - Passage Reach I July 16, 1983. Mainstem discharge = 16,400 cfs.

Point	Distance Between Points (ft)	Depth (ft)
1 (LWE)		0.0
	1.0	
2		0.2
	1.0	
3		0.1
	1.0	
4		0.1
	1.0	
5		0.1
	1.0	
6		0.1
	1.0	
7		0.1
	1.0	
8		0.2
	1.0	
9		0.3
	1.0	
10		0.1
	1.0	
11		0.1
	1.0	
12		0.2
	1.0	
13		0.1
	1.0	
14		0.2
	1.0	
15		0.2
	1.0	
16		0.1
	1.0	
17		0.3
	1.0	
18		0.3
	1.0	
19		0.3
	1.0	
20		0.3
	1.0	
21		0.3
	1.0	
22		0.3
	1.0	
23		0.3
	1.0	
24		0.3
	1.0	
25		0.3
	1.0	
26		0.3
	1.0	
27		0.3
	1.0	
28		0.3
	1.0	
29		0.3
	1.0	
30		0.3
	1.0	
31		0.2
	1.0	
32		0.2
	1.0	
33		0.2
	1.0	
34		0.1
	0.4	
35 (RWE)		0.0

Table 6-A-5. Passage reach cross section data table, Slough 20 - Passage Reach II, July 16, 1983. Mainstem discharge = 16,400 cfs.

Point	Distance Between Points (ft)	Depth (ft)	Point	Distance Between Points (ft)	Depth (ft)
				1.0	
1 (LWE)		0.0	18		0.3
	1.0			1.0	
2		0.1	19		0.2
	1.0			1.0	
3		0.2	20		0.4
	1.0			1.0	
4		0.2	21		0.2
	1.0			1.0	
5		0.3	22		0.3
	1.0			1.0	
6		0.2	23		0.3
	1.0			1.0	
7		0.3	24		0.3
	1.0			1.0	
8		0.4	25		0.3
	1.0			1.0	
9		0.5	26		0.3
	1.0			1.0	
10		0.3	27		0.2
	1.0			1.0	
11		0.4	28		0.1
	1.0			1.0	
12		0.4	29		0.1
	1.0			1.0	
13		0.4	30		0.2
	1.0			1.0	
14		0.3	31		0.2
	1.0			1.0	
15		0.3	32		0.2
	1.0			1.0	
16		0.3	33		0.1
	1.0			1.0	
17		0.3	34		0.1

6-A-5

Table 6-A-5 (continued).

Point	Distance Between Points (ft)	Depth (ft)	Point	Distance Between Points (ft)	Depth (ft)
	1.0			1.0	
35		0.0	40		0.1
	1.0			1.0	
36		0.0	41		0.1
	1.0			1.0	
37		0.2	42		0.1
	1.0			1.0	
38		0.2	43		0.1
	1.0			1.0	
39		0.2	44 (RWE)		0.0

Table 6-A-6. Passage reach cross section data table, Slough 20 - Passage Reach III, July 16, 1983.
Mainstem discharge = 16,400 cfs.

Point	Distance Between Points (ft)	Depth (ft)
1 (LWE)		0.0
	1.0	
2		0.2
	1.0	
3		0.3
	1.0	
4		0.2
	1.0	
5		0.2
	1.0	
6		0.3
	1.0	
7		0.2
	1.0	
8		0.2
	1.0	
9		0.3
	1.0	
10		0.3
	1.0	
11		0.2
	1.0	
12		0.2
	1.0	
13		0.2
	1.0	
14		0.2
	1.0	
15		0.2
	1.0	
16		0.2
	1.0	
17		0.3
	1.0	
18		0.3
	1.0	
19		0.3
	1.0	
20		0.3
	1.0	
21		0.2
	1.0	
22		0.1
	1.0	
23		0.1
	1.0	
24		0.1
	1.0	
25		0.2
	1.0	
26		0.2
	1.0	
27		0.1
	1.0	
28		0.1
	1.0	
29		0.2
	1.0	
30		0.2
	1.0	
31		0.1
	1.0	
32		0.1
	1.0	
33		0.1
	1.0	
34		0.1

Table 6-A-6 (continued).

Point	Distance Between Points (ft)	Depth (ft)	Point	Distance Between Points (ft)	Depth (ft)
	1.0			1.0	
35		0.1	39		0.1
	1.0			1.0	
36		0.1	40		0.1
	1.0			1.0	
37		0.2	41		0.1
	1.0			1.0	
38		0.1	42 (RWE)		0.0

Table 6-A-7. Passage reach cross section data table, Slough 20 - Passage Reach IV, July 16, 1983. Mainstem discharge = 16,400 cfs.

Point	Distance Between Points (ft)	Depth (ft)
1	1.0	0.0
2	1.0	0.1
3	1.0	0.1
4	1.0	0.1
5	1.0	0.1
6	1.0	0.1
7	1.0	0.1
8	1.0	0.2
9	1.0	0.2
10	1.0	0.3
11	1.0	0.3
12	1.0	0.3
13	1.0	0.4
14	1.0	0.3
15	1.0	0.2
16	1.0	0.3
17	1.0	0.2
18	1.0	0.2
19	1.0	0.3
20	1.0	0.4
21	1.0	0.4
22	1.0	0.3
23	1.0	0.3
24	1.0	0.1
25	1.0	0.1
26	1.0	0.3
27	1.0	0.1
28	1.0	0.1
29	1.0	0.1
30	1.0	0.2
31	1.0	0.1
32	1.0	0.1
33	1.0	0.1
34	1.0	0.1
35 (RWE)		0.0

Table 6-A-8. Passage reach cross section data table, Slough 20 - Passage Reach V, July 16, 1983. Mainstem discharge = 16,400 cfs.

