NIAGARA MOHAWK POWER CORPORATION
Syracuse, New York

EVALUATION OF THE ANGLED SCREEN FISH DIVERSION SYSTEM

AT OSWEGO STEAM STATION UNIT 6

RESEARCH PROJECT No. EC 104
April 1981 - March 1983

January 1984

LMS/-84/0011&191/058

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EXECUTIVE SUMMARY

The studies reported herein were undertaken by Lawler, Matusky & Skelly Engineers (LMS) for Niagara Mohawk Power Corporation (NMPC) as a two-year research evaluation of the effectiveness of the fish diversion system at Oswego Steam Station Unit 6. The effectiveness of the system is defined by the ability of the system to divert, alive, the fish entrapped in the circulating cooling water from the primary screenwell back to the source water body. The Oswego installation represents the first full-scale application of the angled screen technology in an operating electric generating station. Concurrent investigations of an angled screen diversion system are now under way at Central Hudson Gas & Electric Company's Danskammer Generating Station.

The fish diversion and transport system installed at Oswego Unit 6 is based on simulations and biological testing of the system components conducted over several years at Alden Research Laboratories by Stone and Webster Engineering (S&W). Unit 6 is an oil-fired steam generator with a rating of 816 MWe and a maximum gross output of 890 MWe. Cooling water (20.5 m^3/s [724 cfs]) is taken from Lake Ontario via a submerged velocity cap inlet, circulated through the condensers, and returned to the lake through a submerged jet diffuser. Fish entering the screenwell with the cooling water flow pass through trash racks and encounter four flush-mounted traveling water screens angled toward a bypass (Figure 2.0-3).

The bypass flow from the primary screenwell enters the suction side of the primary jet pump. This pump discharges into a secondary screenwell where the fish encounter a single flush-mounted traveling screen angled toward another bypass. The secondary bypass leads to the secondary jet pump, which in turn discharges either to the sampling basin or to a pipe embedded in the roof of the intake tunnel.

The secondary diversion system, consisting of the secondary screenwell and secondary bypass, serves to minimize the volume of water used to transport the diverted fish back to the lake.

The transport pipe extends offshore for a distance of approximately 300 m (1000 ft) where it rises vertically and terminates as a horizontal discharge approximately 2 m (6 ft) off the bottom of Lake Ontario.

Fish that failed to divert across the screens and into the bypass were collected from the vertical traveling screens (impingement), while those diverting were collected downstream of the bypass from the sampling basin. The relative numbers of fish impinged vs diverted provided an estimate of diversion efficiency. Long-term (96-hr) viability observations were conducted on a subsample of the diverted fish to estimate the proportion of diverted fish that would survive upon return to the source water body. Viability observations were primarily conducted prior to transport offshore but limited viability observations conducted offshore provided results consistent with the larger data base from onshore sampling. The integration of the total entrapment rate, the diversion efficiency, and the estimated survival provided an estimate of the total number of fish returned alive to the lake.

The fish entrapment rate demonstrated a definite seasonal pattern in species composition and population dynamics. Spring collections were dominated by adult alewife and rainbow smelt; fall collections were dominated by young-of-the-year (YOY) rainbow smelt, alewife, and gizzard shad. While the same species dominated in both years, their abundance differed widely. Adult alewife entrapment was high (>118 fish/hr) in the spring of 1981, while that of adult rainbow smelt was low (<15 fish/hr). In the fall and early winter of 1981, YOY rainbow smelt predominated, with a mean monthly abundance in

December exceeding 160 fish/hr. The spring of 1982 saw smaller numbers of adult alewife compared to the previous spring, but abundances of adult rainbow smelt were substantially higher than the previous spring. The fall of 1982 relative to the fall of 1981 produced very low abundances of all YOY fish except smallmouth bass.

The effectiveness of the diversion system (total diversion efficiency [TDE]) is defined as the ratio of the number of fish entering the secondary diversion bypass (diversion rate) to the number of fish entering the primary screenwell (entrapment rate).

Alewife TDE varied widely, from zero to 97.8%. The primary variable affecting alewife diversion was the condition of the population when entrapped. The difference between the 91.0-97.8% TDE in spring of 1981 and the 40.9-80.3% TDE in spring of 1982 can be attributed to the poor condition of the alewife stock (Section 3.5.2).

Rainbow smelt TDE also varied over the duration of the study. The lowest TDE (43.8%) was reported in the summer of 1982, while the highest value was in the early spring of 1981 when the prespawn adults were diverted at a TDE of 98.8%. Like the alewife, rainbow smelt diversion was related to condition of the entrapped population.

The remaining eight species showed TDEs ranging from 49.8% for mottled sculpin to 100% for smallmouth bass (Table S-1).

Long-term survival observations (96-hr) were applied to the TDE to estimate the number of diverted fish that subsequently survived or the total plant efficiency (TPE). Differential TPE results were observed for YOY and adult alewife, rainbow smelt, and white perch. Typically, the YOY survivals were lower than the corresponding adult survivals (Table S-2).

TABLE S-1

TOTAL DIVERSION EFFICIENCY[a] OF SELECTED SPECIES

Oswego Steam Station Unit 6 - April 1981 - March 1983

MONTH	AW	RSM	WP	GSD	EWSH	STSH	YP	SMB	TSB	MOTS
Apr 1981	97.8	98.8	88.1*	94.8*	92.3*	94.1*	92.6*	100*	70.4*	49.8*
May	91.0	91.8*								
Jun	75.7	91.8*								
Jul	83.6	91.8*								
Aug	36.7	91.8*								
Sep	49.1	76.7								
Oct	80.7	73.0								
Nov	65.6	64.3								
Dec	95.4	74.4								
Jan 1982	0	72.5								
Feb	40.9*	60.2								
Mar	40.9*	77.4	88.1*	94.8*	92.3*	94.1*	92.6*	100*	70.4*	49.8*
Apr	40.9*	82.3*	84.4*	79.3*	71.9*	82.7*	83.3*	88.8*	80.1*	71.8*
May	80.3	82.3*								
Jun	87.6	43.8*								
Jul	88.6	43.8*								
Aug	66.9	55.4								
Sep	66.0	76.4								
Oct	72.2	82.6								
Nov	88.3*	87.7								
Dec	88.3*	85.5								
Jan 1983	88.3*	68.5*								
Feb	88.3*	68.5*								
Mar	65.6	77.2	84.4*	79.3*	71.9*	82.7*	83.3*	88.8*	80.1*	71.8*

[a]As a percent.
*Composited across month

AW - Alewife
RSM - Rainbow smelt
EWSH - Emerald shiner
GSD - Gizzard shad
WP - White perch

STSH - Spottail shiner
SMB - Smallmouth bass
TSB - Threespine stickleback
YP - Yellow perch
MOTS - Mottled sculpin

TABLE S-2

MONTHLY TOTAL PLANT EFFICIENCY[a] BY SPECIES

Oswego Steam Station Unit 6 - April 1981 - March 1983

MONTH	AW <10 cm	AW >10 cm	RSM <10 cm	RSM >10 cm	WP <13 cm	WP >13 cm	EMSH	STSH	GSD	YP	SMB	TSB	MOTS
Apr 1981	13.3	22.6	23.8	64.6	45.7	57.2	80.1	76.4	52.0	90.5	88.2	6.6	38.0
May	1.0	1.6	22.1	0									
Jun	1.9	7.4	22.1	20.4									
Jul	2.7	25.7	18.4	20.4									
Aug	1.2	2.5	18.4	20.4									
Sep	1.9	5.5	12.2	17.0									
Oct	15.8	45.2	23.7	32.3									
Nov	16.1	27.4	11.7	20.6									
Dec	13.8	26.6	5.0	20.7									
Jan 1982	0	0	4.2	44.7									
Feb	3.0	7.4	3.1	38.3									
Mar	3.0	3.4	5.0	46.3	45.7	57.2	80.1	76.4	52.0	90.5	88.2	6.6	38.0
Apr	0	6.0	7.6	57.8	43.8	54.8	62.4	67.2	43.5	81.4	78.3	7.5	54.8
May	0	5.9	7.1	32.7									
Jun	0.7	3.1	3.8	17.4									
Jul	0.7	4.3	3.8	14.1									
Aug	1.1	4.2	4.8	17.8									
Sep	0.9	7.5	6.1	24.6									
Oct	0.4	11.8	7.8	20.4									
Nov	2.0	55.8	11.1	21.7									
Dec	1.4	55.8	20.4	21.1									
Jan 1983	1.4	55.8	16.4	16.9									
Feb	1.4	55.8	16.4	16.9									
Mar	1.0	41.5	18.5	19.1	43.8	54.8	62.4	67.2	43.5	81.4	78.3	7.5	54.8

[a]As a percent.

AW - Alewife
RSM - Rainbow smelt
WP - White perch
EWSH - Emerald shiner
STSH - Spottail shiner
GSD - Gizzard shad
YP - Yellow perch
SMB - Smallmouth bass
TSB - Threespine stickleback
MOTS - Mottled sculpin

X— — Combined across months during periods of low abundance.

A total of 448,870 alewife were entrapped during the two-year period, with an estimated 50,481 of these being returned offshore alive. TPE for the 12,240 YOY alewife was 8.4% as compared to 12.6% for the 38,241 adult alewife (Table S-3).

Using the same procedures for rainbow smelt, a total of 433,862 smelt were entrapped during the two-year period, with 74,807 of these being returned alive. System effectiveness for the 36,442 YOY smelt was 10.0% as compared to 54.3% for the adult smelt (Table S-3). More than 80% of the yellow perch and smallmouth bass entrapped during the study period were returned alive.

The conclusions of the studies of the Oswego Steam Station Unit 6 angled screen diversion system can be summarized as follows:

1. Mechanically and hydraulically, the system is functioning as designed with minimal operational problems.
2. Diversion of fish across the angled screens is highly dependent upon species, their condition (i.e., physiological and/or reproductive state), and their age or size class.
3. The fragile species (alewife, gizzard shad, juvenile smelt) are more susceptible to impingement than are the hardy species (salmonids, smallmouth bass, rock bass, yellow perch).
4. Unless weakened by recent spawning activities, adults of a species typically exhibit a higher diversion efficiency than the young.
5. Survival following diversion was also dependent upon species, their condition, and their age or size class.
6. Survival results based on offshore collections indicated that in-plant collections provided a good estimate of ultimate survival upon discharge off-shore.
7 The condition of the alewife population at the time of entrapment and the stresses applied to the

TABLE S-3

DIVERSION SYSTEM EFFECTIVENESS[a] FOR ALEWIFE, RAINBOW SMELT, AND WHITE PERCH BY SIZE CLASS[b]

Oswego Steam Station Unit 6 - April 1981 - March 1983

	ALEWIFE		RAINBOW SMELT		WHITE PERCH	
	<10[b]	>10[b]	<10[b]	>10[b]	<13[b]	>13[b]
No. Entrapped	145,266	303,604	363,166	70,696	12,423	6,385
No. Impinged	39,686	53,072	107,741	4,380	1,319	445
No. Diverted	105,580	250,532	255,425	66,316	11,104	5,940
No. Surviving	12,240	38,241	36,442	38,365	5,584	3,622
% Effective (TPE)	8.4	12.6	10.0	54.3	50.0	56.7

[a]Estimate based on average monthly collection rates (No./hr) over the period April 1981 through March 1983.

[b]Measured in centimeters.

population upon transport to the screenwell most likely account for the substantial differences in survival results observed in laboratory studies and the actual installation.

8. Overall TPE varied from 6.6 to 17.8% for the fragile species (threespine stickleback, alewife, and rainbow smelt) to 73.5 to 87.0% for the hardy species (spottail shiner, emerald shiner, smallmouth bass, and yellow perch).

