Striped Bass and American Shad Restoration and Monitoring
Annual Report
January – December 2000

By

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STRIPED BASS
AND
AMERICAN SHAD
RESTORATION AND MONITORING

Project #F-41-R-6
Annual Report

January 1, 2000 to December 31, 2000

Prepared By: **Gail Wippelhauser**
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Job I-1

Job Number & Title: #F-41-R-6 (1)
Kennebec River Monitoring

Job Objective: To monitor the recolonization of anadromous fish species on the Kennebec River above Augusta following removal of the Edwards Dam

(a) **Summary:** A total of 70 ichthyoplankton samples were collected at sites in and below the Edwards Dam impoundment in 2000. The samples have been sorted, and preserved for future identification and enumeration.

(b) **Target Date:** 2003

(c) **Status of Progress:** On schedule

(d) **Significant Deviations:** None

(e) **Recommendations:** Continue as planned

(f) **Cost:** $32,244.78

(g) **Data Presentation & Discussion:**

Sampling stations for ichthyoplankton studies were established in and below the former Edwards Dam impoundment. Surface tows with one-meter plankton nets (800 microns) or stationary sets of one-half meter D-shaped plankton nets (1600 microns) were made at each station. Sampling was initiated on May 10, 2000 and ended on June 28, 2000. Twelve sampling sites were established above and thirteen sites below the former dam site (Table 1). A total of 70 samples were collected in 2000 (Table 2). Samples were initially preserved in formalin. They have been sorted and fish eggs and larvae have been tranferred to alcohol for later identification and enumeration.

Table 1: Description and location of ichthyoplankton sampling sites in the Kennebec River. Sites are either above or below the former Edwards Dam.

Site	Site Name	Site Description	Above/ below
D-1	Second Power Line	above Sidney boat launch	A
D-2	Two Mile Rapid	above Sidney boat launch	A
D-3	Sidney Boat Launch	Sidney	A
D-4	Bacon Rapids	below Sidney	A
D-5	Babcock Rapids	above Augusta	A
D-6	Augusta Boat Launch	small cove just above dock	B
D-8	Hallowell Cement Pier	granite pier above downtown Hallowell	B
D-9	Foggy Bottom Marine	just below marina west shore	B
D-10	Below Gardner Bridge	just below bridge near west shore	B
D-11	Brown's Island	southern end of island	B
D-12	Rolling Dam	South Gardner by RR over brook	B
D-13	Lockwood	below powerhouse by Marden's parking lot	A
D-14	Sebasticook	under auto bridge below dam	A
D-15	Messalonskee Stream	in Mesalonskee Stream at mouth	A
D-16	S. Gardiner	cove on west shore below park-up from small marina	B
D-17	Seven Mile Island	150 yards above island-west shore	A
D-18	Goff Brook	east shore-opposite Goff Brook	A
I-1	Augusta	"along Front St. parking lot, above Mem. bridge"	B
I-2A	Hallowell	"Central St. to boat launch, west side"	B
I-3A	Brown's Island	east side of southern end near power lines	B
I-3C	Togus Stream	Randolph	B
I-4B	Buoy #38	Nehumkeag Island in South Gardiner	B
I-7	Sands Island	southern end of island over channel	B
I-99C	Sidney Boat Launch	Sidney	A
I-99F	Goff Brook	Sidney	A

Table 2: Dates and locations for ichthyoplankton samples collected in 2000.

Site	Date Set	Time Set	Date Pulled	Time Pulled	Water Temp	Air Temp
D-13	5/10/00	1230	5/17/00	935		
D-15	5/17/00	1045	5/17/00	1345	14.8	22
D-16	5/17/00	1105	5/17/00	1410	14.8	22
D-1	5/18/00	858	5/18/00	1230	12	19.9
D-3	5/18/00	950	5/18/00	1330	12	20.2
D-11	5/22/00	940	5/22/00	1452		
D-12	5/22/00	1020	5/22/00	1534		
D-9	5/22/00	950	5/22/00	1508		
D-8	5/22/00	920	5/22/00	1420		
D-6	5/22/00	905	5/22/00	1405	11.6	11
D-10	5/22/00	1005	5/22/00	1517	11.6	13.9
I-1	5/23/00	1031	5/23/00	1036	12	
I-2A	5/23/00	1053	5/23/00	1058		
I-3A	5/23/00	1112	5/23/00	1117		
I-4B	5/23/00	1154	5/23/00	1159		
I-7	5/23/00	1208	5/23/00	1213		
D-4	5/24/00	1046	5/24/00	1430	11.4	10.5
I-99C	5/24/00	1415	5/24/00	1420		
D-5	5/24/00	1127	5/24/00	1458		
D-6	5/30/00	1107	5/30/00	1408	15.1	23.1
D-8	5/30/00	1115	5/30/00	1418		
D-11	5/30/00	1129	5/30/00	1432		
D-9	5/30/00	1136	5/30/00	1440		
D-10	5/30/00	1152	5/30/00	1450		
D-12	5/30/00	1208	5/30/00	1510	15.5	20.8
D-15	6/2/00	1055	6/2/00	1455	18.5	17.2
D-2	6/2/00	1115	6/2/00	1515	15.7	
D-1	6/2/00	1135	6/2/00	1535	16.2	21.4
I-7	6/5/00	931	6/5/00	936	17.2	15
I-4B	6/5/00	943	6/5/00	948		
I-3C	6/5/00	1013	6/5/00	1018		
I-3A	6/5/00	1050	6/5/00	1055		
I-2A	6/5/00	1125	6/5/00	1125		
I-1	6/5/00	1140	6/5/00	1145		
D-13	6/8/00	943	6/8/00	1442		
D-15	6/8/00	1009	6/8/00	0		
D-2	6/8/00	1033	6/8/00	1543		
D-14	6/8/00	925	6/8/00	1433		
D-6	6/9/00	838	6/9/00	1303	15.6	20.4
D-8	6/9/00	849	6/9/00	1313		
D-11	6/9/00	857	6/9/00	1328		
D-10	6/9/00	910	6/9/00	1342		
D-12	6/9/00	934	6/9/00	1359		
D-16	6/9/00	946	6/9/00	1405		
D-8	6/12/00	1248	6/12/00	1541		
D-16	6/12/00	1358	6/12/00	1632		
D-12	6/12/00	1349	6/12/00	1622		
D-11	6/12/00	1259	6/12/00	1556		
D-6	6/12/00	1225	6/12/00	1529	14.7	12.8
I-2A	6/12/00	1113	6/12/00	1118		
D-10	6/12/00	1309	6/12/00	1606		
I-3A	6/12/00	1058	6/12/00	1104		
I-3C	6/12/00	1036	6/12/00	1041		

Site	Date Set	Time Set	Date Pulled	Time Pulled	Water Temp	Air Temp
I-4B	6/12/00	1007	6/12/00	1012		
I-7	6/12/00	949	6/12/00	954	15.4	10.8
I-1	6/12/00	1140	6/12/00	0		
I-99F	6/13/00	1433	6/13/00	1435		
D-17	6/13/00	1331	6/13/00	1535	16	21.5
D-18	6/13/00	1346	6/13/00	0		
D-1	6/15/00	1100	6/15/00	1345	15.7	
D-5	6/15/00	1122	6/15/00	1325	15.8	
D-6	6/19/00	1125	6/19/00	1408	20	25
D-8	6/19/00	1134	6/19/00	1421		
D-11	6/19/00	1149	6/19/00	1439		
D-10	6/19/00	1158	6/19/00	1459		
D-12	6/19/00	1211	6/19/00	1516		
D-16	6/19/00	1221	6/19/00	1524		
D-16	6/28/00	1110	6/28/00	0		
D-6	6/28/00	1010	6/28/00	1451	22.9	28.3
D-10	6/28/00	1035	6/28/00	0		

Job I-2

Job Number & Title: #F-41-R-6 (2)
Kennebec River Juvenile Alosid and Striped Bass Survey

Job Objectives: To determine abundance indices for juvenile alosids and striped bass in the Kennebec River

(a) **Summary:** The juvenile alosid survey in the Kennebec River has been conducted at 14 standard sites since 1979 to evaluate the increased abundance of the alosid population following improvement of the river's water quality. A juvenile striped bass survey has been conducted at the 14 standard sites and additional experimental sites since 1994 to evaluated tyhe abundance of the striped bass population. Some of the highest indices on record for juvenile alewives, shad, and blueback herring occurred in 1999 and 2000. The striped bass index appears to fluctute with a peak every 3-4 years.

(b) **Target Date:** 2003.

(c) **Status of Progress:** On schedule

(d) **Significant Deviations:** None

(e) **Recommendations:** Continue as planned

(f) **Cost:** $13,083.56

(g) **Data Presentation & Discussion:**

The juvenile alosid survey in the Kennebec/Androscoggin estuary was established in 1979 to monitor the abundance of juvenile alosids at 14 permanent sampling sites. Four sites are on the Upper Kennebec River, three on the Androscoggin River, four on Merrymeeting Bay, one on the Cathance River, one on the Abagadasset, and one on the Eastern River (Table 1; Fig. 1). All these sites are in the tidal freshwater portion of the estuary. The mean tidal range at head-of-tide in Augusta is four feet, at head-of-tide in Bruswick is six feet, and in Merrymeeting Bay is eight feet. Beginning in 1987, small numbers of juvenile striped bass were captured during the survey. To better monitor the abundance of striped bass, six additional experimental sites, located in the lower part of the estuary (Table 1; Fig. 1), have been sampled since 1994. These sites are located in the tidal salinity-stratified portion of the estuary.

The sampling protocol for all stations is similar to that used in the juvenile shad sampling program on the Connecticut River. Each site is sampled once every other week from mid-May to the end of August. The goal is to sample each site six times during the season. All samples are taken with a beach seine within three hours of high slack water. The seine is made of 6.35-mm stretch mesh nylon, measures 17-m long and 1.8-m deep, and has a 1.8-m x 1.8-m bag at its center. One end of the seine is held stationary at the land/water interface, and the other end is towed by boat perpendicular to shore; after the net is fully extended, the waterside end is towed in an upriver arc and pulled ashore. An area of approximately 220 m^2 is sampled.

The sample is sorted and processed in the field. All alosids and striped bass are counted, and the total length of a maximum of 50 of each species is measured. Other species are identified, enumerated, and the total length of a maximum of 10 of each species is measured. The catch per unit effort (CPUE) index is calculated by dividing the number of individuals caught by the number of seine hauls.

Juvenile Striped Bass Survey

During the 2000 field season, a total of 84 seine hauls at 14 standard stations captured six juvenile striped bass. The CPUE index was 0.07 fish haul^{-1}. An additional 36 seine hauls at the six experimental stations in the lower Kennebec captured 10 striped bass for a CPUE index of 0.28 fish haul^{-1}. The CPUE index for all striped bass captured at all sites was 0.13 fish haul^{-1}. Since 1987, the CPUE index for the 14 standard stations has ranged from 0.01 to 0.35 (Table 2). The striped bass index appears to fluctute with a peak every 3-4 years.

The total length of striped bass ranged from 3.4 to 9.0 cm (Table 3).

Juvenile Alosid Survey

During the 2000 field season, 84 hauls at 14 standard stations captured a total of 20,734 juvenile alewife, 341 American shad, and 1,081 blueback herring. An additional 36 hauls at the six experimental stations captured 253 alewives, 57 American shad, and five blueback herring.

For the standard stations, the greatest CPUE indices for juvenile alewives occurred in the Abagadasset River, followed by Merrymeeting Bay, and the Cathance River (Table 4). In 2000, the CPUE indices for juvenile alewives were the highest on record for the Upper Kennebec, Merrymeeting Bay, and Abagadasset River and the third highest on record for the Cathance River (Table 5).

The greatest CPUE indices for juvenile shad at the standard stations occurred in the Upper Kennebec River, followed by the Eastern River (Table 4). In 2000, the CPUE index for juvenile shad in the Upper Kenenbec River was the highest on record, however, indices for Merrymeeting Bay, the Abagadasset River, and the Cathance River were low compared to 1999 (Table 6).

For standard stations in 2000, the greatest CPUE index for blueback herring occurred in the Cathance River, while the CPUE index for other stations was much lower (Table 4). The CPUE index for the Cathance River in 2000 represents the highest on record for any river segment for this species (Table 7).

TABLE 1: River segment location and number of beach seine hauls for each of 14 standard stations and six experimental stations for the juvenile alosid and striped bass surveys in the estuarial complex of the Kennebec River and Androscoggin River, 2000.

Site Number	River Segment	Survey Type	Number of hauls			
			July	August	September	October
1	Upper Kennebec	Alosid	1	2	2	
2	Upper Kennebec	Alosid	1	2	2	
3	Upper Kennebec	Alosid	1	2	2	
7	Upper Kennebec	Alosid	1	3	2	
9	Merrymeeting Bay	Alosid	1	3	2	
12A	Merrymeeting Bay	Alosid	1	3	2	
12J	Merrymeeting Bay	Alosid	1	3	2	
12L	Merrymeeting Bay	Alosid	1	3	2	
21	Androscoggin	Alosid	1	1	3	2
27	Androscoggin	Alosid	1	1	3	2
29A	Androscoggin	Alosid	1	1	3	2
33	Cathance	Alosid	1	3	2	
45	Abagadasset	Alosid	1	3	2	
51	Eastern	Alosid	1	2	2	1
SB9	Lower Kennebec River	Experimental	1	2	2	1
SB10	Lower Kennebec River	Experimental	1	2	2	1
SB11	Lower Kennebec River	Experimental	1	2	2	1
SB12	Lower Kennebec River	Experimental	1	2	2	1
SB13	Lower Kennebec River	Experimental	1	2	2	1
SB14	Lower Kennebec River	Experimental	1	2	2	1

Table 2. Number of hauls, total catch and CPUE index for juvenile striped bass on the Kennebec River, 1987-2000 for 14 standard stations and 6 experimental stations.

Year	Standard Stations			Experimental Stations			Overall
	Number of Hauls	Total Catch	CPUE Index	Number of Hauls	Total Catch	CPUE Index	CPUE Index
1987	74	26	0.35				
1988	68	3	0.04				
1989	68	1	0.01				
1990	68	4	0.06				
1991	63	16	0.25				
1992	80	1	0.01				
1993	71	1	0.01				
1994	69	23	0.33				
1995	83	2	0.02				
1996	69	4	0.06				
1997	80	9	0.11				
1998	82	14	0.17				
1999	80	13	0.16	34	17	0.50	0.26
2000	84	6	0.07	36	10	0.28	0.13

Table 3. Total length of juvenile striped bass captured in the Kennebec River in 2000.

Site number	Date	River segment	Total Length (cm)
12A	7/20/00	Merrymeeting Bay	3.6
12A	7/20/00	Merrymeeting Bay	4.5
12A	9/14/00	Merrymeeting Bay	8.4
45	8/2/00	Abagadasset River	4
51	8/21/00	Eastern River	8.4
9	8/1/00	Merrymeeting Bay	3.4
SB10	8/17/00	Lower Kennebec River	5.6
SB11	8/17/00	Lower Kennebec River	5
SB11	10/2/00	Lower Kennebec River	9
SB12	8/17/00	Lower Kennebec River	5
SB9	8/17/00	Lower Kennebec River	4.9
SB9	9/1/00	Lower Kennebec River	5.8
SB9	9/1/00	Lower Kennebec River	6
SB9	9/1/00	Lower Kennebec River	6
SB9	9/1/00	Lower Kennebec River	6
SB9	9/1/00	Lower Kennebec River	6.5

Table 4. CPUE index for juvenile alewives, American shad, and blueback herring by river section and month for 2000.

Species	River segment	July CPUE Index	August CPUE Index	September CPUE Index	October CPUE Indexr	Average CPUE Index
alewife	Upper Kennebec River	302.50	4.44	2.00		60.29
alewife	Merrymeeting Bay	1537.50	556.58	76.50		560.04
alewife	Androscoggin River	16.00	0.00	0.11	0.00	2.33
alewife	Cathance River	1155.00	13.67	0.00		199.33
alewife	Abagadasset River	2050.00	867.33	6.50		777.5
alewife	Eastern River	105.0	4.50	1.50	0.00	19.5
alewife	Lower Kennebec River	7.50	5.75	10.08	3.00	7.03
American shad	Upper Kennebec River	0.00	34.22	1.25		15.14
American shad	Merrymeeting Bay	0.00	0.00	1.00		0.33
American shad	Androscoggin River	0.00	0.00	0.33	0.00	0.14
American shad	Cathance River	1.00	0.33	0.00		0.33
American shad	Abagadasset River	2.00	0.00	0.00		0.33
American shad	Eastern River	0.00	1.00	3.00	0.00	1.33
American shad	Lower Kennebec River	0.00	0.00	4.75	0.00	1.58
blueback herring	Upper Kennebec River	0.00	0.00	0.00		0.00
blueback herring	Merrymeeting Bay	0.00	2.00	0.00		1.00
blueback herring	Androscoggin River	0.00	0.00	0.00	0.00	0.00
blueback herring	Cathance River	0.00	350.00	0.00		175.00
blueback herring	Abagadasset River	0.00	0.67	0.00		0.33
blueback herring	Eastern River	0.00	2.50	0.00	0.00	0.83
blueback herring	Lower Kennebec River	0.00	0.00	0.42	0.00	0.14

Table 5. CPUE index for juvenile alewives by river section for 1979-2000. The length and depth of the seine were increased in 1983. A bag also was added to the seine in 1983, and the method of seining was changed, although the area sampled remained essentially the same.

Year	Upper Kennebec River	Merrymeeting Bay	Androscoggin River	Cathance River	Abagadasset River	Eastern River	Mid Kennebec River	Lower Kennebec River
1979	7.91	25.60	2.24	647.00	43.72	157.17	8.44	0.00
1980	0.10	3.67	12.29	5.11	12.50	38.70	3.25	0.00
1981	0.58	7.62	1.57	4.50	6.67	14.17	3.50	0.17
1982	0.67	1.83	0.08	38.33	1.62	3.00	1.63	0.29
1983	16.95	43.58	33.29	40.45	0.21	0.33		
1984	0.13	1.94	0.56	133.76	4.00	27.00		
1985	0.10	1.48	2.13	54.67	8.25	13.33		
1986	0.46	3.32	0.80	22.33	6.29	13.83		
1987	2.17	18.04	0.33	59.00	24.00	7.17		
1988	0.21	11.93	14.73	17.50	117.50	9.63		
1989	2.00	15.77	0.85	52.83	58.00	1.43		
1990	0.25	41.46	0.48	8.43	98.00	14.43		
1991	5.26	41.50	0.72	461.57	12.29			
1992	1.08	83.92	1.22	99.83	53.33	80.00		
1993	9.63	9.44	23.75	2.33	70.33			
1994	0.55	18.40	0.73	1.60	26.00	7.50		
1995	7.25	45.57	3.06	10.50	43.33	90.17		
1996	1.05	35.20	0.20	0.00	62.20	9.00		
1997	7.88	23.21	9.80	0.00	9.33	85.00		
1998	2.33	55.04	1.83	1.40	2.67	4.00		
1999	18.48	58.13	15.13	67.50	1.83	10.83		
2000	60.29	560.04	2.33	199.33	777.50	19.50		7.03

Upper Kennebec River = from the Augusta Dam to the Richmond Bridge
Merrymeeting Bay = Richmond Bridge to Chops Point, excluding tributaries
Androscoggin River = from the Brunswick Dam to southern tip of Mustard Island
Cathance = from the confluence with Merrymeeting Bay to head-of-tide
Abagadasset = from the confluence with Merrymeeting Bay to head-of-tide
Eastern = from the confluence with Merrymeeting Bay to head-of-tide
Mid Kennebec River = Chops Point to Doubling Point
Lower Kennebec River = Doubling Point to Bay Point

Table 6. CPUE index for juvenile American shad by river section for 1979-2000. The length and depth of the seine were increased in 1983. A bag also was added to the seine in 1983, and the method of seining was changed, although the area sampled remained essentially the same.

Year	Upper Kennebec River	Merrymeeting Bay	Androscoggin River	Cathance River	Abagadasset River	Eastern River	Mid Kennebec River	Lower Kennebec River
1979	0.16	0.00	0.00	0.00		0.00	0.00	0.00
1980	0.00	0.36	0.29	0.00		0.00	0.00	0.00
1981	1.08	0.85	0.29	0.50		0.00	0.17	0.00
1982	0.00	0.33	0.17	0.00		0.00	0.63	0.00
1983	0.15	0.20	2.18	3.00		0.00	0.00	
1984	0.90	0.46	0.00	2.00		0.67		
1985	0.69	1.53	0.40	6.50		7.00		
1986	0.10	0.15	0.08	1.00		0.50		
1987	0.15	8.05	0.17	1.25	0.50	0.00		
1988	0.11	1.36	0.00	0.00	0.33	0.51		
1989	1.25	0.29	1.29	0.48	0.00	0.00		
1990	3.50	2.46	0.83	6.83	0.33	4.20		
1991	1.21	0.00	0.00	0.67	1.67	1.17		
1992	0.10	0.67	0.67	3.67	0.00	0.00		
1993	0.00	0.29	3.63	0.00	0.00			
1994	0.00	0.35	1.00	0.00	0.17	0.50		
1995	0.21	0.39	1.89	0.17	0.60	0.33		
1996	4.15	0.25	0.00	0.20	0.33	0.50		
1997	0.00	0.88	0.80	0.00	0.40	0.00		
1998	0.00	1.67	0.00	0.00	0.00	0.00		
1999	0.00	20.46	0.00	42.67	33.00	0.00		
2000	15.14	0.33	0.14	0.33	0.33	1.33		1.58

Upper Kennebec River = from the Augusta Dam to the Richmond Bridge
Merrymeeting Bay = Richmond Bridge to Chops Point, excluding tributaries
Androscoggin River = from the Brunswick Dam to southern tip of Mustard Island
Cathance = from the confluence with Merrymeeting Bay to head-of-tide
Abagadasset = from the confluence with Merrymeeting Bay to head-of-tide
Eastern = from the confluence with Merrymeeting Bay to head-of-tide
Mid Kennebec River = Chops Point to Doubling Point
Lower Kennebec River = Doubling Point to Bay Point

Table 7. CPUE index for juvenile blueback herring by river section for 1979-2000. The length and depth of the seine were increased in 1983. A bag also was added to the seine in 1983, and the method of seining was changed, although the area sampled remained essentially the same.

Year	Upper Kennebec River	Merrymeeting Bay	Androscoggin River	Cathance River	Abagadasset River	Eastern River	Lower Kennebec River
1992	0.00	0.79	20.78	111.50		2.50	
1993	0.00	0.00	0.00	9.50	0.00		
1994	0.00	5.20	0.00	0.00	11.60	26.50	
1995	3.13	22.57	0.67	6.83	17.00	37.50	
1996	0.00	29.45	0.20	0.00	2.80	5.25	
1997	1.42	2.38	0.00	0.00	1.33	83.00	
1998	2.08	16.92	0.72	6.80	0.83	5.50	
1999	0.61	21.29	0.00	37.50	0.50	17.67	
2000	0.00	1.00	0.00	175.00	0.33	0.83	0.14

Upper Kennebec River = from the Augusta Dam to the Richmond Bridge
Merrymeeting Bay = Richmond Bridge to Chops Point, excluding tributaries
Androscoggin River = from the Brunswick Dam to southern tip of Mustard Island
Cathance = from the confluence with Merrymeeting Bay to head-of-tide
Abagadasset = from the confluence with Merrymeeting Bay to head-of-tide
Eastern = from the confluence with Merrymeeting Bay to head-of-tide
Mid Kennebec River = Chops Point to Doubling Point
Lower Kennebec River = Doubling Point to Bay Point

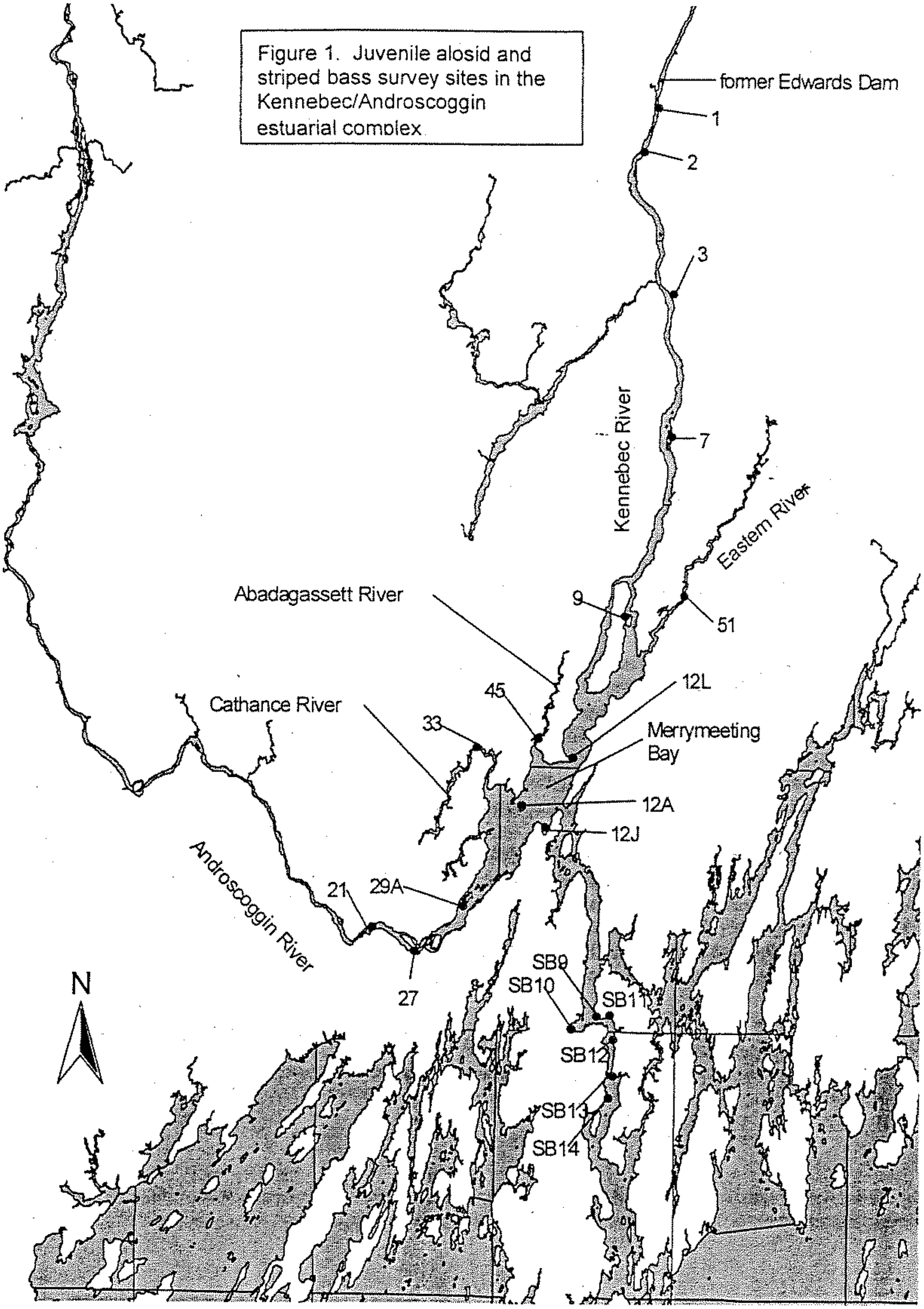


Figure 1. Juvenile alosid and striped bass survey sites in the Kennebec/Androscoggin estuarial complex.
former Edwards Dam
1
2
3
7
Kennebec River
Eastern River
Abadagassett River
9
51
12L
45
Cathance River
33
Merrymeeting Bay
12A
12J
Androscoggin River
21
29A
27
N
SB9
SB10
SB11
SB12
SB13
SB14

Job I-3

Job Number & Title: #F-41-R-6 (3)
Anadromous Fish Coordination and Planning

Job Objectives: To coordinate the Anadromous Fish Restoration Program on the Kennebec River system; to review and make comments on hydropower relicensing projects, including associated studies.

(a) **Summary:** The project leader has also been working with other agencies and private interest groups in seeking removal of the Smelt Hill Dam on the Presumpscot River. He provided oversight for the diadromous fish restoration program on the Kennebec River and coordinated the various restoration and evaluation projects.

(b) **Target Date:** 2003

(c) **Status of Progress:** On schedule

(d) **Significant Deviations:** None

(e) **Recommendations:** Continue as planned

(f) **Cost:** $58,361.64

(g) **Data Presentation & Discussion:**
<u>Coordination of the Diadromous Fish Restoration Program on the Kennebec River System</u>

Sebasticook River Fish Passage
The project leader devoted significant time working with other partners and towns to provide fish passage at three non-hydro dams in the Sebasticook River drainage (Figure 1: Sebasticook Lake Outlet Dam in Newport, Guilford Dam in Newport, and Plymouth Pond Outlet Dam in Plymouth). A fishway was constructed at a fourth non-hydro dam (Figure 1: Pleasant Pond Outlet) in 1999. It is necessary to provide passage at all four dams by 2001 <u>before</u> the Benton Falls (FERC #5073) and Burnham Projects (FERC #11472) are required to install fish passage (Figure 1).

DMR initially requested assistance with fishway constuction from the US Army Corp of Engineers under Section 206. When that process appeared to be too slow and costly, DMR issued a Request for Proposals for engineering assistance, and ultimately contracted with URS in September, 2000. To date, URS has visited the three sites, developed conceptual drawings for fishways at the Sebasticook Lake Outlet Dam and Plymouth Pond Outlet Dam, recommended removal of the Guildford Dam, and developed cost estimates for the three projects.

Project	Estimated cost
Guilford Dam breaching	$111,108.00
Sebasticook lake Outlet Fishway	$215,386.00
Plymouth Dam Fishway	$100,371.00
Total	$426,865.00

The State initially set aside $178,500 in the Kennebec River Fisheries Restoration Fund; additional funding has been obtained to cover the shortfall.

Wetland and Riparian Restoration Partnership
The project leader and staff have met and worked with the US Fish and Wildlife Service (USFWS), Natural Resources Conservation Service, Department of Inland Fisheries and Wildlife (DIFW), National Marine Fisheries Service, Army Corp of Engineers, American Rivers, Trout Unlimited, and other partners in identifying and prioritizing fish habitat improvement projects. This partnership is being coordinated by the USFWS Gulf of Maine Project and American Rivers.

Management Plans
The project leader and representative of the USFWS, DIFW, and Penobscot Indian Nation finalized the ***American Shad Restoration Plan for the Penobscot River.*** This plan has been signed by all the participants.