Point	Distance Between Points (ft)	Depth (ft)	Point	Distance Between Points (ft)	Depth (ft)
				1.0	
1 (LWE)	1.0	0.0	18	1.0	0.1
2	1.0	0.2	19	1.0	0.2
3	1.0	0.1	20	1.0	0.2
4	1.0	0.2	21	1.0	0.2
5	1.0	0.1	22	1.0	0.1
6	1.0	0.3	23	1.0	0.1
7	1.0	0.3	24	1.0	0.1
8	1.0	0.3	25	1.0	0.1
9	1.0	0.2	26	1.0	0.1
10	1.0	0.1	27	1.0	0.1
11	1.0	0.2	28	1.0	0.2
12	1.0	0.3	29	1.0	0.1
13	1.0	0.2	30	1.0	0.1
14	1.0	0.1	31	1.0	0.1
15	1.0	0.1	32	1.0	0.1
16	1.0	0.1	33	1.0	0.1
17		0.2	34		0.1

6-A-10

Table 6-A-8 (continued).

Point	Distance Between Points (ft)	Depth (ft)	Point	Distance Between Points (ft)	Depth (ft)
35	1.0	0.1	45	1.0	0.1
36	1.0	0.1	46	1.0	0.1
37	1.0	0.1	47	1.0	0.1
38	1.0	0.1	48	1.0	0.1
39	1.0	0.1	49	1.0	0.1
40	1.0	0.1	50	1.0	0.0
41	1.0	0.1	51	1.0	0.1
42	1.0	0.2	52	1.0	0.1
43	1.0	0.2	53	1.0	0.1
44	1.0	0.2	54 (RWE)	0.5	0.0

Table 6-A-9. Passage reach cross section data table, Slough 21 - Passage Reach I, September 13, 1983. Mainstem discharge = 16,400 cfs.

Point	Distance Between Points (ft)	Depth (ft)	Point	Distance Between Points (ft)	Depth (ft)
				1.0	
1 (LWE)		0.0	7		0.3
	1.0			1.0	
2		0.1	8		0.4
	1.0			1.0	
3		0.2	9		0.3
	1.0			1.0	
4		0.1	10		0.4
	1.0			1.0	
5		0.2	11		0.4
	1.0			4.0	
6		0.2	12 (RWE)		0.0

The last four feet of the cross section are blocked by large boulders making fish passage impossible.

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May 10, 1984

APPENDIX 6-B

Analysis of the Influence of Local
Flow Conditions on Fish Passage

by

Larry Rundquist

and

Janet Hearns

Woodward Clyde Consultants

1984

OBJECTIVE

The objective of this passage analysis is to estimate the flows that correspond to successful and unsuccessful passage within specific sloughs and side channels in the middle reach of the Susitna River. This phase of the investigation concentrates on local flow conditions only. It does not include an evaluation of the influence of mainstem discharge on the backwater at the mouth of a site or overtopping at the upstream end of the site which can also influence passage in these areas.

METHODS

Data Base

The data base for the slough passage analysis varied between sloughs. Available data at all sloughs included:

- o slough thalweg and water surface profiles,
- o at least one surveyed transect, and
- o aerial photography coverage of the slough for Susitna mainstem flows of 9,000, 12,500, 16,000, 21,000 and 23,000 cfs.

Many of the sloughs had several surveyed transects located on riffles or within pools of the sloughs which corresponded to staff gage or flow measurement sites. Rating curves were available for most flow measurement sites. Sloughs 9, 9A, 20, and 21 had transect data for one to three passage reaches within the slough; these transects had a width equal to that of the water surface at the time of the survey, which usually corresponded to a relatively low flow.

Analyses

The available data were not sufficient to conduct a direct analysis of slough flows required for passage within the sloughs. An indirect approach was developed based on the concept of "at-a-station" channel geometry relations introduced by Leopold and Maddock (1953). They used discharge measurement data at a number of gaging stations in the United States to obtain power relations for width and depth in terms of discharge at a particular station. These relations are given by

$$W = a\ Q^b$$
$$D = c\ Q^f$$

They found that the geometry varied considerably between cross sections and thus, the coefficients varied. Many streams, however, had similar rates of change of geometry. Based on a sample of 20 river cross sections in the Great Plains and the Southwest, Leopold and Maddock obtained average exponent values of 0.26 for width and 0.40 for depth. They found that the exponents are a function of the shape of the channel and the hydraulics of the flow.

Further study has been made on relations of the hydraulic geometry of stream channels by Leopold, Wolman and Miller (1964). It was found that channels in the humid eastern United States and in the wet mountain area of the central and north Rocky Mountains have a slower rate of increase of width (low b) than those of channels in the semiarid Southwest or the High Plains. This is due, at least in part, to the typical shape of the channel cross section in the various regions. Some values of the exponents in the hydraulic geometry relations are given in Table 6-B-1.