9. The angled screen diversion system is an applicable and proven technology that will operate with minimal additional maintenance beyond that required for the traditional vertical traveling screens. Its effectiveness as a mitigation device will depend upon the species of interest, their age or size class, and the condition in which the individuals are delivered to the system.

CHAPTER 1.0

INTRODUCTION

This report summarizes the results of a two-year research program to evaluate the effectiveness of the fish diversion system at Niagara Mohawk Power Corporation's (NMPC) Oswego Steam Electric Generating Station Unit 6 (OSS-6). The unit began commercial operation in July 1980 with a once-through cooling water system outfitted with a fish diversion and return system based on laboratory studies conducted by Stone and Webster Engineering Corporation (1977).

The effectiveness of the diversion system was determined relative to a conventional once-through cooling water system consisting of a screenwell with vertical traveling screens. A fish entering the screenwell of a conventional system either swims out against the entrapping flow (virtually impossible in an offshore intake system) or is impinged and removed by the vertical traveling screen. The principle of the diversion system is to induce the fish entering the screenwell to divert across the traveling screens and enter a bypass that will lead back to the source water body. In an effective diversion system, this process occurs with minimal harm or damage to the diverted fish.

The total plant effectiveness (TPE) of the OSS-6 diversion system is defined as the ability of the system to reduce or eliminate impingement and to divert, alive, the fish entrapped in the cooling water flow from the screenwell back to the source water body. Angled screens have been used at hydro stations to divert fish (primarily trout and salmon) from turbine intakes (Farr 1974; Marquette and Long 1971) or into a fish passage (Gunsolus and Eicher 1950; Eicher 1960; Bates and VanDerwalker 1970). The Oswego installation is the first full-scale application of the angled screen technology in an

operating electric generating station. Concurrent investigations of an angled screen diversion system are now under way at Central Hudson Gas & Electric Company's Danskammer Point Generating Station.

To determine the effectiveness of the system, the effectiveness of the screens in diverting the organisms entrapped in the screenwell (diversion efficiency) and the mortality associated with the diversion process (survival) were investigated. The studies concentrated on survival subsequent to passage through the diversion system but prior to transport back to the source water body. A less intensive sampling effort evaluated the ultimate survival observed upon release offshore and compared these results to the survival results based on in-plant sampling.

Chapter 2.0 of this report describes the angled screen system as well as the important hydraulic characteristics. Chapter 3.0 presents the estimates of the efficiency of the primary and secondary diversion systems as well as the overall efficiency of the angled screen system in diverting fish. Chapter 4.0 provides the viability data and a discussion of the observed trends. Chapter 5.0 integrates the diversion efficiency results with the viability results to estimate the total plant efficiency for selected species.

Chapters 6.0 and 7.0 summarize the results from two special studies. Chapter 6.0 evaluates of the potential for reentrapment of diverted fish, and Chapter 7.0 summarizes the data from a study to assess predator species adjacent to the offshore fish diversion discharge relative to a control location 0.8 km (0.5 mi) away.

Chapter 8.0 summarizes the results in the previous chapters and discusses these results relative to other studies.

CHAPTER 2.0

SYSTEM DESCRIPTION

2.1 SYSTEM DESIGN

The design of the Oswego Unit 6 fish diversion system is based on the results of hydraulic and biological testing of the system components conducted over several years at Alden Research Laboratories by Stone and Webster Engineering (S&W 1977).

Unit 6 is an oil-fired steam generator with a rating of 816 MWe and a maximum gross output of 890 MWe. Cooling water is taken from Lake Ontario via a submerged inlet, circulated through the condensers, and returned to the lake through a submerged jet diffuser. The intake structure is a hexagonally shaped velocity cap located approximately 370 m (1200 ft) from the existing shoreline (Figure 2.0-1). At the low water datum of 74.1 (243 ft) (International Great Lakes Datum 1955), the water is 6.7 m (22 ft) deep and the clearance between the top of the intake structure and the water surface is 3.7 m (12 ft). A 1-m (3-ft) sill at the bottom minimizes silting of the intake. Each side of the hexagonal intake has a 1.5 m high by 6.5 m wide (5 x 21 ft) aperture (Figure 2.0-2). Intake apertures are outfitted with heated bar racks to prevent the formation of frazil ice. The intake is designed such that the horizontal approach velocity is approximately 30 cm/sec (1.0 fps) at maximum circulating water flow.

The circulating water flow (cooling water, service water, and fish diversion flow) is delivered to the plant through an 11.2-m^2 (121-ft^2) tunnel. The design circulating water pump flow rate is 20.5 m^3/sec (724 cfs). Since some of the pump flow is recirculated through the diversion system to the screenwell, the velocity in