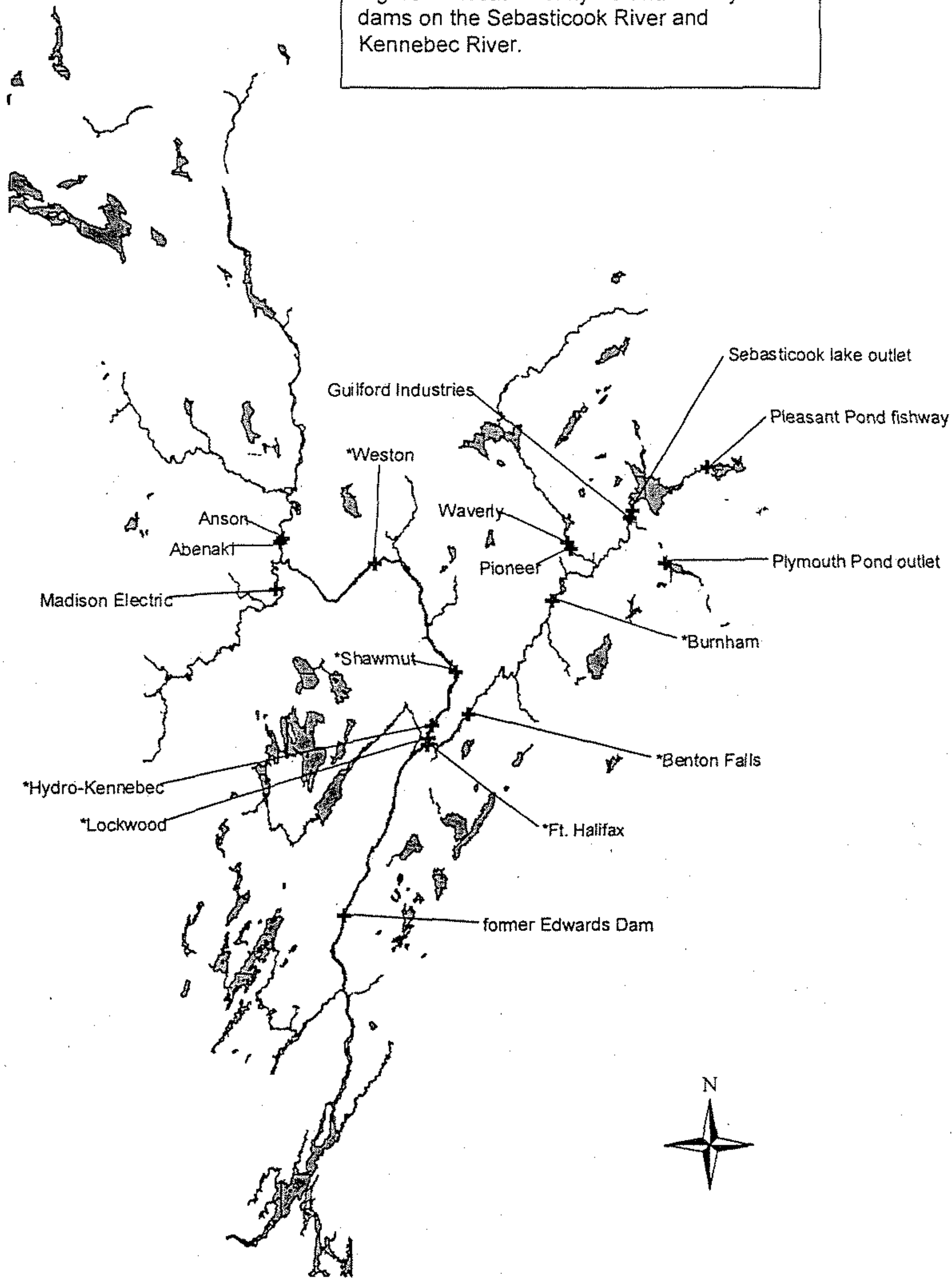
Hydropower Relicensing Projects Review and Comments

The project leader continued to provide input into the relicensing of the five dams on the Presumpscot River (FERC #2897, 2931, 2932, 2942 and 2984); the Anson and Abenaki Projects (FERC #2365 and 2364) on the Kennebec River; and the Great Works Dam (FERC #2312) and Howland Dam (FERC # 2721) on the Penobscot River. In addition, the project leader commented on fish passage design for the Ft. Halifax Dam (FERC # 2552); and on monitoring and study plans for the Ft. Halifax Dam (FERC # 2552), Benton Falls Dam (FERC #5073), Burnham Dam (FERC #11472) on the Sebasticook River, the Lockwood Dam (FERC #2574), and Hydro-Kennebec dam (FERC #2611on the Kennebec River, and the South Berwick (FERC #11163) on the Salmon Falls River.

The project leader collaborated with the Atlantic Salmon Commission and DIFW to develop joint fisheries management goals for the Presumpscot River, and has requested fish passage for anadromous species at the five dams in comments on FERC's Scoping Document 1. In previous stages of consultation, DMR had only requested passage for American eel. This change is due to the anticipated removal of the Smelt Hill Dam, the closing of the pulp mill in Westbrook, and citizen development of a watershed plan for the Presumpscot River.

The project leader participated in meetings related to the decommissioning and removal of the Central Maine Power-owned Smelt Hill Project on the Presumpscot River in Falmouth. The Maine Department of Environmental Protection (MDEP) and MDMR are working with the Army Corps of Engineers through the Section 206 Program to remove this dam. The Coastal Conservation Association has raised funds to purchase the dam and provide the 35% required match. MDMR will eventually assume ownership of the dam and MDMR/MDEP will apply to the FERC to decommission and remove this project site. The project leader commented on the draft Environmental Report issued by the Corps of Engineers.

Figure 1. Location of hydro and non-hydro dams on the Sebasticook River and Kennebec River.



Job I-4

Job Number & Title: #F-41-R-6 (4)
Shad Restoration

Job Objective: To restore American shad to the Kennebec, Androscoggin, Saco, and Medomak Rivers

(a) **Summary:** Approximately 2.66 million eggs (> 2 mm) were collected by strip-spawning American shad from the Connecticut River and 4.75 million eggs (> 2 mm) were obtained from tank-spawning at the Waldoboro shad hatchery. Eggs in the tank-spawning systems were produced by 276 adult shad from the Connecticut River, 143 from the Saco River, and 25 from the Kennebec River. In 2000, approximately 3.3 million shad fry were stocked in the Kennebec River; 500,000 in the Sebasticook River; 530,000 in the Androscoggin River; 146,000 in the Medomak River; and 259,000 in the Saco River as mitigation for the use of Saco adults for broodstock.

(b) **Target Date:** 2003

(c) **Status of Progress:** On schedule

(d) **Significant Deviations:** None

(e) **Recommendations:** Obtain more eggs from the Saco River, as well as native stock from the estuarial complex of the Kennebec and Androscoggin Rivers

(f) **Cost:** $101,358.57

(g) **Data Presentation & Discussion:**

Restoration of American shad in Maine began with the stocking of adults in the Androscoggin River in 1985 and the Kennebec River in 1987. In 1992, the Time & Tide Resource Conservation & Development Council and the Maine Department of Marine Resources established a pilot shad hatchery for the production of shad fry. Since 1992, the hatchery has undergone two expansions designed to increase the production of fry for stocking.

The shad hatchery project is a cooperative effort between the Department of Marine Resources (DMR), Kennebec River Hydro Developers Group (KHDG), Time & Tide Mid-Coast Fisheries Development Project (Time & Tide), and the Town of Waldoboro. Time & Tide is a nonprofit organization established by the to receive and expend funds for resource enhancement projects in Maine's mid-coast area. In 2000, the shad hatchery operation was under the supervision of contractual consultant Samuel Chapma, who gained expertise in culture techniques while employed as an Aquaculture Specialist with the University of Maine.

The shad hatchery is located in Waldoboro, Maine. From 1992 to 1997, it consisted of an 18' x 19' aluminum building that housed incubators and tanks, a large storage building, and three adjacent earthen ponds. In 1997, DMR and Time & Tide obtained funds from the Maine Outdoor Heritage Fund and the KHDG to expand the hatchery. The large storage building was renovated to house the expanded hatchery, the number of fry incubation tanks was increased from two to six, and one tank spawning system was constructed. In 1999, DMR and Time & Tide obtained funds from the Maine Outdoor Heritage Fund and the KHDG for additional renovations at the hatchery and the construction of two more tank spawning systems. Details of the hachery operation can be found in the *Waldoboro Shad Hatchery: 2000 Annual Report* (Appendix A).

Connecticut River Shad Egg Collection

Fertilized eggs were obtained from the Connecticut River above the Holyoke Dam in South Deerfield, MA, for incubation at the shad hatchery. Normandeau Associates Incorporated (NAI), former contractor for the Susquehanna River Program on the Connecticut River, was retained by DMR to collect eggs. In 2000, a Scientific Collectors Permit from the State of Massachusetts was requested by Maine to obtain five million fertilized shad eggs; the permit allowed employees of Normandeau Associates to strip eggs and milt from a maximum of 1,000 adult shad. Five Normandeau employees utilized two boats to drift for ripe adult shad at night. They fished a total of 10 days from May 30 through June 10, 2000 (Table 1). On shore, the eggs were packaged and prepared for interstate transport according to NAI standards. The eggs were transported by vehicle to Maine, where they were disinfected with buffered betadyne solution, then divided and placed into incubators.

A total of 73.725 liters of eggs were received by DMR in 2000. Eggs were sieved at the hatchery to remove those < 2 mm, which are considered inviable and are not incubated. A total of 69.2 liters of eggs >2 mm (approximately 2,658,616 eggs) were incubated, and produced 1,677,928 fry at hatch for an average viability 59.1% (Table 1). Due to the volume of eggs handled and the limited number of culture tanks at the hatchery, these fry were combined with fry resulting from the tank spawning of adult shad from Connecticut River. Therefore, it is not possible to report an unambiguous final number of fry resulting from the egg collection.

Eggs From Adult Tank Spawning

A total of 276 adult shad from the Connecticut River (MA), 143 adult shad from the Saco River (ME) and 25 adult shad from the Kenenbec River (ME) were transported successfully to the shad hatchery between 6/4 and 7/21 and placed into the tank spawning systems (Table 2). Broodstock from the Saco River were segregated in one spawning tank. Kennebec River broodstock were intitially segregated in a second spawning tank, but had to be mixed with Connecticut River broodstock after June 23, because the third spawning tank could not accomodate all the Connecticut River fish. The mixing of adults coupled with the limited number of culture tanks makes it impossible to report an unambiguous number of stocked fry resulting from each source of broodstock. Details of the tank-spawning can be found in Appendix A, Tables 2-4.

The 143 shad from the Saco River produced 1,579,095 fry at hatch (Appendix A, Table 2) . Prior to the introduction of Connecticut River fish, the 25 Kenenbec River shad produced 178, 871 fry at hatch (Appendix A, Table 3). The mixed Kennebec River and Connecticut River fish produced at total of 1,827,311 fry at hatch (Appendix A, Table 4). Average viability of eggs > 2 mm for Saco broodstock was 83.4%, for Kennebec River broodstock was 86.2%, and for mixed Kennebec/Connecticut broodstock was 66.6% (Appendix A, Tables 2-4). Average survival after hatch for all eggs combined was 92.1% (Appendix A, Table 5).

Fry Stocking

Fry were transported in a 125-gallon circular fiberglass tank mounted on a half-ton pickup truck. During transport, a small oxygen tank provided adequate amounts of dissolved oxygen. Approximately 4,781,273 fry were stocked in 2000 (Table 3). A total of 3,346,727 fry were stocked in the mainstem of the Kennebec River, and 500,004 were stocked in the Sebasticook River, a tributary of the Kennebec. An additional 259,090 fry were stocked in the saco River, 529,558 in the Androscoggin River, and 145, 894 in the Medomak River.

Table 1. Fish collected during the 2000 shad egg collection effort by Normandeau Asociates, Inc.

Date	Bucks	Hard Roe	Runny Roe	Spent Roe	Released alive	Number Sacrificed	Total catch	Number of drifts	Liters of eggs	Number of eggs	Percent viability	Water temp (C)
5/30	7	6	23	16	22	30	52	10	7.5	217,962	67.0	15.0
5/31	10	15	36	11	26	46	72	9	15.0	493,086	82.7	16.0
6/1	8	13	27	20	33	35	68	9	9.0	354,402	39.9	17.5
6/2	6	5	26	33	38	32	70	6	8.8	322,176	74.0	18.0
6/4	9	39	62	39	78	71	149	8	11.0	478,730	22.6	17.5
6/5	17	16	28	21	37	45	82	10	9.4	292,246	75.0	17.0
6/6	0	24	2	36	62	0	62	4	0			15.5
6/7	0	0	0	0	0	0	0	7	0			15.0
6/9	12	13	24	11	24	36	60	14	5.1	249,451	91.0	16.0
6/10	3	29	45	28	57	48	105	11	3.4	250,563	74.0	17.0
Total	72	160	273	215	377	343	720	88	69.2	2,658,616	65.78	

Table 2. Transfers of American shad broodstock, 2000

River of origin	Trapping site	Date	Receiving site	Number loaded	Number of mortalities	Number in spawning tank
Kennebec	Fort Halifax	6/1	Hatchery	3	0	3
Kennebec	Fort Halifax	6/12	Hatchery	2	0	2
Kennebec	Fort Halifax	6/13	Hatchery	5	0	5
Kennebec	Fort Halifax	6/15	Hatchery	3	0	3
Kennebec	Fort Halifax	6/21	Hatchery	7	0	7
Kennebec	Fort Halifax	6/22	Hatchery	5	0	5
Subtotal				**25**	**0**	**25**
Saco	Cataract Lift	6/12	Hatchery	81	1	80
Saco	Cataract Lift	6/30	Hatchery	41	0	41
Saco	Cataract Lift	7/21	Hatchery	22	0	22
Subtotal				**144**	**1**	**143**
Connecticut	Holyoke Lift	6/4	Hatchery	61	1	60
Connecticut	Holyoke Lift	6/15	Hatchery	64	5	59
Connecticut	Holyoke Lift	6/16	Hatchery	64	5	59
Connecticut	Holyoke Lift	6/19	Hatchery	20	3	17
Connecticut	Holyoke Lift	6/23	Hatchery	59	5	54
Connecticut	Holyoke Lift	6/26	Hatchery	34	7	27
Subtotal				**302**	**26[b]**	**276**
TOTAL NUMBER TRANSPORTED TO HATCHERY:						**444**

b - 8.6% trucking mortality

Table 3. Summary of American shad fry stocking, 2000.

Date stocked	Source	Number of fry hatched	% survival after hatch	Number stocked	Receiving Site	Release Point
6/23	CT	553,817	79.1	438,231	Kennebec	Fort Halifax Park
6/23	CT	488,008	72.6	354,502	Kennebec	Fort Halifax Park
6/27	CT	253,294	97.4	246,770	Kennebec	Mill Island Park
6/30	CT	482,767	87.0	420,231	Kennebec	Below Shawmut
7/17	S	293,073	99.5	291,608	Kennebec	Below Shawmut
7/18	S	418,386	95.0	397,542	Kennebec	Mill Island Park
7/24	CT-K	567,614	95.6	539,410	Kennebec	Below Shawmut
7/27	CT-K	193,834	96.8	179,574	Kennebec	Fairfield boat ramp
7/27	S	221,569	93.5	207,356	Kennebec	Fairfield boat ramp
8/4	S-CT-K	273,928	99.1	271,503	Kennebec	Below Shawmut
Subtotal				**3,346,727**		
7/3	CT-K	127,658	85.6	109,395	Sebasticook	Below Burnham
7/17	CT-K	426,676	91.5	390,609	Sebasticook	Below Burnham
Subtotal				**500,004**		
7/10	S	285,264	90.8	259,090	Saco	Saco
7/10	CT-K	536,985	99.6	529,558	Androscoggin	Auburn boat launch
8/14	S-CT-K	145,896	99.7	145,894	Medomak	Below Rt 1 bridge
Total		**5,268,769**		**4,781,273**		

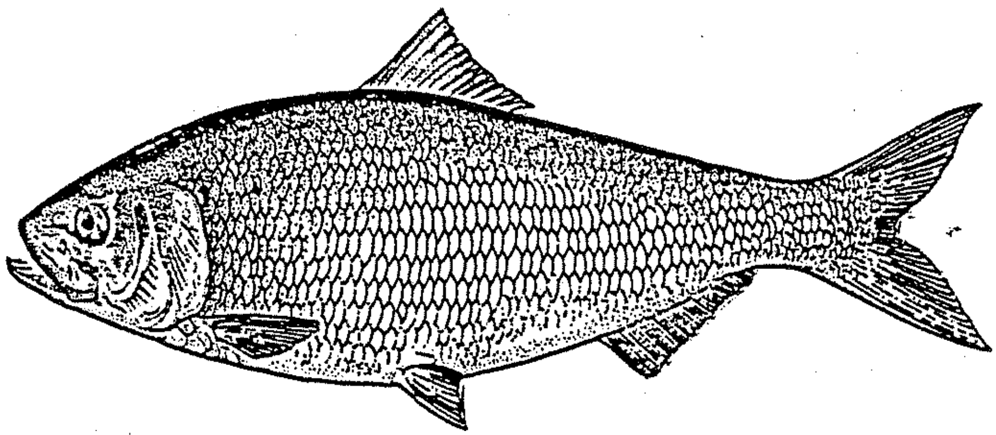
Table 6. Summary of Waldoboro Shad Hatchery Fry Stocking

Location	1992	1993	1994	1995	1996	1997	1998	1999	2000
Kennebec River									
Sidney boat ramp			4,000			349,974	421,408		
Waterville boat ramp		180,000	57,000	375,467	702,808	1,134,934	932,408	374,243	
Fort Halifax park									792,733
Hydro-Kennebec boat ramp								1,646,595	
Mill Island Park									644,312
Fairfield boat ramp									386,930
Below Shawmut dam									1,522,752
Sebaticook River									
Below Burnham dam					320,000	474,313	744,163	466,731	500,004
Above Burham dam								372,337	
Medomak River									
Medomak Pond			20,000	169,566	325,636	191,600	260,573	17,251	
Medomak River	200,000	55,000	6,000						145,894
Saco River									
Below Bar Mills						484,635	408,525	151,774	259,090
Androscoggin River									
Auburn boat launch								316,967	529,558
Total	200,000	235,000	87,000	545,033	1,348,444	2,635,456	2,767,077	3,345,898	4,781,273

APPENDIX A
To
F-41-R-4(6)
Shad Restoration

WALDOBORO SHAD HATCHERY
ANNUAL PROGRESS REPORT
2000

WALDOBORO SHAD HATCHERY



2000

ANNUAL REPORT

Carolyn, Samuel and Andrew Chapman

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INTRODUCTION

In 1992, the Time and Tide Resource Conservation and Development Area Council, in cooperation with and financed by the Maine Department of Marine Resources, established a pilot shad hatchery in the town of Waldoboro, Maine. This operation was run in an 18' x 19' aluminum shed that had no running water or sanitary facilities. Water for the hatchery's operation was piped in from an artesian well overflow 325' from the site. The technology was adopted from the Susquehanna River Van Dyke Shad Hatchery and proved to be very sound and reliable. The Waldoboro Hatchery has successfully operated from 1992 to 2000 and during that period provided 13,295,073 fry for distribution by the DMR.

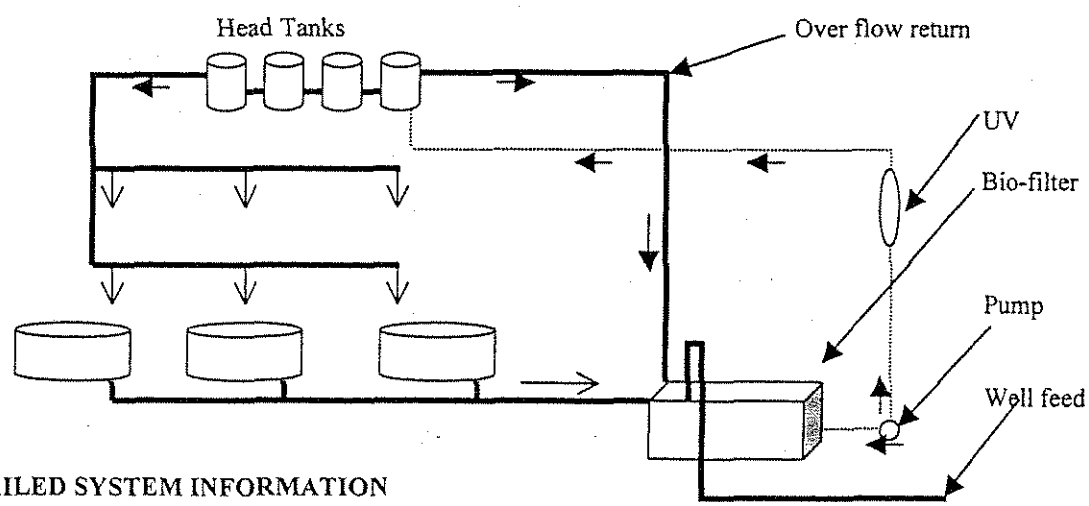
In 1997, the Maine Department of Marine Resources' Stock Enhancement Division (DMR-SED) received funds from The Maine Outdoor Heritage Fund to increase production capacity and implement new in-house technology for obtaining eggs from adult shad held in a spawning tank system at the Waldoboro Hatchery. These funds, administered through the Time and Tide Resource Conservation Area Council, allowed a complete renovation of the Waldoboro Hatchery and the installation of a recirculating spawning system. This new tank spawning system increased total egg availability and boosted hatchery production from an annual average of 600,000 to 2,700,000 during the 1997 season. In 1998, this system produced 3,660,739 shad eggs.

In 1999, the DMR-SED received another grant from The Maine Outdoor Heritage Fund and matched it with money from the Kennebec River Restoration Fund in order to create space to add two more tank-spawning systems for increased shad egg production at the hatchery. The first system was installed in time for the 1999 season and the second was installed at the end of that season, when funds became available. With the addition of one more spawning system in 1999, the number of eggs produced was increased to 4,142,122. In 2000, after the second system was installed, the total number of eggs produced increased to 6,917,407. These eggs, in combination with 3,314,882 from the Connecticut River egg take, resulted in the stocking of 4,781,273 shad fry in 2000.

The additional two tank-spawning systems, coupled with a year's experience in their operation, has provided an increased production of eggs and the new capability of maintaining Saco River shad as a river specific spawning group.

BASIC HATCHERY CULTURE SYSTEM

Well water to the culture area comes through a raised head tank, a bank of four separate tanks, which provides constant low-pressure gravity fed water through a 2" PVC pipe system.



DETAILED SYSTEM INFORMATION

Water coming into the building goes through a 50-micron filter and a UV sterilizer before entering the head tank. The tank is built on a shelf close to the ceiling in order to provide water pressure and height for the pipes above the culture tanks. Excess flow to the head tanks is allowed to return to a bio-filter recirculation tank where it is mixed with new water coming into the building, heated, aerated, and pumped back up into the head tanks. Seven 6' diameter x 3' deep fiberglass tanks were constructed locally and are positioned under the pipe system in a floor plan that allows easy access for culture and cleaning. Plastic upwelling incubators sit on tables beside the tanks. Newly hatched fry swim up to the top of the incubators and are automatically drained into the fry culture tanks. Shad fry are held in the tanks 10-20 days after hatching and need to be fed. Brine shrimp are the main shad fry diet and a system to conveniently feed all the tanks is needed. Two fiberglass 125-gallon, conical bottom tanks were set up to provide the hatched brine shrimp for the fry. A 250-gallon fiberglass tank holds a day's supply of brine shrimp and is connected to a system of pipes, valves, and a timer that automatically feeds a plentiful diet of newly hatched shrimp over a 22-hour period to all the culture tanks at once. The fiberglass tanks used to culture the shad fry are 6' in diameter and 3' deep, with a slight slope to the center drain. This drain is a threaded 2" fitting that is designed to accept a 2" standpipe, which in turn maintains the tank water level. All water flow out of the fry culture tanks is filtered and piped into the outflow end of the head tank bio-filter recirculation system. If a water crisis should develop, the larval culture tanks can be put into a temporary recirculation loop through the bio-filter tank with no stress to the fish in the tanks.

Tank effluent normally drains to a nearby pond, but the drain arrangement may be changed by opening and closing a series of valves in order to allow fry that are ready to be stocked to drain directly into the stocking tank on the bed of a ¾ -ton pickup.

TANK SPAWNING SETUP

The system consists of one 12' and two 15' diameter x 4' deep adult shad holding tanks that gravity drain into separate 3'x 3' x 8' bio-filter tanks from which treated water is pumped back into the spawning tanks at a rate of approximately 30 gallons per minute. Depending upon its size, each round spawning tank receives 5-7.5 gallons per minute of new water. Each bio-filter tank is now fitted with three 3000-watt stainless steel immersion heaters, each set of which provides as much heating capacity as a standard 30,000 BTU, 40-gallon home hot water heater. The previous use of 4000 watts of immersion heaters was an undersized heating capacity for maintaining optimal tank spawning temperatures early in the season. Each bio-filter tank has had its degassing capabilities augmented with the addition of aeration towers with extra surface-to-water enhancing media.

Because shad eggs sink, the spawning tank has to drain from the center bottom. To accomplish this, an 8" plastic collar is placed around the 4" overflow. This collar causes the water to drain from the center bottom of the tank, carrying along with it any eggs that naturally drift to the center. Water coming from the spawning tank enters the bio-filter tank through a 3" pipe tee that is drilled full of ¾" holes and acts as a muffler in slowing down the water velocity and evenly diffusing water currents. Knitted polyethylene bags of ½ mm mesh are tied onto both legs of the water muffler to collect the eggs released by the adult shad. The bags are changed each morning and the collected eggs placed in incubators.

TANK SPAWNING SYSTEM

2000 OPERATION:

The system was operated in the manner described in the 1999 report. The eggs from the tank spawning systems were produced without the use of hormones.

QUALITY OF BROODSTOCK:

Broodstock adult shad transported to the hatchery by truck can exhibit obvious bruising about the head and inside the eyes, as well as severe scale loss. Any incoming shad that exhibit bruising about the head are either DOA or die soon after being transferred to the spawning tank. In addition to the bruised and traumatized shad, there is a significant percentage that are lightly battered and descaled. These shad soon become festooned with heavy patches of fungus and eventually die. Careful selection by the transport crew of only vigorous and blemish-free fish has shown to have a dramatic positive effect on the overall survival of the transported shad.

Having the additional two 15' diameter tank spawning systems allowed a separation of the Connecticut and Saco River origin shad at the hatchery. This enabled hatchery personnel to observe a difference in survival rates between the two populations. In 2000, it was clear that the handling during capture was a major factor in the survival of the broodstock shad after they were introduced into the hatchery tank spawning systems. The Saco River shad arrived in very good condition, exhibiting minimal scale loss and very little of the bruising/open sores that often develop from the capture and transport process. The Connecticut River shad arrived at the hatchery in a battered and bruised condition, with many open lesions about their bodies. Survival to the end of the spawning season of the Saco River shad was 85 out of 144 (58%), while survival of the Connecticut River shad was 7 out of 222 (3.2%).

The ME-IF&W Fish Health Laboratory was asked to examine the spawning tank mortalities of 2000. The state pathologist determined that the same bacteria as in 1999, vibrio and pseudomonas, were present. Also as in 1999, the infections in the shad were attributed to open lesions being a pathway for bacterial invasion. Despite being kept in well water while at the hatchery, large numbers of glochidia were found on the gills of the Connecticut River shad in the hatchery in 2000. This indicates that massive mortality due to glochidia on the shad gills in 1999 may be attributed to the glochidia infecting the shad in the Connecticut River and not coming from the hatchery water, as thought at that time. Due to a better understanding of the spawning tank operation in 2000, the rate of broodstock mortality was reduced, allowing for an increased egg production from CT River shad.

EGG VIABILITY

It has been noticed that some batches of eggs exhibit low viability due to the presence of small immature eggs. These eggs contribute to nutrient loading and the promotion of fungal growth in the egg incubators, which would be lessened if the small eggs were removed. From 1998-2000, all eggs delivered to or produced at the hatchery are sieved on a variety of mesh sizes. Past investigation has revealed that most eggs <2mm are not viable. Generally, only the eggs that are retained on a 2mm screen are selected for incubation.

The viability of eggs >2mm in the first six deliveries from the CT River egg take averaged 60.2%. Because of this generally low viability, it was decided to try using a 0.45% saline solution in the fertilization process. Instead of the typical filtered river water, 0.45% irrigation saline was added to the egg and sperm mixture to initiate sperm motility. When this technique was employed on the second to last batch of eggs of the season, it resulted in viability of 91%. The last batch of eggs was also fertilized using a 0.45% saline solution, as well as being hardened and shipped in a 0.45% saline solution. The viability of the last batch of eggs was 74%.

ENUMERATION OF CULTURE TANK MORTALITY

During the 2000 hatchery season, the waste that is routinely siphoned from the bottom of the culture tanks was sampled to determine larval mortality after hatching and up to the point of stocking. Individual tanks were/are not cleaned daily. It takes several days for detritus to develop and show on a tank bottom; therefore, the time interval varies from one batch of larvae to the next. When a tank was cleaned, the bottom waste from one culture tank was siphoned into several plastic buckets and diluted to 15 liters in each bucket. The contents of a bucket were suspended by mixing with an open hand. While a bucket was being mixed, three 10 ml samples were removed and emptied into three individual petri dishes. The live and dead larvae were counted separately, but both were counted as mortality. An average of the three samples, live and dead, was determined as larvae per milliliter. The number of mortalities per bucket was estimated by multiplying the average of the three samples by 15,000. Finally, total mortality was estimated as the sum of the means of all the buckets.

When a culture tank standpipe screen was changed, its outside was rinsed into a bucket and the same method that was used to determine mortality from tank bottom waste was used to determine the number of dead larvae removed from the screen. Note sheets on the individual bucket and tank counts were not kept and that data is not available.

HATCHERY PRODUCTION SUMMARY FOR 2000

Normandeau Egg Take:

A total of 73.725 liters of eggs taken from netted Connecticut River shad were received at the hatchery. These 73.725 liters represented a total of 3,314,882 shad eggs, 656,250 of which were <2mm and 2,658,616 >2mm. As noted previously, eggs <2mm are generally unviable, immature eggs. The eggs >2mm had an average viability of 59.1% that produced 1,677,928 fry at hatch. Due to the volume of eggs handled and the limited number of culture tanks at the Waldoboro Hatchery, the Normandeau egg take fry were combined with other Connecticut River fry produced at the hatchery. It is not possible to give an unambiguous number of fry produced from the Normandeau eggs (Table 1).

Waldoboro Hatchery Tank Spawning System:

Saco River Shad - 15' MOHF tank (Fall 1999)

A total of 144 Saco River adult shad were delivered to the hatchery for tank spawning in three shipments: June 12 (81), June 30 (41), and July 22 (22). During the time the Saco River broodstock were in the hatchery system, they produced 42.059 liters of eggs. This volume represented a total of 3,040,910 eggs: 1,037,775 <2mm and 2,003,135 >2mm. The eggs <2mm are considered unviable and were thus discarded. The eggs >2mm had an average viability of 83.48% that produced 1,685,908 fry at hatch. These fry were cultured in segregated tanks from shad of other river origins. After enumerating culture tank losses, 1,572,517 fry were stocked (Table 2).