Li (1974) presented a theoretical development of hydraulic geometry relations for channels in homogeneous, coarse alluvium and small drainage basins. The assumptions of the derivation conclude that all particles on the boundary of the channel are at a condition of incipient motion at bank-full. Li obtained equations of the form:

$$W = a\ Q^{0.24}$$
$$D = c\ Q^{0.46}$$

Table 6-B-1. Average values of exponents in the At-A-Station Hydraulic Geometry Relations (after Leopold, et. al. 1964).

	b	f
Average values midwestern United States	.26	.40
Brandywine Creek, Pennsylvania	.04	.41
Ephemeral streams in semiarid United States	.29	.36
Average of 158 gaging stations in United States	.12	.45
Ten gaging stations on Rhine River	.13	.41

Symbols: Q discharge

W channel top width $W = a\,Q^b$

D hydraulic depth $D = c\,Q^f$

The exponents vary only slightly with the angle of repose of the bed and bank material and with the lift to drag ratio.

Slough Geometry Relations. It has been noted that the width and depth of a stream channel increase at some uniform rate with increasing flow. This is not always true, however. A logarithmic plot of the width or depth with flow may be a curved line or it may be a series of straight line segments with one or more breaks in slope. These types of plots may be due to variability of bed and bank material type, a break in the slope of the banks, channelization at low flows, or some other nonuniformity in the bed and banks.

Riffle transects with developed rating curves were available for Sloughs 9, 11, and 21 and Upper Side Channel 11. The transect data were input to a computer program that uses the Manning equation to calculate the hydraulic geometry and flow for a range of selected water surface elevations. The reach gradient was used for the energy slope and Manning n was varied until the output from the computer matched the rating curve reasonably well. All four transects were fairly well calibrated using a Manning n value of 0.110.

Power form relations for hydraulic (mean) depth as a function of flow were developed from the computer model output. Exponents in the equations were 0.38 for Sloughs 9 and 11, 0.39 for Slough 21, and 0.45 for Upper Side Channel 11. These compare well with the values reported by Leopold, Wolman and Miller (1964). The range of coefficients from 0.13 at Upper Side Channel 11 to 0.26 at Slough 11 was enough to cause the range of flows for a single depth to be large. The coefficients were not correlated to the reach gradient, which was the only variable that was available for passage reaches which lacked transect data. Thus, the wide range of calculated flows for a given depth could not be reduced based on the available data base.

The hydraulic geometry relations were modified by plotting the mean depth against the unit flow (total flow divided by top width). The resulting lines were straight and parallel (on log-log paper) and the variation in coefficients could be reasonably explained in terms of reach gradient variation (Figure 6-B-1). Additional transects without rating curves were input to the Manning equation computer model using the reach gradient and the average Manning n value of 0.110 to compute their hydraulic geometry; these data were also plotted on Figure 6-B-1. The resulting set of curves can be used to evaluate the unit flows for selected mean depths in a passage reach having a known reach gradient. Specific application of Figure 6-B-1 for the passage reach analysis is discussed in more detail in a subsequent section.

Channel top width was also plotted against flow (Figure 6-B-2). These curves for the four transects having rating curves were generally non-parallel and non-linear, indicating a bad fit to the power form equation presented above. This is likely due to the existence of shelf-like areas on some transects which cause a large increase in width for a small flow.

<u>Passage Depth Definition</u>. Passage depth is the depth of water at a transect which a fish must navigate through in order to proceed upstream. Using the mean depth as the indicator depth for fish passage

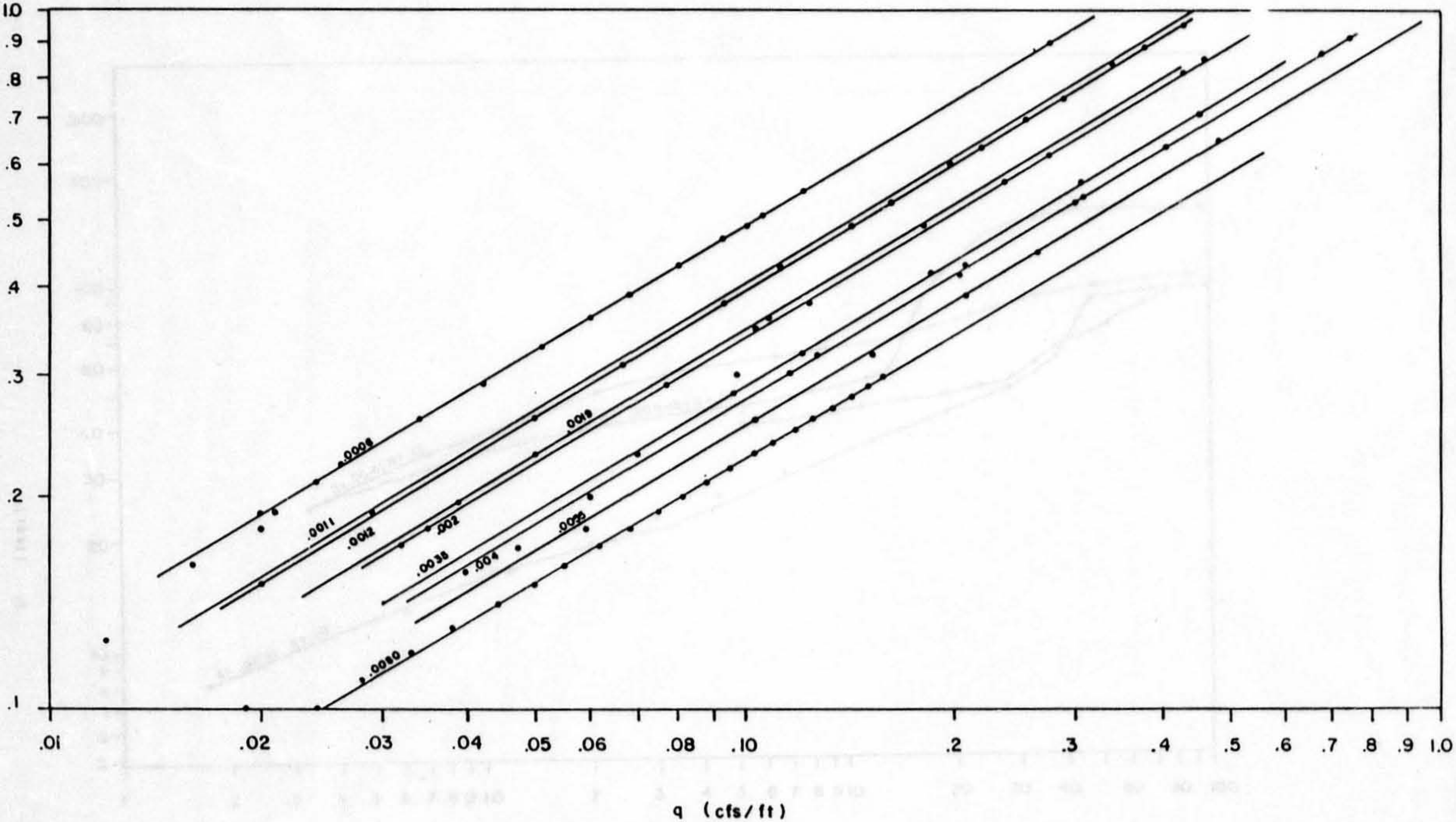
Table 6-B-1. Average values of exponents in the At-A-Station Hydraulic Geometry Relations (after Leopold, et. al. 1964).