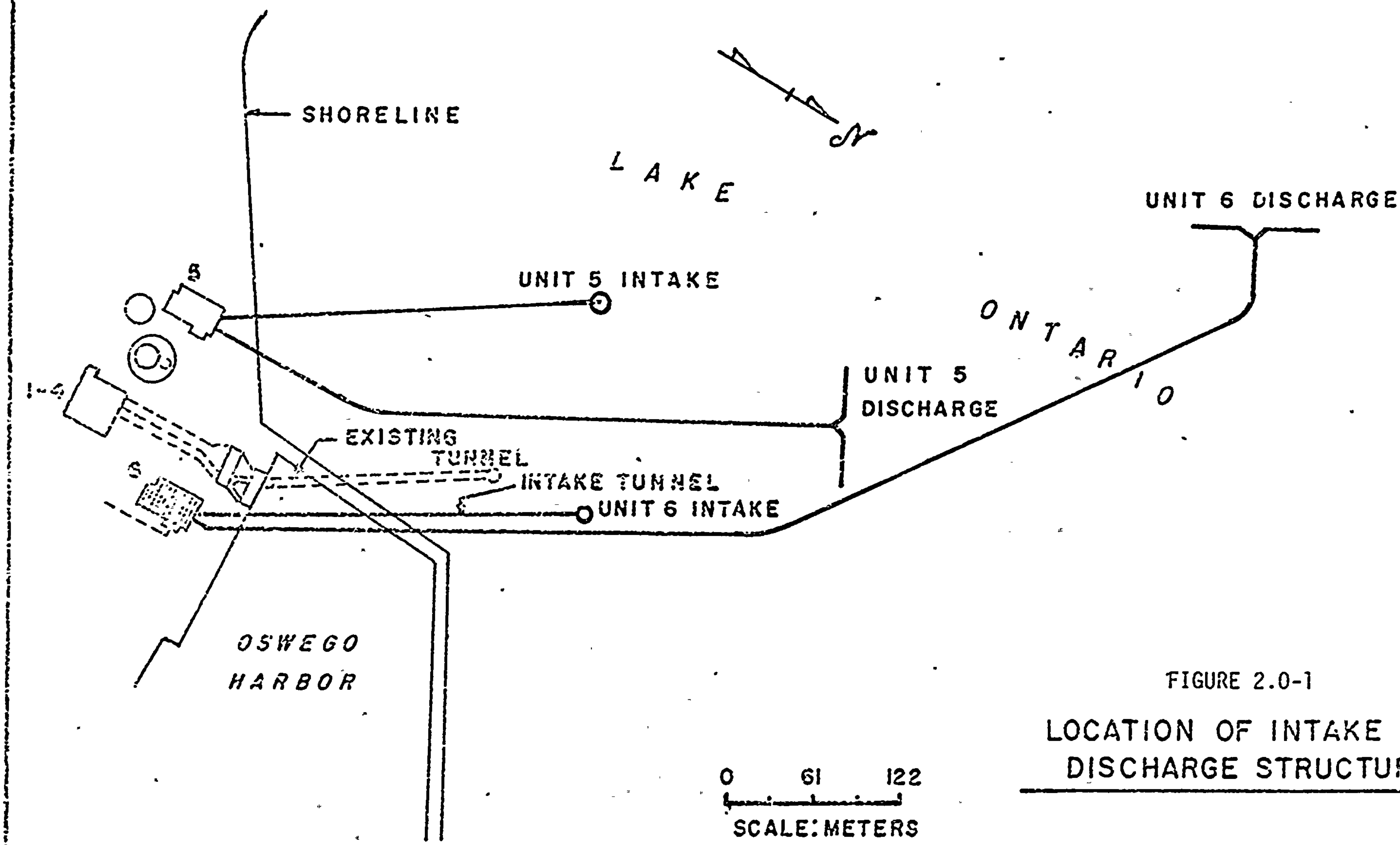


FIGURE 2.0-1

LOCATION OF INTAKE AND DISCHARGE STRUCTURES

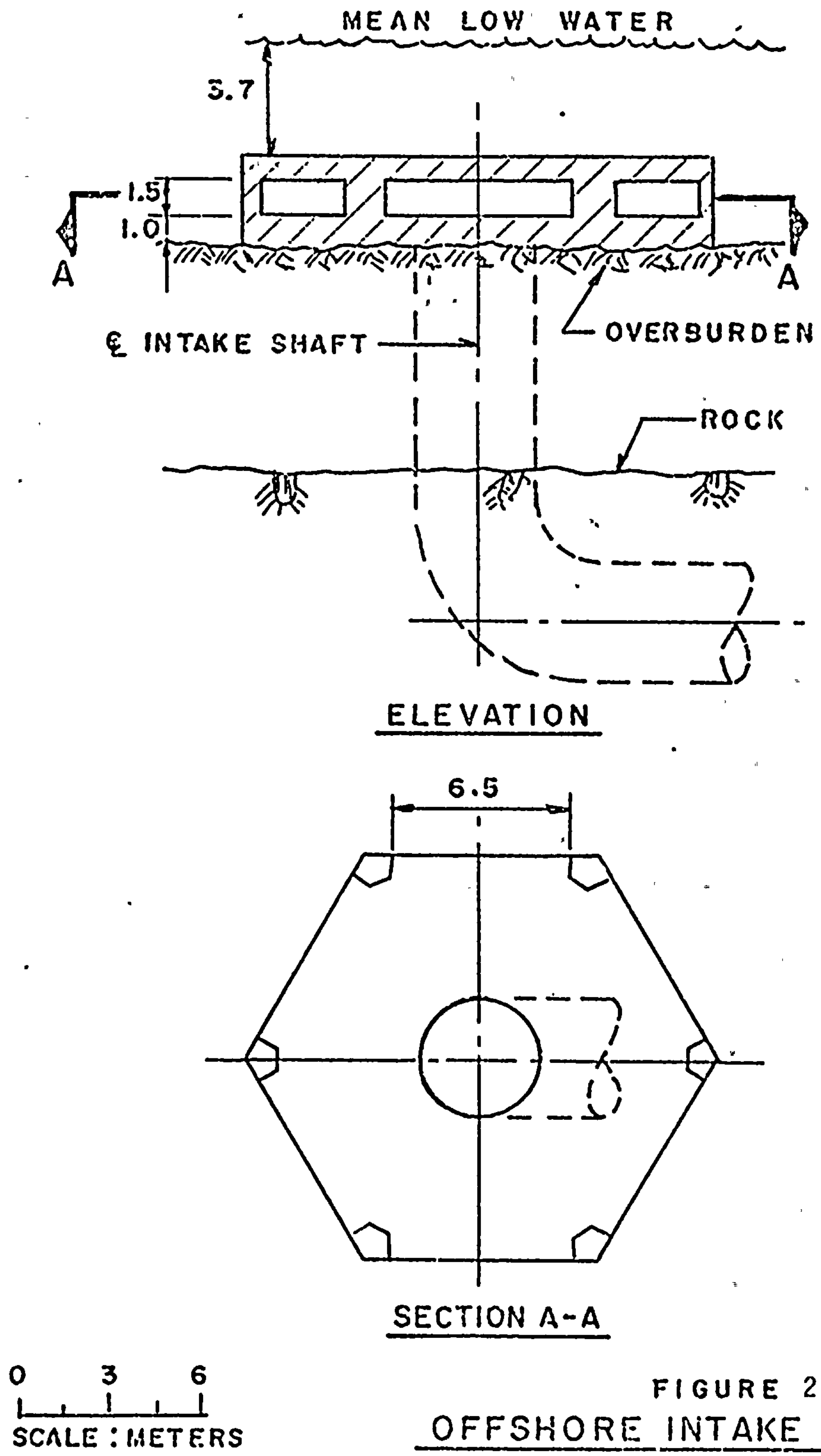


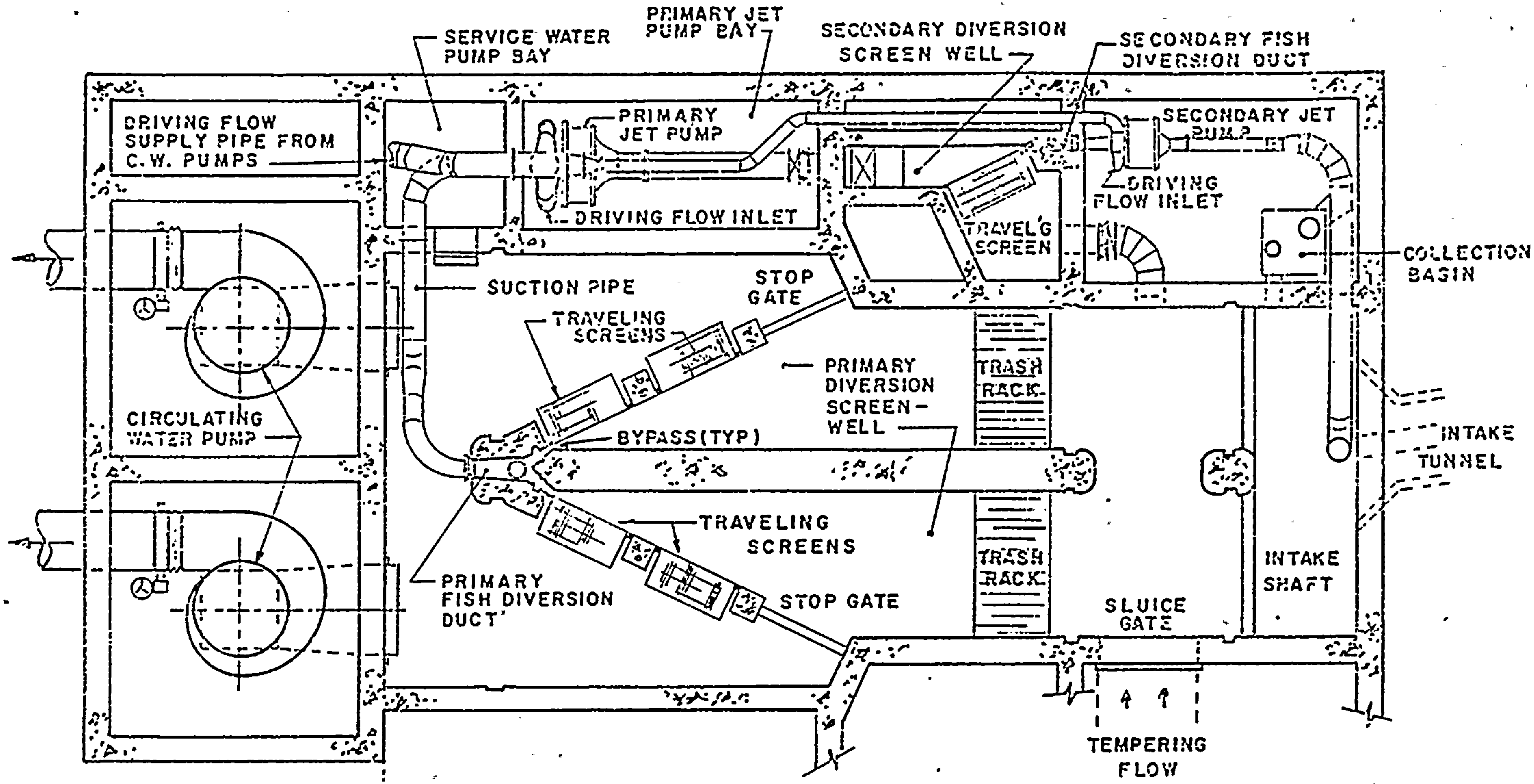
FIGURE 2.0-2
OFFSHORE INTAKE STRUCTURE
UNIT NO.6 OSWEGO STEAM STATION
NIAGARA MOHAWK POWER CORPORATION

the tunnel is less than 182 cm/sec (6.0 fps). The circulating water flow enters the intake screenhouse through a vertical intake shaft rising approximately 30 m (100 ft) in approximately 20 sec. From there the water flows into two screenbays in the primary screenwell, each 5.2 m (17 ft) wide, with a water column depth that varies from 7.3 to 10.1 m (24 to 33 ft).

Fish entering the screenwell pass through trash racks with 7.6-cm (3-in.) clear spacings, and encounter flush-mounted traveling screens angled toward a 15-cm (6-in.) wide bypass. Each bay is sized to accept three 3-m (10-ft) wide traveling screens separated by 1-m (39-in.) wide concrete piers. At present, each bay is equipped with two screens, and the third opening is blocked off with stop gates for a possible future screen. The screens are angled 25° to the direction of flow, with their downstream ends converging but separated by a 1.5-m (5-ft) wide pier (Figure 2.0-3).

Two dry-pit circulating water pumps draw the flow through the screenwell. Each pump suction opening is on the centerline of a screenbay and level with the bottom of the screenwell. The bypass suction flow is designed such that the ratio of the average screenwell approach velocity to the average bypass entrance velocity is 1:1. Each 15-cm (6-in.) wide bypass slot extends the full depth of the water column. The two slots converge in the horizontal plane as well as the vertical plane at a 45° angle to two 0.6-m (24-in.) diameter pipes. The two pipes become a single 0.8-m (32-in.) diameter pipe that becomes the suction pipe of the primary peripheral jet pump. The mixing tube of the primary jet pump is 0.9 m (36 in.) in diameter, resulting in an area ratio of driving nozzle to mixing tube of 0.18. The primary jet pump discharges to a 1.6-m (5.4-ft) wide secondary screenwell.

The secondary screenwell contains one angled traveling screen identical in design to the main screens except for its depth.



0 1.2 3.7
SCALE: METERS

FIGURE 2.0-3

PLAN OF SCREENWELL LAYOUT

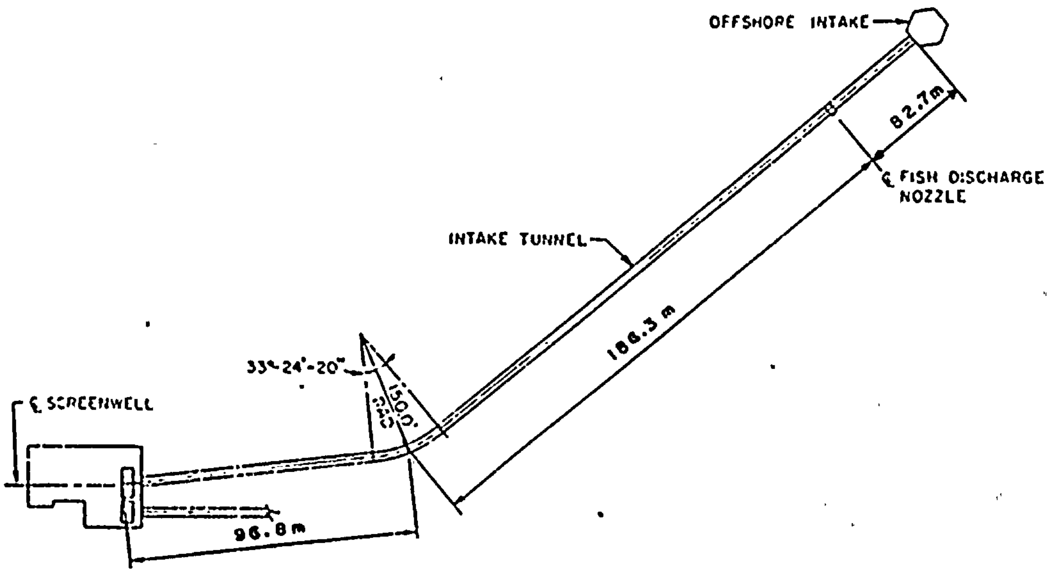
UNIT NO.6- OSWEGO STEAM STATION

The water depth in the secondary bay varies from 2.4 to 4.6 m (8 to 15 ft), depending on lake elevation and the number of operating pumps. Most of the water discharged from the primary jet pump flows through the secondary screen and is returned to the primary screenwell through a 1.1-m (42-in.) diameter pipe. The fish move across the secondary screen into another 15-cm (6-in.) wide bypass slot. The secondary bypass slot converges in the vertical plane to a 46-cm (18-in.) diameter pipe. At the secondary jet pump, this pipe reduces to a 43-cm (17-in.) diameter suction pipe. The mixing tube of the secondary pump is 51 cm (20 in.) in diameter, yielding an area ratio of driving nozzle to mixing tube of 0.22. The ratio of the average secondary bay approach velocity to the average secondary bypass velocity varies from 1:1 to 1:1.3. The secondary jet pump discharges into a 76-cm (30-in.) diameter discharge pipe embedded in the roof of the intake tunnel for a distance of approximately 280 m (925 ft) off shore where it rises vertically and terminates as a horizontal discharge approximately 2 m (6 ft) off the bottom and 83 m (270 ft) from the intake (Figure 2.0-4).

Downstream of the secondary jet pump and prior to leaving the screenhouse, the discharge flow can be diverted into a 2.4 x 2.4 m (8 x 8 ft) sampling basin. A pair of electrically driven gate valves direct the flow either off shore during normal operation or into the basin during sampling. A description of the sampling basin is provided in Section 3.1.1.

2.2 PHYSICAL PERFORMANCE TESTING

As part of the evaluation of the system operation, a study was conducted to evaluate the physical performance of the diversion system relative to the design parameters discussed in Section 2.1. This performance testing was divided into three tasks: (1) documentation of velocity distributions, (2) verification of flow through



KEY PLAN
CIRC WATER INTAKE TUNNEL
NO SCALE

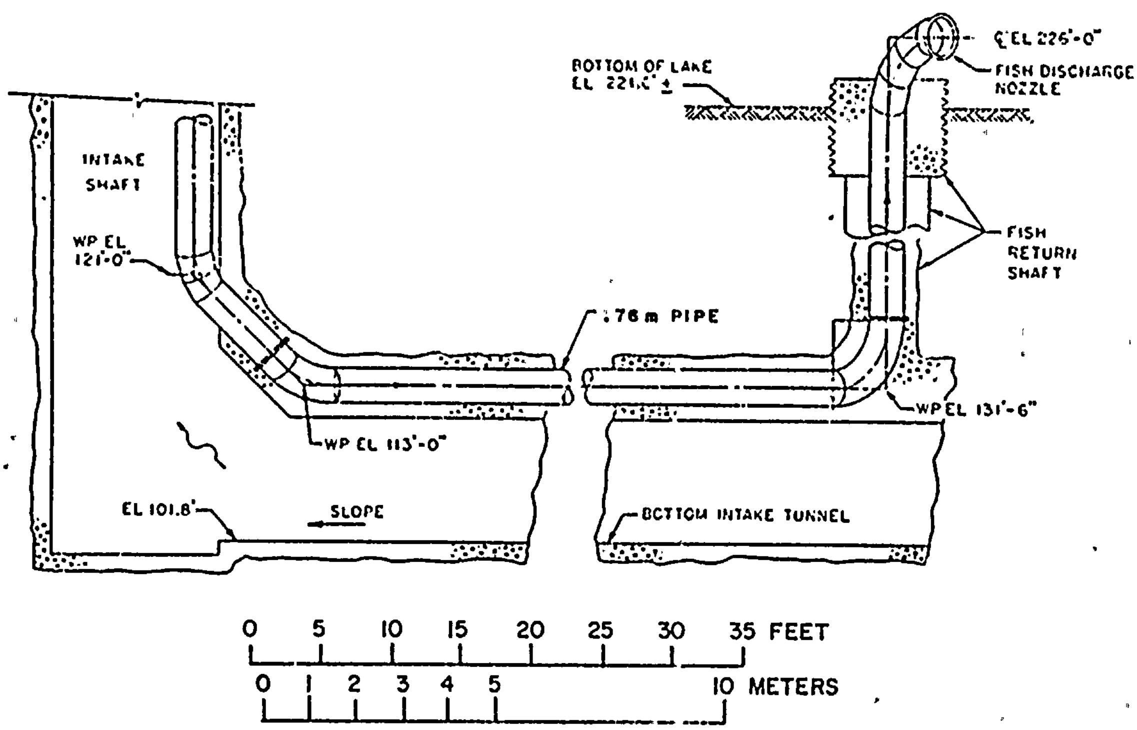


FIGURE 2.0-4
FISH RETURN PIPE
UNIT NO. 6 – OSWEGO STEAM STATION

the jet pumps and transport pipe, and (3) determination of the flow rate into the fish sampling basin relative to the discharge to the lake.