Kennebec River Shad – 12' MOHF tank (1997)

A total of 25 Kennebec River adult shad were delivered to the hatchery between June 1 and June 22. They were delivered in several trips: June 1 (3), June 12 (2), June 13 (5), June 15 (3), June 20 (7), and June 22 (5). On June 23, Connecticut River adult shad were added to the Kennebec River shad being held at the hatchery. While segregated, the Kennebec River shad produced 5.294 liters of eggs, representing 356,364 eggs. From June 10 to June 16, six batches of eggs were collected. They were measured and found to be 112 to 130 eggs per 10". Those eggs that ranged from 112 to 119 eggs per 10" were just barely retained on a 2mm sieve and upon examination, were determined to be developing, but still immature eggs. Since these eggs are dribbled out of the adult shad as they swim around in the tanks and are not a part of any spawning process, their role in determining overall egg viability is disregarded. Another source of <2mm immature eggs, from the females that die during the spawning process, are observed dropping from the females when they are removed from the tank. These eggs are always <2mm and immature. The eggs produced in these six batches amounted to 71,026 eggs and 19.9% of the total produced.

From June 17 to June 23, five batches of eggs were produced from spawning activity and contained viable eggs >2mm, varying in size from 84 to 92 eggs per 10"; unviable eggs <2mm measured 130+ eggs per 10". These five batches were used to determine overall viability of the Kennebec River shad broodstock. In total, these five batches resulted in 198,188 eggs >2mm, which had an average viability of 86.2% and produced 178,871 fry. Additionally, 87,150<2mm eggs were produced, but were deemed unviable and discarded. Due to the volume of eggs handled and the limited number of culture tanks in the Waldoboro Hatchery, the Kennebec River fry were combined with Connecticut River fry produced at the hatchery. While it is not possible to give an unambiguous number of fry stocked from the Kennebec River eggs, the tank batch they were combined with may be traced to the river of stocking (Table 3).

Connecticut/ Kennebec River Mixed Broodstock - 15' tank (NFWF funds, 1999)

A total of 222 live Connecticut River shad were combined with 22 Kennebec River shad and produced 59.005 liters of eggs. This volume represents a total of 4,914,272 eggs, 2,476,248 >2mm and 2,438,024 <2mm. The eggs >2mm had an average viability of 66.6% that produced 1,827,311 fry at hatching. The eggs <2mm were unviable and discarded. Due to the volume of eggs handled, the limited number of culture tanks, and the desire to maintain pure tanks of Saco fry, the Normandeau egg take fry were combined with Kennebec River and other Connecticut River fry produced at the hatchery. It is not possible to give an unambiguous number of fry stocked from the Connecticut River source eggs produced in the Waldoboro Hatchery spawning systems (Table 4).

Fry Stocking Summary:

Kennebec & Sebasticook Rivers 3,846,731

Saco River	259,090
Androscoggin River	529,558
Medomak River	145,545*

*The observed number stocked does not match this figure

POND CULTURE

No shad fry were intentionally removed and stocked into the ponds for rearing. The fall fingerlings produced are the result of either fry escaping from the hatchery culture tanks or from live fry caught when mortalities were enumerated in the waste sampling buckets.

The fry culture tanks have a 500-micron nylon screen that fits tightly over the tank standpipe in order to prevent the fry from escaping down the drains. Even so, there have been and continue to be, numbers of fry that get through the screening and make it into the drains and ponds. Sometimes when the standpipe screens are changed, a few larvae escape into the drains.

The mortality enumeration process counted both the dead and live larvae removed. Sometimes it was possible to return to a fry tank "some" of the larvae that could be observed swimming near the surface of the water in the enumeration buckets. Sometimes it was not possible to remove and return any of the larvae to a culture tank. There was no counting done of the fry returned to a tank or those left in with the dead and dumped into Pond #1. The numbers generated during the enumeration process were not kept, so it is not possible to provide an estimate of fry added to the ponds.

RECOMMENDATIONS FOR 2001

1. The positive role of Ca, Na, and Mg ions in the fertilization process has been demonstrated in other fish species. General water hardness may play a role in fertilization success, embryo development, and as a stress mitigator in older fish. When NaCl was used in the fertilization water of net egg take eggs in 2000, a much higher viability was attained. In 2001, all net egg take eggs should be fertilized in a 0.45% NaCl-CaCl, 50-50 solution. The exact proportions are not critical. The eggs should then be processed as they normally are and shipped in regular (unsalted) filtered river water. The NaCl-CaCl saline solution can be prepared from industrial grade salts ahead of time in convenient handling volumes and will add negligible cost to the operation in either time or money.

2. The DMR-SED transport crew should be given the license to pick and choose high quality adult shad for transport and the fish lift operation staff should be informed of this.

3. Strategies for obtaining shad broodstock for the hatchery tank spawning systems should be worked out ahead of time and be in place in time to put adult shad in the spawning systems as early as possible. Adult pathology sampling should be performed on the first 60 shad at the Holyoke fish lift. Adult shad should be provided to the hatchery before in-system stocking is accomplished.

TABLE 1. Connecticut River Net Egg Take Data

Date	Incubator	Mls eggs	Eggs/10"	Eggs/liter	Total eggs	% Viability	# Fry hatch
31-May	A	7500>2mm	74	29,063	217,962	67	146,035
		250<2mm	130+	150,000	37,500	0	0
1-Jun	B	7650>2mm	78	32,547	248,984	83	205,910
		450<2mm	130+	150,000	67,500	0	0
	C	7500>2mm	78	32,547	244,102	83	201,872
2-Jun	D	9000>2mm	82	39,378	354,402	40	141,406
		550<2mm	130+	150,000	82,500	0	0
3-Jun	E	8800>2mm	80	36,611	322,176	74	238,410
		400<2mm	130+	150,000	60,000	0	0
5-Jun	F	5500>2mm	85	43,521	239,365	23	54,096
		475<2mm	130+	150,000	71,250	0	0
	G	5500>2mm	85	43,521	239,365	23	54,096
6-Jun	H	4700>2mm	76	31,090	146,123	75	109,592
		350<2mm	130+	150,000	52,500	0	0
	I	4700	76	31,090	146,123	75	109,592
10-Jun	J	5100>2mm	88	48,912	249,451	91[1]	227,000
		400<2mm	130+	150,000	60,000	0	0
11-Jun	K[3]	3400>2mm	101	73,695	250,563	74[2]	185,417
	L[3]	1500<2mm	130+	150,000	225,000	2[2]	4,500
						μ = 59[4]	$\sum$ = 1,677,928

[1] 0.045% NaCl used at fertilization
[2] 0.45% NaCl used at fertilization, hardening, and shipping
[3] K and L were shipped as one batch of eggs, but sieved and incubated separately
[4] Mean viability of eggs >2mm

TABLE 2. Saco River Egg and Fry Production

Date	# Adult Shad	Incubator	Mls eggs	Eggs/10"[1]	Eggs/liter[1]	Total eggs	% Viability	# Fry hatch
12-Jun	81							
13-Jun	81	1	132	105	83,402	11,009	0	0
			160	130	150,000	24,000	0	0
14-Jun	81		175	130	150,000	26,250	0	0
	81		10	130	150,000	150	0	0
16-Jun	79		15	130	150,000	225	0	0
	79		10	130	150,000	150	0	0
18-Jun	78	2	800	94	60,039	48,031	95	45,629
	78		45	130	150,000	6,750	0	0
19-Jun	78	3	650	91	53,724	34,921	78	27,238
20-Jun	74	4	1,550	90	52,286	81,043	84	68,076
	74		405	130	150,000	60,750	0	0
21-Jun	73	5	345	98	66,896	23,079	93	21,463
	73		22	130	150,000	3,300	0	0
22-Jun	71	6	1,000	90	52,286	52,286	86	44,966
	71		422	130	150,000	63,300	0	0
23-Jun	70	7	1,750	88	48,912	85,596	91	77,892
	70		56	130	150,000	8,400	0	0
24-Jun	70	8	1,790	86	44,647	79,919	0	0
	70		52	130	150,000	7,800	0	0
25-Jun	70	9	1,755	89	50,897	89,324	92	82,178
	70		77	130	150,000	11,550	0	0
26-Jun	70	10	2,055	86	44,647	91,750	93	85,328
	70		71	130	150,000	10,650	0	0
27-Jun	70	11	845	96	63,570	53,717	58	31,156
	70		125	130	150,000	18,750	0	0
29-Jun	69	12	1,850	94	60,039	111,072	85	94,411
	69		250	130	150,000	37,500	0	0
30-Jun	69	13	1,125	94	60,039	67,544	90	60,790
	69		210	130	150,000	31,500	0	0
30-Jun	110					0		0
1-Jul	110	14	4,650	92	55,217	256,759	80	205,407
	110		750	130	150,000	112,500	0	0
2-Jul	110	15	1,650	93	57,569	94,988	72	68,391
	110		375	130	150,000	56,250	0	0
3-Jul	110	16	1,690	96	63,570	107,433	78	83,798
	110		150	130	150,000	22,500	0	0
6-Jul	107	17	1,800	93	57,569	103,624	63	65,283
	107		340	130	150,000	51,000	0	0
7-Jul	106	18	400	97	65,436	26,174	97	25,389
	106		150	130	150,000	22,500	0	0
9-Jul	103	19	900	92	55,217	49,695	83	41,247
	103		45	130	150,000	6,750	0	0
11-Jul	103	20	1,505	90	52,286	78,690	96	75,542
	103		125	130	150,000	18,750	0	0
12-Jul	103	21	315	89	50,897	16,032	88	14,108
	103		30	130	150,000	4,500	0	0

TABLE 2 (CONTD) Saco River Egg and Fry Production

Date	# Adult Shad	Incubator	Mls eggs	Eggs/10"[1]	Eggs/liter[1]	Total eggs	% Viability	# Fry hatch
13-Jul	102	22	800	91	53,724	42,979	87	37,392
15-Jul	101	23	1,190	95	61,770	73,506	92	67,626
	101		52	130	150,000	7,800	0	0
16-Jul	101	24	114	109	93,362	10,643	52	5,534
			171	130	150,000	25,650	0	0
17-Jul	101	25	106	101	73,695	7,812	0	0
			34	130	150,000	5,100	0	0
18-Jul	99	26	1,030	97	65,436	67,399	88	59,311
	99		56	130	150,000	8,400	0	0
19-Jul	98	27	400	95	61,770	24,708	95	23,473
	98		16	130	150,000	2,400	0	0
21-Jul	98	28	350	99	69,404	24,291	91	22,105
	98		44	130	150,000	6,600	0	0
22-Jul	97		32	106	86,093	2,754	0	0
	97		242	130	150,000	36,300	0	0
22-Jul	119					0		0
23-Jul	119	29	1,365	99	69,157	94,736	73	69,157
	119		400	130	150,000	60,000	0	0
24-Jul	119	30	345	101	73,695	25,425	81	20,594
	119		125	130	150,000	18,750	0	0
25-Jul	116		320	130	150,000	48,000	0	0
26-Jul	115	31	150	105	83,402	12,510	68	8,507
	115		250	130	150,000	37,500	0	0
27-Jul	114	32	375	105	83,402	31,275	94	29,399
	114		250	130	150,000	37,500	0	0
29-Jul	101	33	295	102	75,976	22,412	79	17,705
	101		44	130	150,000	6,600	0	0
31-Jul	92		425	130	150,000	63,750	0	0
2-Aug	85	ADULTS RELEASED TO DMR-SED					0	0
							$\mu = 83.4$[2]	$\sum = 1,579,095$

[1] Entries of 130 eggs/10" and 150,000 eggs / liter indicate eggs that are <2mm

[2] Mean viability of eggs >2mm

TABLE 3. Kennebec River Shad Egg Production

Date	# Adult shad	Incubator	Mls eggs	Eggs/10"[1]	Eggs/liter	Total eggs	% Viability	# Fry hatch
1-Jun	3							
10-Jun	2							
11-Jun	2		13	130	150,000	1,950	0	0
12-Jun	4		45	130	150,000	6,750	0	0
14-Jun	9		80	119	~120000	9,600	0	0
15-Jun	12		180	130	150,000	9,600	0	0
16-Jun	12		100	130	150,000	15,000	0	0
	12		100	112	99,761	9,976	0	0
17-Jun	12		5	130	150,000	750	0	0
		k1	1,400	84	42,433	62,206	95	59,096
18-Jun	11		37	130	150,000	4,050	0	0
19-Jun	10							
20-Jun	9							
	9	k2	350	92	55,217	19,326	61	11,789
20-Jun	16		20	130	150,000	3,000	0	0
21-Jun	16							
		k3	890	84	42,433	37,765	98	37,010
22-Jun	13		15	130	150,000	2,250	0	0
		k4	450	89	50,897	22,904	85	19,468
22-Jun	18	k5	367	130	150,000	55,050	0	0
23-Jun	18							
		k6	1,100	89	50,897	55,987	92	51,508
23-Jun			88	130	150,000	13,200	0	0
CONNECTICUT RIVER SHAD ADDED----NOW A MIXED BROODSTOCK								
							μ = 86.2[2]	$\sum$ = 178,871

[1] Entries of 130 eggs/10" and 150,000 eggs / liter indicate eggs that are <2mm

[2] Mean viability of eggs >2mm

TABLE 4. Connecticut and Kennebec River Mixed Egg Production

Date	# Adult shad	Incubator	Mls eggs	Eggs/10"[1]	Eggs/liter	Total eggs	% Viability	# Fry hatch
4-Jun	59							
5-Jun	49	1	75	87	47,017	3,526	0	0
			60	130	150,000	9,000	0	0
6-Jun	49		100	130	150,000	15,000	0	0
7-Jun	49	2	1,050	88	48,912	51,358	38	19,516
8-Jun	46	3	650	93	57,569	37,420	39	14,594
			300	130	150,000	45,000	0	0
9-Jun	45		710	130	150,000	106,500	0	0
10-Jun	45	4	650	88	48,912	31,792	31	9,856
			112	130	150,000	16,800	0	0
11-Jun	42	5	85	98	66,896	5,686	0	0
			110	130	150,000	16,500	0	0
12-Jun	40	6	950	98	66,896	63,551	63	39,783
			1,260	130	150,000	189,000	0	0
13-Jun	39	7	900	94	60,039	54,035	30	16,211
			467	130	150,000	67,050	0	0
14-Jun	38		122	130	150,000	18,300	0	0
15-Jun	102							0
16-Jun	157		475	130	150,000	71,250	0	0
17-Jun	150		127	93	57,569	7,311	0	0
			2,550	130	150,000	37,500	0	0
18-Jun	139	8	200	106	86,093	17,219	0	0
			335	130	150,000	50,250	0	0
19-Jun	151	9	1,840	98	66,896	123,089	44	54,159
			750	130	150,000	112,500	0	0
20-Jun	140	10	225	95	61,770	13,898	19	2,641
			575	130	150,000	86,250	0	0
21-Jun	133	11	150	98	66,896	10,034	0	0
			350	130	150,000	52,500	0	0
22-Jun	124	12	1,750	95	61,770	108,098	66	71,345
			720	130	150,000	108,000	0	0
23-Jun	109	13	1,100	97	65,436	71,980	34	24,473
			1,057	130	150,000	158,550	0	0
24-Jun	95	14	2,365	90	52,286	123,656	71	87,796
			900	130	150,000	135,000	0	0
25-Jun	88	15	5,190	91	53,724	278,828	86	239,792
			820	130	150,000	123,000	0	0
26-Jun	109	16	5,260	88	48,912	257,277	88	226,404
			820	130	150,000	123,000	0	0
27-Jun	106	17	3,900	92	55,217	215,346	93	200,272
			190	100	71,507	13,586	0	0
			807	130	150,000	121,077	0	0

TABLE 4 (CONTD) Connecticut and Kennebec River Mixed Egg Production

Date	# Adult shad	Incubator	Mls eggs	Eggs/10"[1]	Eggs/liter	Total eggs	% Viability	# Fry hatch
28-Jun	104	18	4,575	95	61,770	282,598	75	211,949
			1,012	130	150,000	151,800	0	0
29-Jun	119	19	880	96	63,570	55,942	74	41,397
			875	130	150,000	131,250	0	0
30-Jun	108	20	2,200	97	65,436	143,959	80	115,167
			500	130	150,000	75,000	0	0
1-Jul	100	21	2,280	94	60,039	136,888	88	120,461
			160	130	150,000	24,000	0	0
2-Jul	88	22	1,225	94	60,039	73,547	80	58,838
			150	130	150,000	22,500	0	0
3-Jul	84	23	370	98	66,896	24,752	80	19,802
			250	130	150,000	37,500	0	0
5-Jul	74	24	1,350	93	57,569	77,718	79	61,397
			325	130	150,000	48,750	0	0
6-Jul	71	25	500	98	66,896	33,448	95	31,776
			39	130	150,000	5,850	0	0
7-Jul	69	26	750	94	60,039	54,029	94	50,787
			42	130	150,000	6,300	0	0
9-Jul	66	27	400	94	60,039	24,016	54	12,969
			260	130	150,000	39,000	0	0
10-Jul	66	28	600	97	65,436	39,261	94	36,905
			315	130	150,000	47,250	0	0
14-Jul	24	29	1,090	97	65,436	71,325	82	58,487
			190	130	150,000	28,500	0	0
19-Jul	10							0
25-Jul	?	30	14	99	69,404	971	55	534
			92	130	150,000	13,800	0	0
26-Jul	?		39	130	150,000	5,850	0	0
27-Jul	7							
							μ =66.6[2]	Σ = 1,827,311

[1] Entries of 130 eggs/10" and 150,000 eggs / liter indicate eggs that are <2mm
[2] Mean viability of eggs >2mm

TABLE 5. 2000 Shad Fry Stocking Data

Date Stocked	Tank	Source	Incubators	# Fry hatch	% Survival after hatch	# Stocked	Range of Stock Age	Receiving Site
23-Jun	1	CT	A	146,035				
			B	205,910				
			C	201,872				
				553,817	79.1	438,231	13-18	Kennebec
23-Jun	2	CT	D	141,406				
			E	238,410				
			F	54,096				
			G	54,096				
				488,008	72.6	354,502	9-14	Kennebec
27-Jun	3	CT	H	109,592				
			I	109,592				
			1	0				
			2	19,516				
			3	14,594				
				253,294	97.4	246,770	10-14	Kennebec
30-Jun	4	CT	J	227,000				
			K	185,417				
			L	4,500				
			4	9,856				
			5	0				
			6	39,783				
			7	16,211				
				482,767	87	420,231	8-14	Kennebec
3-Jul	5	CT-K	K1	59,096				
			K2	11,789				
			K5	0				
			8	0				
			9	54,159				
			10	2,614				
			11	0				
				127,658	85.6	109,395	9-12	Sebasticook
10-Jul	6	S	1	0				
			2	45,629				
			3	27,238				
			4	68,076				
			5	21,463				
			6	44,966				
			7	77,892				
				285,264	90.8	259,090	9-17	Saco

TABLE 5 (CONTD) 2000 Shad Fry Stocking Data

Date Stocked	Tank	Source	Incubators	# Fry hatch	% Survival after hatch	# Stocked	Range of Stock Age	Receiving Site
10-Jul	2-a	CT-K	K3	37,010				
			K4	19,468				
			K6	51,508				
			12	94,411				
			13	60,790				
			14	205,407				
			15	68,391				
				536,985	99.6	529,558	7, -16	Androscoggin
17-Jul	1-a	S	8	0				
			9	82,178				
			10	85,328				
			11	31,156				
			12	94,411				
				293,073	99.5	291,608	9, -18	Kennebec
17-Jul	3-a, 16, 17	CT-K	16	226,404				
			17	200,272				
				426,676	91.5	390,609	12, -15	Sebasticook
18-Jul	5-a	S	13	60,790				
			14	205,407				
			15	68,391				
			16	83,798				
				418,386	95	397,542	6-13	Kennebec
24-Jul	4-a	CT-K	18	211,949				
			19	41,397				
			20	115,167				
			21	120,461				
			22	58,838				
			23	19,802				
				567,614	95.6	539,410	14-20	Kennebec
27-Jul	6-a	CT-K	24	61,397				
			25	31,776				
			26	50,787				
			27	12,969				
			28	36,905				
				193,834	96.8	179,574	7-16	Kennebec
27-Jul	2-b	S	17	65,283				
			18	25,389				
			19	41,247				
			20	75,542				
			21	14,108				
				221,569	93.5	207,356	6-16	Kennebec

TABLE 5 (CONTD) 2000 Shad Fry Stocking Data

Date Stocked	Tank	Source	Incubators	# Fry hatch	% Survival after hatch	# Stocked	Range of Stock Age	Receiving Site
4-Aug	1-b	S, 22-28	22	37,392				
		CT-K, 29	23	67,626				
			24	5,534				
			25	0				
			26	59,311				
			27	23,473				
			28	22,105				
			29	58,487				
				273,928	99.1	271,503	5-19	Kennebec
14-Aug	2-c	S, 29-33	29	69,157				
		CT-K30	30	20,594				
			31	8,507				
			32	29,399				
			33	17,705				
			CT-K30	534				
				145,896	99.7	145,894	11-17	Medomak
				$\sum$ = 4,877,432	**μ = 92.1**	**$\sum$ = 4,781,273**		

Job I-5

Job Number & Title: #F-41-R-6 (5)
Fish Passage Maintenance

Job Objectives: To maintain fish passage facilities in non-hydro dams for the passage of anadromous fish species

Summary: The Department of Marine Resources operates and maintains 19 fishways, and assists in the operation and maintenance of 12 fishways at non-hydro dams owned by other public entities. These fishways are located from Maine's Cumberland to Washington Counties. In addition, DMR inspected another 14 sites where fish passage was a concern. A total of 259 inspections were made at 45 sites in 2000.

(b) **Target Date:** 2003

(c) **Status of Progress:** On schedule

(d) **Significant Deviations:** None

(e) **Recommendations:** Increase funding for maintenance

(f) **Cost:** $42,789.56

(g) **Data Presentation & Discussion:**
The Maine Department of Marine Resources operates and maintains 19 fishways, and assists in the operation and maintenance of 12 non-hydro dams owned by other public entities. These fishways are located from Cumberland County to Washington County (Figure 1). In addition, DMR inspects other sites during the year where fish passage may be impeded.

During 2000, a total of 259 inspections were made at 45 sites (table 1). As a general rule, DMR personnel closely monitors and adjusts fishways in central and southern Maine (Highland Lake, Bridge Street, Elm Street, Jones Pond, Pitcher Pond, and Coopers Mills), whereas DMR fishways in Washington County (West Bay Pond, Gardner Lake, Boyden Lake, and Pennamaquan Lake) are inspected occasionally for damage and to ensure they are functioning properly. Many fishways in Washington County are adjusted by towns with dedicated alewife fisheries.

In 2000, the gates at Smelt Hill were opened to allow passage of anadromous fish. Alewives once again migrated up the Presumpscot River into Mill Stream. However, two major problems arose at Highland Lake as a result of reconstruction of the dam and upper portion of the fishway. Flow throught the newly constructed portion of the fishway could not be regulated, because slots were not installed for baffles, and flow has been diverted from the original stream channel, because site contours were not repaired following construction. DMR has been working with the Town of Westbrook and the Department of Environmental Protection to remedy these defects. Once again, volunteers from the Coastal Conservation Association assisted DMR in monitoring the alewife migration.

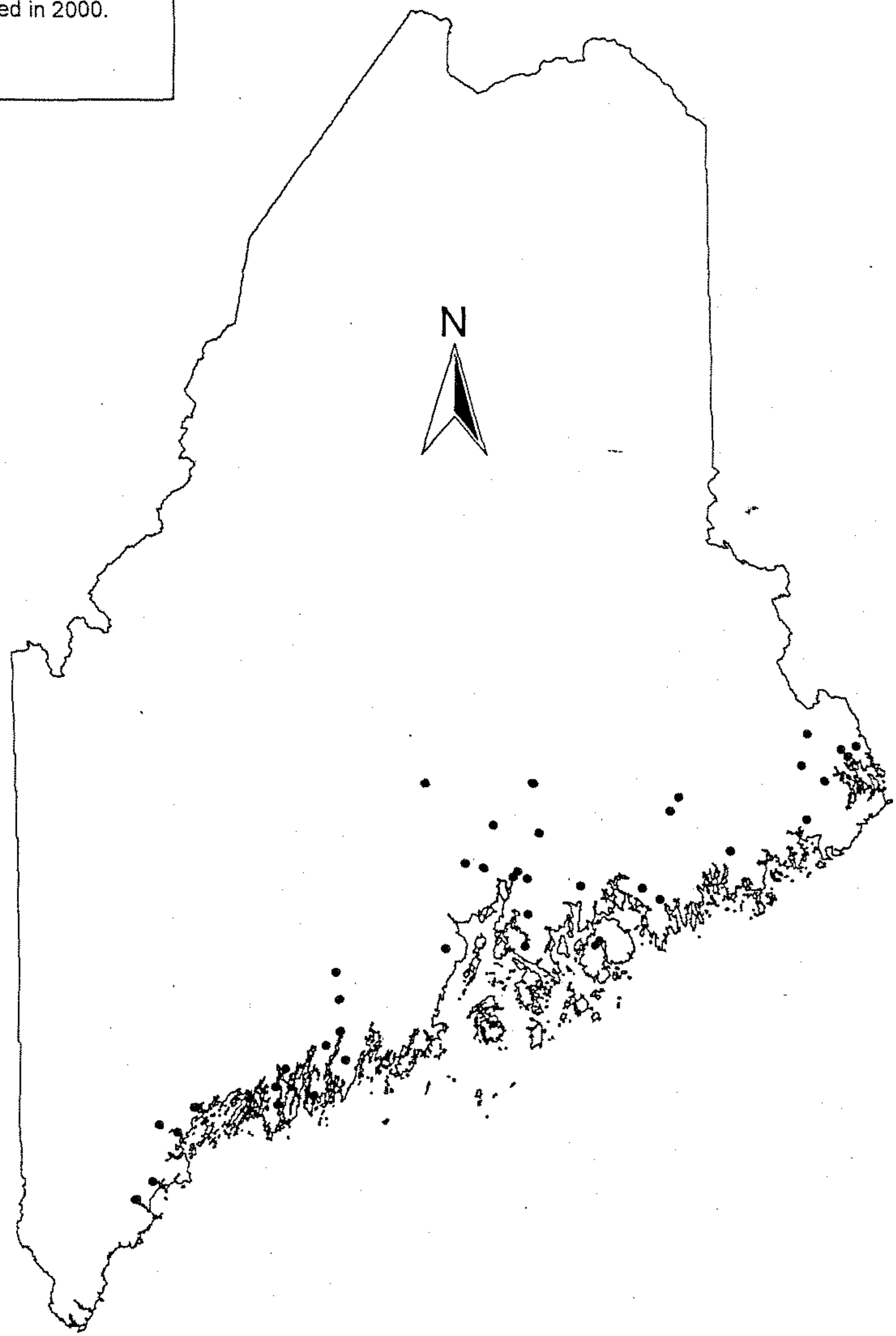
As part of our fishway maintenance program, 53 baffles, 10 baffle tops, and 1 trash rack were replaced at sites where they were either missing or damaged. All 36 baffles were replaced at Highland Lake, one baffle and five tops were replaced at Bristol, four tops were replaced at Cathance Stream, one top at Coopers Mills, one trash rack at Dedham Falls, five baffles at Gardner Lake, five baffles at Pennamaquan Upper, and six baffles at West Bay Pond.

An informal volunteer program was continued in 2000. Members of the Royal River Watershed Association assisted in maintaining and operating the Bridge Street and Elm Street fishways on the Royal River in Yarmouth.

Table 1. Summary of visits to fishways in 2000.

Site	Site name	Watershed	Type of fishway	Owner	Visits
6	Boyden Lake	Boyden Stream	Denil	DMR	3
8	Bridge Street	Royal River	Denil	DMR	19
9	Bristol	Pemaquid River	Denil	DMR	5
14	Cathance Stream	Cathance Stream	Alaskan steeppass	DMR	5
24	Elm Street	Royal River	Denil	DMR	17
25	Flanders Stream	Flanders Stream	Denil	DMR	4
27	Gardner Lake	East Machias River	Denil	DMR	4
29	Highland Lake	Presumpscot River	Denil	DMR	23
30	Jones Pond	Scarborough Marsh	Alaskan steeppass	DMR	2
35	Meddybemps Lake	Dennys River	Alaskan steeppass	DMR	3
47	Philips Lake	Orland River	Alaskan steeppass	DMR	5
49	Pitcher Pond	Ducktrap River	Denil	DMR	8
52	Pleasant River	Pleasant River	Denil	DMR	2
53	Pleasant River Lake	Pleasant River	Alaskan steeppass	DMR/IF&W	2
58	Sherman Lake	Sheepscot River	Alaskan steeppass	DMR	6
64	West Bay Pond	West Bay Pond	Denil	DMR	5
65	West Harbor Pond	West Harbor Pond	Alaskan steeppass	DMR	5
20	Dedham Falls	Orland River	Denil	Unknown	5
43	Pennamaquan Lower	Pennamaquan River	Denil	IF&W	3
45	Pennamaquan Upper	Pennamaquan River	Denil	IF&W	3
63	Walker Pond	Bagaduce River	Cement Sluice	Unknown	1
66	Wight Pond	Bagaduce River	Breached Dam	Unknown	2
31	Long Pond	Long Pond Stream	Pool&Weir	Unknown	6
17	Coopers Mills	Sheepscot River	Denil	IF&W	13
28	Great Works	Cathance Stream	Alaskan steeppass	IF & W	3
1	Alamoosook Lake	Orland River	Denil	Champion Paper	4
5	Bog Brook Flowage	Narraguagus	Alaskan steeppass	IF & W	3
15	Center Pond	Kennebec River	Denil	Phippsburg	5
22	Dyer Long Pond	Sheepscot Rver	Denil	Saltonstal	9
40	Nequasset Lake	Kennebec River	Denil	Bath Water Company	6
41	Orland Dam	Orland River	Slot	Champion Paper	5
61	Toddy Pond	Orland River	Pool&Weir	Champion Paper	4
67	Winnegance Lake	Kennebec River	Denil	DOT/Bath	5
2	Benton Falls	Sebasticook River			10
10	Burnham	Sebasticook River			10
19	Damariscotta Lake	Damariscotta River	Rock Pool	Consolidated Hydro Inc	12
26	Frankfort Dam	Marsh Stream	Denil	Express Hydro Services	13
59	Smelt Hill	Presumpscot River	Fish lift	CMP	1
62	Upper Marsh Stream	Marsh Stream	Denil	Peter Graham	11
16	Chickawaukee Lake				1
18	Culvert-Greely Rd				1
21	Dennys River	Dennys River			1
48	Pierce Pond				2
54	Runaround Pond				1
56	Sennebec Lake				1

Figure 1. Location of fishways visited in 2000.



Job I-6

Job Number & Title: #F-41-R-6 (6)
Northeast Fish Passage Engineering Assistance

Job Objectives: To provide technical assistance for hydraulic engineering, design, construction, and operation of fish passage facilities at non-FERC jurisdictional dams and other barriers in the northeast

(a) **Summary:** Job active

(b) **Target Date:** 2003

(c) **Status of Progress:** On schedule
(d)
(d) **Significant Deviations:** None

(e) **Recommendations:** Continue as planned

(f) **Cost:** $5,857.71

(g) **Data Presentation & Discussion:** The State of Maine and the US Fish and Wildlife Service signed a Memorandum of Agreement in May, 2000, for fish passage and engineering sevices through December 31, 2000. The USFWS egineers provided technical assistance on the following fish passage hydraulic engineering and design projects:

a. Center Pond fishway, Phippsburg
USFWS provided conceptual designs for extending the fishway into the pond
b. White's Pond, Palmyra
USFWS reviewed drawings of outlet structure reconstruction, and recommended installation of steeppass section. Section has been installed.
c. Highland Lake Dam, Westbrook
USFWS prepared a report on problems associated with the dam and fishway reconstruction that need to be corrected
d. Blackman Stream, Bradley and Sedgunkedunk Stream, Orrington
DMR, USFWS, and ASF visited 4 dams on Blackman Stream and 3 dams on Sedgunkedunk Stream. USFWS prepared conceptual drawings for fish passage at these sites.
e. Culvert fish passage
USFWS commented on MEDOT Culvert/Fish Passage Work Group Report of Findings September 1997.