	b	f
Average values midwestern United States	.26	.40
Brandywine Creek, Pennsylvania	.04	.41
Ephemeral streams in semiarid United States	.29	.36
Average of 158 gaging stations in United States	.12	.45
Ten gaging stations on Rhine River	.13	.41

Symbols: Q discharge

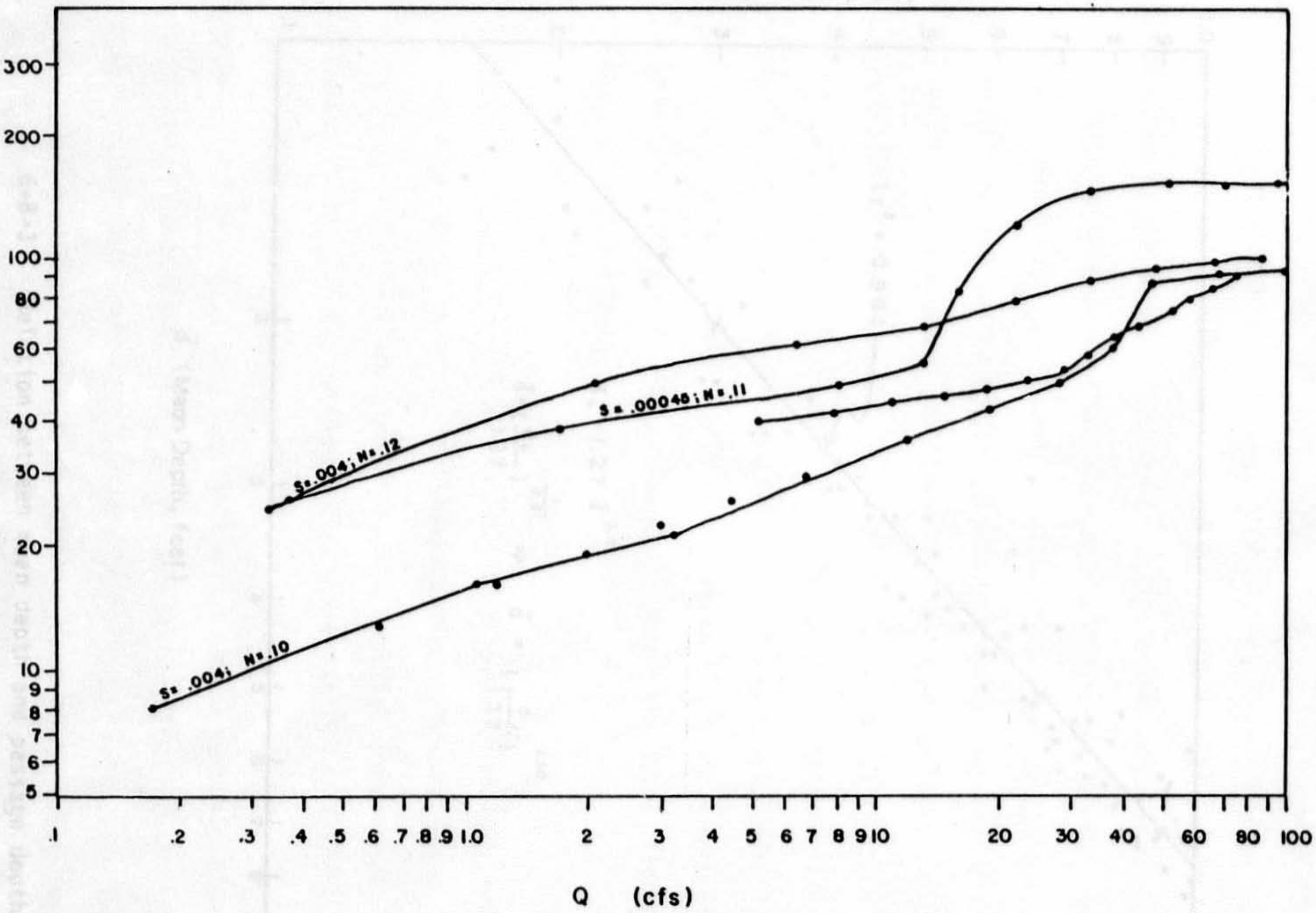
W channel top width $W = a\ Q^b$

D hydraulic depth $D = c\ Q^f$

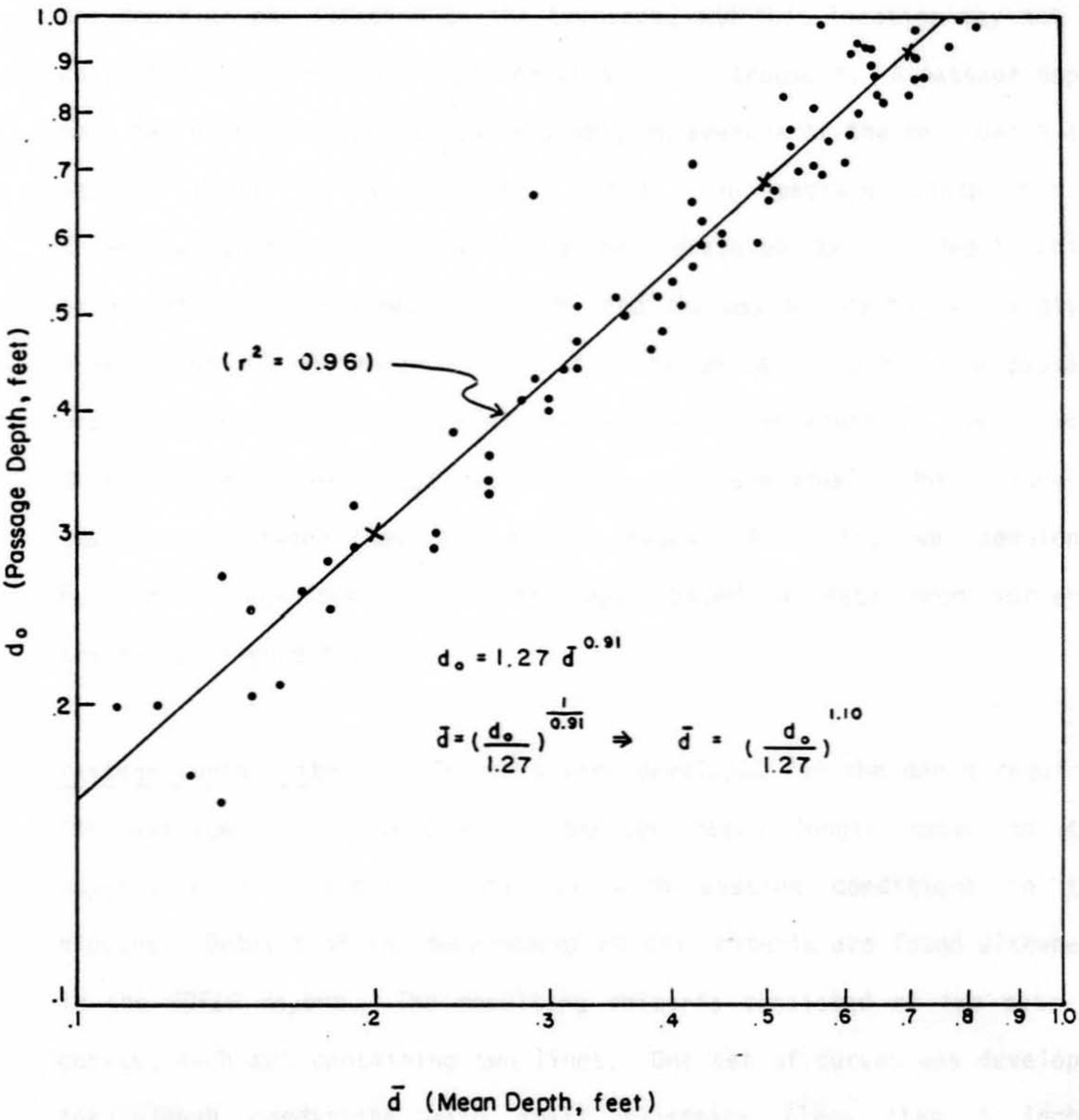


6-B-1 Relation between mean depth and unit flow .

6-B-11



6-B-2 Relation between top width and total discharge.



6-B-3 Relation between mean depth and passage depth.

is somewhat conservative, since the maximum depth can be as large as 50 percent greater than the mean depth. Use of the maximum or thalweg depth is not a very good indicator of passage since it often represents the depth at one location on the transect, and this location may not be connected to the maximum depth on an adjacent transect. A passage depth term has been developed which is simply an average of the mean depth and maximum depth of a transect. Thus, the passage depth for a triangular-shaped transect would be the average of the mean depth, which is two-thirds of the maximum depth, and the maximum depth, which gives five-sixths of the maximum depth for the passage depth. The passage depth for a rectangular-shaped transect would be equal to the maximum depth, since the mean depth and maximum depth are equal. Most transects would fall between these two extreme cases. A relation was developed between passage depth and mean depth based on data from surveyed transects (Figure 6-B-3).