2.2.1 Velocity Distributions

Velocity measurements were taken at the trash racks and at each of the five traveling screens - four in the primary diversion system and one in the secondary. Measurements were conducted under two-pump operation with the tempering gates open or closed. All valves on the jet pumps were opened completely and the total discharge flow was directed to the lake.

The velocity measurements were made with a Marsh-McBirney Model 511 electromagnetic water current meter. This instrument senses the two orthogonal components (two channels) of flow in a plane normal to the longitudinal axis of the probe.

Measurements made at the trash racks were conducted by mounting the probe on a specially designed frame that maintained proper probe orientation, i.e., one channel perpendicular to the bar racks and the other tangent to it. The frame and probe were then lowered to the desired depth and measurements were recorded.

Measurements performed at the traveling screens were conducted by mounting the probe directly on the face of the screen and rotating the screen in reverse until the probe was at the desired depth. The probe was located 25 cm (10 in.) in front of the trash rack or screen.

Because of the limited space between the traveling screens and the concrete floor, the velocity probe had to be mounted on the screen from inside the screenwell. This was accomplished by LMS personnel

positioned in a boat within the screenwell. The size of the boat and the difficulty of operating it under these conditions precluded measuring at the downstream extremities of the screens where the primary screenwell tapered to the 15-cm (6-in.) bypass. The same factors allowed for the measurement of only one lateral location within the secondary screenwell.

At each location of the probe, five measurements and the velocity range (at a 1-sec time constant) observed over a 45-60 sec interval were recorded for each channel. A schematic showing the screen numbering system is provided in Figure 2.0-5. The mean velocities for each set of measurements at a given location are used for presentation purposes. Velocities at the trash racks (Table 2.0-1) typically decrease with depth. Velocities in the upper 4 m (13 ft) of the water column exceeded 20 cm/sec (0.65 ft/sec), while those in the lower half were less than half those found near the surface. Non-uniform flow was evident. Velocity measurements could not be performed under tempering conditions because of excessive turbulence. During tempering, water shoots from the northeast side of the primary screenwell across the bottom of the screenwell, impacts on the northwest wall of the primary screenwell, and rebounds across the screenwell to the surface. A high observed surface current runs across the screenwell from northwest to southeast.

The results of the measurements performed on the four screens located in the primary screenwell (Tables 2.0-2 and 2.0-3) indicate flow perpendicular to the screens between 7.0 and 19.8 cm/sec (0.22 to 0.65 ft/sec), with most measurements falling between 12 and 13 cm/sec (0.39 to 0.42 ft/sec). There are no areas of reverse flow and the velocities are within the range of variations expected in large open channels.

FIGURE 2.0-5

OSWEGO STEAM STATION UNIT 6

Schematic

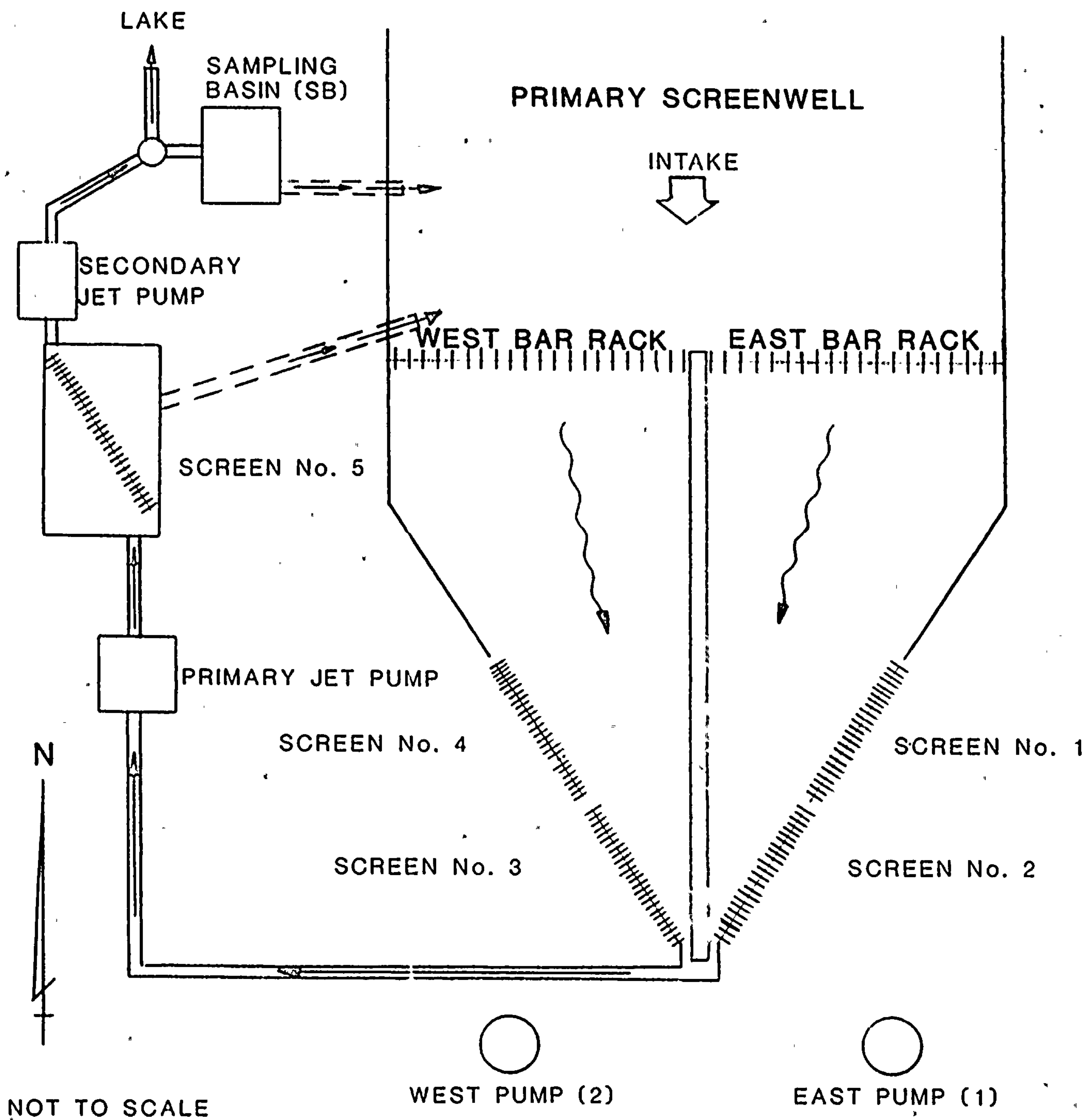


TABLE 2.0-1

TRASH RACK VELOCITIES (cm/sec)

Oswego Steam Station Unit 6

DEPTH (m)	CHANNEL	WEST TRASH RACK[a]				EAST TRASH RACK[a]			
		WEST	CENTER	EAST	MEAN	WEST	CENTER	EAST	MEAN
0.2	1	-25.8	-16.0	-40.8	-27.5	-24.8	-31.0	-30.0	-28.6
	2	-23.6	-35.0	- 9.4		+ 3.2	+18.0	+21.2	
0.6	1	-30.6	-21.4	-29.0	-27.0	-20.2	-27.6	-27.4	-25.1
	2	-11.2	-22.2	-13.4		- 5.4	+16.0	+ 7.6	
2.1	1	-29.8	-19.0	-22.4	-23.7	-27.6	-25.2	-29.4	-27.4
	2	- 1.2	+ 8.4	+ 1.0		- 8.6	+10.4	+ 7.2	
4.3	1	-22.4	-24.4	-24.8	-23.9	-25.6	-20.0	-17.2	-20.9
	2	+15.0	+15.8	+ 8.6		- 9.2	-13.2	- 2.2	
6.4	1	- 3.8	-12.2	-17.4	-11.1	-19.2	-13.4	- 9.6	-14.1
	2	+ 7.0	+12.8	+ 3.4		- 3.6	- 6.6	- 1.6	
8.5	1	+ 3.6	- 2.6	- 2.0	- 0.3	- 5.6	+ 6.8	+ 8.8	+ 3.3
	2	+ 7.6	- 3.6	+ 3.6		+ 4.2	+ 2.8	- 0.8	

Channel 1 - Velocity perpendicular to the trash rack: (+) South to north (outflow)
(-) North to south (inflow)

2 - Velocity parallel to the trash rack: (+) East to west
(-) West to east

[a]See Figure 2.0-5.

TABLE 2.0-2

VELOCITIES (cm/sec) AT THE TWO EASTERN IMPINGEMENT SCREENS

Oswego Steam Station Unit 6

DEPTH (m)	CHANNEL[b]	SOUTHEAST SCREEN[a] (No. 2)				NORTHEAST SCREEN[a] (No. 1)			
		SOUTH	CENTER	NORTH	MEAN RESULTANT[c]	SOUTH	CENTER	NORTH	MEAN RESULTANT[c]
0.5	1	NA	-13.6	-12.8	39.3	-13.4	-19.8	-17.6	39.1
	2	NA	-33.4	-40.6		-32.0	-30.4	-42.8	
1.9	1	NA	-13.0	-14.4	38.7	-12.6	-16.0	-13.2	37.5
	2	NA	-33.8	-38.6		-30.0	-33.8	-40.6	
4.3	1	NA	-13.8	-13.8	38.4	-12.8	-17.2	-12.8	35.3
	2	NA	-32.8	-38.8		-23.4	-35.0	-38.2	
6.1	1	NA	-14.2	-12.4	37.3	-12.8	-15.4	-12.6	35.4
	2	NA	-31.8	-37.8		-27.6	-32.2	-38.2	
7.9	1	NA	-16.4	-16.6	36.9	-12.0	-14.6	-13.0	34.8
	2	NA	-32.8	-33.2		-27.2	-33.2	-36.2	

[a] See Figure 2.0-5

[b] Channel 1 - Velocity perpendicular to the screen: (-) Through the screen (inflow)
(+) Away from the screen (outflow)

2 - Velocity parallel to the screen: (+) Away from the bypass
(-) Toward the bypass

[c] Mean resultant represents vector sum of both channels.

NA - Not accessible.