Copies of reports are attached, but large format engineering plans are not included.

United States
Department of the Interior
Fish and Wildlife Service
300 Westgate Center Drive
Hadley, MA 01035-9589

Please contact sender if you do not receive all of the pages or if they are illegible.

ENGINEERING

(413) 253-8288

Fax: (413) 253-8451

FACSIMILE TRANSMISSION COVER SHEET

DATE: August 1, 2000

TO: Sandra Lary

AGENCY: Maine Marine Fisheries

FAX #: 207-624-6024

SUBJECT: Fish Passage at Culverts - Background Information from Bell's Handbook

FROM: Curtis Orvis, Hydraulic Engineer, Team Leader

NOTE: Attached is the chapter from Bell's Handbook on swimming speeds of fish. I'll send the copy in the mail.

Page 1 of 11

FISHERIES HANDBOOK
of
Engineering Requirements and Biological Criteria

FISH PASSAGE DEVELOPMENT and EVALUATION PROGRAM
Corps of Engineers, North Pacific Division
Portland, Oregon

1990

Chapter 6

Swimming Speeds of Adult and Juvenile Fish

- Importance of cruising, sustained and darting swimming speeds to fish facility structures.
- Amount of energy loss in transfer of muscular energy to propulsion.
- Forces working against fish movement.
- Effects of exhaustive exercise.
- Ratio of sustained speed to darting speed and cruising speed to darting speed.
- Attractive velocities at obstructions and fishways.
- Effects of velocity gradients.
- Method of determining the time fish can maintain various speeds.
- Velocities to be used in designing upstream facilities.
- Pulsing velocities and turbulence effects.
- Swimming speeds affected by oxygen and other functions of fish.
- Effect of temperature on swimming effort.
- Visual reference and effect of darkness and light.
- Pollution effects.
- A. Relative Swimming Speeds of Adult Fish.
- B. Relative Swimming Speeds of Young Fish.
- C. Relative Swimming Speeds (Mackenzie River and Alaska data).
- D. Swimming Speed of Sockeye Fry at Chilko Lake.
- E. Maximum Sustained Cruising of Sockeye and Coho Underyearlings in Relation to Temperature.
- References Reviewed

SWIMMING SPEEDS OF ADULT AND JUVENILE FISH

In the development of fish facility structures, three aspects of swimming speeds are of concern.

1. Cruising - a speed that can be maintained for long periods of time (hours).

2. Sustained - a speed that can be maintained for minutes.

3. Darting - a single effort, not sustainable.

Exhibit A and B show the relative swimming speeds of selected adult and juvenile species. Exhibit C shows swimming speeds for MacKenzie River fish. Exhibit D shows the swimming effort of sockeye salmon fry at Chilko Lake.

Fish normally employ cruising speed for movement (as in migration), sustained speed for passage through difficult areas, and darting speed for feeding or escape purposes. Each speed requires a different level of muscular energy, and it may be assumed that there is a 15 per cent loss in the transfer of muscular energy to propulsion.

The force on the fish may be considered equivalent to that associated with any object, either moving within water or stationary in moving water. Energy involved may be computed by the following equation.

$$F = C_d A W \frac{V^2}{2g}$$

where F = force (in pounds)
C_d = drag coefficient = .2 (salmon)
Area = cross sectional area in square feet
W = weight of water (62.4 pounds per cubic foot)
V = summation of velocities in feet per second
g = gravity (32.2 feet per second per second)

Thus, force through a distance gives foot-pounds and can be converted to British thermal units or calories.

As energy requirements are related to the square of the apparent velocity, the reason why fish tire rapidly as the velocity increases is evident from the above formula. The build-up of lactic acid as a result of unusual activity can be fatal. A number of investigators have indicated that fish may recuperate rapidly after exhaustive exercise. Conversely, it has been noted that up to 2 hours are required for fish to recover and assume normal movement after tiring exercise.

An early investigator (Reference No. 36) used the weight of the fish to establish a ratio of sustained speed to darting speed of approximately .5 to .7. This has been borne out by recent investigations in which lengths of fish were used as a measure.

The data indicate that a fish's cruising speed level may be 15 to 20 per cent of its darting speed level. This is further supported by data from experiments on jumping fish by computing the velocities at which the fish leave the surface by using the following formula and comparing the results with the results of the swimming tests.

$$V = \sqrt{2gh}$$

where V = initial velocity in feet per second (at water surface)
g = gravity (32.2 feet per second per second)
h = height in feet of jump above water surface

Investigations have shown that fish are able to sense low levels of velocity and may orient themselves to a velocity of 0.16 fps and may sense changes of 0.328 fps (Reference 48). They, hence, may seek and find the most favorable areas, which makes it difficult to use average velocities in determining the effects of swimming speeds. It is suggested that normal distribution curves be utilized for this purpose.

Adults frequently seek higher velocities at obstructions, which may be utilized to attract them to fishway entrances. Such velocities should be well under the darting speed of the species and sizes involved but may exceed their cruising speed.

Swimming speeds are affected by available oxygen and swimming effort may be reduced by 60 per cent at oxygen levels of one-third saturation. Oxygen levels also affect other functions of fish.

Temperatures at either end of the optimum range for any species affects swimming effort. A graphic presentation (Exhibit E) has been prepared from Reference 16 and shows that a reduction of swimming effort of 50 per cent may occur as a result of adverse temperatures.

In dealing with problems at specific sites where swimming speed is important, such as the protection of juveniles ahead of protective screening or the guidance of fish (both adult and juvenile), the effects of temperature and oxygen must be evaluated.

As fish sense changes in velocity, they may avoid moving from one gradient to another, particularly from a lower to a higher gradient. When guiding or directing fish, smooth transitions and accelerations are desirable in order to prevent them from stopping, hesitating or refusing to enter a particular area.

It is assumed that fish use visual references in their movement and, therefore, behave differently in darkness than in light. Stimuli other than velocity may guide the fish's movement within established levels of cruising and sustained speed. Downstream migrating fish may lock into a velocity and be swept along at speeds that are well in excess of their cruising speeds.

In a series of tests (Reference 49) it was shown that fish tested passed through an endless pipe system more rapidly when the system was lighted. With opposing velocities of 2 to 2.5 fps, the best swimming performance was obtained.

An increase of 23 per cent in passage time was found when the system was in darkness, and the maximum distance attained by the sockeye tested was about 1 mile under light and 0.26 mile under darkness. The ground speed of the fish was under 2 fps.

In the design of upstream facilities, velocities must be kept well below the darting speeds for general passage.

SWIMMING SPEEDS OF ADULT AND JUVENILE FISH

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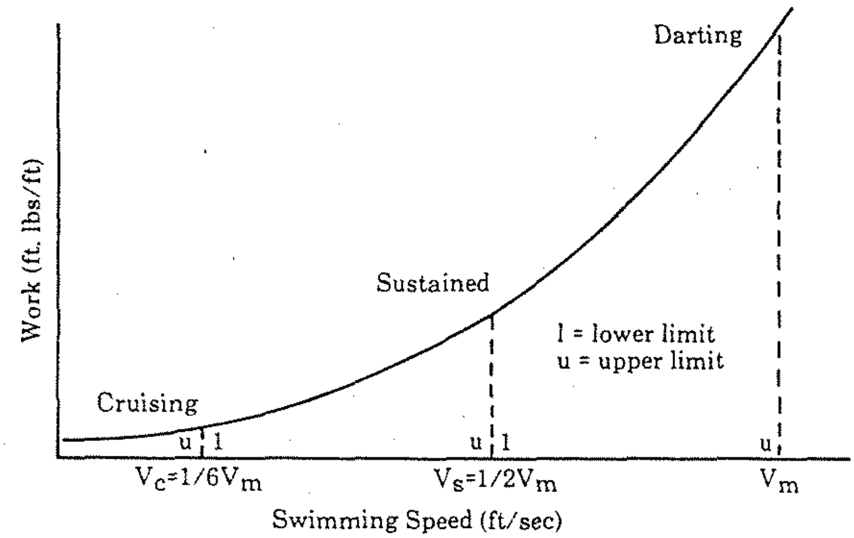
SWIMMING SPEEDS OF ADULT AND JUVENILE FISH

A means of determining the time that fish are capable of maintaining various speeds is given below:



$k = \frac{C_d A \ 62.4 \text{ lbs.}}{2g}$ assuming C_d does not vary throughout the swimming ranges.

A = Cross sectional area in square feet.

V_m = Maximum swimming velocity in feet per second.

D(Swimming Distance) = VT

Work = kV^2D or kV^3T

The maximum time that darting can be maintained is estimated at 5 to 10 seconds, thus the time that maximum sustained speeds can be maintained is shown by the relationship

$$kV_s^3T_s = kV_m^3T_m$$

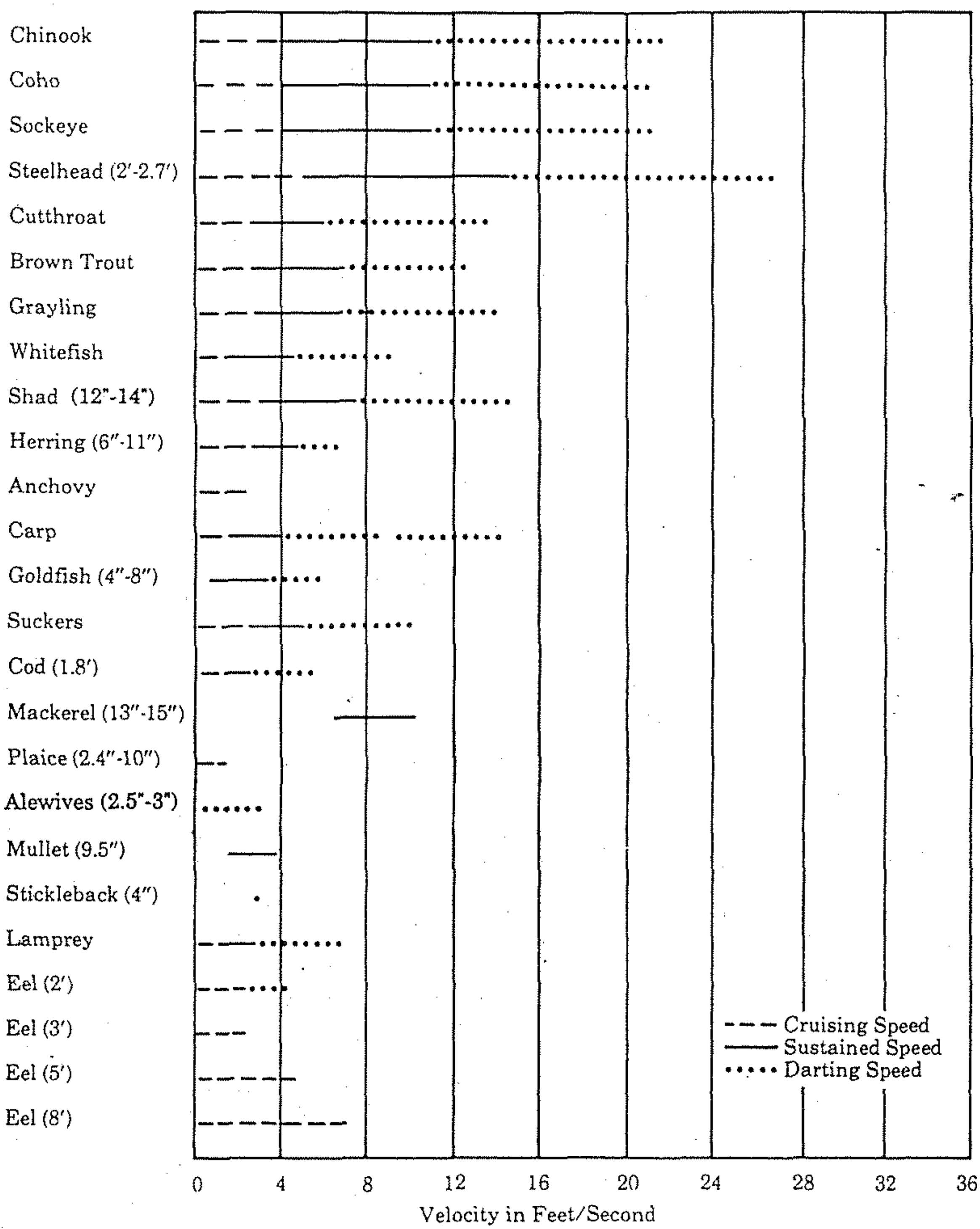
where $kV_m^3T_m$ = maximum energy factor at optimum temperature.

Velocities should not be averaged as the energy factor varies with the square of instantaneous velocity. Pulsing velocities can increase the instantaneous energy requirements by four times throughout the darting speed range. This may account for the variations in performance time found in the tests on swimming speeds. Because of turbulence and pulsing, a maximum darting time of 7-1/2 seconds is a suggested value. As fish are capable of swimming for hours at the upper ranges of their cruising speeds, it is assumed that no oxygen deficiency occurs at this level. Above this level, fish apparently are not capable of passing water over their gills at the rate necessary to obtain this increased oxygen required for the additional energy expenditure.

In addition to the effects of oxygen and temperature swimming performance is also adversely affected by various pollutants. Selected references are included to indicate the source material for those pollutants that are of major concern.

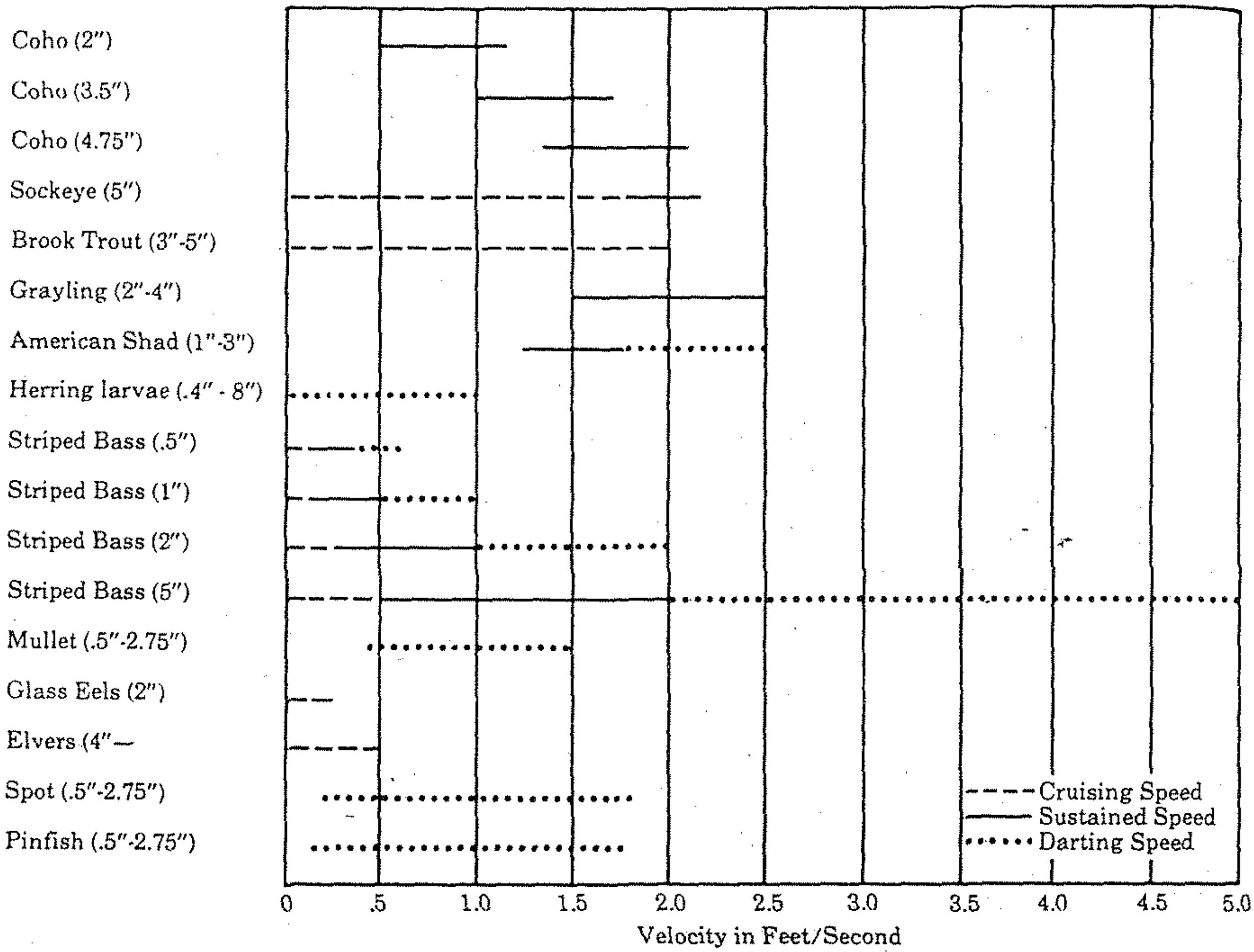
SWIMMING SPEEDS OF ADULT AND JUVENILE FISH

A
Relative Swimming Speeds of Adult Fish



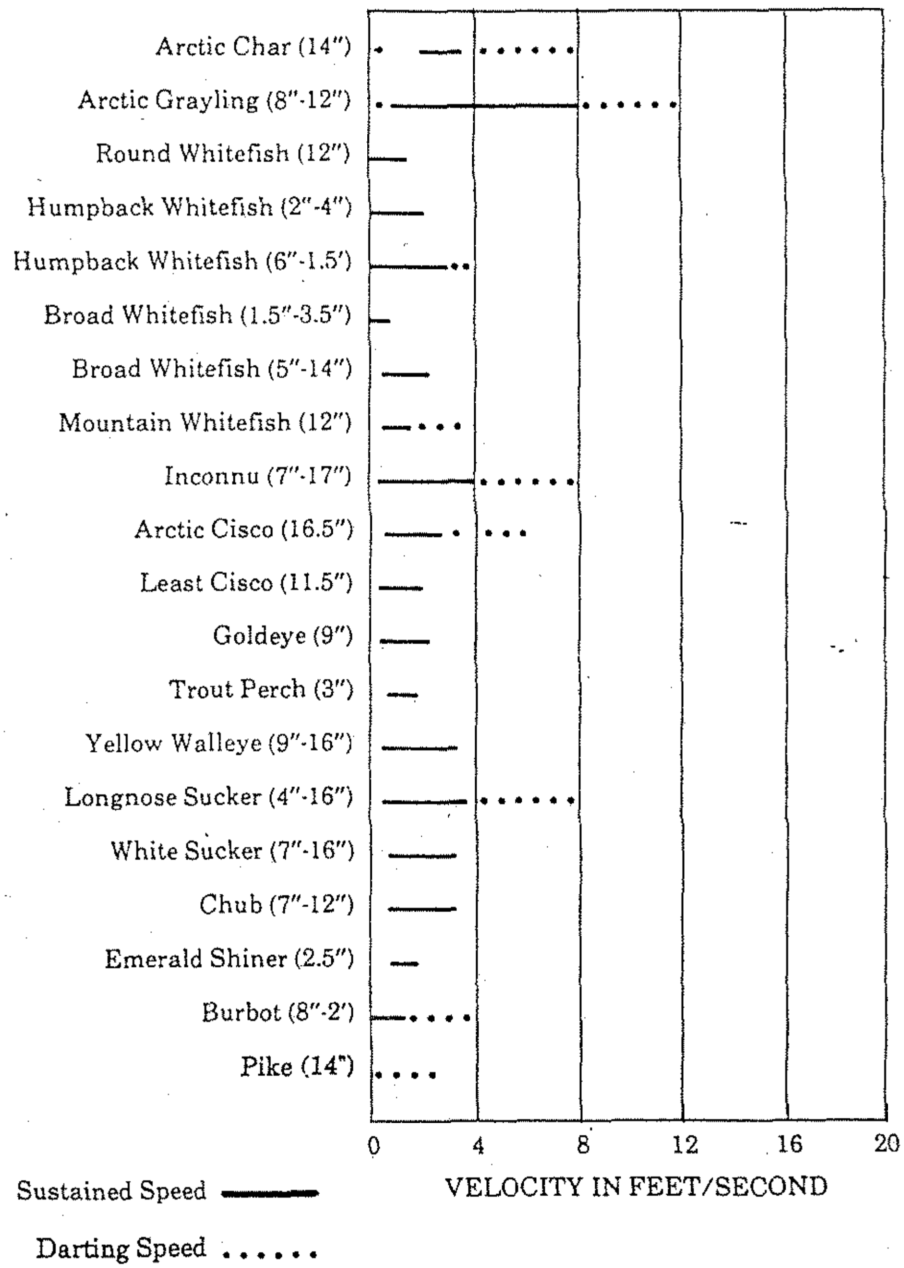
SWIMMING SPEEDS OF ADULT AND JUVENILE FISH

B
Relative Swimming Speeds of Young Fish



SWIMMING SPEEDS OF ADULT AND JUVENILE FISH

C
Relative Swimming Speeds



MacKenzie River data used for sustained speed.

Ala‘ ⌟ data used to extend swimming speed to darting level.

SWIMMING SPEEDS OF ADULT AND JUVENILE FISH

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FACSIMILE TRANSMISSION COVER SHEET

DATE: August 1, 2000

TO: Sandra Lary

AGENCY: Maine Marine Fisheries

FAX #: 207-624-6024

SUBJECT: Fish Passage at Culverts - Background Information from Culvert Passage Manual from FHWA/DOT/USDA

FROM: Curtis Orvis, Hydraulic Engineer, Team Leader

NOTE: Attached is the biological section from the Baker and Votapka report 1990. I'll send the copy in the mail.

Page 1 of 13

FISH PASSAGE THROUGH CULVERTS

Rep No FHWA-FL-90-006

BIOLOGICAL CONSIDERATIONS

ADULT FISH

The vast majority of past research and reports regarding fish passage at road drainage structures has been oriented to adult anadromous fish. The traditional approach to assessing fish capabilities has been to divide swimming speeds of adult fish into various activity categories such as cruising, sustained, and burst speed, Bell, 1973, Dane, 1978. The cruising speed is usually defined as the speed at which a fish can swim for an extended period of time without tiring. Sustained speed is the speed a fish can maintain for a prolonged period, (typically several minutes or hours), but results in fatigue. Burst speed is defined as the speed at which a fish can swim for just a very short time frame (one to several seconds).

The sustained speed has been often identified as the appropriate criterion for determining whether water velocity would block migrating fish. Not surprisingly, there is substantial overlap among these categories of swimming speed depending on the environmental conditions and testing methods utilized in measuring the performance of various species of fish.

Figure 3 identifies some swimming capabilities of common fish. Each species has different swimming capabilities. Figure 4 shows the variation in swimming speeds for various adult fish. In addition, different sizes of the same fish species commonly have different capabilities. Figures 5 & 6 display some of the swimming capabilities of common species of fish of different sizes.

Other Limiting Factors

Other factors can also affect the capability of adult fish attempting to traverse culverts and highway structures. Culverts that require fish to leap or jump over falls or other obstructions present a unique barrier to fish. A wide variety of hydrologic, physical, and behavioral considerations dictate whether a given fish will overcome a barrier. Stuart, 1962, provides a comprehensive discussion of these factors for salmon and trout.

The sex and physical condition of the fish attempting passage, including past injuries, diseases and sexual maturity, can affect the capability of adult fish passage. Specific site conditions such as water temperature, levels of water pollution, and the darkness of a culvert are limiting factors. Generally, these factors are not major considerations in determining fish passage conditions. Dane, 1978, gives an excellent overview of a number of these considerations.

The length of the structure is commonly used as a significant criterion in determining the fish passage capability of an installation. However, length is not a single criterion by itself. Velocity over a given length in relation to fish capabilities is a more appropriate consideration.

Culvert installation guidelines commonly assume that all fish of a particular species are uniform performers. Actually, fish capabilities vary within the same species. Equally important is the location of the structure in relation to the migratory corridor. Capabilities are generally thought to decline as spawning fish migrate upstream.

JUVENILE FISH

Although the majority of research on fish passage has historically been geared to adult anadromous fish passage (especially salmon and steelhead trout), juvenile anadromous species also exhibit a variety of upstream migrations. Skeesick, 1970, was one of the first authors to document a consistent upstream migration of juvenile coho salmon in the fall of each year. The 10-year study on Spring Creek - Wilson River, Oregon, did not investigate the reasons for the upstream migration of juveniles, although it speculated that "the juvenile coho moved into the small streams to escape the high flow, turbid-water environment in the main rivers in the spring."

Other authors; Bustard and Narver, 1975, Cederholm and Scarlett, 1982, Scarlett and Cederholm, 1984, have documented fall and winter migrations of juvenile anadromous fish especially into tributary streams and riverine ponds. Particularly susceptible to blockages are juvenile anadromous fish, such as steelhead trout, sockeye, chinook, and coho salmon, that remain in fresh water for substantial periods of time before migrating downstream. Of these species, juvenile sockeye salmon are particularly vulnerable in some of the stream systems that require an upstream migration to reach suitable rearing habitat, Dane, 1978.

Some studies, however, have shown a lack of upstream fish movements, making blanket statements regarding juvenile patterns of movement difficult. It is clear that upstream migrations of juvenile anadromous fish and movement into tributaries do occur. These migrations are very much at risk by drainage structures, especially those only designed for adult fish migration. In a stream system managed for wild fish production, blocking juve-

Specie	Cruising Speed	Sustained Speed	Burst Speed
Brown Trout	0 - 2.3	2.3 - 6.1	6.1 - 12.8
Carp	0 - 1.3	1.3 - 3.9	3.9 - 8.4
Chinook	0 - 8.9	8.9 - 10.8	10.8 - 21.9
Coho	0 - 8.9	8.9 - 10.5	10.5 - 21.7
Grayling	0 - 2.6	2.6 - 6.9	6.9 - 14.1
Lamprey	0 - 1.0	1.0 - 3.0	3.0 - 6.2
Shad	0 - 2.3	2.3 - 7.2	7.2 - 15.1
Sockeye	0 - 3.3	3.3 - 10.2	10.2 - 20.7
Steelhead	0 - 4.6	4.6 - 13.8	13.8 - 26.6
Suckers	0 - 1.3	1.3 - 5.2	5.2 - 10.2
Trout	0 - 2.0	2.0 - 6.6	6.6 - 13.5
Whitefish	0 - 1.3	1.3 - 4.27	4.3 - 8.9

Figure 3. Relative swimming speeds ft/sec of average size adult fish as reported by Bell (1973).

Species	Max FT/Sec.	Experiments
Atlantic Salmon	8.53	Kreitmann (1928)
Atlantic Salmon	6.56	Schmassmann (1928)
Atlantic Salmon	26.58	* HRI of Leningrad
Atlantic Salmon	12.47	As above but not in large numbers
Atlantic Salmon	7.87 - 9.18	HRI of Leningrad
Brown Trout	12.79	Kreitmann (1933)
Brown Trout	5.58	Schmassmann (1928)
Brown Trout	7.22	HRI of Leningrad
Carp	1.21	Kreitmann (1933)
Chinook Salmon	14.43	Paulik and DeLacy (1957)
Chinook Salmon	21.98	Collins and Elling (1960)
Chinook Salmon	21.98	Weaver (1963)
Coho Salmon	12.14	HRI of Leningrad
Coho Salmon	17.38	Same
Grayling	7.22	Kreitmann (1933)
Lamprey	6.23	Same
Pike	1.41	Kreitmann (1933)
Sockeye Salmon	10.17	Paulik and DeLacy (1957)
Steelhead Trout	26.57	Same
Steelhead Trout	26.57	Collins and Elling (1960)
Steelhead Trout	12.14	Paulik and DeLacy (1957)
Tench	0.46	Kreitmann (1933)
Trout	11.48	Denil (1938)
Whitefish	4.59	HRI of Leningrad

* Hydrotechnical Research Ins. of Leningrad

Figure 4. Maximum swimming speed of fish. Watts, 1974.

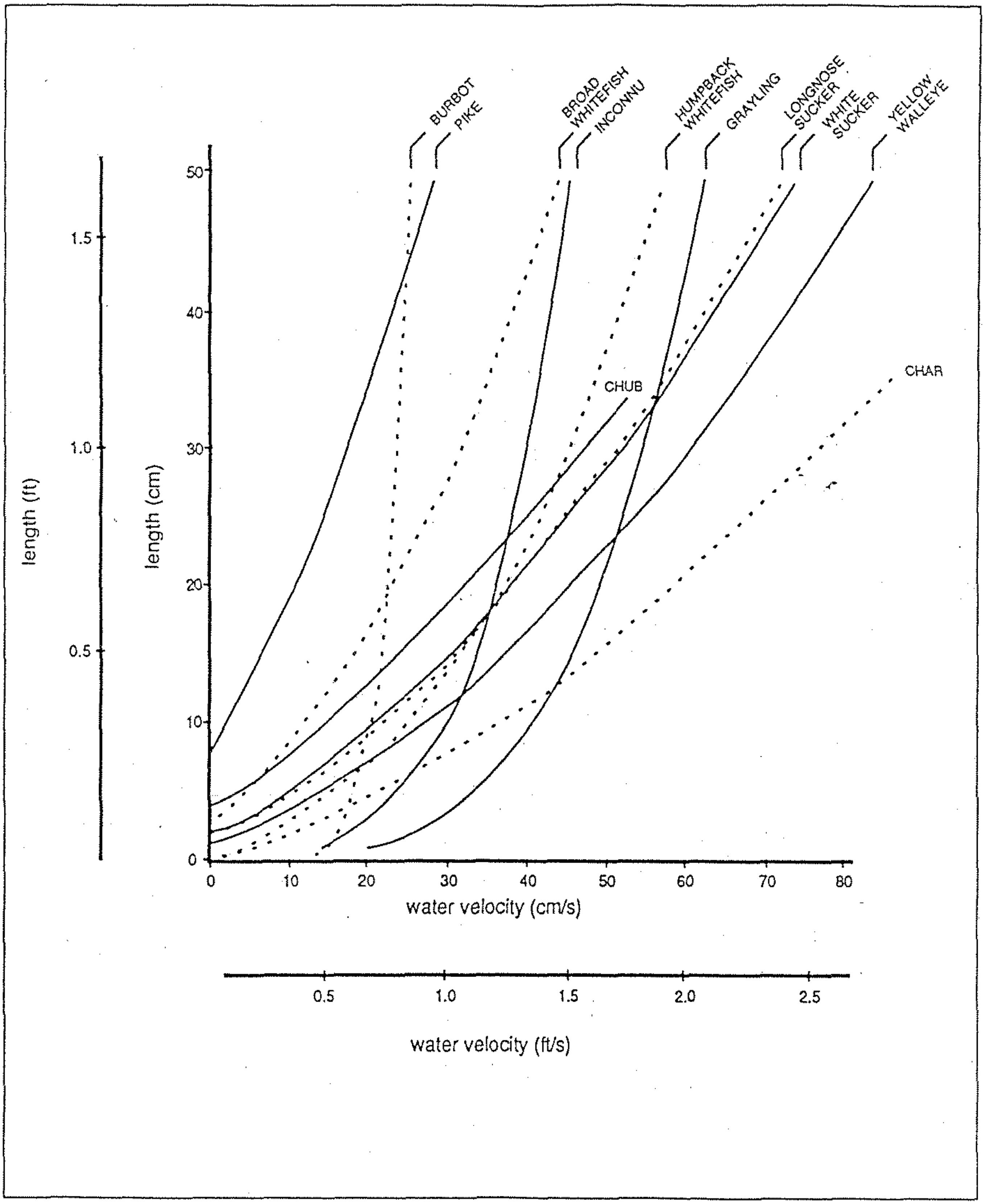

Figure 5. Relationship between fork length and ability to move 100m in 10 min in water velocities up to 80 cm/s for fish from the MacKenzie River. Jones, Kiceniuk, and Bamford,1974.