Passage Depth Criteria. Criteria were developed for the depth required for passage as a function of passage reach length based on the experience of biologists familiar with passage conditions in the sloughs. Details of the development of the criteria are found elsewhere in the ADF&G report. The resulting criteria consisted of two sets of curves, each set containing two lines. One set of curves was developed for slough conditions with small substrate (less than 3 inches diameter), uniform transects, straight channel, and velocities less than 2 fps. These conditions are fairly typical in many of the sloughs. The other set of curves was developed for sloughs with large substrates, non-uniform transects, braided channel with numerous dead ends, and velocities typically greater than 2 fps. Each set of curves had three categories of passage separated by the two curves (Figure 6-B-4). The three categories are defined below:

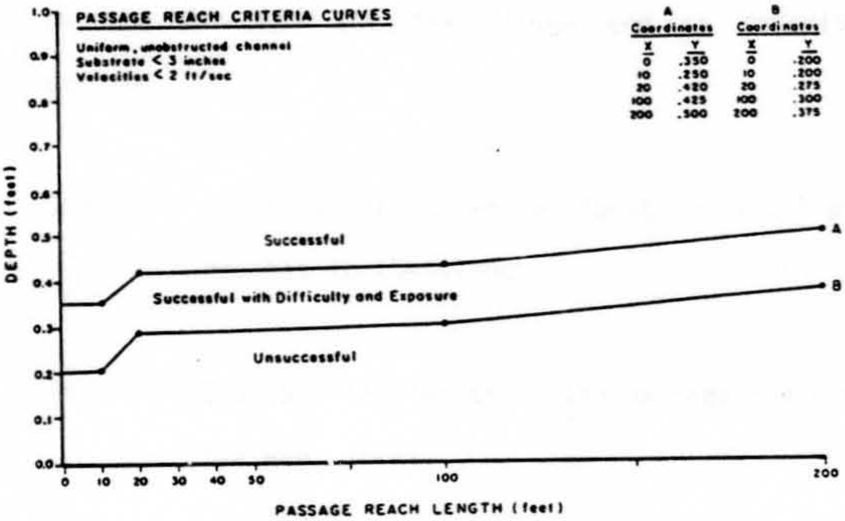
Successful Passage (unrestricted): fish access into and/or passage within the spawning area to spawning sites is uninhibited, and would not affect production in this area.

Successful Passage With Difficulty & Exposure: fish access into and/or passage within the spawning area is accomplished, but with stress and predation; although a sufficient number of fish pass to allow continued production in the area, this condition, over a long period of time, could result in a reduction in production.

Unsuccessful Passage: fish access into or within an area to a spawning area may be accomplished by a limited number of fish; however, if exposure to excessive stress and increased predation (which are associated with these conditions persist) the population would eventually be eliminated.

The curves separating these categories are thus threshold conditions and are of most interest in this analysis.

Passage Reach Length. The passage reach lengths were determined by ADF&G based on the thalweg and water surface surveys. This typically corresponded with the distance between pools. It was assumed that the reach length remained constant with flow, since pool stage did not vary substantially with change in flow, especially over the small range of flow considered in this analysis.



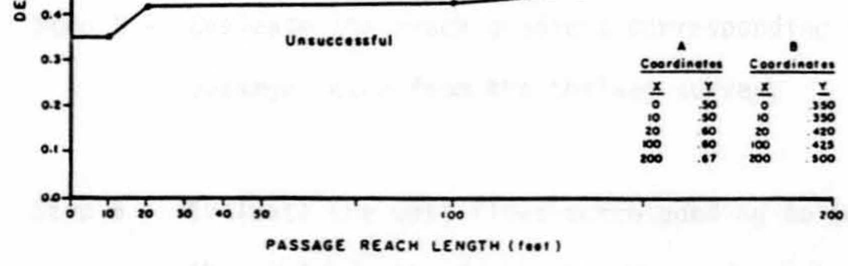


Figure 6-B-4 Passage depth criteria as a function of passage reach length.

Application to Sloughs. The general application of the relations, criteria, and data described above is summarized in this section in the form of a series of steps. Specific applications to each slough depended on the database for the slough and is described in the following section.

- o Step 1 - Identify the number and location of all passage reaches in the slough.

- o Step 2 - Evaluate the length of the passage reach from the thalweg survey.

- o Step 3 - Identify the passage depths for threshold values corresponding to successful and unsuccessful passage based on the reach length and the passage depth criteria (Figure 4).

- o Step 4 - Determine the mean depths that corresponds to the identified threshold passage depths (Figure 3).

- o Step 5 - Evaluate the reach gradient corresponding to each passage reach from the thalweg survey.

- o Step 6 - Evaluate the unit flows corresponding to both threshold depths for each passage reach by using the curve with the applicable reach gradient (Figure 1).

- Step 7 - Plot a width versus flow curve for all surveyed transects on the slough.

- Step 8 - Measure the width of flow at the surveyed transect and at each passage reach on each of the five sets of aerial photographs.

- Step 9 - Use the measured top width at the surveyed transect for each set of photographs to evaluate the slough flow for each of the photographs.

- Step 10 - Modify the slough flow, if necessary, to account for upwelling or tributary inflow between the surveyed transect and each passage reach.

- Step 11 - Use the slough flow and the corresponding top width measured from the aerial photographs to define several points on a curve of width versus discharge for each passage reach.

- Step 12 - Plot lines of constant unit flow at the values obtained for both threshold depths. The intersection of these lines with the width versus flow curve developed for each passage reach gives the total flow that corresponds to both threshold depths.