TABLE 2.0-3

VELOCITIES (cm/sec) AT THE TWO WESTERN IMPINGEMENT SCREENS

Oswego Steam Station Unit 6

DEPTH		NORTHWEST SCREEN[a] (No. 4)				SOUTHWEST SCREEN[a] (No. 3)			
(m)	CHANNEL[b]	NORTH	CENTER	SOUTH	MEAN RESULTANT[c]	NORTH	CENTER	SOUTH	MEAN RESULTANT[c]
0.5	1	-12.6	-16.0	-13.8	37.0	-13.0	-12.4	NA	41.9
	2	-37.8	-37.8	-26.8		-42.6	-37.2	NA	
1.8	1	-11.8	-15.4	-11.6	32.5	-12.2	-10.8	NA	36.9
	2	-35.4	-30.4	-23.4		-40.6	-29.4	NA	
4.3	1	- 8.0	-13.6	-13.6	33.6	-12.2	-11.0	NA	33.6
	2	-38.4	-32.0	-23.0		-33.2	-29.8	NA	
6.1	1	- 9.2	-15.0	-11.8	36.5	-13.2	-11.4	NA	36.1
	2	-43.6	-34.0	-25.2		-35.2	-32.6	NA	
7.9	1	- 7.0	-12.6	-10.6	49.4	-14.8	-11.8	NA	37.8
	2	-65.0	-51.6	-27.8		-35.0	-35.8	NA	

[a]See Figure 2.0-5.

[b]Channel 1 - Velocity perpendicular to the screen: (-) Through the screen (inflow)
(+) Away from the screen (outflow)

2 - Velocity parallel to the screen: (+) Away from the bypass
(-) Toward the bypass

[c]Mean resultant represents the vector sum of both channels.
NA - Not accessible.

The velocity parallel to the screen was between 23.0 and 65.0 cm/sec (0.75 to 2.1 ft/sec), with most measurements between 29.0 and 38.6 cm/sec (0.95 and 1.24 ft/sec). With the exception of the high velocities (65.0 and 51.6 cm/sec [2.13 and 1.69 ft/sec]) measured along the bottom of the northwest screen (No. 4), the velocities recorded parallel to the screens are near the 30 cm/sec (1.0 fps) design criteria set by S&W. The resultant velocity, or the vector sum of the perpendicular and tangent velocity components, averaged between 32.5 and 49.4 cm/sec (1.07 and 1.62 ft/sec). This represents the actual approach velocity to which a fish is subjected in the near field of the screen.

The actual water depth in the screenwell during the survey was 9.6 m (31.7 ft) and the maximum depth at which a measurement was taken was 7.9 m (25.9 ft). A protective plate or boot on the bottom of the vertical traveling screens provided a quiescent area 1 to 1.5 m (3 to 5 ft) deep from the bottom of the screenwell to the top of the protective plate where the water started passing through the screen. The piping system servicing the high-pressure sand-wash system also contributed localized disruptions to the uniform flow patterns within the screenwell. Several 20-mm (8-in.) diameter pipes extend vertically along the center wall from above the water surface to the bottom of the screenwell and across the screenwell floor. Their position, approximately 1.5 to 2.4 m (5 to 8 ft) upstream of the bypass, undoubtedly produced localized turbulence that could not be documented by the velocity measurements (see Section 3.4.2).

Table 2.0-4 illustrates the effect that tempering has on the velocity observed at the screens. Two screens, one at the apex (No. 3), and the other at the upstream end of the screenwell (No. 1), were chosen to show the effect. The measurements were made at the centerline of each screen. Tempering created a lesser effect on the

TABLE 2.0-4

EFFECT OF TEMPERING ON SCREENWELL VELOCITIES

Oswego Steam Station Unit 6

DEPTH (m)	NORTHEAST SCREEN[a] No.1 CHANNEL[b]	PERCENT TEMPERING 0	20	SOUTHWEST SCREEN[a] No. 3 CHANNEL[b]	PERCENT TEMPERING 0	14
0.3	1	-17.7	-14.0	1	-15.2	-20.1
	2	-30.8	-32.9	2	-39.3	-67.1
1.5	1	-17.7	-10.4	1	ND	ND
	2	-32.0	-21.3	2	ND	ND
2.7	1	-17.7	-12.8	1	-12.5	-17.7
	2	-34.1	-23.8	2	-32.6	-51.2
5.2	1	-16.2	- 9.1	1	-12.8	-17.7
	2	-30.5	-24.4	2	-36.6	-49.4
6.4	1	-15.5	- 9.1	1	-13.7	-21.3
	2	-30.5	-18.3	2	-35.0	-44.2
7.6	1	-16.5	-15.2	1	-12.2	-18.9
	2	-32.0	-14.6	2	-35.7	-38.7

[a]Figure 2.0-5.

[b]Channel

1 - Velocity perpendicular to the screen:
(+) Away from the screen (outflow)
(-) Through the screen (inflow)

2 - Velocity parallel to the screen:
(+) Away from the bypass
(-) Toward the bypass

ND - Not determined.

through-screen velocity than on the parallel velocity component. Higher velocities were recorded near the bypass than at the upstream screen.

Because of the limited access in the secondary screenwell, only one vertical velocity profile could be measured at the single secondary diversion screen. The data collected in April 1981 indicate a high level of turbulence with flow through the screen reversing direction (Table 2.0-5). Near the surface and bottom, flow passes into the screen, while at mid-depth the flow reverses and moves out through the screen.

The high surface velocity along the screen (61.2 cm/sec [2.0 ft/sec]) exceeds the capacity of the bypass and produces a reversal of flow or countercurrent along the bottom of the screen. The irregular flow distribution was produced by the introduction of flow into the secondary screenwell from the primary jet pump at a 30° angle off the bottom of the screenwell toward the screen and bypass.

A ruptured liner in the exit port from the jet pump pipe into the secondary screenwell caused a constriction in the flow pattern that created the high velocities and resulting turbulence. This condition was identified and corrected in August 1981. The velocity measurements were repeated in April 1982. While a vertical velocity gradient was observed, the turbulence previously observed was greatly reduced (Table 2.0-6). Tempering had little effect on the velocity distribution across the secondary screen but increased water depth, created by partially closing the gate valve between the secondary and primary screenwells, reduced the velocities slightly (Table 2.0-6).

TABLE 2.0-5

VELOCITIES (cm/sec)
AT THE SECONDARY SCREEN

Oswego Steam Station Unit 6

DEPTH (m)	CHANNEL[b]	SECONDARY SCREEN[a] (No. 5) CENTER
0.5	1	-13.0
	2	-61.2
2.4	1	+ 8.2
	2	-32.2
3.0	1	+12.4
	2	+ 5.8
3.6	1	- 8.4
	2	+29.6

[a]See Figure 2.0-5.

[b]Channel 1 - Velocity perpendicular to the screen:
(+) Away from the screen (outflow)
(-) Through the screen (inflow)

2 - Velocity parallel to the screen:
(+) Away from the bypass
(-) Toward the bypass

TABLE 2.0-6

SECONDARY SCREENWELL VELOCITIES UNDER VARIOUS OPERATING CONDITIONS

Oswego Steam Station Unit 6

DEPTH (m)	CHANNEL[b]	PERCENT TEMPERING 0	PERCENT TEMPERING 12	SECONDARY SCREENWELL[a] GATE VALVE 50% CLOSED; 0% TEMPERING
0.3	1	-40.2	-38.4	-20.1
	2	-62.8	-42.7	-39.6
0.9	1	-28.0	-15.2	- 9.1
	2	-54.9	-49.4	-40.8
1.5	1	-17.1	- 9.1	-12.1
	2	-60.4	-51.2	-34.7
2.1	1	- 7.3	-11.0	- 2.1
	2	-59.1	-45.7	-29.9
2.7	1	+ 7.9	+ 7.9	+ 4.3
	2	-32.3	-29.9	-17.1
Secondary screen-well water depth (m)		4.11	4.66	4.53

[a]See Figure 2.0-5.

[b]Channel 1 - Velocity perpendicular to the screen:
(+) Away from the screen (outflow)
(-) Through the screen (inflow)

2 - Velocity parallel to the screen:
(+) Away from the bypass
(-) Toward the bypass

2.2.2 Verification of Flows

The second task included in the physical performance testing program consisted of evaluating the operation of the jet pumps and transport pipe relative to the initial S&W design criterion.

Based on the 1978 design calculations, the primary jet pump flow ratio is 0.83 and the secondary ratio is 0.47. In November 1979, S&W derived the orifice plate and elbow flowmeter calibration curves and made measurements through the system. True lake level was not determined for the series of measurements, and therefore the head loss associated with passage through the intake tunnel and the transport head loss from the secondary jet pump to the lake could not be calculated. It appears though that the tunnel head loss was less than the predicted 1.3 m (4.4 ft). Based on water levels in the primary and secondary screenwells, the primary jet pump was providing a lift of only 0.38 m (1.25 ft). The flow rates, however, were near those used in the design calculations. The remainder of the lift for the transport flow to the lake was provided by the secondary jet pump; the flow rate to the lake (0.52 m^3/sec [17 cfs]) was slightly lower than that used in the design calculations (0.54 m^3/sec [19 cfs]).

The observations by LMS in March 1981 were generally consistent with those made by S&W in November 1979. LMS also measured a lift between the primary and secondary screenwell of 0.38 m (1.25 ft), although the flows measured differ. We are in agreement with S&W that the primary jet pump is running with a flow ratio near 0.9; however, the secondary jet pump is running with a flow ratio near 0.7. The lake transport flow (0.40 m^3/sec [14 cfs]) measured by LMS is well below the design value and the secondary jet pump seems to be providing most of the lift for the system.

2.2.3 Sampling Basin Flow Rate

The final task included in the physical performance testing program consisted of evaluating the flow rate into the fish sampling basin. Under two-pump operation, with the basin gate valve fully open and the lake discharge gate valve completely closed, the flow rate into the basin was 0.65 m^3/sec (23 cfs), with a basin water level of 74.98 m (246 ft). As previously mentioned, the flow rate to the lake with the sampling basin gate valve closed and the lake discharge gate valve open was 0.40 m^3/sec (14 cfs).

By closing down the sample basin drain valve 30%, the water level with the basin gate valve open and the lake discharge gate closed was raised to 75.26 m (246.9 ft) and the flow into the basin was reduced to 0.40 m^3/sec (14 cfs). This operating condition provides a sampling condition representative of normal plant operation.

Our conclusion is that the overall system is functioning satisfactorily but that under tempering conditions the turbulence in the primary screenwell most likely contributes to the observed mortality during these periods. Flow to the primary screens is reasonably uniform and the entry velocity to both the primary and secondary bypasses is on the order of 30 cm/sec (1.0 ft/sec). The lifts being provided by the two jet pumps are below the design conditions, however, especially in the case of the primary jet pump.

CHAPTER 3.0

DIVERSION EFFICIENCY

3.1 EXPERIMENTAL DESIGN

The biological testing program was designed with three distinct study objectives. These were to determine:

1. The efficiency of the angled screen
2. The effectiveness of the fish bypass
3. The viability of fish that enter the bypass system and are eventually returned to Lake Ontario

The first two objectives are discussed in this chapter followed by a discussion of the viability results in Chapter 4.0. The following definitions are used throughout this report:

- The efficiency of the angled screen (primary diversion efficiency, PDE) is determined by comparing the proportion of fish entering the primary diversion bypass with the number entering the screenwell. The difference between these numbers is the number collected on the primary traveling screens.
- The effectiveness of the fish bypass (secondary diversion efficiency, SDE) is defined as the proportion of the fish entering the secondary diversion bypass to the number entering the primary diversion bypass. The difference between these numbers is the number collected on the secondary traveling screen.
- The overall effectiveness of the diversion system (total diversion efficiency, TDE) is defined as the proportion of fish entering the secondary diversion bypass to the number of fish entering the primary screenwell.

During the two years of study, impingement on the five vertical traveling screens was monitored over a specific duration (8- or 24-hr periods). During this time, samples of the diverted fish were collected. Typically, two diversion abundance samples were collected over an 8-hr impingement period and three over a 24-hr period. The samples were spaced across the impingement duration to reflect any potential diurnal periodicity.