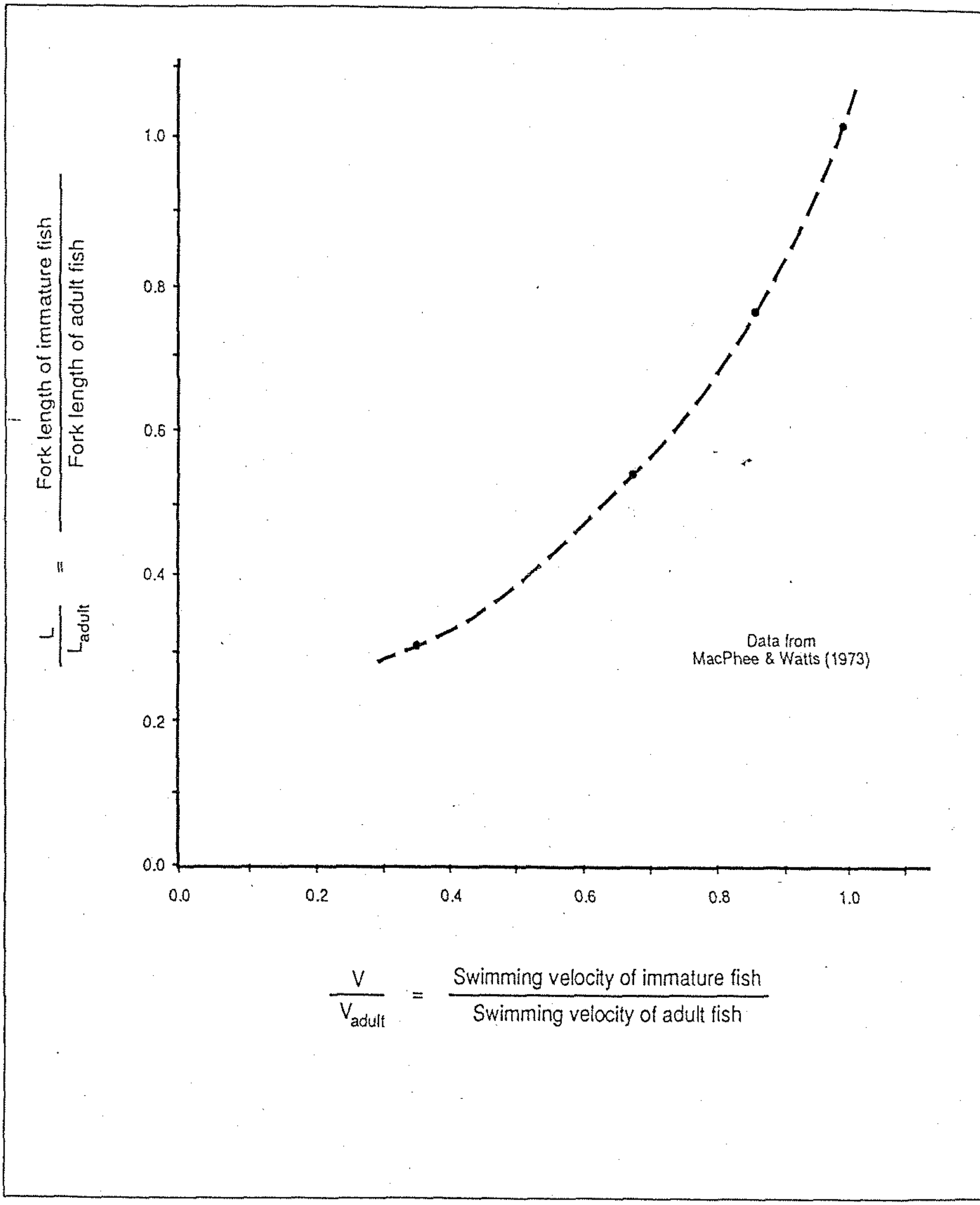

Figure 6. Relative swimming velocity versus relative length of fish based on grayling data. McPhee and Watts, 1976.

nile fish movements into tributary streams can lower production by arbitrarily limiting the capability to rear fish and increasing juvenile mortality, Leider, Chilcote, and Loch, 1986.

Upstream migrations of juvenile resident fish have also been documented in several studies. Typically, these have been fall migrations of juveniles from mainstem streams into tributaries. In these cases, the presence of culverts or other drainage structures on smaller tributary streams can make upstream juvenile movements difficult, Bernard and Israelsen, 1982.

The degree to which juvenile fish passage is needed at drainage structures is not well established. Some authors believe that it is not a high priority in culvert design, while others can cite specific passage situations where juvenile fish passage is essential.

With this uncertainty, it is perhaps not surprising that regulations requiring culverts to be capable of juvenile fish passage have been slow in developing. One exception to this has been in Washington State, which has site specific requirements (as determined by the Regional habitat manager) to provide upstream salmonid fingerling passage to overwintering habitat such as tributaries draining ponded off channel areas, Washington Dept. of Fish and Game, 1989. These types of habitat have been found to be extremely important in the survival and production of coho salmon, Peterson and Reid, 1984.

RESIDENT FISH SPECIES

Resident fish species also exhibit a variety of instream movements. These include adfluvial spawning migrations of cutthroat trout, and other salmonid fish species, as well as instream movements of resident fish from unknown causes. Like anadromous fish, upstream movements of resident fish are commonly blocked by culverts and drainage structures. Water velocities that can accommodate adult salmon and steelhead passage commonly obstruct resident fish species. Culvert outfalls easily jumped by older resident fish can block younger fish.

n streams containing only resident populations of fish, he decision is regularly made (consciously or inadvert-ently) to obstruct upstream fish passage. Since resi-lent fish species can reproduce above natural (and resumably man-caused) barriers, fish production is ommonly assumed to be relatively unchanged in year-ound stream systems. Genetic segregation, however, ould characterize the upstream fish populations. If a arrier were placed below an occasionally dry channel, complete loss of resident fish production above the arrier would ultimately follow.

In some streams, fish passage has been purposely caused by installing culverts and highway structures to obstruct certain fish movement. This practice has occurred in a number of locations, particularly in the eastern United States to prevent the movement of undesirable fish species (personal communication with Roger Radtke, USDA - Forest Service). This type of design can unintentionally obstruct the passage of fish less capable of those considered during structure design.

IMPACTS OF DELAYED FISH MIGRATION

A predominant philosophy that has historically governed fish passage considerations has been that fish migrations should not be delayed at road drainage structures. This belief, while being theoretically attractive, has conflicted with the reality that most drainage structures impede fish passage to some degree. In addition, many fish species exhibit limitations on their own upstream migrations during periods of heavy runoff or during adverse fish passage conditions. In some instances, the attempt to avoid any interference with fish passage has led to the placement of large drainage structures that are extremely expensive and probably impede the passage of fish at lower streamflows.

Although many culvert installations have caused delays in fish migrations, there has been remarkably little research on the effects of various delays. The majority of research has been directed at assessing the impacts of delayed migration on Arctic grayling and a few other species, Dryden and Stein, 1975, Tillsworth and Travis, 1987, and Behlke, Kane et al., 1989. One definitive study on the effects of spawning delays on Arctic grayling is Carlson, 1987. That study demonstrated that some delay did not appear to adversely affect spawning effort or success. As delays lengthened, an increasingly adverse impact to spawning occurred.

Some researchers have proposed that no more than a 3 to 6 day delay should occur at culvert crossings. The lack of site specific streamflow information at many streams, however, makes precise determination of flow regimes difficult. Hence it is impossible to specifically incorporate a precise window of acceptable delay. Because of varying streamflows and streamflow calculations, a culvert designed to potentially delay fish for 3 days could commonly delay fish for substantially shorter or longer periods of time.

TIMING OF FISH MIGRATIONS

Figure 7 displays the periods of spawning of some fish species in Montana, Idaho, and Eastern Washington. This figure is meant only as a guide for the engineers to show that various species of fish spawn at different times. It is imperative that the engineer consult with the fish biologist to determine the species of fish and the migration period to properly design a culvert to allow fish passage. These periods will vary in different parts of the country for various species of fish.

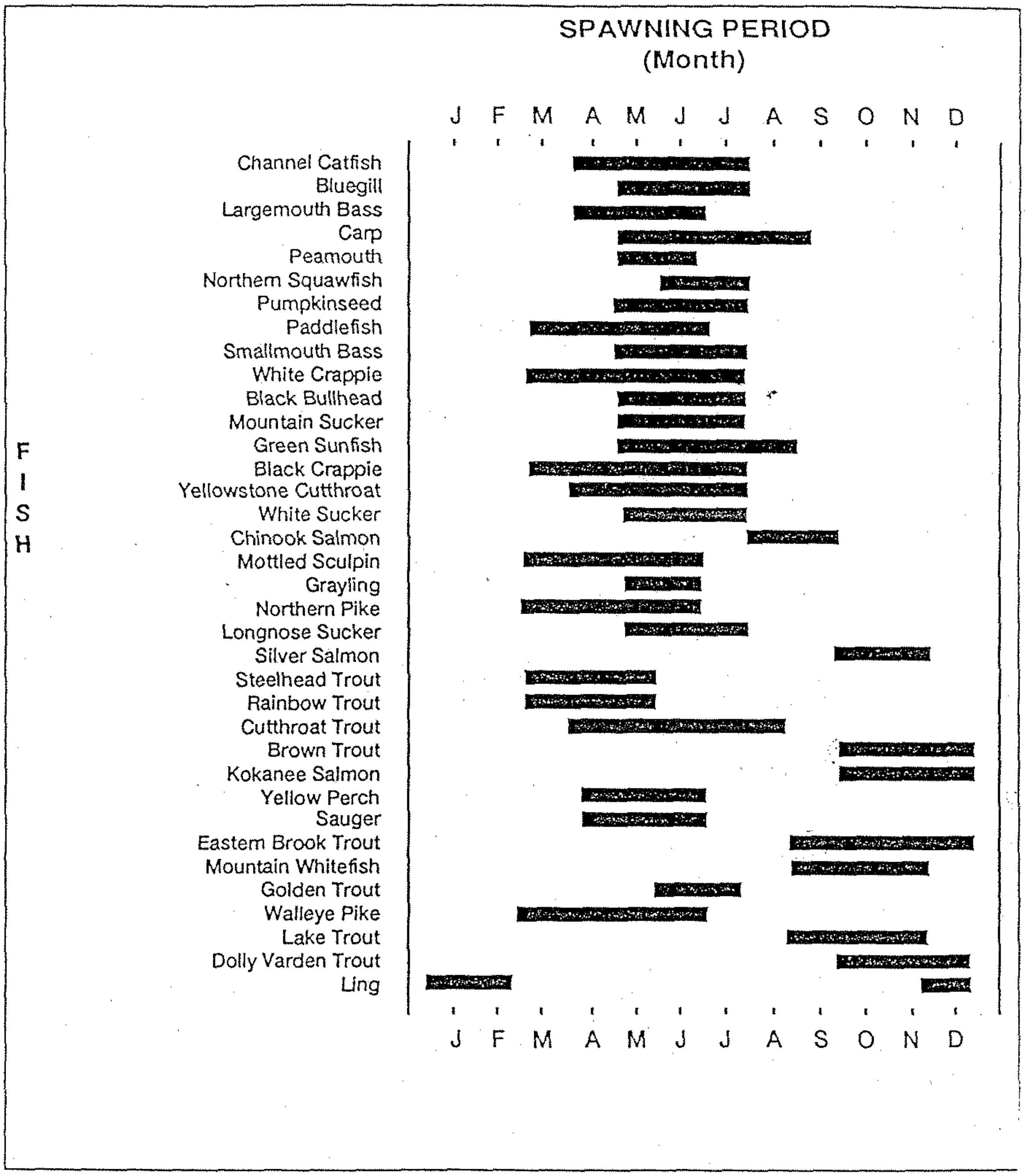

Figure 7. Period during which some fishes spawn in the Northern Region.

gabion baskets filled with local rock, concrete sills, or logs. Figures 29 & 30. The purpose of these dams is to raise the tailwater elevation and flood the culvert outlet. The end result is enhanced fish access and reduced culvert velocity at the outlet. The low head dams down stream should therefore be limited to a 1-ft drop or have a weir to allow for fish passage. It may be necessary to install several downstream dams to get the desired elevation if the culvert outfall barrier is excessive.

The general purpose of these tailwater control structures is fourfold.

1. The structure provides a resting pool for migrating fish before they swim into the higher velocity culvert.

2. Creating a backwater into the pipe allows for adequate water depths in the culvert. However, backwatering reduces the pipe capacity. Retrofitting small diameter pipes in this manner may not let the culve pass peak flows. For large diameter pipes, this loss c capacity is usually negligible.

3. A backwater reduces the velocity at the culve outlet thereby enhancing fish migration.

4. Much of the energy from the culvert is dissipate in the pool created by the tailwater control section. Th pool provides a transition zone between the culvert an the natural channel downstream.

Determining if a perching problem will occur is essenti in proper culvert design. One method for calculating th probability is to use Manning's Equation to determine th flow in the pipe. If velocities are expected to increas substantially through the pipe, then perching at th culvert outfall is likely to occur. This can be mitigated b providing tailwater structures as outlined above or b

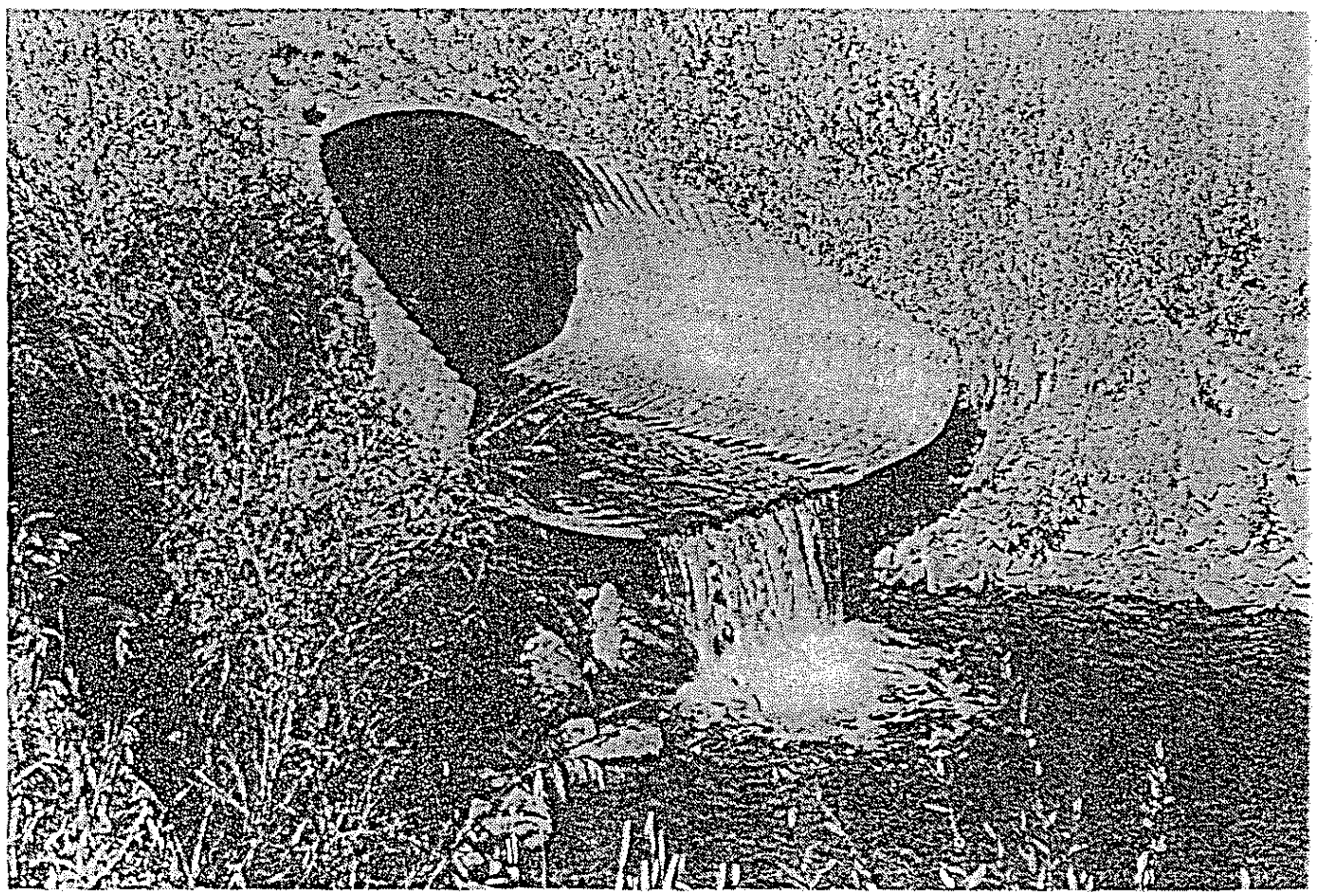

Figure 28. Perching.

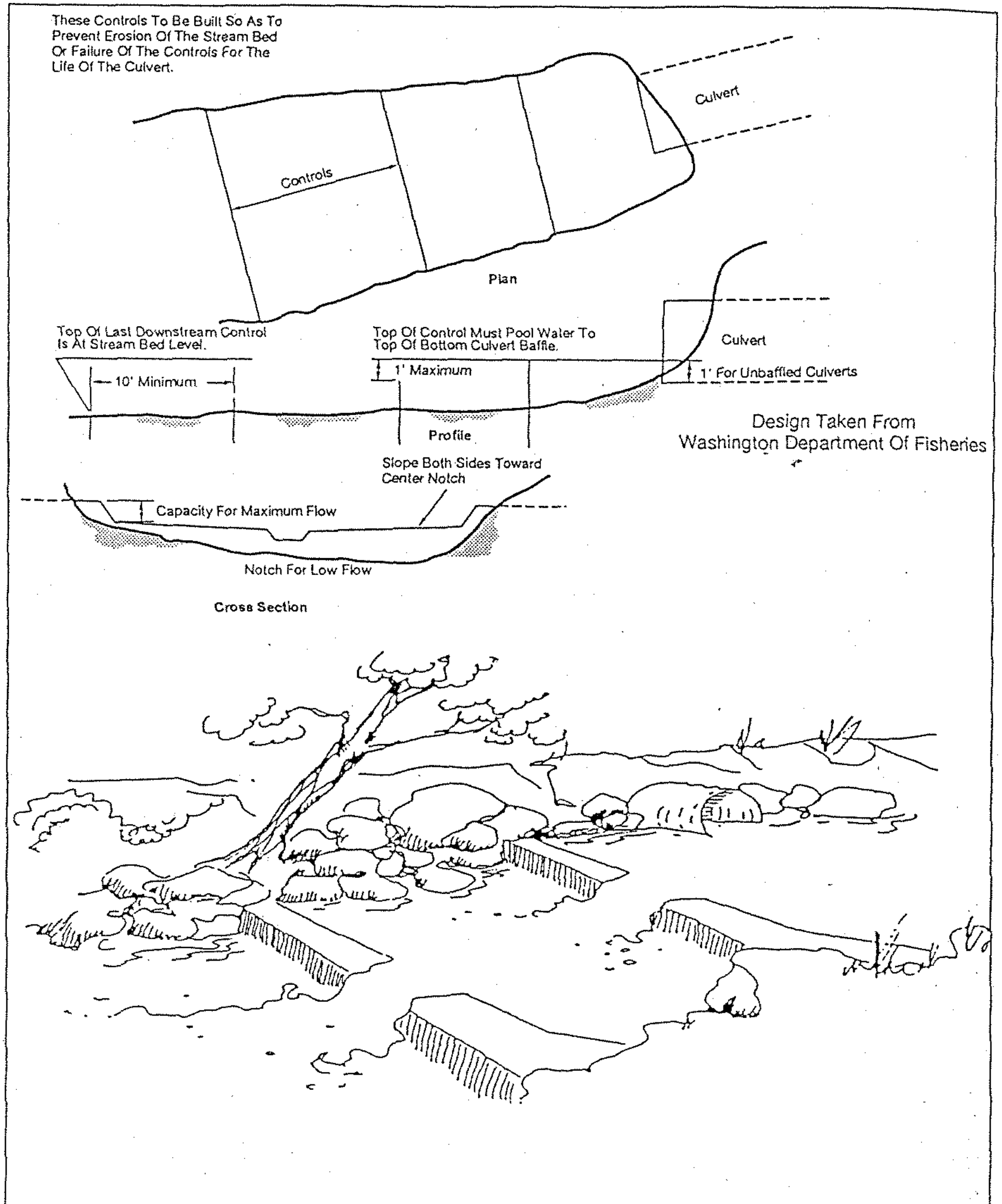

Figure 29. Gabion or concrete sills can raise tailwater elevations to facilitate fish entry into culverts. Evans and Johnston, 1980.

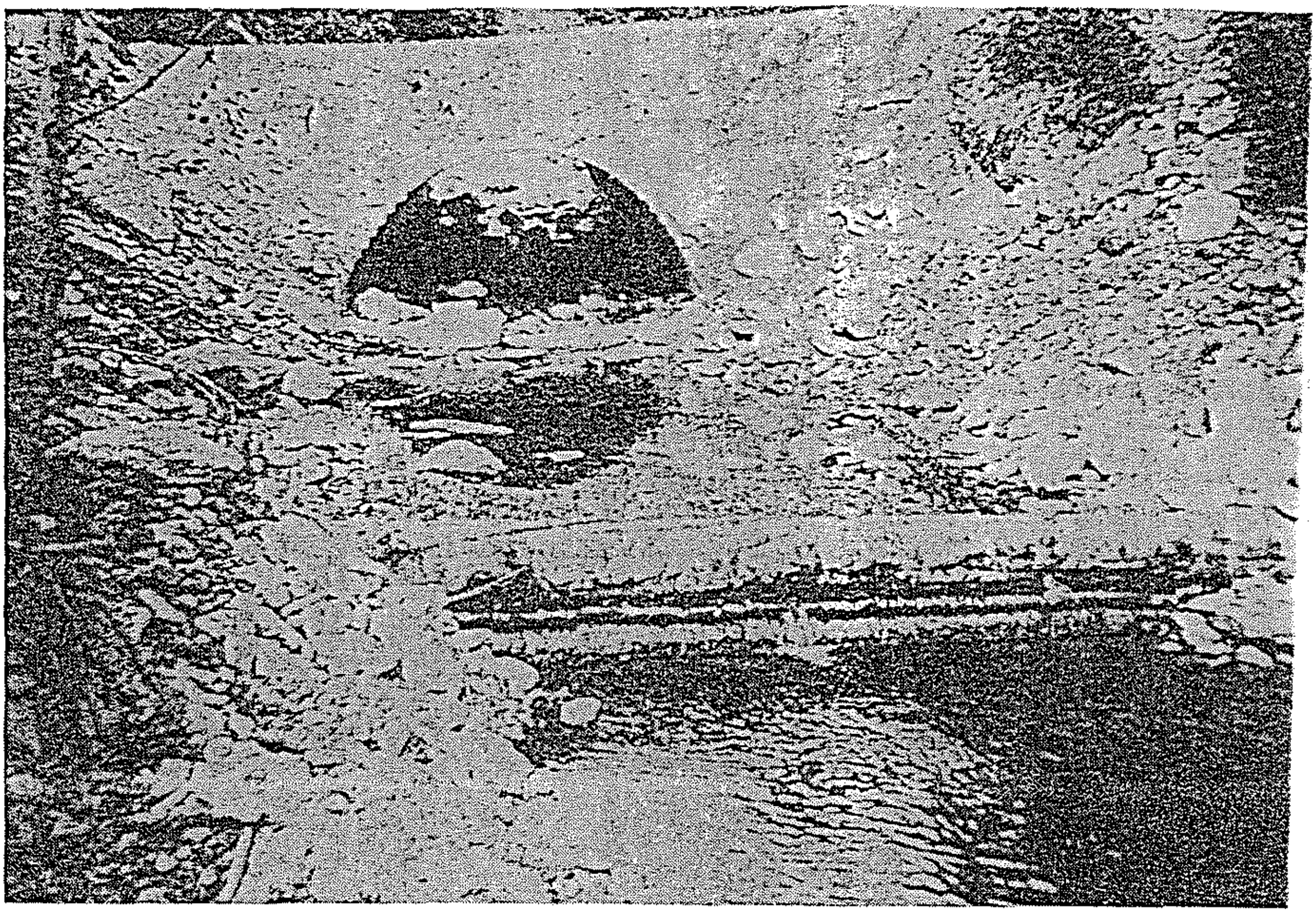

Figure 30. Correct perching problem.

riprapping the outlet.

Perching is not confined to higher gradient culverts but can occur at very low culvert gradients and at low water velocities. Any velocity increase above natural levels (for example, by decreasing the stream width) will tend to accelerate velocities in the culvert, even if the culvert is installed at or below natural stream grade. Perching can also be caused by improper installation where the outlet is higher than the natural streambed.

One way to anticipate and effectively prevent perching is to construct a culvert outfall basin to dissipate the energy of the water flow which many times is concentrated at the culvert outlet. The length and width of such a basin should be about twice the diameter of the culvert and the depth should be about 2 ft below the invert elevation of the culvert outlet. These outfall basins should be amoured with riprap large enough to prevent streambed scour. However, the most cost effective solution may be to design a pipe large enough in diameter that still does not incr velocities.

Inlet Drops, Figure 31.
Observation indicates that approximately 10 perce the culverts subjected to detailed examination in Al were seen to have drops at the culvert inlet, Kane Wellen, 1985. These drops can become a barri upstream fish migration at high or even moderate f In all cases they felt that these drops were d deposition of material from either the natural strea or adjacent roadway embankments. These drops have been the result of several conditions:

1. When the deposition was from natural strea material, it resulted from lower velocities at th stream end of the culvert as the culvert was laic flatter grade than the stream.

2. The use of undersized pipe could have ca backwater condition that promoted deposition.

end result is downstream destruction of fish habitat with sedimentation and loss of capital investment of roads and highways.

Should debris control be a consideration, the designer has three options for handling debris. First, the debris can be controlled upstream or at the inlet of the culvert. In this case, frequent maintenance may be required. A relief culvert placed higher on the embankment and in higher fills can often be installed as insurance that the entire embankment is not lost. Second, the designer may elect to try to pass the debris through the culvert. This may result in a larger culvert than needed just to pass the water flow. Third, as a last resort, the designer may elect to install a bridge where debris is so heavy that neither of the other options will work or if the values of downstream fisheries are so high that excess sedimentation cannot be allowed.

In performing a debris study the following factors should be considered:

1. Type of debris.

2. Quantity of debris.

3. Potential of the stream to carry debris based on factors such as water depth, channel width, and alignment.

4. Expected changes in type and quantity of debris due to future land use.

5. Streamflow velocity in the vicinity of the culvert.

6. Accessibility for periodic maintenance.

Publication	Suggested Maximum Gradient
Evans and Johnston (1972)	At or near zero
USDA - Forest Service (1979) R5	3% less than stream grade
State of Alaska, DOT&PF, Hydraulic manual	Flat grade
Morsel et al (1981)	0.5%
Dane (1987)	Less than 5% with baffles
Dryden & Stein (1975)	Prefer 0% gradient; less than 5% with baffles
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Figure 32. Suggested maximum gradients.

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4. Title and Subtitle FISH PASSAGE THROUGH CULVERTS		5. Report Date NOVEMBER 1990
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7. Author(s) Calvin O. Baker (Fish Biologist) Frank E. Votapka, P.E. (Civil Engineer)		8. Performing Organization Report No.
9. Performing Organization Name and Address USDA - Forest Service Technology & Development Center 444 East Bonita Avenue San Dimas, CA 91773		10. Work Unit No. (TRAIS) CTIP STUDY P-3
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15. Supplementary Notes

This study was part of the Coordinated Federal Lands Highway Technology Implementation Program (CTIP)

16. Abstract

As the number and range of many fish species have declined and the recreation demand for fish has increased, the importance of protecting the remaining populations has also multiplied. At new culvert installations, fish passage considerations and needs have increased in complexity. A high percentage of existing drainage structures are approaching or have passed their life expectancy. The task of replacing, modifying, and/or retrofitting the surviving structures will dwarf past programs for providing fish passage through culverts.

This report is intended to review, summarize, and update current information on fish passage through culverts. The scope of the report is limited to highway drainage structures, not including bridges. This distinction was made in an effort to concentrate on those road drainage structures that are most commonly used in fish passage situations. The publication is primarily issued for the fish biologists, engineers, and hydrologists who will be designing the projects and making current decisions on fish passage at drainage structures.

17. Key Words Anadromous; cruising speed; sustained speed; burst speed; adfluvial; culverts; hydraulic jump; riprap; perching; aufeis.	18. Distribution Statement No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161

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AGENCY: Maine Marine Fisheries

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Technical Report Documentation Page

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16. Abstract

As the number and range of many fish species have declined and the recreation demand for fish has increased, the importance of protecting the remaining populations has also multiplied. At new culvert installations, fish passage considerations and needs have increased in complexity. A high percentage of existing drainage structures are approaching or have passed their life expectancy. The task of replacing, modifying, and/or retrofitting the surviving structures will dwarf past programs for providing fish passage through culverts.

This report is intended to review, summarize, and update current information on fish passage through culverts. The scope of the report is limited to highway drainage structures, not including bridges. This distinction was made in an effort to concentrate on those road drainage structures that are most commonly used in fish passage situations. The publication is primarily issued for the fish biologists, engineers, and hydrologists who will be designing the projects and making current decisions on fish passage at drainage structures.

17. Key Words Anadromous; cruising speed; sustained speed; burst speed; adfluvial; culverts; hydraulic jump; riprap; perching; aufeis	18. Distribution Statement No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161

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MEMORANDUM

To: Sandra Lary, Maine Department of Marine Resources

From: Curtis Orvis, Hydraulic Engineer

Subject: Site Inspection Report for Field Review of Blackman Stream Barriers to Anadromous Fish Passage from the Penobscot River downstream from Veazie Dam into Chemo Pond, Maine and .