- o Step 13 - Tabulate the required depths and flow for both successful and unsuccessful passage for each passage reach.

Whiskers Creek

The data base for the Whiskers Slough Site that proved useful for passage analysis includes transects at the slough mouth and at the slough discharge site (ADF&G gage 101.253) located in the slough above Whiskers Creek, and a thalweg profile for Whiskers Slough. Additional data include flow measurements in Whiskers Creek (ADF&G gage 101.2T2B). These flow measurements were not useful because neither the discharge site nor the creek thalweg have been surveyed. Thus, no reliable rating curve with which to generate a width-discharge curve could be developed for the creek site. Because both passage reaches are located below Whiskers Creek, the flow contributions of the creek had to be accounted for. This was done using the following approach.

A rating curve was developed for the slough discharge site. The general method could not be used because the transect is located at a pool, and the general approach only applies to riffles. Once an appropriate Manning n and energy slope were selected for the flow site, the same values were used to generate a rating curve at the slough mouth. The width-flow curve at the slough mouth was plotted and used to generate width-flow curves for both passage reaches. It was assumed that the flow remained the same between Passage Reach I and the mouth. Once the width vs. flow curves were plotted for the passage reaches, total flow was found by locating the required unit flow on each of the curves.

Mainstem II Side Channel

The data base for Mainstem II consists of a thalweg profile and five surveyed transects located at two discharge sites, one in each of the two forks, and three staff gage sites below the confluence of the forks. Photographic enlargements, available for mainstem flows of 9,000; 12,500; and 16,000 cfs, do not provide adequate resolution with which to generate width versus flow curves for the passage reaches based on the rating curve for the flow site. Therefore, passage flows are based on field observations by E. Woody Trihey and Associates.

Slough 9

Since all three passage reaches had been surveyed, the passage analysis at Slough 9 was a straight-forward application of the general approach to developing rating curves. No extrapolation of the rating curves beyond the limits of the survey data was necessary.

Slough 9A

The data base at Slough 9A includes a thalweg profile and four flow measurements taken on October 25, 1982. Because the measurements were taken on the same day and span almost the entire length of the slough, they provide an indication of the volume of upwelling within the slough. Three of the discharge sites coincide with passage reaches I, III, and V. Rating curves for these sites were developed using the general method described previously; the measured flows were used as a calibration check. The calculated and measured flows compared to within 7 to 9 percent.

Passage flows at reaches II, IV, and VI were determined using the top width vs. flow curves for passage reaches I, III, and V and applying adjustments for groundwater upwelling and relative differences in top width. This information was provided by ADF&G personnel.

Slough 11

The data base at Slough 11 includes a thalweg profile and surveyed transects at the mouth and at a flow site about 1,000 ft upstream of the mouth. The quality of aerial photography at this slough is very poor; the only set of photos on which any resolution is possible is that which was taken at a mainstem flow of 21,000 cfs. This does not provide adequate information with which to generate width versus flow curves for the passage reaches based on the rating curve at the flow site. Therefore, passage flows are based on field observations provided by E. Woody Trihey and Associates.

Upper Side Channel 11

Access analysis for Upper Side Channel 11 was based on the rating curve developed for the flow site at ADF&G gage 136.251. This site is coincident with Passage Reach II. The overall gradient through both reaches is the same, and aerial photographs indicate that the width of flow at both sites is similar. Thus, the top width versus flow curve that was developed directly for Passage Reach II was also applied to Passage Reach I. Because the slopes were the same for both reaches, a direct plot of passage depth vs. flow yields the same results.

Slough 20

Rating curves for the three passage reaches in Slough 20 were calculated using the general methodology described previously and depth measurements from each site. There were no flows with which to calibrate these curves. The general method was not used to calibrate the rating curve at the flow site (ADF&G gage 140.155) because the site is located in a pool, and the method is only applicable at riffle sites.

Because passage reaches were quite shallow at the time they were surveyed, their rating curves do not extend to the depths required for passage analysis. The curves were extended by scaling the width of each site, including the flow site, off the set of large scale aerial photographs (1"=50'; mainstem flow equal 21,000 cfs). Assuming that flow within the slough remained constant, the width of each passage reach was plotted against the flow at the gaging site. This provided an extension that was sufficient to determine the total flow corresponding to the required unit flow at each passage reach.

Although the extensions do not account for any upwelling in the slough, the shape of the extended portions of the curves is such that the impact of disregarding this effect is not substantial.

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Side Channel 21

Three of the five passage reaches in Side Channel 21 coincided with surveyed transects and/or flow sites at either staff gages or IFG study sites. Passage Reach III is located at the flow site situated at Transect 4 of the lower IFG study site (ADF&G gage 140.6S4). The rating curve was developed using the general methodology described previously using the flow measurements as a calibration check. No modifications to the rating curve or width versus flow curve were needed in order to obtain the passage flows.

Passage Reach IV is coincident with the transect surveyed at ADF&G gage 140.6S2. A rating curve was generated using the general method and applied without modification.

Passage Reach V is situated at the downstream end of the Upper IFG study site and is coincident with Transects 1-3. A rating curve at Transect 3 was developed using the general approach described previously. No changes were made to the rating curve in order to determine the passage flows.

No data were available at Passage Reaches I and II other than the aerial photo enlargements. Passage is not a problem, however, at the mainstem flows represented in the photographs, so they did not prove particularly useful for this analysis. Thus, for simplicity and lack of a better approach, the passage flows for Passage Reaches I and II were taken from the width versus flow curve for Passage Reach III.