Abundances of impinged and diverted fish were converted to number impinged or diverted per hour for comparison purposes.

The primary diversion efficiency (PDE) is defined as the proportion of fish entering the primary diversion bypass in comparison to the number entering the screenwell.

The number of fish entering the screenwell (E_R, the entrapment rate) is calculated as the sum of the total impingement rate (Screens 1-5) and the diversion rate:

$$E_R = IMP_{1-4} + IMP_5 + DIV$$

where:

IMP_{1-4} = impingement rate on Screens 1-4 (No. collected/hr)

IMP_5 = impingement rate on screen 5 (No. collected/hr)

DIV = collection rate from the sampling basin (No. collected/hr)

The number of fish entering the primary bypass (PB_R, the primary bypass rate), is calculated as the sum of the impingement rate of the secondary diversion system (Screen 5) and the diversion rate:

$$PB_R = IMP_5 + DIV$$

Therefore:

$$PDE = \frac{PB_R}{E_R} = \frac{IMP_5 + DIV}{IMP_{1-4} + IMP_5 + DIV}$$

The monthly PDE is calculated by summing the individual bypass rates and the entrapment rates:

$$PDE_{monthly} = \frac{\sum_{i=1}^{n} PB_R}{\sum_{i=1}^{n} E_R}$$

where n = number of surveys conducted in the month

The secondary diversion efficiency (SDE) is defined as the proportion of fish entering the secondary diversion bypass as compared to the number of fish entering the primary diversion bypass. The number of fish entering the primary bypass (PB_R) as previously described is the primary bypass rate and the number of fish entering the secondary diversion bypass is synonymous with the diversion rate. Thus:

$$SDE = \frac{DIV}{PB_R} = \frac{DIV}{IMP_5 + DIV}$$

The monthly SDE was calculated using the same procedure previously described for calculating the monthly PDE.

When small numbers of fish were present in any given month, the interval was extended for two or more months. The entire two-year study period was composited for most of the species that were collected in low abundances.

3.2 SAMPLING AND ANALYSIS PROCEDURES

An impingement collection period was initiated upon completion of one full wash cycle (prewash). Collection nets were then installed to sample either each of the five screens individually (April 1981-March 1982) or Screens 1-4 and Screen 5 separately (April 1982-March 1983). The nets were checked upon completion of each screen wash cycle to prevent debris overload. At the completion of the sample duration (8 or 24 hrs) the collection nets were removed and all organisms separated from the debris. All impinged fish were identified to species if possible, enumerated, recorded, and frozen for subsequent analysis.

Diversion abundances were determined from collections taken from the sampling basin, a 2.4 x 2.4 m (8 x 8 ft) pit in the northwest corner of the screenhouse. Routine diversion abundance collections conducted during an 8-hr impingement collection included one 30- or 60-min sample taken during the first and last hour of the impingement survey. During a 24-hr survey, three 30- or 60-min collections were taken across the duration of sampling. Viability collections of diverted fish were also used for diversion abundance estimates. Typically six 15- or 30-min viability collections were made concurrent with an impingement survey and sandwiched between the diversion abundance collections.

To initiate a sample basin collection, the lake discharge flow was switched into the sampling basin. Piezometer tubes were monitored to assure that the water flow into the sampling basin equaled the previous lake discharge flow. At sample termination, the gate valve

was again switched, diverting the flow back to the lake. The basin was then slowly drained to a depth of approximately 0.3 m (1 ft).

A fish crowder was lowered along the inclined screen and moved manually across the basin floor to gently crowd the collected fish to one side of the basin for sorting purposes. All fish were classified as live (swimming normally), stunned (exhibiting some locomotion but not swimming normally), or dead (showing no signs of life), identified to species if possible, enumerated by life condition (live, stunned, or dead), recorded, and frozen for subsequent analysis.

All fish collected from impingement or the sample basin during a survey and not tested for latent survival were preliminarily analyzed before being composited for secondary analysis. Preliminary analysis consisted of species identification, enumeration, tag checks, and biomass determination. No damaged or decomposing fish were included in biomass measurements or composited for secondary analysis.

Secondary analysis consisted of individual length and weight measurements. If a composite contained more than 100 individuals per species, a random numbers table was used in the selection of a nonbiased subsample.

3.3 SAMPLING SCHEDULE

The April 1981 - March 1982 sampling was conducted as the first year of the two-year program to evaluate the effectiveness of the angled screen diversion system. It included seasonal intensive sampling and routine sampling. At the beginning of the spring, fall, and winter seasons, an intensive three-day, 24-hr/day survey was conducted to determine the diel trends in fish distribution. Based on these results, a routine survey was performed three times

per week in the spring, fall, and winter and once per week in the summer. The effort was reduced during the summer because of the low numbers of fish present. Each routine survey was 8 hrs long and was performed coincident with the diel period of highest fish abundances (as determined from the intensive survey). During each intensive and routine survey there was a specific program of impingement, diversion abundance, and survival sampling. Table 3.0-1 summarizes the scheduled sampling effort for each month. Because sampling concentrated on the periods of highest abundances, caution should be used when evaluating the yearly estimates of impingement abundance from these data.

The second year (April 1982 - March 1983) of the evaluation of the diversion system was conducted with the first year of the required State Pollution Discharge Elimination System (SPDES) monitoring program. Surveys were performed on a variable schedule, depending upon fish abundance. SPDES impingement sampling required sixteen 24-hr impingement collections in April, twenty in May, six in August, and four in each of the remaining months. Diversion abundance was determined during each impingement survey. Table 3.0-1 summarizes the sampling schedule.

3.4 IMPINGEMENT

3.4.1 Yearly Impingement Abundances

Thirty-one species of fish were represented in the 203 impingement collections (Table 3.0-2). Dominant species were rainbow smelt and alewife, with lesser numbers of white perch, emerald shiner, gizzard shad, and spottail shiner. The estimated monthly impingement of these species is presented in Table 3.0-3. These estimates are calculated from monthly impingement rates (No./hr) based on the average impingement rate from all impingement sampling conducted within the month. As the intent of this program was to evaluate the

TABLE 3.0-1

SAMPLING SCHEDULE: APRIL 1981 - MARCH 1983

Oswego Steam Station Unit 6

STUDY PERIOD	SAMPLING REGIME	IMPINGEMENT	DIVERSION ABUNDANCE	VIABILITY
Apr 1981-Mar 1982	Intensive	36 continuous 2-hr collections Apr,Oct,Jan	18 30-min collections concurrent with impingement	3 surveys[b] concurrent with impingement
	Routine Spring Fall Winter	3 8-hr collections per week	1 survey[a] per impingement survey	1 survey[b] per impingement survey
	Summer	1 8-hr collection per week	1 survey[a] per impingement survey	1 survey[b] per impingement survey
Apr 1982-Mar 1983	Routine			
	April	16 24-hr collections	1 survey[a] per impingement survey	3 surveys[b] per week
	May	20 24-hr collections	1 survey[a] per impingement survey	3 surveys[b] per week
	June-July	4 24-hr collections	1 survey[a] per impingement survey	1 survey[b] per week
	August	6 24-hr collections	1 survey[a] per impingement survey	1 survey[b] per week
	September, January-March	4 24-hr collections	1 survey[a] per impingement survey	1 survey[b] per week
	October - December	4 24-hr collections 2 8-hr collections per week	1 survey[a] per impingement survey	3 surveys[b] per week

[a] A survey represents 2 or 3 30- or 60-min collections depending upon fish abundances.
[b] A survey represents 6 15- or 30-min collections depending upon fish abundances.

TABLE 3.0-2

SPECIES LIST OF ORGANISMS COLLECTED AT THE OSWEGO STEAM STATION

April 1981 - March 1983

COMMON NAME	SCIENTIFIC NAME	IMPINGED PRIMARY	IMPINGED SECONDARY	DIVERTED
American burbot	*Lota lota*	x		x
American eel	*Anguilla rostrata*		x	x
Alewife	*Alosa pseudoharengus*	x	x	x
Black bullhead	*Ictalurus melas*			x
Brown bullhead	*Ictalurus nebulosus*	x		x
Brown trout	*Salmo trutta*			x
Bowfin	*Amia calva*			x
Bluegill sunfish	*Lepomis macrochirus*	x	x	x
Brook silverside	*Labidesthes sicculus*			x
Brook stickleback	*Culaea inconstans*	x		
Chinook salmon	*Oncorhynchus tshawytscha*			x
Central mudminnow	*Umbra limi*	x		x
Creek chub	*Semotilus atromaculatus*			x
Common shiner	*Notropis cornutus*			x
Emerald shiner	*Notropis atherinoides*	x	x	x
Fantail darter	*Etheostoma flabellare*	x	x	
Freshwater drum	*Aplodinotus grunniens*	x		
Goldfish	*Carassius auratus*	x		x
Gizzard shad	*Dorosoma cepedianum*	x	x	x
Johnny darter	*Etheostoma nigrum*	x	x	x
Lake chub	*Couesius plumbeus*			x
Largemouth bass	*Micropterus salmoides*			x
Longnose dace	*Rhinicnthys cataractae*	x		x
Logperch	*Percina caprodes*	x		x
Lake trout	*Salvelinus namaycush*	x		x
Madtom	*Noturus spp.*	x		
Mottled sculpin	*Cottus bairdi*	x	x	x
Pumpkinseed	*Lepomis gibbosus*	x		x
Rainbow smelt	*Osmerus mordax*	x	x	x
Rainbow trout	*Salmo gairdneri*			x
Rock bass	*Ambloplites rupestris*	x	x	x
Sea lamprey	*Petromyzon marinus*	x		x
Smallmouth bass	*Micropterus dolomieui*	x	x	x
Stonecat	*Noturus flavus*	x		x
Spottail shiner	*Notropis hudsonius*	x	x	x
Trout-perch	*Percopsis omiscomaycus*	x	x	x
Threespine stickleback	*Gasterosteus aculeatus*	x	x	x
White bass	*Morone chrysops*	x	x	x
White perch	*Morone americana*	x	x	x
White sucker	*Catostomus commersoni*	x		x
Yellow perch	*Perca flavescens*	x		x

TABLE 3.0-3

ESTIMATED MONTHLY IMPINGEMENT[a]

Oswego Steam Station Unit 6

MONTH	RAINBOW SMELT	ALEWIFE	WHITE PERCH	GIZZARD SHAD	EMERALD SHINER	SPOTTAIL SHINER
Apr 1981	94	1,088	22	0	0	0
May	261	7,938	7	0	7	0
Jun	65	10,188	14	0	0	0
Jul	0	3,125	15	0	0	0
Aug	0	469	0	0	0	97
Sep	1,844	10,944	0	144	50	44
Oct	21,003	16,093	402	558	201	74
Nov	28,303	1,073	259	187	151	7
Dec	31,300	44	7	7	104	7
Jan 1982	10,326	379	22	156	74	89
Feb	2,271	54	7	61	155	0
Mar	1,949	126	112	97	260	45
Apr	9,446	23,515	360	58	194	79
May	179	3,772	7	14	0	0
Jun	1,037	1,440	0	0	7	0
Jul	60	3,229	0	0	0	0
Aug	469	849	394	0	15	67
Sep	1,339	4,018	43	0	36	245
Oct	424	1,429	37	0	37	156
Nov	633	151	0	21	0	0
Dec	253	30	14	0	0	0
Jan 1983	417	7	0	60	7	0
Feb	128	0	20	7	7	0
Mar	320	2,797	22	0	0	0
Total	112,121	92,758	1,764	1,370	1,305	910

[a]Based on monthly mean impingement rate (No./hr) from all impingement collections.

fish diversion system, the sampling effort was intensified during periods of heaviest fish abundance. The sampling was not conducted on a random design, and therefore the derived estimates should not be assumed to be statistically valid estimates of total impingement but rather a tool for evaluative purposes.