On Monday morning, August 7, 2000 I traveled by GSA vehicle to the Division of Marine Fisheries Office at Augusta to meet Sandra Lary. We traveled to the Eddington Salmon Club on the left side of the Penobscot where we met::

Ralph Keefe, Atlantic Salmon Federation (ASF) and
Warren Richardson, ASF. At the barriers we met
Randall Spencer, Atlantic Salmon Commission

Target species

River herring are the main species targeted for restoration to the Blackman Stream. Additional species now being considered include American eel and riverine fish. Alewife would also be targeted for the Sedgeunkedunk Stream into Brewer Lake and White's Pond at Palmyra in the Sebasticook River basin.

Blackman River Barriers
Beaver Dam at Chemo Pond Outlet

We traveled into the Penobscot Experimental Forest to the outlet to Chemo Pond where we inspected a beaver dam that is about 50 feet wide which has a man-made dam for a foundation. The beaver dam could be breached, but would require continued maintenance. Installation of a steeppass would also require maintenance since the beavers would be expected to try to plug the outflow in the steeppass. The drop appeared to be less than 2 feet at the low flow observed. During the spring, water could be expected to flow over the top of the beaver dam. The control of the water surface of Chemo Pond was questioned. At high water levels in the Pond there has been concern in the past for flooding and floating of septic systems. There did not seem to be a concern at the late summer levels observed.

Site 2 - Mill Dam on the Historic Forest Museum Property (Downstream from Chemo Pond)

The Mill dam has 2 overflow spillway outlets and a diversion to a mill race and sawmill. The earthen and stone masonry structure has bridges over the outlets and the tailwater channel merges a short distance downstream from the dam. Looking downstream the spillway on the right side was measured to be 13 feet wide and the distance from the bridge deck to the tailwater was measured to be about 10 feet. From the deck to the sill of the spillway was about 4'9" leaving a drop of 5'3" in head at the dam. Within 20 horizontal feet downstream from the spillway crest another natural drop of about 3 vertical feet exists in the right channel. The barrier could be used to guide fish to an adjacent entrance of a fishway that exits in the power canal or through the spillway. Another alternative would be to heighten the barrier and install the fishway on the left spillway. The crest on the left spillway was measured to be 8-feet wide and from the deck to the tailwater a distance of 8.5 feet was measured. The spillway crest was 6 feet below the bridge deck leaving a drop from the headpond to the tailwater of 2.5 feet. The natural location for a steeppass or denil fishway would be on the left bridge abutment on this left channel.

Site 3 - State Highway 178 Culvert Site (Immediately Upstream from the Penobscot River)

The existing vertical slot fishway on the left wall of the 20-foot(+/-) wide bridge culvert is in need of repair. The baffle slots and walls are in tact, but the side wall parallel to the culvert wall is badly eroding, spalling, and/or void where only bent re-bar is left. The pools were measured to be 8-feet long and 4-feet wide and up to 2 feet deep at the slots. There are 11 pools over the length of the culvert. A barrier weir exists at the upstream end to divert low flows into the fishway. The fishway and culvert was dry during the inspection. Some gravel would need to be cleaned out of the fishway along with the rehabilitation of the side walls. We speculated that the damage was caused by ice.

Site 4 - Breached Timber Crib Dam to Divert Water to a Diversion Pipe/Canal

The rock filled timber crib section on the right abutment had been breached. Some reworking of the boulders and cobbles in the channel would make the barrier passable. The other option would be to reconstruct the dam to hold water to the proper operating levels in the concrete denil fishway on the left abutment. The concrete appeared to be in good repair, but baffles would also need to be installed. The denil fishway was measured to be 3-foot wide with 17 baffle slots. The slope was estimated to be 1:6 which Maine would construct for herring.

Site 5 - Old Orono-Veazie Water Supply Dam

The intake to the water pipeline appeared to be open with a small flow passing through the outlet works on the right abutment. A low-level sluice exists in the concrete gravity wall of the dam adjacent to the right abutment and outlet works. Stop logs fill the slot in the sluice to a level 6 feet above the tailwater. The width of the sluice was measured to be 6 feet. The spillway adjacent to the sluice was measured to be 44 feet long (crest length) and the width at the top was 3 feet and estimated to be 5 to 7 feet thick a the base of the wall. Sediment had filled the channel upstream from the stoplogs to a level 4'4" below the top of the stoplogs.

Sedgeunkedunk Stream Barriers

Eastern Fine Paper Company Dam

The concrete gravity section at the Paper Company Dam is about 12' 3" high. We were unable to access the boardwalk over the crest but it appeared to be 25 to 30-foot long. The intake which supplies mill water has a high-density polyethylene trash rack to screen the flow. Mr. Tibbets is the environmental manager for the owner and can be reached at 989-7070.

Fields Pond Dam

The second barrier up from the Penobscot River is the Fields Pond Dam. It is a concrete gravity wall with 7 overflow slots that are 5-feet wide by 1 foot high. The outlet works is in the center and was measured to be 6.5 feet wide. From the top of the wall on the center sluice to the tailwater a distance of 6'3" was measured and from the top of wall to the headpond it was 4 feet. Thus, at the low-flow operating level the head differential was about 2.5 feet, but the water level was below the sill elevation for the spillway.

Brewer Lake

The earthen dam at Brewer Lake has a newly replaced wooden spillway and outlet works. The 19-foot wide spillway crest has 3 gates that were closed during the inspection. The 6-foot wide sluiceway on the left side of the spillway crest had some flow passing over an adjustable weir crest. The upstream water level was about 1.5 feet above the spillway sill and the tailwater was about 4.6 feet below the sill making the differential head at the dam about 6.1 feet.

Madawaska Stream Barriers (Tributary to the Sebasticook River)

Whites Pond Dam

The breach at the Whites Pond occurred naturally within a year from the last re-construction. The boulders and cobbles could be reworked to improve passage or if the dam were rebuilt a steeppass or pool and weir fishway could be constructed along with the re-construction.

Madawaska Bog Dam

The next downstream barrier from Whites Pond is owned by the State of Maine and operated for wildlife purposes at the Madawaska Bog. The gravity concrete spillway was measured to be 24'9" wide with 2-foot high flash boards installed on the crest. The differential head from the tailwater to the crest was measured to be about 4'4" and the 5-foot wide sluice gate on the right abutment was measured to be about 3'8" high.

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
300 Gateway Center Drive
HADLEY, MASSACHUSETTS
(413) 253-8288
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TRANSMITTAL — ENGINEERING

TO: Maine Department of Marine Resources
21 State House Station
Augusta, Maine 04333-0021

DATE: December 18, 2000

Attention: Mr. Tom Squiers

PROJECT: Tech. Asst Fish Passage

We are sending you the following items

□ attached via ______________

□ Prints — □ Copy of letter

□ Shop Drawings — □ Specifications

□ Original Drawings — Other ______________

Copies	Date/No.	Description
1	1992	Drawings for Maine Logging Museum Fishway Plans
1	2000	Site Inspection Sketches of the Blackman Stream Barriers

□ For approval — □ Approved as submitted

X For your use — □ Approved as noted

X As requested — □ Revise & Resubmit

X For review and comment — □ Disapproved

□ ______________

We have developed some the preliminary layouts of the barriers for the Blackman Stream and Sedgeunkedunk Stream . If there is a particular type of fishway for which you would have a preference or only want one of the listed types drawn in concept, please advise. We can process any additional design changes as needed.

Copy to: Sandra Lary, NRCS

Signed Curtis J. Orvis

Curtis J. Orvis, Hydr. Eng.
Team Leader

STATE OF MAINE
DEPARTMENT OF
MARINE RESOURCES
21 STATE HOUSE STATION
AUGUSTA, MAINE
04333-0021

ANGUS S. KING, JR.
GOVERNOR

GEORGE D. LAPOINTE
COMMISSIONER

October 20, 2000

Brian Swan
Dept of Marine Resources
#21 State House Station
Augusta, ME 04333-0021

Dear Brian:

Enclosed are comments on the *Culvert/Fish Passage Work Group Report of Findings – September 1997*. As you may recall, after reviewing the document, I felt it would be helpful to seek additional technical guidance from U.S. Fish & Wildlife Service fish passage engineers with whom DMR contracts for fish passage consultation in Maine. The draft memo dated August 4, 2000 contains comments provided by Curt Orvis; the letter dated October 2000, are comments from Dick Quinn.

Both Curt and Dick have been very helpful in addressing fish passage issues throughout Maine to ensure continued improvements in habitat accessibility for both resident and migratory fish species. Their input should be a beneficial starting point for the Work Group's planning purposes by providing adequate fish passage, and both have extended offers for further assistance to the Work Group on this important issue.

Curt also mentioned that the following website may be helpful to the group: http://www.stream.fs.fed.us/fishxing. You may also request the CD-ROM version of FishXing from the USDA-Forest Service, San Dimas Technology and Development Center, 444 East Bonita Ave., San Dimas, CA 91773 [Tel: (909) 599-1267].

Please contact me if I can be of further assistance.

Sincerely,

Sandra J. Lary

SANDRA J. LARY
MARINE RESOURCES SCIENTIST

SJL/jcw
Cc w/attachments: (1997 Report of Findings, Orvis Comments, Quinn Comments)
Peter Bourque/Steve Timpano/John Boland, IFW
Richard Bostwick, DOT
Linda Mercer/Tom Squiers DMR
Fred Kircheis, ASC
Dan Morris, NOAA

OFFICES AT STEVENS SCHOOL COMPLEX, HALLOWELL
PHONE: (207) 624-6550 www.state.me.us/dmr FAX: (207) 624-6024

Culvert/Fish Passage Work Group
Report of Findings

September 1997

Culvert/Fish Passage Work Group
Report of Findings

Executive Summary:

State and federal regulations require that fish passage be maintained when existing culverts are repaired or replaced. The Culvert/Fish Passage work group investigated passage issues and recommends that the Department adopt written policy to aid in regulatory compliance. This will assist new and veteran employees by providing formal guidance without deviating from present established procedures such as those regarding in house environmental review and agency coordination.

Introduction:

Numerous highway and railroad culverts in Maine are reaching the end of their serviceable life. In order to safely maintain the state's existing infrastructure, these culverts must be either replaced or rehabilitated before they fail. Replacing all of them will be expensive. Rehabilitation, when feasible, offers the opportunity to extend the useful life of a culvert for a fraction of replacement cost. For instance, a new concrete invert in a rehabilitated culvert has the potential to extend the useful life of a pipe ten or more years. Slip lining a culvert with a smaller diameter pipe essentially provides a design life equivalent to a brand new culvert installation.

Besides being expensive there are other disadvantages of full replacement. Replacing a culvert located in a roadway section with a high fill (i.e. Having five feet or more of cover material over top of it) may require that traffic be detoured around a worksite for an extended period of time. (The duration of detour will vary depending upon the depth of fill over the pipe and other site specifics.) Use of repair procedures at the same location may eliminate the need for traffic diversion.

Replacing a culvert can also be more environmentally damaging than rehabilitating it. For example, less soil disturbance is involved with slip lining an existing culvert than with replacing it. New wetland impacts, or impacts beyond what was impacted when a culvert was initially installed, can often be avoided. Such impacts would be the result of flattening slopes at the inlet and outlet of the new culvert. Current design standards require at least a 2:1 slope, whereas existing slopes may be only 1¾:1 or 1½:1.

Although there is an opportunity to reduce project cost by putting off ultimate replacement, culverts that are repaired have the potential to impede fish passage. They can block spawning runs of migrating fish as well as the seasonal movement of resident fish species. This is especially true if a culvert was installed improperly at its initial installation. An improperly installed culvert can hinder or prohibit fish passage by making a drop at the outlet end. (It could be installed this way initially or scour at the outlet may create the situation.) Undersized pipes and those that are installed at too steep of a slope can also result in stream velocities that are too high for fish to negotiate. Like improperly installed culverts, selection of repair methods without consideration for fish passage may make a marginal passage situation completely impassable.

Because of regulatory requirements and the role the Maine Department of Transportation (MDOT) plays in environmental stewardship, fish passage issues must be considered on nearly all projects involving highway culverts and culverts within state owned rail right of way. The obvious exceptions are when culverts are strictly drainage structures and do not convey waters supporting fisheries. The Natural Resources Protection Act (M.R.S.A., Title 38, Section 480 Q) requires that fish passage be maintained as a result of culvert installations or replacements, whether or not a permit is needed. It is just one example of regulatory requirements MDOT adhere to which deals with fish passage. The goal of the Culvert/Fish Passage Work Group was to develop recommendations for the installation and repair of highway culverts which are consistent with state and federal policies and regulatory requirements and at the same time allow the Department to make use of currently available technology.

Mission Statement: To develop recommendations for installation/repair of culverts which will enable the Department to make efficient use of slip lining, plastic pipes, concrete inverts, etc. and be consistent with state and federal fish passage policies and regulatory requirements.

1. Fish Passage Policies and Requirements of State and Federal Regulatory and Natural Resource Agencies:

Current regulatory requirements associated with fish passage and culverts were investigated by the work group. Under the Department of the Army Programmatic General Permit for the state of Maine (federal regulation), item #17 of the general conditions states that "...all temporary and permanent crossings of waterbodies shall be suitably culverted, bridged or otherwise designed to withstand and to prevent the restriction of high flows, and to maintain existing low flows, and so as not to obstruct the movement of aquatic life indigenous to the waterbody beyond the actual duration of construction."

Maine's Natural Resources Protection Act (NRPA) requires fish passage be maintained for replacement and for the maintenance and repair of existing road culverts (M.R.S.A. Sec 480 Q). The NRPA Permit By Rule Standards for Reconstruction or Replacement Projects (Chapter 305, Sec 10, C, 2) reads as follows. "The project will not permanently block any fish passage in any watercourse containing fish beyond what restriction may already exist and will improve passage if transportation related restrictions exist unless concurrence from the Department of Inland Fisheries and Wildlife and the Department of Environmental Protection's Division of Environmental Assessment is received that the improvement is not necessary."

At present, the Maine Department of Marine Resources (MDMR) and the Maine Department of Inland Fisheries and Wildlife (MDIF&W) have fish passage policies relating to hydropower and dam facilities but no written policies specific to highway culverts. Additional state statutes, M.R.S.A. 12, Sec 6121-6123 and Sec. 7701-A - 7701-C, refer to dams, fishways and other artificial obstructions. In a legal sense, "other artificial obstructions" could encompass highway and railroad culverts.

Unfortunately, regional fisheries biologists in Maine do not always have information on all the streams within their regions. This has sometimes been perceived as meaning there is minimal concern regarding DOT work on small unnamed tributaries when in fact these may be locally important fisheries. Upon completion of culvert work by the Department in these streams, fish passage must still be possible.

(Besides fish passage issues, floodplain and flood insurance regulations need to be considered in the repair and maintenance of highway culverts. The Federal Emergency Management Agency (FEMA) is responsible for all activities within a 100-year floodplain that may cause an increase in flooding.)

2. Fish Species and Passage Requirements:

The fishery resources of the state of Maine play an important role in coastal and inland ecosystems. Species such as alewife, blueback herring and American shad provide forage for numerous fish and wildlife species in both inland and coastal habitats. The fishery also contributes significantly to the economy, both commercially and recreationally. Protection of this valuable resource must be an important consideration in all of the Department's activities. The species listed below can be particularly vulnerable during their annual spawning migrations.

Catadromous Species:
American eel

Anadromous Species:
Rainbow ~~S~~smelts
Blueback herring
Alewi~~ves~~fe
Atlantic Salmon
Atlantic sturgeon
Shortnose sturgeon
American Shad
Sea run brook trout
Sea run brown trout

Freshwater Species:

Smelts
Brook trout
Brown trout
Rainbow trout
Landlocked Salmon

Blockage or impedance at a road crossing during a spawning run can have a catastrophic effect on the size and health -of a population for years if little spawning habitat exists downstream in the drainage from the culvert. It can also physically separate a single population into several smaller populations and a reduction in genetic exchange and diversity could have negative impacts. Permanent blockage can even eliminate a particular species from a portion or portions of a watershed altogether. An example of this is when there is no spawning habitat available downstream from the culvert. As a result, species which do not inhabit the upstream area on a year round basis but utilize it for spawning only, cannot reproduce successfully. Areas used as nursery habitat that are not accessible to juveniles when they leave the spawning habitat would decrease the survival success of juveniles.

Examples of naturally occurring physical blockage to fish passage includes falls, strong rapids, and beaver dams. Obviously, not all of these blockages will impede fish movement. Some stronger swimming species may be able to traverse sections of rapid water and even jump smaller falls. Larger individuals might also be able to jump certain beaver dams and juveniles may find passageways through the debris comprising a dam. Physical blockage by culverts can have a similar effect. They may not block all species or individuals.

Some researchers believe that light-dark effects such as at the inlet and outlet of a long culvert also have the potential to impede passage. To improve passage, they recommend minimizing removal of vegetation at the culvert ends when such cutting is necessary and planting of vegetation at the culvert ends if none exists. This allows for a more gradual adjustment to the eyes of fish to changing light conditions at the inlet and outlet when entering and exiting a pipe.

During the summer months when cold water species seek areas of spring influence to escape the heat, excessive cutting of vegetation along a streambank and warm runoff from parking areas, road surfaces, rip rap etc. can cause water temperatures in a stream to rise to an intolerable level for some fish species. Passage through culverts may be important in order to escape lethal temperatures by allowing movement of fish to a cooler reach of the stream. Cutting of riparian vegetation also reduces buffer zone erosion capability and can increase/facilitate sediment runoff into a stream, potentially decreasing the survival of fish species.

The two most significant issues relative to highway culverts and fish passage are drops created at a culvert outlet (discussed earlier in this document) and high velocities. The problem of a perched outlet can be addressed by proper culvert installation. In some instances, placement of a small stone checkdam downstream from an existing culvert can raise the tailwater elevation enough to eliminate a drop and allow passage. (Provided passage at the checkdam is maintained through a v-notch in the stone or through openings between larger stones of the dam.) Before the problem of increased velocity can be put in proper perspective, swimming capabilities of fish must be considered.

Swimming speeds of fish depend upon species, maturity and size of fish, characteristics of individual fish, and water temperature. Three types of swimming speed are discussed in the literature. The speed a fish can maintain for only a few seconds is known as burst speed. The speed a fish can swim for a duration of several minutes is sustained speed. The speed a fish can maintain for an extended period of time is called cruising speed. Of these, sustained speed is most important in determining passage for culverts less than 46 meters (150 feet) in length. For longer pipes, passage should be evaluated using cruising speed. Sustained speeds for an adult trout range from 0.6 to 2.4 meters (2.0 to 8.0 feet) per second and cruising speeds from 0.0 to 0.6 meters (0.0 to 2.0 feet) per second. **Adults of weaker swimming fish species, such as smelts and alewives, may have maximum sustained speeds of only 0.6 meters (2.0 feet) per second.** I suggest that we forward this to Curt Orvis to review for recommendations on this. Alosids are strong swimmers, smelt are not, and there are other species to include. Min and max velocity; pipe length; av velocity vs. mid-flow vs. boundary; and would these be velocities for a level pipe? What do you think?

3. Proposed Fish Passage Policy:

MDOT's BMP manual (Best Management Practices for Erosion and Sediment Control, May 1992) contains several brief discussions on fish passage. This document was developed to provide guidance to personnel for meeting required erosion and sediment control standards. It is now being rewritten in order to conform with the state's new stormwater regulations. The latest draft mentions the need to contact the Department's Office of Environmental Services (OES) regarding fisheries issues, who in turn are to coordinate with applicable agencies. MDOT presently coordinates with MDIF&W (Maine Department of Inland Fisheries and Wildlife), MDMR (Maine Department of Marine Resources), ASA (Atlantic Salmon Authority), and NMFS (National Marine Fisheries Service) on a project by project basis. For environmental coordination regarding fish passage issues to function as intended, all parties involved must have sufficient information to determine if impedance could occur as a result of a project. They must also be knowledgeable of the resource potentially impacted by the project and of the capabilities of species involved.

Contact with departments of transportation in other states reveal parallel circumstances to our own. Maryland, Minnesota, Michigan, New York, North Carolina, Pennsylvania, Virginia, Washington and Wisconsin were called in reference to fish passage issues. None of these states have written policy. Some handle these issues by memorandum of understanding (MOU) with fisheries agencies. Washington state, for example, has a MOU between the Fisheries, Wildlife, and Transportation departments concerning compliance with their Hydraulic Code. However in most of the states contacted, fish passage is dealt with on a project by project basis through coordination with the natural resource agencies. Other methods of dealing with fish passage issues include use of guidelines and recommendations such as the state of North Carolina's

"Stream Crossing Guidelines for Anadromous Fish Passage" and New York State DOT's "recommendations" for fish passage that were recently incorporated into their draft highway design manual.

It is the belief of this work group that confusion on the part of DOT personnel regarding fish passage issues can be minimized through establishment of written policy. Department policy has not always been recorded on paper in the past. Whether written or unwritten, it often consists of bits and pieces of information gleaned from several documents. A general environmental policy statement was published by Commissioner Dana Connors in the Summer 1990 issue of Maine DOT. Although it set new direction for the Department, it offered little in the way of specific guidance. For these reasons, the Culvert/Fish Passage Work Group proposes that the MDOT environmental policy statement be supplemented to provide additional direction to employees.

Proposed Culvert/Fish Passage Policy

- New Culverts shall be installed with inverts at or below streambed elevation. Pipes less than 1219 mm (48 inches) in diameter should be embedded 76-152 mm (3-6 inches). Pipes greater than 1219 mm (48 inches) in diameter are to be embedded 152-305 mm (6-12 inches) into the stream bottom
- When installing or replacing multiple pipes (i.e. Parallel culverts) at the same location, one culvert shall be installed with invert at or below streambed elevation to allow fish passage during low flow conditions, additional pipe(s) shall be installed at a higher elevation to provide hydraulic capacity at high water.
- The following evaluation process shall be implemented to ensure fish passage considerations are included in every project involving highway and railroad culverts:

Evaluation of Highway Culverts for Fish Passage

Guidelines for Meeting Regulatory Requirements for Repair and Replacement of Culverts.

I. No Fish Present –– Maintenance and Design? (or whether or not fish are present?) Is To be determined by OES or highway maintenance supervisor. Fisheries agencies (MDIF&W, MDMR, ASA) shall be contacted to determine this if there is any question.

A. No fish passage concerns for maintenance, repair, or replacement of existing culvert (i.e. If the culvert is strictly a drainage structure that does not carry a stream). Use BMPs and obtain any necessary environmental permits.

II. Fish are Present -- Maintenance and Design coordination with OES mandatory. OES shall contact and coordinate with applicable fisheries agencies (MDIF&W, MDMR, and ASA)

A. Potential Fish Passage Concerns

1. If species are determined not to be of ecological, recreational or commercial importance ———————by fisheries agencies, no fish passage concerns.

2. Ecological, Commercial and/or recreational importance ~~fisheries~~ exists. (Special requirements may be involved based upon fisheries contact.)

a. Maintenance and repair of culvert

i. Slip lining

a.) If the existing culvert is hanging (i.e. has a perched outlet) or there is a barrier to fish passage immediately upstream or downstream of the existing structure (unless the blockage can be removed at a future date or there plans to install a fishway at the barrier), slip lining is permissible. How is a slip lining going to help with a perch outlet, isn't it just a linig for the inside of the pipe?

b.) Hydraulic analysis shall be conducted by Design Division to determine velocity of proposed slip lined pipe at Q1.1. (If brook trout are present, a velocity less than 2.4 meters (8 feet) per second would permit slip lining option. This velocity has been selected because it should allow passage during the critical fall spawning period. **If rainbow trout, rainbow smelt, or alewives are present, a velocity of 1.2 meters (4 feet) per second** (need more info on this and for other species) at Q1.1 should allow passage by these species several days after Q1.1 during their annual spring spawning migrations. Slip lining is permissible if this velocity requirement can be met. Use of corrugated liners should be considered an option if sufficient hydraulic capacity can be provided)

c.) When slope of existing culvert is 0.0%, slip lining is permissible with smoothbore plastic pipe.

When slope of existing culvert is less than 0.5% but greater than 0.0%, slip lining is permissible with concrete pipe.

When slope of existing culvert is less than 1.0% but greater than 0.5%, slip lining is permissible with corrugated pipe.

d.) For culvert systems greater than 61 meters (200 feet) in length, fish passage likely not possible, therefore slip lining is a viable option.

e.) Slip lining should be considered for repair of overflow pipes when there are multiple parallel pipes.

ii. New concrete invert (Note -- Water quality standards for pH must be met.)

a.) If existing culvert is hanging (i.e. has a perched outlet) or there is a barrier to fish passage immediately upstream or downstream of the existing structure (unless the blockage can be removed at a future date or there are plans to install a fishway at the barrier), a new concrete invert is permissible.

b.) Hydraulic analysis shall be conducted by Design Division to determine velocity of culvert with new concrete invert at Q1.1. (If brook trout are present, a velocity less than 2.4 meters (8 feet) per second would permit new concrete invert. This velocity has been selected because it should allow passage during the critical fall spawning period. **If rainbow trout, rainbow smelt, or alewives are present, a velocity of 1.2 meters (4 feet) per second** need more guidelines for these species and others at Q1.1 should allow passage by these species several days after Q1.1 during their annual spring spawning migrations. A new concrete invert is permissible if this velocity requirement can be met.)

c.) When slope of existing culvert is less than 0.5%, installing a new concrete invert is permissible. Between 0.5% and 1.0% slope, a new concrete invert may be a viable option if roughness can be incorporated to slow velocities.

d.) For culvert systems greater than 61 meters (200 feet) in length, fish passage likely no occurring, therefore installation of a new concrete invert can be considered as an option.

b. Culvert Replacement

i. Culvert shall be installed with invert at or below streambed elevation. Pipes less than 1219 mm (48 inches) in diameter should be embedded 76-152 mm (3-6 inches). Pipes greater than 1219 mm (48 inches) in diameter are to be embedded 152-305 mm (6-12 inches) into the stream bottom.

ii. Replacement of existing culvert with smoothbore plastic pipe.

a.) Hydraulic analysis shall be conducted Design Division to determine velocity of replacement pipe at Q1.1. (If brook trout are present, a velocity less than 2.4 meters (8 feet) per second would permit usage of smoothbore plastic pipe. This should allow passage during the critical fall spawning period. If rainbow trout, **rainbow smelt, or alewives are present, a velocity of 1.2 meters (4 feet) per second** need more guidelines for these species and others at Q1.1 should allow passage by these species several days after Q1.1 during annual spring spawning migrations. Therefore, replacing existing pipe with a smoothbore plastic culvert is permissible.)

b.) When less than a 0.3 meter (1 foot) elevation difference exists between the inlet and outlet of a culvert exists, replacing it with a smoothbore plastic pipe can be considered an option.

c.) For culvert systems greater than 61 meters (200 feet) in length, fish passage likely not occurring, therefore replacement with smoothbore plastic pipe is permissible.

B. Definite Fish Passage Concerns. Based upon OES coordination with fisheries agencies, certain options may be eliminated and/or introduce special requirements and conditions. Any waters where passage by the following species is involved:

Atlantic salmon
Landlocked salmon
Brook trout
Brown trout
Rainbow trout
Rainbow trout
Alewives

Should the whole list be included here?
Rainbow smelt
Blueback herring
Alewife
Atlantic Salmon
Atlantic sturgeon
Shortnose sturgeon
American Shad

4. Work Group Recommendations:

In order to assure future compliance with state and federal regulatory requirements related to fish passage and highway culverts and to minimize project delays due to environmental coordination, the work group offers the following recommendations.

- The proposed fish passage policy (or similar policy approved by fisheries agencies) set forth in the previous section of this document should be adopted. This policy should be included in the appendix of the Department's BMP manual.
- OES should purchase flowmeter to be used in environmental evaluation of proposed projects.
- Fisheries agencies should be asked to conduct an inventory of culvert locations in their regions where they feel passage in an issue--so that we can fix things if necessary the next time around (i.e. when culvert is repaired or replaced). This could improve and speed up future

environmental coordination. (Really, Maintenance and Operations should conduct statewide culvert inventory also to aid in routine maintenance and infrastructure.)

- If possible, the Department should improve culvert inspection techniques and procedures to identify needs do that culverts can be replaced or repaired before failure occurs and allow ample time for required agency coordination regarding environmental matters.
- Training should be offered to Maintenance and Design personnel dealing with fish passage issues. This can be incorporated in the annual erosion and sediment control workshops held for the maintenance divisions. Separate training for Design should be incorporated in environmental training conducted for that division.
- A fund should be established for use by maintenance divisions (possibly on a grant basis) for recouping excess expenditures on a project which stem from environmental concerns.

Implementation of these recommendations may not always ensure regulatory compliance but will demonstrate the Department's environmental commitment to the people of Maine and to all who enjoy our state's natural resources.

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Appendix:

(include policies, guidelines etc. from other state DOTs)

UNITED STATES GOVERNMENT
U.S. FISH AND WILDLIFE SERVICE
300 WESTGATE CENTER DRIVE
DIVISION OF ENGINEERING
HADLEY, MASSACHUSETTS 01035-9589

DATE: August 4, 2000

MEMORANDUM

To: Sandra Lary, Fisheries Biologist
Maine Department of Marine Fisheries

From: Curt Orvis, Hydraulic Engineer

Subject: DRAFT Review of *Culvert Fish Passage Work Group Report of Findings* dated September 1997 for Maine Marine Resources

General Comments

In general, the report has reviewed the majority of the literature available on culvert design for fish passage and attempted to summarize a basic design approach in the section on policy and evaluation. We concur with installing one culvert lower than others in a multiple pipe crossing, but prefer to have all pipes buried in the streambed to effectively run the streambed through the culvert(s). The main concern with the evaluation is that it appears to be focused on slip-lining existing culverts and overlooks some of the more important issues in removing barriers at culverts.

The Washington Department of Fish and Wildlife (WDFW) manual gives 5 conditions that create migration barriers: 1) excessive drop at the culvert outlet; 2) high velocity within the culvert barrel; 3) inadequate depth with the culvert barrel; 4) turbulence within the culvert; and, 5) debris accumulation at the culvert inlet.

Installing new culverts into the streambed

The proposed criteria suggests installing new pipes smaller than 48 inches in diameter only 3 to 6 inches into the streambed. Pipes larger than 48-inches are installed 6 to 12 inches into the streambed. This criteria will constrict the flow and the natural channel at the invert of the pipe. The width of channel in a 4-foot diameter pipe embedded 6-inches into the streambed is about 2.6 feet. Again for a 4-foot pipe, buried a full 12-inches the channel width within the pipe is about 3.6 feet. This inherently constricts the flow and creates a higher velocity zone within the culvert. A better approach is provided in the WDFW manual. The design formula for the minimum width of the bed within the culvert is 1.2 times the channel width plus 2 feet. The channel width is computed at a 2-year recurrence flood discharge. Thus, the culvert should be sized to provide a width slightly greater than the natural stream width. The dominant discharge is often considered the bank forming discharge and typically has a 2-year recurrence interval. Our preference is to install a bottomless arch culvert that allows for natural movement of bedload and debris. The second choice would be a pipe arch that is embedded to the full width.

Installing or replacing multiple pipes or culverts

We concur with the need to place a low flow channel culvert below the streambed and lower than the other pipes at a site for passage of fish.