Slough 22

In addition to a surveyed thalweg, Slough 22 has surveyed transects at the mouth (ADF&G gage 144.3W3), mid-slough (ADF&G gage 144.3S4) and at the flow site just below the tributary (ADF&G gage 144.3S6). Aerial photo enlargements are available for a mainstem discharge of 21,000 cfs only.

Rating curves were developed for the gage sites at the mouth and mid-slough. Both these sites are riffles, so the general method described previously was applicable. Passage Reach I coincides with the gage site at the mouth, so passage flows could be determined directly from the rating curve.

Passage Reach II is situated about 300 ft upstream of the mid-slough gage site and has a reach gradient of 20.7 ft/mi as compared to 6.3 ft/mi at the mid-slough gage. The enlarged aerial photos taken at a mainstem discharge of 21,000 cfs indicate that Passage Reach II is roughly twice as wide as the mid-slough gage site. A width vs. flow curve for the passage reach was generated from the width vs. flow curve for the mid-slough gage site by assuming that flow remained constant between the two sites, but at all flow the top width at the passage reach was double that at the gage. The validity of the numbers obtained in this manner depends primarily upon how well the width relationship holds at flows other than the one shown in the aerial photos.

RESULTS AND DISCUSSION

Table 2 summarizes the results of the passage analysis for the nine sloughs in which passage problems were identified. Based on the existing data, the numbers presented are a reasonable estimate of the slough flows needed to meet the passage criteria for successful and unsuccessful passage. However, because the data were not easily applied to this type of analysis, it is strongly suggested that field verification of the calculated values be included in the 1984 field program.

In addition, further field investigation may reveal additional passage problems that were not apparent on the thalweg and water surface surveys, and/or eliminate some reaches that were previously identified as problems.

Table 6-B-2. Summary of slough flows needed to meet passage criteria for successful and unsuccessful passage.

			SUCCESSFUL PASSAGE				DIFFICULT PASSAGE			
Site	PR	Length (ft)	Passage Depth (ft)	Mean Depth (ft)	Unit Flow	Flow (cfs)	Passage Depth (ft)	Mean Depth (ft)	Unit Flow	Flow (cfs)
Whiskers Creek	I	226	0.50	0.36	0.145	10.5	0.38	0.26	0.089	4.2
	II	50	0.42	0.30	0.107	10.1	0.28	0.19	0.050	5.0
Mainstem II	I	Point	0.50	0.36	---	5	0.35	0.24	---	3
	II	200	0.67	0.49	---	5	0.50	0.36	---	3
	III	Point	0.50	0.36	---	5	0.35	0.24	---	3
	IV	40	0.60	0.44	---	5	0.42	0.30	---	3
	V	200	0.67	0.49	---	5	0.50	0.36	---	3
	VI	260	0.67	0.49	---	5	0.50	0.36	---	3
9	I	167	0.48	0.34	0.073	2.3	0.35	0.24	0.041	1.2
	II	292	0.67	0.49	0.137	3.2	0.50	0.36	0.080	1.7
	III	83	0.60	0.44	0.115	10.15	0.42	0.30	0.060	5.8
9A	I	20	0.60	0.44	0.150	2.4	0.42	0.30	0.079	1.0
	II	10	0.50	0.36	0.220	3.4	0.35	0.24	0.110	1.5
	III	175	0.65	0.48	0.360	5.5	0.48	0.34	0.200	2.4
	IV	10	0.50	0.36	0.078	0.5	0.35	0.24	0.040	0.2
	V	130	0.62	0.45	0.270	2.8	0.45	0.32	0.150	1.4
	VI	240	0.67	0.49	0.122	2.0	0.50	0.36	0.108	1.8
11	I	35	0.42	0.30	---	4.0	0.28	0.19	---	2.5
	II	35	0.42	0.30	---	4.0	0.28	0.19	---	2.5
	III	61	0.42	0.30	---	4.0	0.29	0.20	---	2.5
	IV	26	0.42	0.30	---	8.0	0.28	0.19	---	5
(right channel)	V	30	0.42	0.30	---	4.0	0.28	0.19	---	2.5
(left channel)	V	41	0.42	0.30	---	4.0	0.28	0.19	---	2.5

Table 6-B-2 (continued)

Upper Side Channel 11	I	40	0.60	0.44	0.22	16.0	0.42	0.30	0.115	7.0
	II	670	0.67	0.49	0.26	20.0	0.50	0.36	0.155	10.1
20	I	90	0.42	0.30	0.091	3.4	0.30	0.20	0.046	1.6
	II	100	0.43	0.30	0.091	4.1	0.30	0.20	0.046	1.9
	III	95	0.60	0.44	0.172	8.5	0.43	0.30	0.091	4.1
Side Channel 21	I	10	0.50	0.36	0.105	8.0	0.35	0.24	0.053	3.1
	II	15	0.55	0.40	0.125	10.0	0.39	0.27	0.065	4.1
	III	175	0.65	0.48	0.290	27.5	0.48	0.34	0.163	14.0
	IV	200	0.67	0.49	0.240	30.0	0.50	0.36	0.145	16.5
	V	200	0.67	0.49	0.079	4.2	0.50	0.36	0.065	3.2
22	I	40	0.60	0.44	0.118	14.0	0.42	0.30	0.063	3.6
	II	220	0.67	0.49	0.257	9.0	0.50	0.36	0.154	20.0

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APPENDIX B

LITERATURE CITED

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