Fish impingement demonstrated a definite seasonal pattern (Table 3.0-3). Spring collections were dominated by adult or subadult alewife (total length > 10.0 cm) and lesser numbers of rainbow smelt; fall collections were dominated by young-of-the-year (YOY) rainbow smelt, alewife, and gizzard shad (total length $\leq$ 10.0 cm). While the same species dominated in both years, their impingement abundance differed widely (Table 3.0-4). Alewife impingement was high in the spring of 1981, while that of rainbow smelt was low. In the fall and early winter of 1981, YOY rainbow smelt predominated, with an estimated monthly impingement in December exceeding 31,000 fish. The spring and early summer of 1982 saw smaller numbers of alewife compared to the previous spring and early summer; impingement of rainbow smelt was substantially higher than during the previous spring. Lower abundances of all fish except spottail shiner and YOY smallmouth bass were seen in the fall of 1982 relative to the fall of 1981.

Size distribution of the impinged alewife, rainbow smelt, and white perch followed the same general pattern during both years of the study. Most of the impinged alewife during the spring were from 15 to 20 cm in total length, while the majority of those impinged in September were less than 5.0 cm. Throughout the fall, 5- to 10-cm alewife dominated the alewife collections (Table 3.0-5). Rainbow smelt followed a similar distribution but few adults relative to YOY were impinged (Table 3.0-6). White perch adults (>20 cm) were predominant during the spring, while young from 5 to 10 cm were most often impinged during the fall (Table 3.0-7).

TABLE 3.0-4

ESTIMATED MONTHLY IMPINGEMENT[a] BY SIZE CLASS[b]

Oswego Steam Station Unit 6 - April 1981 - March 1983

MONTH	RAINBOW SMELT TOTAL	RAINBOW SMELT >10[b]	RAINBOW SMELT ≤10[b]	ALEWIFE TOTAL	ALEWIFE >10[b]	ALEWIFE ≤10[b]	WHITE PERCH TOTAL	WHITE PERCH >13[b]	WHITE PERCH ≤13[b]
Apr 1981	94	65	29	1,088	947	141	22	0	22
May	261	188	73	7,938	4,922	3,016	7	7	0
Jun	65	21	44	10,188	8,864	1,324	14	14	0
Jul	0	0	0	3,125	3,094	31	15	7	8
Aug	0	0	0	469	234	235	0	0	0
Sep	1,844	74	1,770	10,944	0	10,944	0	0	0
Oct	21,003	0	21,003	16,093	161	15,932	402	0	402
Nov	28,303	283	28,020	1,073	0	1,073	259	0	259
Dec	31,300	0	31,300	44	0	44	7	0	7
Jan 1982	10,326	103	10,223	379	189	190	22	4	18
Feb	2,271	23	2,248	54	27	27	7	7	0
Mar	1,949	175	1,774	126	126	0	112	69	43
Apr	9,446	2,739	6,707	23,515	22,104	1,411	360	295	65
May	179	50	129	3,772	3,734	38	7	7	0
Jun	1,037	0	1,037	1,440	1,426	14	0	0	0
Jul	60	0	60	3,229	3,229	0	0	0	0
Aug	469	14	455	849	611	238	394	35	359
Sep	1,339	0	1,339	4,018	563	3,455	43	0	43
Oct	424	51	373	1,429	29	1,400	37	0	37
Nov	633	32	601	151	0	151	0	0	0
Dec	253	38	215	30	15	15	14	0	14
Jan 1983	417	259	158	7	0	7	0	0	0
Feb	128	115	13	0	0	0	20	0	20
Mar	320	150	170	2,797	2,797	0	22	0	22
Total	112,121	4,380	107,741	92,758	53,072	39,686	1,764	445	1,319

[a]Based on monthly mean impingement rate (No./hr) from all impingement collections.

[b]Measured in centimeters.

TABLE 3.0-5

ALEWIFE IMPINGEMENT LENGTH FREQUENCY

Oswego Steam Station Unit 6 - April 1981-March 1983

LENGTH INTERVAL[a]	PERCENT OF TOTAL MEASURED WITHIN LENGTH INTERVAL											
	1981									1982		
	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
3.1- 5.0	0	0	b	0		74	17	0	0			0
5.1-10.0	13	38	13	1		26	82	100	100			0
10.1-15.0	21	17	12	12		0	2	0	0			15
15.1-20.0	65	45	73	87		0	0	0	0			85
>20.1	1	b	1	0		0	0	0	0			0
Mean	15.4	13.3	15.8	16.6	-	4.9	5.9	6.8	6.9	-	-	16.8
n	407	629	472	68	0	62	309	25	4	0	0	13

LENGTH INTERVAL[a]	PERCENT OF TOTAL MEASURED WITHIN LENGTH INTERVAL											
	1982									1983		
	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
3.1- 5.0	0	0	0	0	25	54	10	14	0	0		0
5.1-10.0	6	1	1	0	3	32	88	86	50	100		0
10.1-15.0	11	32	38	44	6	1	0	0	50	0		0
15.1-20.0	82	66	61	55	63	13	2	0	0	0		100
>20.1	1	2	0	1	3	0	0	0	0	0		0
Mean	16.6	16.2	15.9	15.5	13.7	6.6	6.1	6.2	8.5	9.7	-	17.2
n	328	447	105	114	71	71	41	7	2	1	0	26

[a] Measured in centimeters.
[b] Less than 0.5%.

TABLE 3.0-6

RAINBOW SMELT IMPINGEMENT LENGTH FREQUENCY

Oswego Steam Station Unit 6 - April 1981-March 1983

LENGTH INTERVAL[a]	PERCENT OF TOTAL MEASURED WITHIN LENGTH INTERVAL											
	1981									1982		
	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
3.1- 5.0	3	0	0			38	10	16	17	12	9	14
5.1-10.0	28	28	67			58	89	83	83	87	90	77
10.1-15.0	64	24	0			4	b	1	0	1	1	7
15.1-20.0	6	48	33			0	b	0	0	1	1	2
>20.1	0	0	0			0	0	0	0	0	0	0
Mean	10.9	13.2	9.7	-	-	5.6	6.1	5.8	5.6	6.0	5.9	6.7
n	36	25	3	0	0	24	429	571	1599	733	135	125

LENGTH INTERVAL[a]	PERCENT OF TOTAL MEASURED WITHIN LENGTH INTERVAL											
	1982									1983		
	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
3.1- 5.0	4	0	0	0	2	50	19	6	0	0	0	0
5.1-10.0	67	72	100	100	95	50	69	89	85	38	10	53
10.1-15.0	18	15	0	0	2	0	12	3	10	50	50	47
15.1-20.0	10	13	0	0	0	0	0	3	5	12	40	0
>20.1	1	0	0	0	0	0	0	0	0	0	0	0
Mean	8.7	9.0	6.5	7.3	7.9	6.0	7.0	7.0	8.2	11.5	13.4	10.1
n	321	39	35	4	41	28	26	36	20	24	10	15

[a] Measured in centimeters.
[b] Less than 0.5%.

TABLE 3.0-7

WHITE PERCH IMPINGEMENT LENGTH FREQUENCY

Oswego Steam Station Unit 6 - April 1981-March 1983

LENGTH INTERVAL[a]	PERCENT OF TOTAL MEASURED WITHIN LENGTH INTERVAL											
	1981									1982		
	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
3.1- 5.0	0	0	0				34	0	0	0	0	0
5.1-10.0	100	0	0				66	100	100	80	0	38
10.1-15.0	0	0	0				0	0	0	0	0	15
15.1-20.0	0	0	0				0	0	0	0	0	15
>20.1	0	100	100				0	0	0	20	100	31
Mean	8.1	35.0	25.8	-	-	-	5.6	6.8	7.8	10.4	26.5	14.7
n	18	1	1	0	0	0	44	10	1	5	1	13

LENGTH INTERVAL[a]	PERCENT OF TOTAL MEASURED WITHIN LENGTH INTERVAL											
	1982									1983		
	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
3.1- 5.0	0	0			32	20	0		50		0	0
5.1-10.0	18	0			59	80	100		50		100	100
10.1-15.0	14	50			0	0	0		0		0	0
15.1-20.0	4	0			3	0	0		0		0	0
>20.1	64	50			6	0	0		0		0	0
Mean	19.9	23.2	-	-	7.5	5.9	7.0	-	5.3	-	7.6	8.1
n	162	2	0	0	34	5	4	0	2	0	2	3

[a]Measured in centimeters.

3.4.2 Differential Impingement by Screen

Impingement rates for each of the five vertical traveling screens were compared to identify whether differential rates existed and what, if any, parameters contributed to the observed differences. Table 3.0-8 provides the relative impingement rates for each of the five screens for five select species: alewife, rainbow smelt, emerald shiner, spottail shiner, and white perch. The data for the two dominant species, alewife and rainbow smelt, are presented as a yearly average as well as broken down into three-month increments. The smaller increments permit evaluation of the distinct age class differences between spring and fall collections of alewife and rainbow smelt. The remaining species were not impinged in high enough numbers to allow this type of analysis.

Typically, higher numbers of fish were impinged on the screens closest to the bypass (Screens 2 and 3) than by those located upstream. Screen 3 generally impinged more fish than Screen 2, but abundances vary by species and season. Observations during screen rotation indicate that most impingement occurs on the third of the screen closest to the bypass. This phenomenon was also observed by Schuler (1973) in his experiments and was attributed to the higher velocity that existed near the apex of his test apparatus. Although limited access precluded making measurements just upstream of the bypass of the OSS-6 diversion system, velocity measurements made along other sections of the screens (Section 2.2) showed no significant nonuniform flow distributions along the face of Screens 2 or 3.

If the impingement process were related to the ability of fish to divert along a given width (distance) of screen, then impingement on the individual screens would increase as the distance diverted is

TABLE 3.0-8

RELATIVE IMPINGEMENT ON EACH OF THE FIVE VERTICAL TRAVELING SCREENS

Oswego Steam Station Unit 6 - April 1981-March 1982

SPECIES	TIME PERIOD	PERCENT OF TOTAL IMPINGEMENT SCREEN No.[a] 1	2	3	4	5
Alewife	Total Year	4	10	30	4	52
	Apr-Jun	3	5	8	6	79
	Jul-Sep	6	19	48	3	25
	Oct-Dec	5	12	44	3	36
	Jan-Mar	6	23	70	0	1
Rainbow smelt	Total Year	5	19	48	4	24
	Apr-Jun	3	9	15	6	67
	Jul-Sep	4	21	62	8	5
	Oct-Dec	4	16	51	5	24
	Jan-Mar	8	36	32	4	21
Emerald shiner	Total Year	3	38	44	5	10
Spottail shiner	Total Year	3	44	18	9	26
White perch	Total Year	8	16	25	4	48

[a]Refer to Figure 2.0-5

increased. Observations of the screens during rotation and wash indicate that the distribution of fish on Screens 1 and 4 appears random, while the high percentage of fish collected on Screens 2 and 3 are on the third of the screen closest to the bypass. This suggests that the impingement process is not related solely to the swimming ability of the fish but rather is a function of its behavior. To open-water pelagic fish (alewife and rainbow smelt), the constriction at the bypass possibly elicits an avoidance response that reduces the potential for successful diversion. By attempting to maintain themselves just upstream of the constriction to the bypass, the fish are subjecting themselves to a greater potential for impingement. This would explain the observed elevated impingement rate at Screens 2 and 3.

An additional factor possibly contributing to the observed impingement on Screens 2 and 3 may be the presence of several 20-cm (8-in.) diameter pipes extending vertically along the center wall from above the water surface to the bottom of the screenwell. Their position approximately 1.5 to 2.4 m (5 to 8 ft) upstream of the bypass may produce a localized eddy in the area of the bypass that elicits an avoidance response from some fish. Studies conducted by Schuler (1973) indicated that test specimens moved into and through the bypass only if the flow in the bypass was free from turbulence. Eddy currents or backwellings significantly reduced the passage of fish into the bypass channel.