Specific Comments on the evaluation process

I. No fish present - No comment except that barriers may want to be maintained where non-native species could access and damage upstream habitats. One example would be control of carp expansion.

II. Fish are Present

1. Species - We concur with adding the anadromous species to the list including: American eel, rainbow smelt, blueback herring and alewife, American shad, Atlantic salmon, Atlantic sturgeon, shortnose sturgeon, white and yellow perch, sea-run brown and brook trout, and possibly striped bass, but suggest that the age or life stage must also be considered. For example, juveniles may be moving upstream or downstream into natal areas or for finding forage.

2. Requirements -Swim speed evaluation - It is unclear where the Brook Trout swim capability of 8 fps is derived from in the literature. If the adult trout are greater than 6-inches a maximum velocity of 4 fps is recommended by WDFW for pipe 10 to 60 feet long and is reduced to 2 fps for pipes longer than 200 feet. The FHWA guide gives a sustained speed of 2 to 6.6 fps for trout. The water velocity in the culvert needs to be less than the maximum sustained speed capability of the fish for it to progress upstream through the pipe.

The swim speed capability is considered to vary with length of fish. Without species and life stage specific data we offer the following guideline:

Cruising speed: sustainable for 2 hours	2 to 4 body lengths per second	(longer culverts)
Sustained speed: several minutes	4 to 7 body lengths per second	(moderate culverts)
Burst speed: only a few seconds	8 to 12 body lengths per second	

3. Fish Passage Policy

a. Maintenance and Repair

i. Slip lining -

a. The paragraph is confusing, but if the pipe is perched should it state that slip-lining is NOT permissible unless the barrier is removed by downstream weirs or a fishway?

b. Hydraulic analysis - This analysis is over simplified, but we have no criteria that provide for passage for fish to a 1.1-year recurrence interval flood. Our approach is to review the drainage area, and flows during the fish passage periods and calculate depths and velocities in the channel and through the culvert at low, average, and high flows to assess performance.

Swim speed evaluation - See aforementioned comments on swim speed.

c. Slope - If the barriers are reduced by downstream weirs there is less concern on roughness from type of slip-lining. In general, the flatter the better and the maximum of 1% slope is reasonable. The other criteria on velocity and swim speed should outweigh this criteria.

d. Culverts longer than 200 feet - We totally disagree with this statement. There are runs of alewife on the coast of Massachusetts that pass through more than 1000 feet of culvert during a spawning migration. The criteria should be to lower the slope and velocity to cruising speed of the targeted fish to allow passage during the longer time period.

e. Slip lining at multiple pipes - Is this needed? From this report is appears that slip-lining is considered first anyway.

ii. New concrete invert -

a. Perched invert - It is recommended to 1. Bottomless Pipe arch 2. Bury the concrete invert 3. Remove the barrier by constructing downstream weirs if the replacement is in kind.

b. Hydraulic analysis - See aforementioned comments under maintenance and repair

c. Slope - See aforementioned comments under maintenance and repair

d. Length of culvert - See aforementioned comments under maintenance and repair

b. Culvert replacement -

i,ii -The comments on installing new culverts into the streambed apply.

a. Hydraulic analysis - Again hydrologic and hydraulic analysis is needed to evaluate flows throughout the fish passage periods. In general, a maximum discharge of 3 to 4 times the average annual discharge is the upper limit of the passage flows for which fish will be moving.

b. slope - The 1 foot of differential head is generally adequate as long as the culverts are greater than 100 feet long, in other words 1 percent slope maximum. The criteria on flows, velocities and swim speeds take precedence.

c. long culverts - For the longer culverts, the slope should be less and velocities lower since the fish will need to pass in a longer time frame. See the aforementioned criteria.

We appreciate the opportunity to comment on this report. Please feel free to contact Curt Orvis at 413-253-8288 for any questions or clarification.

***************** DRAFT **********************DRAFT********************

Hi Curt: October, 2000

Finally had a chance to get to writing up comments on the ME proposed policy on culverts.

Your comments generally reflect areas of concern to us, but I have a few additional comments and/or caution flags.

In sizing a new culvert, page 1 of your letter, you indicate your preference to follow Washington's guidelines of 1.2 times the design flow plus 2', where the design flow is the bankfull discharge. While this is unquestionably their (WDFW) policy, we recently fought over a project called Waugh Chapel Road on Towsers Branch, MD, where the bank-full Q's were computed out to be something on the order of 200 cfs - for a 3.5 +/- square mile drainage basin. We continued to tell them (Brightwater Env) to use commonly recurring flows for fish passage in their design also – such as the 8 cfs normal flow, 2 cfs min, and 30 cfs max that are the fish passage flows, so that commonly occurring flows present when fish are trying to move are considered in the culvert analyses - not just the bank-full and the 100 year flows. They didn't, and the results are history.

The Rosgen bankful - 1.5 to 2 year flood may be fine for determining the overall width of the culvert necessary to meet specific stream restoration concerns, it didn't give us anywhere near the necessary depth of flow necessary for fish passage on Waugh Chapel, or Capital Raceway or Whitemarsh Run - which is obviously where I am leading to next - nothing is mentioned about depths of flow necessary for passage - we try to have a minimum depth of 8" at minimum design Q's and 12" at normal Q's thru culverts - if Q's are spread out over a very wide culvert, we will not have anywhere near the 8" minimum depth - hence the usage of constrictors/plates on the upstream end along with possible small height wall down the culvert barrel - producing a channel maybe 2' wide minimum, but where we try to get our 8" min depth, but still allow adequate width of the culvert for design/morphology concerns - for the Rosgen bankfull Q's. Which gets back to designing the culvert properly for varying flow conditions - which again is not mentioned anywhere. It definitely has to be addressed.

A comment that I feel has to be added is that the manual never mentions the fact that at some flow conditions, the culverts may be passable, while at other flows, the culverts may be a barrier - again - varying flow conditions which must be looked at.

In your comment letter, 2nd page, II, 2. One suggested addition would be to place boulders/baffles within the culvert on very long culvert lengths so that it creates slack water behind them - obviously has to be considered in the flow analyses.

Your comment under 3,a,i,d - culverts > 200 feet - MA's culvert that you refer to is about 900' long, so you may want to change wording to culverts almost 1000 foot long.

I agree with you that their handling of slip pipes is confusing – report never mentions that flow carrying capacity is lost by placing in a liner.

Specific comments that I have on the actual policy - page 4 - 2 pars before item 3. Discussion on check dams is very confusing to me - we certainly don't advocate using barriers made out of gabions, and "discourage" usage of walls made out of stone because they would not contain low flows and allow the necessary head build up - concrete, wood planks, tightly fitted rocks - but with an understanding that they be checked for integrity after each and every significant flow event. I find it difficult to see how a v-notch can be placed in a stone check dam. Suggest more usage of full depth notches designed on the - have we mentioned this before – minimum fish

UNITED STATES GOVERNMENT
U.S. FISH AND WILDLIFE SERVICE
300 WESTGATE CENTER DRIVE
DIVISION OF ENGINEERING
HADLEY, MASSACHUSETTS 01035-9589

DATE: November 1, 2000

MEMORANDUM

To: Tom Squiers, Commissioner
Sandra Lary, Fisheries Biologist
Maine Department of Marine Fisheries

From: Curt Orvis, Hydraulic Engineer

Subject: DRAFT Review of Impacts to the Existing Denil Fishway from Safety of Dams Reconstruction of the Highland Lake Dam on the Mill Brook in the City of Westbrook, Cumberland County, Maine.

General Comments

In general, the subject reconstruction halted the upstream and downstream passage of alewives through the existing Denil Fishway into Highland Lake on the Mill Brook, a tributary to the Presumpscot River. Although considerable care appeared to be taken in not disturbing the fishway during construction and reconstructing the exit channel with water stops, 4 baffles were left out in the second upstream leg of the fishway. The basic impact was to create a velocity barrier at the exit channel or upstream end of the fishway. It also appeared that the owners and operators of the dam and fishway need more guidance on functions and operations of the fishway in order to successfully pass alewife. Some additional considerations will be needed for downstream passage. This memorandum report is an attempt to explain those details.

Background

Although the original dam was constructed in the 1930's, the drawings for the fishway were dated 1986 when separate construction would have started. The 2-foot wide Denil fishway had an entrance channel at about 45 degrees to the spillway overflow. The first downstream leg contained 13 baffles and 12 spaces at 1.5 feet before a turn pool changed the flow direction. The second, upstream leg, also at a 1:6 slope, had 27 baffles with 26 spaces equating to a horizontal distance of 39 feet. The exit channel contained stop log slots and an aluminum de-watering gate as well as wooden trash racks at the water intake. A non-overflow section upstream from the fishway entrance diverted the spillway overflow to avoid adverse eddies or mis-guidance of adult alewives. The 5-foot high side walls to the Denil fishway provided sufficient depth to operate at a depth from 3.42 feet to about 4.5 feet in the exit channel and throughout the fishway. This would equate to a discharge rate from about 3 cfs to about 80 cfs which would be the operating range of river flows for the fishway. The water surfaces were checked on the 1986 drawings (Number 4) and would not contact the support beams at the top of the fishway walls. The intended upstream operation would be to raise the aluminum gate (in the exit channel) fully at the start of operations in the spring and allow flow to pass through the 40 baffles of the fishway to the entrance.

For downstream passage, the 22 to 23 foot wide spillway would operate with enough depth and frequency to allow downstream passage of juveniles and remaining adults during rain events from mid-August through November. The outflow from the fishway and spillway passed downstream through 2 natural channels of reasonable width to provide a zone of passage at the average annual discharge of about 19 cfs. During periods of low flow stop logs could be placed in the denil fishway and lower than normal quantities of water passed through a series of intermediate plunge pools to the tailwater. Measurements taken in 1998 prior to the reconstruction showed the fishway to be constructed as depicted in the 1986 drawings.

Re-Construction Changes

Measurements taken in September, 2000, suggest that the spillway crest may be slightly higher (.08') and the exit channel as much as .1 feet lower than the original design. A table comparing drawing and measured elevations from the original and 1999 reconstruction follows.

Highland Lake Fishway - Maine

Elevations from drawings and field measurements

Original Fishway Data		Datum Adj.	Calculated	Measured	New Design
Top of Dam	100.28	93.6	193.88		196
Crest	96.92	93.6	190.52		190.6
Top Exit Wall	100.28	93.6	193.88		193.8
Exit Invert	93.50	93.6	187.10		187
Top Turn Pool Wall	92.00	93.60	185.60	-1.4	185.6
Turn Pool Invert	87.00	93.60	180.60		
Top Entrance Wall	89.50	93.60	183.10	-3.9	183.1
Entrance Invert	84.00	93.6	177.60		--
Streambed	83.50	93.6	177.10		
Slope 1:6	0.167				
Top Trash Rack	100.17	93.6	193.77		
Bottom Trash Rack	92.83	93.6	186.43		
Top Bottom Beam on Rack	93.50	93.6	187.10		
Number of Baffles	40				36
Crest Length	23.00				95
Top New Wing Wall	93.40	93.6	187.00		187

Problem with Eliminating 4 Baffles

The most difficult change to re-mediate is the redirection of the flow and loss of 4 baffles at the exit channel. The location of the inflection point was moved downstream during the re-connection of the fishway to the new dam. The contact point on the fishway floor appears to be roughly at the location of the upstream most baffle, but the slot would have to change directions. A level turn pool for horizontal distance of 5 feet on each side of the inflection point is needed to accommodate baffles and turning flow. With a bottom jet of about 3 cfs passing under the de-watering gate during the September 2000 inspection, it was difficult to determine if the exit channel floor is now sloping from the gate to the last remaining baffle. It may be possible to add baffles in the straight section of the exit channel, but the need is to have the baffles in the sloping section of the fishway. An interim fix may be to add incrementally increasing bottom plates to a number of baffles to raise the slope slightly to meet the new grade of the fishway at the exit. One would not expect that baffles which changed direction could be easily constructed in place or function properly.

Other Concerns

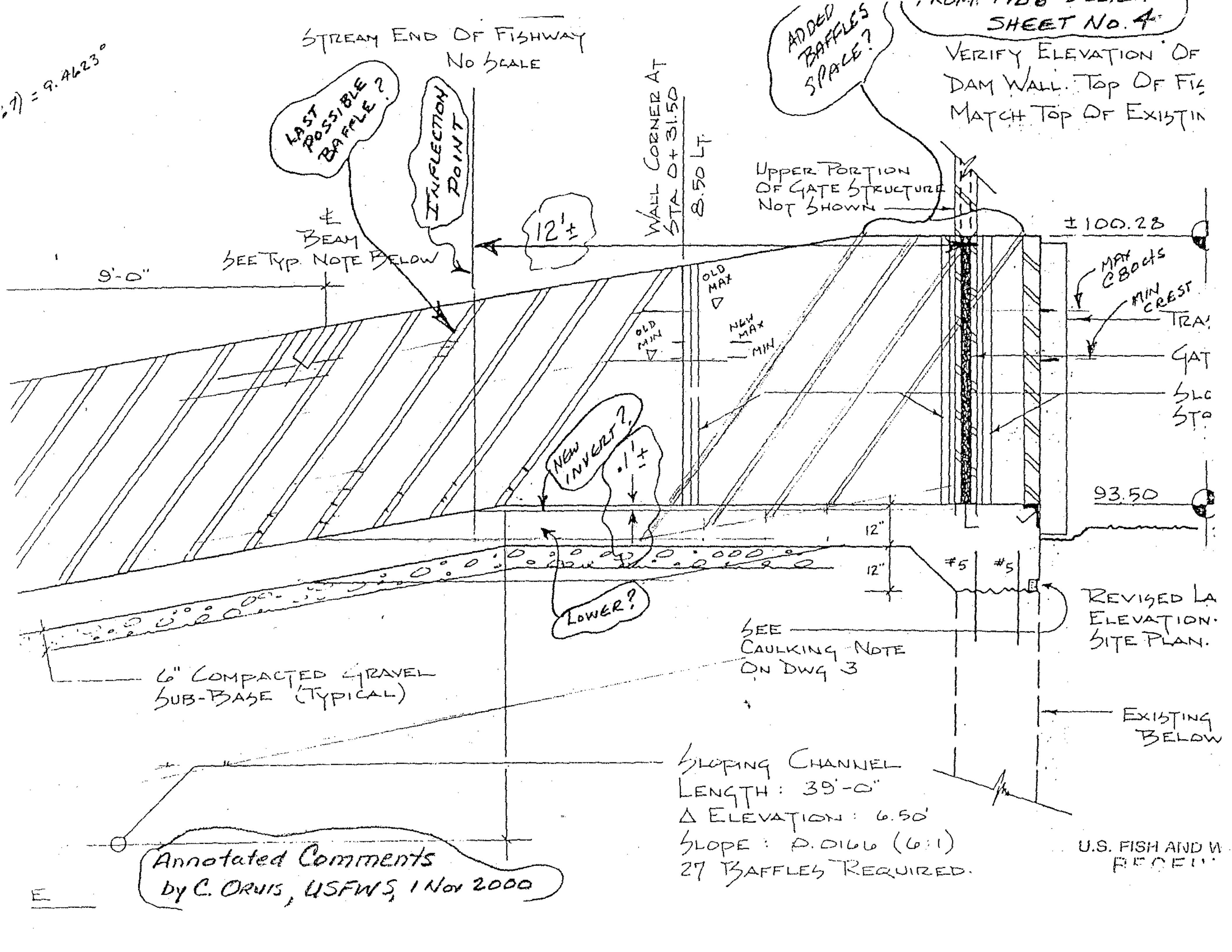
Additional efforts are needed before next spring to develop interim measures that will allow passage. The entrance channel was left high and dry during our low-flow inspection. A guide-wall, diversion, or low-flow channel needs to be developed and tailwater evaluated to be sure that the flow from the entrance continues to attract adult alewives. The need for a notch in the dam and flash-boards to create a non-overflow section also should be evaluated.

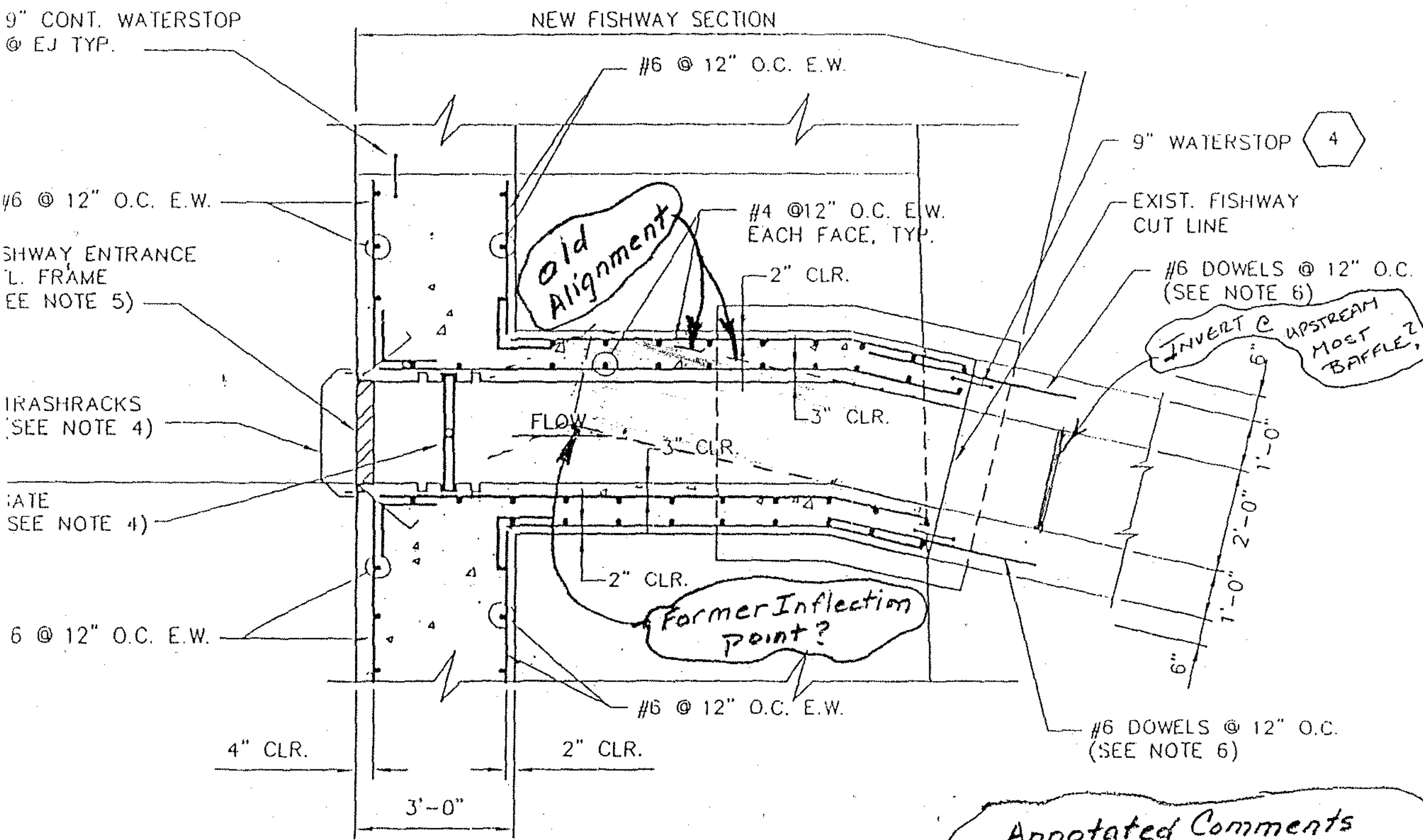
Downstream Passage Options

In order to recreate the pre-construction effectiveness and zone of passage for out-migrating juveniles and adults, alternate downstream passage routes were considered. The existing width of the spillway gates approaches the original spillway width. It may be possible to insert stop logs or bulkheads into one or both gate slots and raise the gates fully during the out-migration period. The other option is to create a gate within a gate. A typical 3-foot wide by 6-foot long collection box could be added to the reservoir side of the sluice gate. For this option the flow out the square sluice gate would need to be evaluated and water control stop logs or gates added to the box to allow for cleaning and avoid reservoir draw-down. We would not expect any options on the gates to be well-received by the City or Dam safety engineers. The existing spillway could be notched at either abutment to provide a 3-foot wide by 2-foot deep opening in the crest. The least construction cost alternative is to use the existing fishway, place stoplogs in the exit channel slots, and remove baffles to create intermediate plunge pools. It does require maintenance and site inspections. The outflow from the reservoir should be from a surface overflow weir. At low-flow periods with only the 2-foot wide fishway operating, an overflow depth of 7 inches would allow passage of the minimum flow of about 3 cfs. In order to create the overall pre-construction effectiveness both the existing fishway option and notch are needed.

We appreciate the opportunity to comment on the re-construction. Annotated comments are attached on portions of the design drawings for clarity. Please feel free to contact Curt Orvis at 413-253-8288 for any questions or clarification.

****************** DRAFT **********************DRAFT*********************

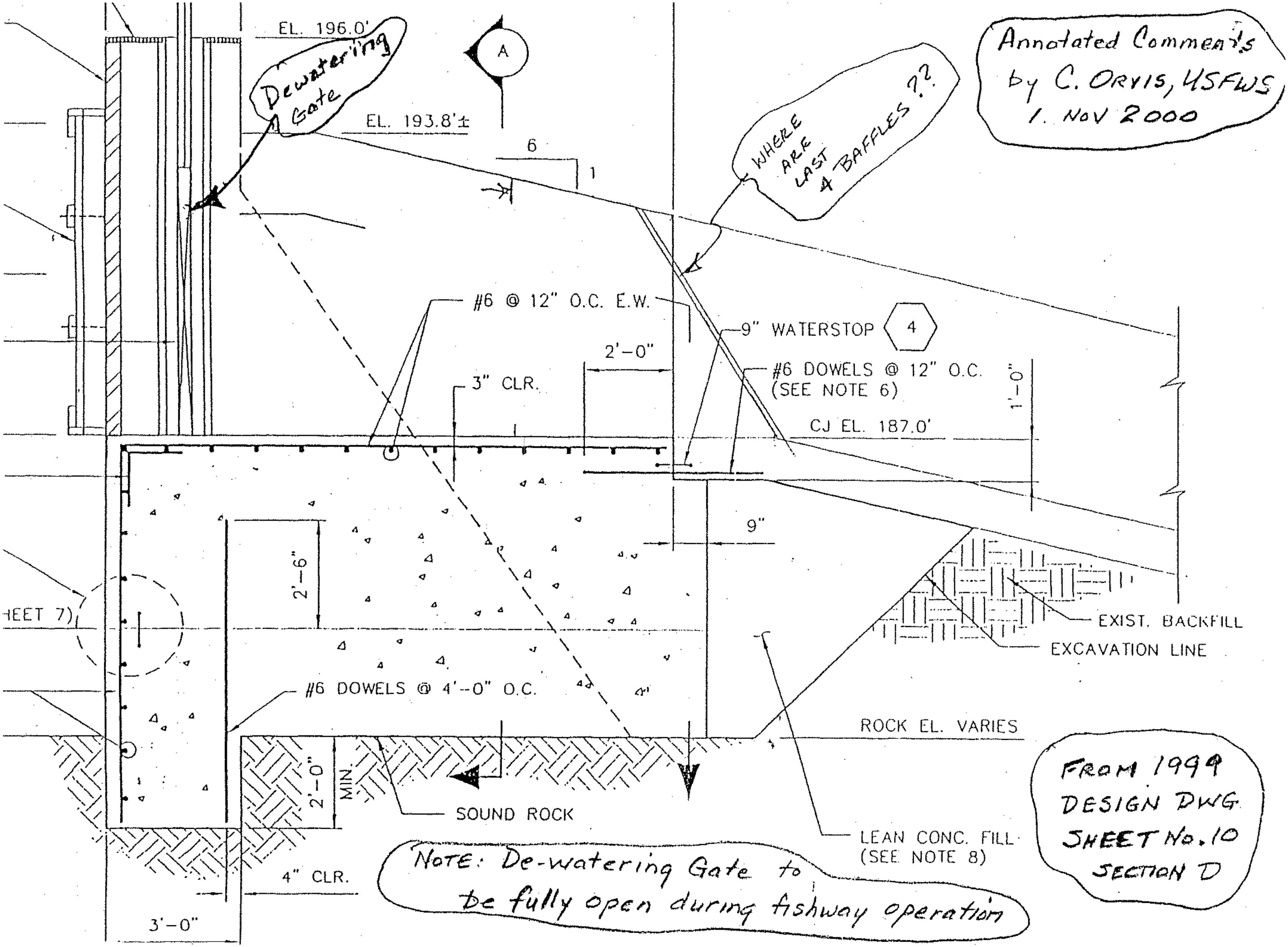

Stream End Of Fishway
No Scale
= 9.4623°
Last possible baffle?
Inflection point
12' ±
℄ Beam
See Typ. Note Below
9'-0"
Wall Corner At
Sta 0+31.50
8.50 Lt
Upper Portion
Of Gate Structure
Not Shown
Added baffles space?
Sheet No. 4
Verify Elevation Of
Dam Wall. Top Of Fis
Match Top Of Existin
±100.28
Max C80cfs
Min crest
Old max
Old min
New max
Min
New invert?
.1' ±
Lower?
93.50
12"
12"
#5
#5
Revised La
Elevation.
Site Plan.
See
Caulking Note
On Dwg 3
6" Compacted Gravel
Sub-Base (Typical)
Existing
Below
Sloping Channel
Length: 39'-0"
Δ Elevation: 6.50'
Slope: 0.0166 (6:1)
27 Baffles Required.
Annotated Comments
by C. Orvis, USFWS, 1 Nov 2000
U.S. FISH AND W



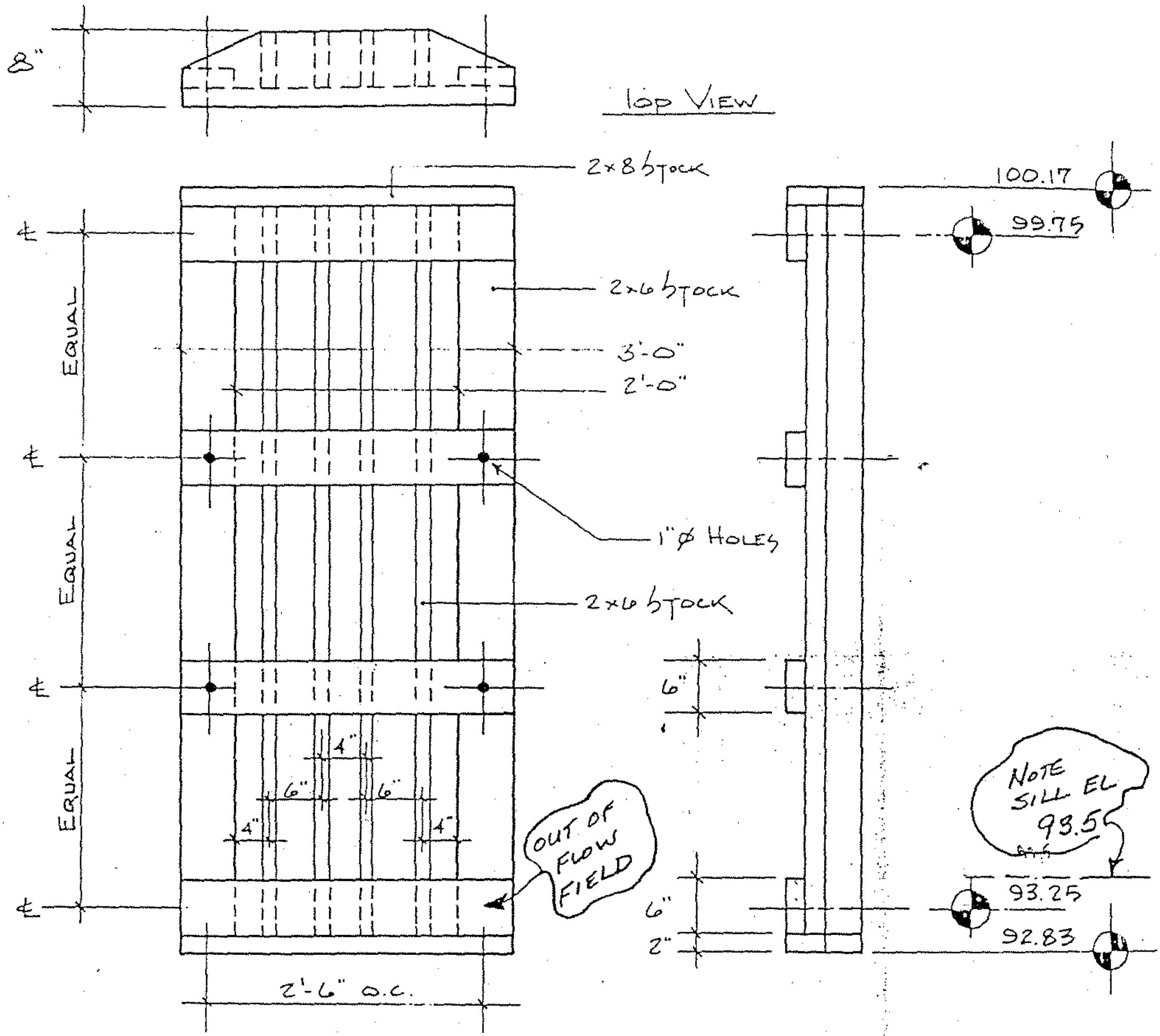
SECTION B
3/8"=1'-0"

Annotated Comments
by C. ORVIS, USFWS
1. NOV 2000

FROM 1999 DESIGN DRAWING
SHEET No. 10


Annotated Comments by C. ORVIS, USFWS 1. NOV 2000
EL. 196.0'
Dewatering Gate
A
EL. 193.8'±
6
1
WHERE ARE LAST 4 BAFFLES ??
#6 @ 12" O.C. E.W.
9" WATERSTOP
4
2'-0"
#6 DOWELS @ 12" O.C. (SEE NOTE 6)
3" CLR.
1'-0"
CJ EL. 187.0'
9"
2'-6"
HEET 7)
EXIST. BACKFILL
EXCAVATION LINE
#6 DOWELS @ 4'-0" O.C.
ROCK EL. VARIES
2'-0" MIN.
SOUND ROCK
FROM 1999 DESIGN DWG SHEET No. 10 SECTION D
LEAN CONC. FILL (SEE NOTE 8)
4" CLR.
3'-0"
NOTE: De-watering Gate to be fully open during fishway operation

FROM 1986 DESIGN
SHEET No. 5



TRASH RACK

SIDE VIEW

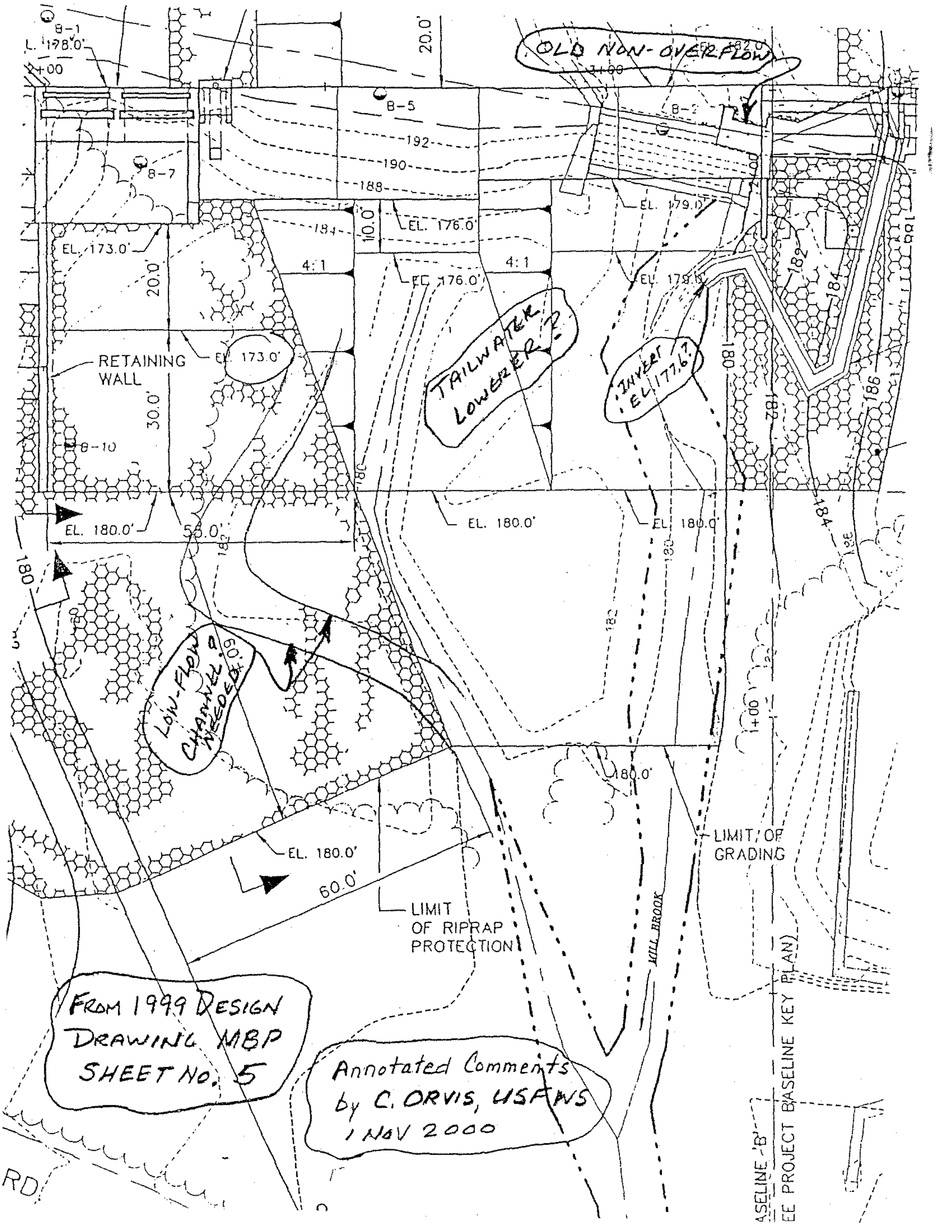
SCALE: 3/4" = 1'-0"

Annotated Comments by C. ORVIS USFWS 1 Nov 2000

NOTES:

1. TRASH RACK TO BE CONSTRUCTED FROM WELL SEASONED QUARTER-SAWN WHITE OAK. USE S4S FULL DIMENSIONAL STOCK

2. TRASH RACK SHALL BE CONSTRUCTED USING



OLD NON-OVERFLOW
B-1
EL. 178.0'
B-5
B-2
B-7
192
190
188
184
20.0'
10.0'
EL. 176.0'
EL. 179.0'
EL. 173.0'
4:1
EL. 176.0'
TAILWATER LOWER ??
INVERT EL 177.6?
RETAINING WALL
EL. 173.0'
30.0'
B-10
EL. 180.0'
53.0'
LOW-FLOW CHANNEL NEEDED?
180.0'
EL. 180.0'
60.0'
LIMIT OF RIPRAP PROTECTION
LIMIT OF GRADING
MILL BROOK
FROM 1999 DESIGN DRAWING MBP SHEET No. 5
Annotated Comments by C. ORVIS, USFWS 1 NOV 2000
BASELINE 'B'
(SEE PROJECT BASELINE KEY PLAN)
RD

UNITED STATES GOVERNMENT
U.S. FISH AND WILDLIFE SERVICE
300 WESTGATE CENTER DRIVE
DIVISION OF ENGINEERING
HADLEY, MASSACHUSETTS 01035-9589

DATE: November 7, 2000

MEMORANDUM

To: Tom Squiers, Commissioner
Sandra Lary, Fisheries Biologist
Maine Department of Marine Fisheries

From: Curt Orvis, Hydraulic Engineer

Subject: Review of Proposed Steeppass Fishway for Whites Pond, Palmyra to be Included in the Re-construction of the Dam at the Natural Lake in Somerset County, Maine.

General Comments

In general, a steeppass fishway should be adequate in width and depth to pass alewives into the Whites Pond which has a drainage area less than 10 square miles. We offer the following design recommendations and concerns for upstream and downstream passage of alewives with the reconstruction of the dam.

Upstream Passage

The drainage area upstream from the dam was estimated to be 7.5 square miles. The average discharge at the dam is estimated to be 15 cfs, based on the regional flow equation of 2 times the drainage area. The operating range would be from the water level at the crest (all flow down the steeppass) to a maximum discharge of 60 cfs or 4 times the average annual discharge. The water surface over the 40-foot wide crest would be about 0.6 feet higher than the crest at the maximum operating headwater. The minimum flow in the fishway should be 1-foot deep over the 5-inch high baffles (17" or 1.42'total). This means the invert of the steeppass should be set at elevation 267.58 for a crest at elevation 269.0 The top of the steeppass would then be 2.25 feet higher or at elevation 269.83 which allows operation to the maximum water level of 269.6 with about 0.2 feet of freeboard. The resulting slope for the steeppass would be about 1:5 which is acceptable. The question that remains is what are the tailwater elevations through the operating flows up to 60 cfs and will there be a velocity barrier on the rip-rap that would preclude fish from locating the entrance?

The location of the steeppass should be moved to the side of the spillway or bank line. Access to the exit channel box is needed to de-water and operate the fishway. It may be possible to relocate the exit in the higher bank-side section of the sheet piling cutting a rectangular opening below and above the crest. A non-overflow section is needed at the crest, adjacent to the exit channel box in order to ensure that adverse eddies will not drown out or divert fish from entering the steeppass.

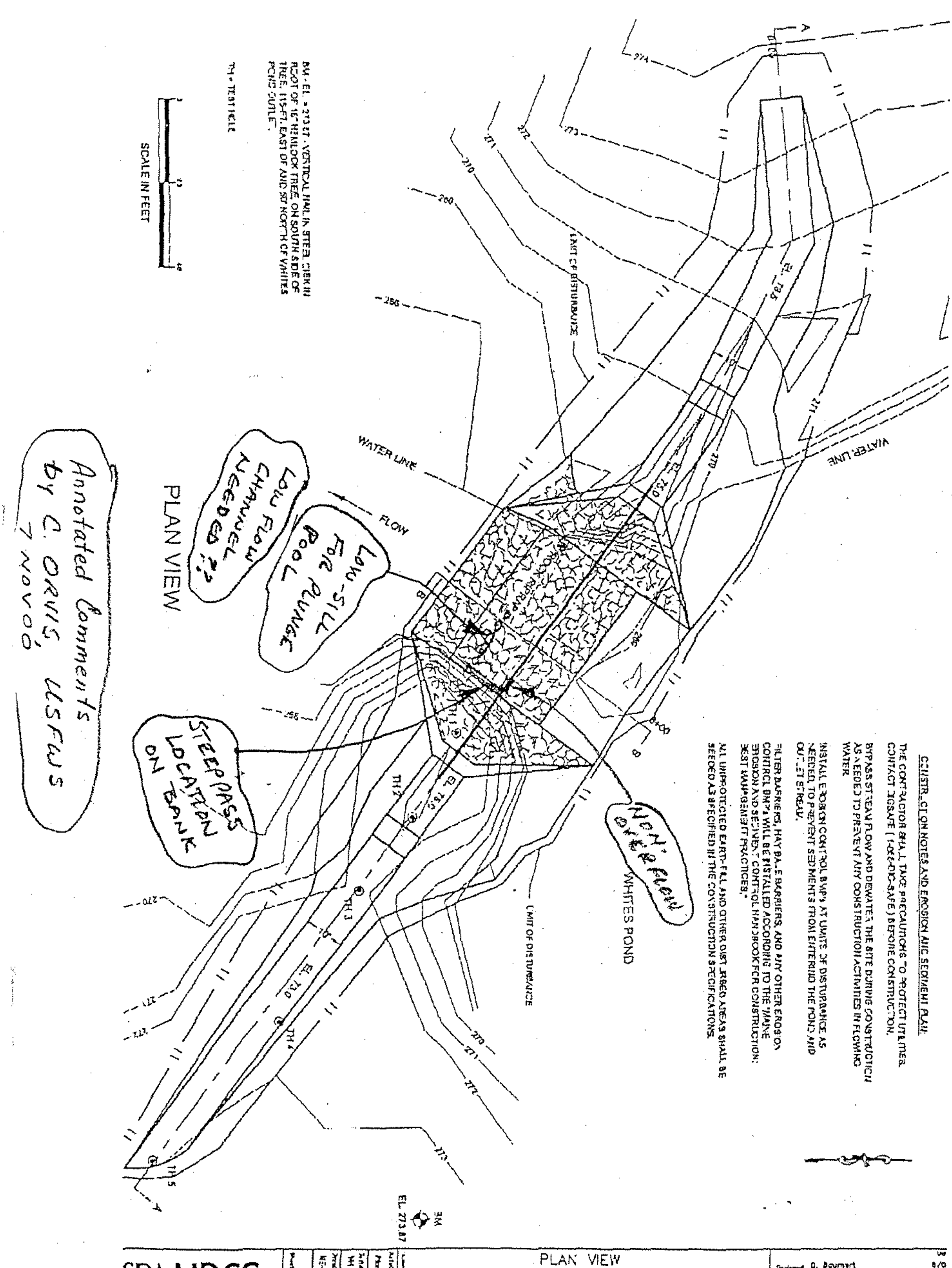
Downstream Passage Options

Considerations need to be included for downstream passage of juveniles and remaining adults during rain events from mid-August through November. As designed, the 40-foot wide spillway may spread out the flow too much to allow zone of passage depths over the crest and in the downstream 40-foot wide spillway channel. The typical measure taken to provide for downstream passage is to create a notch in the dam that conveys flow to a plunge pool in the tailwater area. The proposed non-overflow section could also have a 3-foot wide by 1 to 2-foot deep notch for downstream fish passage. Another way to provide for downstream passage is through the sidewall of a lengthened exit channel. Flow would again drop from the exit channel to a plunge pool. The spill gate would be closed during the upstream passage period from April through mid-June and the steeppass fishway would be closed during the late summer and fall out-migration period.

Will additional consideration need to be made for American eel? If so, a separate eel-specific fishway could be constructed along the side of the steeppass fishway. Adult eel would also follow the route taken by adult and juvenile river herring.

We appreciate the opportunity to comment on the re-construction. Annotated comments are attached on portions of the design drawings for clarity. Please feel free to contact Curt Orvis at 413-253-8288 for any questions or clarification.

Attachments

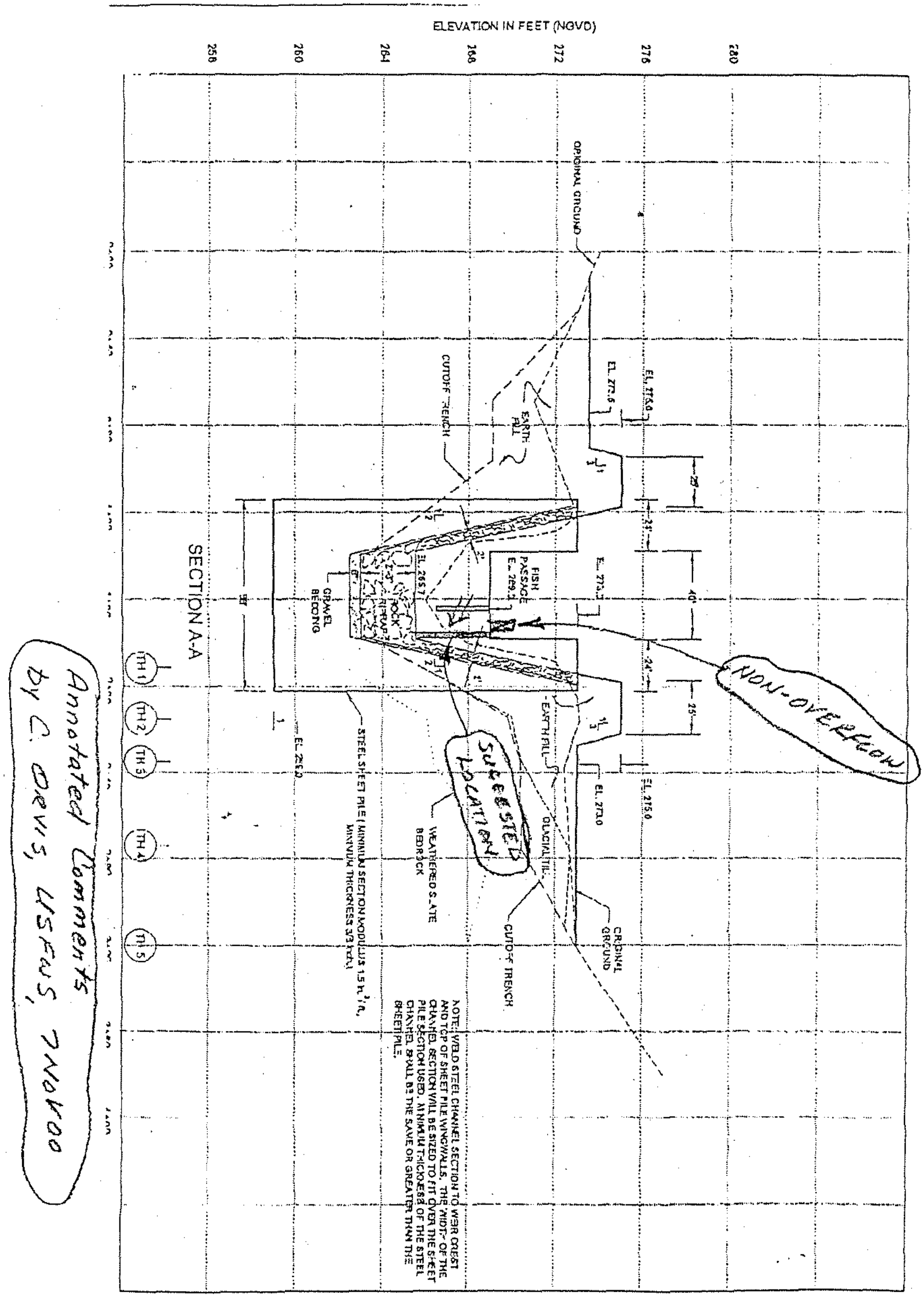


PLAN VIEW
WHITES POND OUTLET STRUCTURE
SOMERSET COUNTY

Designed D. Baumert 8/0
Drawn D. Stuart 8/0
Checked

USDA NRCS
Natural Resources Conservation Service

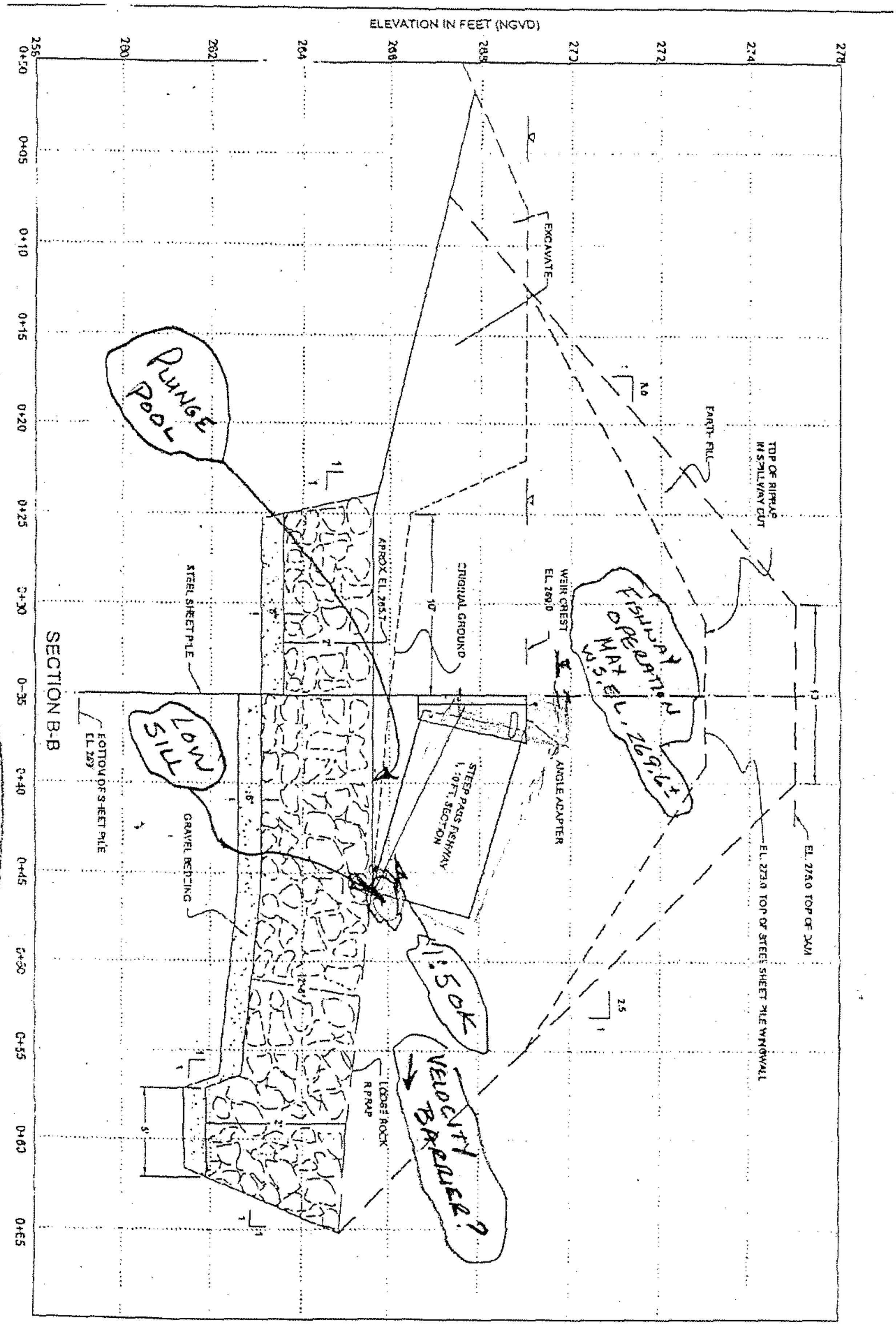
NOV-07-2000 08:56 ME. DEPT. MARINE RESOURCE 207 624 6024 P.02/04



DA NRCS
Natural Resources Conservation Service

SECTION A-A CENTERLINE PROFILE
WHITES POND
SOMERSET COUNTY

Designed D. Boutin — 9/00
Drawn R. Blake — 9/00
Checked



Annotated Comments by C. Orvis, LLS Flws, 7Nov06

DA NRCS

SECTION B-B
WHITES POND OUTLET STRUCTURE
SOMERSET COUNTY

Designed D. Powell 6/00
Drawn 8/00

MEMORANDUM

To: Sandra Lary, Maine Department of Marine Resources

From: Curtis Orvis, Hydraulic Engineer

Subject: Site Inspection Report for Field Review of Blackman Stream Barriers to Anadromous Fish Passage from the Penobscot River downstream from Veazie Dam into Chemo Pond, Maine and .

On Monday morning, August 7, 2000 I traveled by GSA vehicle to the Division of Marine Fisheries Office at Augusta to meet Sandra Lary. We traveled to the Eddington Salmon Club on the left side of the Penobscot where we met::

Ralph Keefe, Atlantic Salmon Federation (ASF) and
Warren Richardson, ASF. At the barriers we met
Randall Spencer, Atlantic Salmon Commission

Target species

River herring are the main species targeted for restoration to the Blackman Stream. Additional species now being considered include American eel and riverine fish. Alewife would also be targeted for the Sedgeunkedunk Stream into Brewer Lake and White's Pond at Palmyra in the Sebasticook River basin.

Blackman River Barriers
Beaver Dam at Chemo Pond Outlet

We traveled into the Penobscot Experimental Forest to the outlet to Chemo Pond where we inspected a beaver dam that is about 50 feet wide which has a man-made dam for a foundation. The beaver dam could be breached, but would require continued maintenance. Installation of a steeppass would also require maintenance since the beavers would be expected to try to plug the outflow in the steeppass. The drop appeared to be less than 2 feet at the low flow observed. During the spring, water could be expected to flow over the top of the beaver dam. The control of the water surface of Chemo Pond was questioned. At high water levels in the Pond there has been concern in the past for flooding and floating of septic systems. There did not seem to be a concern at the late summer levels observed.

Site 2 - Mill Dam on the Historic Forest Museum Property (Downstream from Chemo Pond)

The Mill dam has 2 overflow spillway outlets and a diversion to a mill race and sawmill. The earthen and stone masonry structure has bridges over the outlets and the tailwater channel merges a short distance downstream from the dam. Looking downstream the spillway on the right side was measured to be 13 feet wide and the distance from the bridge deck to the tailwater was measured to be about 10 feet. From the deck to the sill of the spillway was about 4'9" leaving a drop of 5'3" in head at the dam. Within 20 horizontal feet downstream from the spillway crest another natural drop of about 3 vertical feet exists in the right channel. The barrier could be used to guide fish to an adjacent entrance of a fishway that exits in the power canal or through the spillway. Another alternative would be to heighten the barrier and install the fishway on the left spillway. The crest on the left spillway was measured to be 8-feet wide and from the deck to the tailwater a distance of 8.5 feet was measured. The spillway crest was 6 feet below the bridge deck leaving a drop from the headpond to the tailwater of 2.5 feet. The natural location for a steeppass or denil fishway would be on the left bridge abutment on this left channel.

Site 3 - State Highway 178 Culvert Site (Immediately Upstream from the Penobscot River)

The existing vertical slot fishway on the left wall of the 20-foot(+/-) wide bridge culvert is in need of repair. The baffle slots and walls are in tact, but the side wall parallel to the culvert wall is badly eroding, spalling, and/or void where only bent re-bar is left. The pools were measured to be 8-feet long and 4-feet wide and up to 2 feet deep at the slots. There are 11 pools over the length of the culvert. A barrier weir exists at the upstream end to divert low flows into the fishway. The fishway and culvert was dry during the inspection. Some gravel would need to be cleaned out of the fishway along with the rehabilitation of the side walls. We speculated that the damage was caused by ice.

Site 4 - Breached Timber Crib Dam to Divert Water to a Diversion Pipe/Canal

The rock filled timber crib section on the right abutment had been breached. Some reworking of the boulders and cobbles in the channel would make the barrier passable. The other option would be to reconstruct the dam to hold water to the proper operating levels in the concrete denil fishway on the left abutment. The concrete appeared to be in good repair, but baffles would also need to be installed. The denil fishway was measured to be 3-foot wide with 17 baffle slots. The slope was estimated to be 1:6 which Maine would construct for herring.

Site 5 - Old Orono-Veazie Water Supply Dam

The intake to the water pipeline appeared to be open with a small flow passing through the outlet works on the right abutment. A low-level sluice exists in the concrete gravity wall of the dam adjacent to the right abutment and outlet works. Stop logs fill the slot in the sluice to a level 6 feet above the tailwater. The width of the sluice was measured to be 6 feet. The spillway adjacent to the sluice was measured to be 44 feet long (crest length) and the width at the top was 3 feet and estimated to be 5 to 7 feet thick a the base of the wall. Sediment had filled the channel upstream from the stoplogs to a level 4'4" below the top of the stoplogs.

Sedgeunkedunk Stream Barriers

Eastern Fine Paper Company Dam

The concrete gravity section at the Paper Company Dam is about 12' 3" high. We were unable to access the boardwalk over the crest but it appeared to be 25 to 30-foot long. The intake which supplies mill water has a high-density polyethylene trash rack to screen the flow. Mr. Tibbets is the environmental manager for the owner and can be reached at 989-7070.

Fields Pond Dam

The second barrier up from the Penobscot River is the Fields Pond Dam. It is a concrete gravity wall with 7 overflow slots that are 5-feet wide by 1 foot high. The outlet works is in the center and was measured to be 6.5 feet wide. From the top of the wall on the center sluice to the tailwater a distance of 6'3" was measured and from the top of wall to the headpond it was 4 feet. Thus, at the low-flow operating level the head differential was about 2.5 feet, but the water level was below the sill elevation for the spillway.

Brewer Lake

The earthen dam at Brewer Lake has a newly replaced wooden spillway and outlet works. The 19-foot wide spillway crest has 3 gates that were closed during the inspection. The 6-foot wide sluiceway on the left side of the spillway crest had some flow passing over an adjustable weir crest. The upstream water level was about 1.5 feet above the spillway sill and the tailwater was about 4.6 feet below the sill making the differential head at the dam about 6.1 feet.

Madawaska Stream Barriers (Tributary to the Sebasticook River)

Whites Pond Dam

The breach at the Whites Pond occurred naturally within a year from the last re-construction. The boulders and cobbles could be reworked to improve passage or if the dam were rebuilt a steeppass or pool and weir fishway could be constructed along with the re-construction.

Madawaska Bog Dam

The next downstream barrier from Whites Pond is owned by the State of Maine and operated for wildlife purposes at the Madawaska Bog. The gravity concrete spillway was measured to be 24'9" wide with 2-foot high flash boards installed on the crest. The differential head from the tailwater to the crest was measured to be about 4'4" and the 5-foot wide sluice gate on the right abutment was measured to be about 3'8" high.

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
300 Gateway Center Drive
HADLEY, MASSACHUSETTS
(413) 253-8288
FAX: (413)253-8541

TRANSMITTAL

ENGINEERING

TO: Maine Department of Marine Resources
21 State House Station
Augusta, Maine 04333-0021

DATE: December 18, 2000

Attention: Mr. Tom Squiers

PROJECT: Tech. Asst Fish Passage

We are sending you the following items

☐ attached via ______________

☐ Prints
☐ Shop Drawings
☐ Original Drawings

☐ Copy of letter
☐ Specifications
Other ______________

Copies	Date/No.	Description
1	1992	Drawings for Maine Logging Museum Fishway Plans
1	2000	Site Inspection Sketches of the Blackman Stream Barriers

☐ For approval
X For your use
X As requested
X For review and comment
☐ ______________

☐ Approved as submitted
☐ Approved as noted
☐ Revise & Resubmit
☐ Disapproved

We have developed some the preliminary layouts of the barriers for the Blackman Stream and Sedgeunkedunk Stream. If there is a particular type of fishway for which you would have a preference or only want one of the listed types drawn in concept, please advise. We can process any additional design changes as needed.

Copy to: Sandra Lary, NRCS

Signed Curtis J. Orvis
Curtis J. Orvis, Hydr. Eng.
Team Leader

Forwarded to [illegible]

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
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TRANSMITTAL

ENGINEERING

TO: Maine Department of Marine Resources
21 State House Station
Augusta, Maine 04333-0021

DATE: June 29, 2000

Attention: Ms. Sandra Lary

PROJECT: Tech. Asst Fish Pass

We are sending you the following items

☐ attached via ____________

☐ Prints

☐ Copy of letter

☐ Shop Drawings

☐ Specifications

☐ Original Drawings

Other ____________

Copies	Date/No.	Description
1	June 2000	Drawings for Center Pond Phippsburg

☐ For approval

X For your use

X As requested

X For review and comment

☐ ____________

☐ Approved as submitted

☐ Approved as noted

☐ Revise & Resubmit

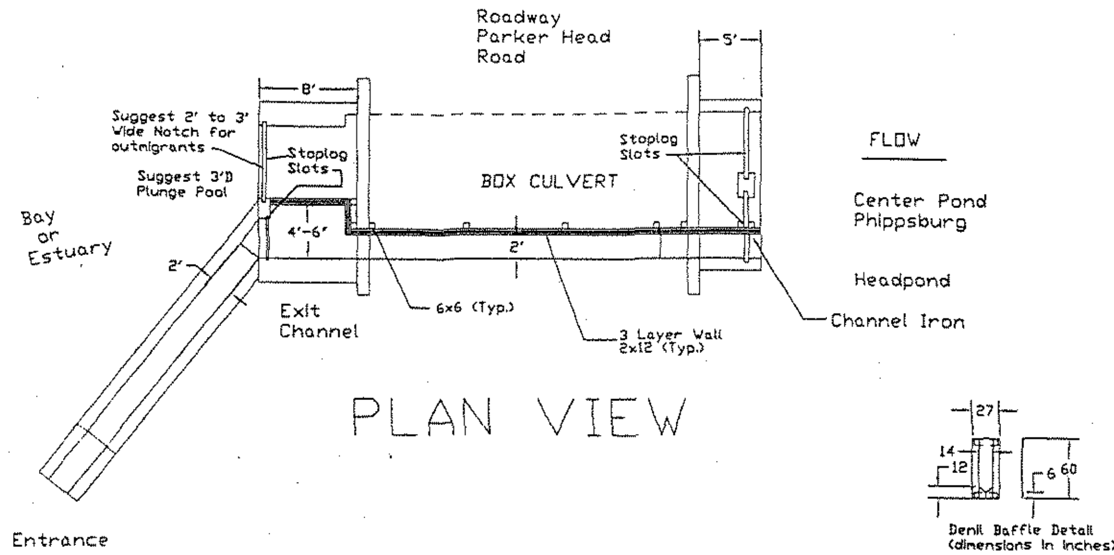
☐ Disapproved

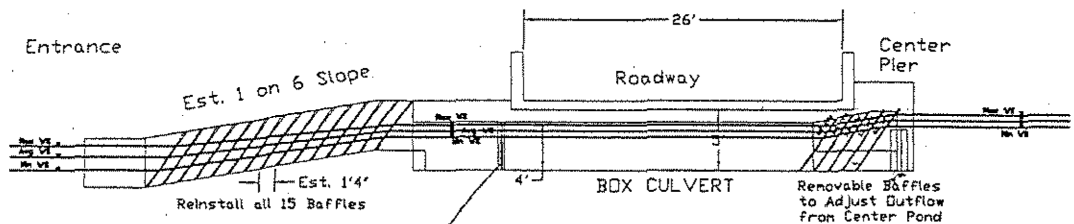
We have developed some conceptual drawings for the wall at Center Pond. If these are an acceptable location and layout we can make full size sheets for their/your use. We can process any design changes as needed.

Copy to: Tom Squiers

Signed Curtis J. Orvis

Curtis J. Orvis, Hydr. Eng.
Team Leader





3 Layer Wall
2x12 (Typ.)

PROFILE VIEW

Conceptual Sketch Proposed Conditions (wooden wall)
Center Pond Fishway, Phippsburg, Maine
for Maine Department of Marine Fisheries
by C. Orvis, USFWS, July ~~1999~~ 2000
Sheet 2 of 2