The impingement rate on Screen 5 relative to Screens 1-4 differs widely by species. This variability is discussed in terms of the effectiveness of the primary and secondary diversion system in Section 3.5.1.

3.5 DIVERSION EFFICIENCIES

3.5.1 Primary and Secondary Diversion Efficiency

3.5.1.1 Relative Efficiency. The monthly mean entrapment rates (the sum total of the impingement and diversion rates) for 10 selected species are presented in Table 3.0-9. These rates were used to calculate the primary diversion efficiency (PDE) and the secondary diversion efficiency (SDE) (Tables 3.0-10 and 3.0-11). Only alewife and rainbow smelt were numerous enough for seasonal trends in diversion efficiency to be identified. The PDE data (Table 3.0-10) indicate a consistent decrease in diversion efficiency for most of the species during the two years sampled (April 1981 - March 1982 and April 1982 - March 1983). This trend is most clearly demonstrated in the spring alewife and rainbow smelt results. Spring of 1981 saw a major nearshore migration of adult alewives that was reflected in a high entrapment rate of predominantly subadult and adult alewife from April through July. Little natural mortality was observed in the area, and diversion rates (Table 3.0-10) were high. The following spring (1982), lake water temperatures remained below normal and large numbers of alewives were observed floating dead in Oswego Harbor and along the shoreline at the time of the annual onshore alewife migration. This high natural mortality was reflected in low diversion efficiencies. The low abundances of YOY alewife in the fall of 1982 relative to the fall of 1981 is a further indication of the poor condition of the spring 1982 alewife spawning stock.

While natural mortality of rainbow smelt was not observed during April of either 1981 or 1982 (month of peak entrapment of adult smelt), the same environmental stress that contributed to the alewife mortality may have contributed to the decreased diversion efficiency during the spring of 1982 relative to 1981.

TABLE 3.0-9

ESTIMATED MONTHLY ENTRAPMENT RATE[a]

Oswego Steam Station Unit 6 - April 1981 - March 1983

MONTH	AW	RSM	EWSH	GSD	WP	STSH	SMB	TSB	YP	MOTS	GRAND TOTAL[b]
Apr 1981	74.5	12.5	0.4	1.2	1.0	0.5	0	0	0.4	0.2	94.0
May	118.7	4.5	0.1	0	1.0	0.4	0	0	0.4	0.6	128.9
Jun	58.2	0.8	0.3	0.3	0.2	0.3	0	0	0.3	0	63.6
Jul	25.6	0.3	0	0	0.1	0.7	0.3	0.1	0	0	27.4
Aug	1.5	0	0	0	0	2.0	1.6	0	0.4	0.1	5.6
Sep	29.9	16.6	10.0	3.0	0	0.5	0	0	0.2	1.0	62.5
Oct	112.1	104.8	8.3	19.3	8.9	5.5	0.2	0	0.5	2.2	267.9
Nov	10.4	110.1	3.6	6.6	2.6	0.7	0	2.4	0.3	1.1	141.7
Dec	2.0	164.1	1.1	1.2	0.2	0.2	0	6.3	0	0.4	178.6
Jan 1982	2.8	50.4	0.7	0.8	0.4	0.6	0.2	0.2	0.4	5.0	63.8
Feb	0.4	8.5	1.4	0.2	0.4	0	0.4	0.1	0	0.7	12.9
Mar	0.4	11.6	0.9	0.4	2.5	0.2	0.2	0.2	0.2	0.4	19.4
Apr	55.3	75.0	1.1	0.2	4.3	0.8	c	0.4	0.6	0.6	143.6
May	25.7	0.8	0.5	c	0.1	0.2	0.2	0	0.2	0.2	29.8
Jun	16.1	2.2	0.2	0	0.2	0	0	0	0.2	0.1	20.9
Jul	38.0	0.9	0.4	0	0.4	0.4	0.4	0	0.2	0.3	42.2
Aug	3.4	1.7	0.2	0	1.7	0.7	1.9	c	0.5	0.4	12.6
Sep	16.4	9.8	1.0	0.3	0.4	2.1	0.4	0	0	0.2	32.3
Oct	6.9	3.3	0.3	0.4	0.1	1.0	2.0	0	0	0.9	15.6
Nov	1.9	7.1	0	1.1	0.3	0.4	0.7	0	0.2	0.5	14.9
Dec	0.4	2.3	0.2	0.2	0.4	0	0	0	0	0.3	4.0
Jan 1983	0.2	2.1	c	0.2	0	0	c	0	c	c	3.0
Feb	0	0.3	c	c	0.3	0	0	0	0	c	0.8
Mar	10.9	1.9	0.2	0.2	0.1	0	0	0	0	0.8	14.6

[a] No./hr (sum total of impingement, diversion, and viability studies).
[b] All species collected; includes small numbers of other species.
[c] <0.1.

AW - Alewife
RSM - Rainbow smelt
EWSH - Emerald shiner
GSD - Gizzard shad
WP - White perch
STSH - Spottail shiner
SMB - Smallmouth bass
TSB - Threespine stickleback
YP - Yellow perch
MOTS - Mottled sculpin

TABLE 3.0-10

SECONDARY DIVERSION EFFICIENCY[a] OF SELECTED SPECIES

Oswego Steam Station Unit 6 - April 1981 - March 1983

MONTH	AW	RSM	WP	GSD	EWSH	STSH	YP	SMB	TSB	MOTS
Apr 1981	99.2	99.7	93.8*	97.3*	93.2*	95.9*	92.6*	100*	84.5*	62.0*
May	97.6	97.3*								
Jun	96.8	97.3*								
Jul	95.4	97.3*								
Aug	100	97.3*								
Sep	51.5	77.9								
Oct	87.7	78.5								
Nov	91.0	70.2								
Dec	99.0	82.4								
Jan 1982	1.8	80.3								
Feb	41.0*	62.5								
Mar	41.0*	78.8								
Apr	41.0*	83.5*	85.3*	82.7*	75.6*	87.1*	83.3*	91.1*	81.2*	77.5*
May	81.1	83.5*								
Jun	90.9	80.4*								
Jul	93.0	80.4*								
Aug	73.8	58.3								
Sep	74.8	86.5								
Oct	87.2	90.6								
Nov	95.6*	90.1								
Dec	95.6*	91.2								
Jan 1983	95.6*	68.5*								
Feb	95.6*	68.5*								
Mar	65.9	77.2								
Program Composite Mean	83.3*	79.8*	90.3*	96.9*	91.8*	93.3*	87.0*	92.2*	84.4*	64.5*

*Composited across months

[a]As a percent (%)

AW - Alewife
RSM - Rainbow smelt
EWSH - Emerald shiner
GSD - Gizzard shad
WP - White perch
STSH - Spottail shiner
SMB - Smallmouth bass
TSB - Threespine stickleback
YP - Yellow perch
MOTS - Mottled sculpin

TABLE 3.0-11

SECONDARY DIVERSION EFFICIENCY[a] OF SELECTED SPECIES

Oswego Steam Station Unit 6 - April 1981 - March 1983

MONTH	AW	RSM	WP	GSD	EWSH	STSH	YP	SMB	TSB	MOTS
Apr 1981	98.6	99.1	93.9*	97.4*	99.0*	98.1*	100*	100*	83.3*	80.3*
May	93.2	94.3*								
Jun	78.2	94.3*								
Jul	87.6	94.3*								
Aug	36.7	94.3*								
Sep	95.4	98.4								
Oct	92.1	93.1								
Nov	94.1	91.6								
Dec	96.4	90.2								
Jan 1982	0	90.2								
Feb	99.8*	96.2								
Mar	99.8*	98.2								
Apr	99.8*	98.6*	99.0*	95.9*	95.1*	94.9*	100*	97.5*	98.6*	92.7*
May	99.0	98.6*								
Jun	96.3	54.5*								
Jul	95.3	54.5*								
Aug	90.6	95.1								
Sep	88.3	88.3								
Oct	82.7	91.2								
Nov	92.3*	97.4								
Dec	92.3*	93.7								
Jan 1983	92.3*	100*								
Feb	92.3*	100*								
Mar	99.5	100								
Program Composite Mean	93.0*	93.0*	95.9	97.4*	98.7*	97.3*	100*	99.8*	84.0*	82.8*

*Composited across months

[a]As a percent (%)

AW - Alewife
RSM - Rainbow smelt
EWSH - Emerald shiner
GSD - Gizzard shad
WP - White perch
STSH - Spottail shiner
SMB - Smallmouth bass
TSB - Threespine stickleback
YP - Yellow perch
MOTS - Mottled sculpin

The remaining species typically exhibited lower PDEs in the second year of study, but this could be related to their peak period of occurrence and plant operating conditions. During the first year of study, entrapment was greatest for most of these species during October. Much less entrapment was seen during the second year, and most of this occurred during April. In October 1981, the plant did not temper the intake flow with heated discharge water, as it did the following April. Besides the thermal stress applied to the entrapped fish, tempering creates turbulence in the primary screenwell that contributes to impingement.

The low PDE values for mottled sculpin are indicative of the demersal habitat preferred by this species. These fish commonly sit on the screens, and are not diverted along the screen. Threespine stickleback behave similarly, but not to the extent of the sculpin.

Seasonal variation in PDE was most evident in the spring entrapment of primarily subadults and adults and the fall entrapment of young-of-the-year. As previously discussed, PDE values varied between years based on the relative condition of the fish stock entrapped; however, the subadult/adult alewife and rainbow smelt typically had higher diversion efficiencies than did the corresponding young-of-the-year.

The SDE values varied much less than the PDE values. Values characteristically exceeded 90%. Low SDE values (54.5%) for rainbow smelt during June and July 1982 were probably a function of the small sample size available for testing.

3.5.1.2 Relative Impingement Abundance. The effectiveness of the primary and secondary system was discussed in Section 3.5.1.1 in terms of percent diversion. Table 3.0-12 relates these data to the entrapment rate by providing the estimated monthly impingement for

the primary vs the secondary diversion system. Over the two-year period, an estimated 112,121 rainbow smelt and 92,758 alewife were impinged at Unit 6, and 78 and 69% of these, respectively, were collected on Screens 1-4. The primary diversion system accounted for 56% of the gizzard shad impingement and 85% of the emerald shiner impingement (Table 3.0-12).

3.5.1.3 Length-Frequency. Length-frequency distribution of fish collected in the primary diversion system was indistinguishable from that found for fish collected from the secondary diversion system. Length-frequency data for rainbow smelt, alewife, and white perch collected on Screens 1-4 and Screen 5 are presented in Tables 3.0-13 through 3.0-15, respectively. Both the adult (primarily spring) and juvenile (primarily fall) demonstrate the same distribution between screens.

3.5.2 Total Diversion Efficiency

The overall effectiveness of the diversion system (total diversion efficiency, TDE) is defined as the ratio of the number of fish entering the secondary diversion bypass (diversion rate) to the number of fish entering the primary screenwell (entrapment rate). Thus:

$$TDE = \frac{DIV}{E_R} = \frac{DIV}{IMP_{1-4} + IMP_5 + DIV}$$

or

$$TDE = PDE \times SDE$$

Table 3.0-16 provides the TDE for the 10 dominant species. Alewife and rainbow smelt were abundant enough to permit identification of

TABLE 3

ESTIMATED MONTHLY IMPINGEMENT BY DIVERSION SYSTEM

Oswego Steam Station Unit 6 - April 1981 - March 1983

MONTH	RSM 1°	RSM 2°	AW 1°	AW 2°	WP 1°	WP 2°	EMSH 1°	EMSH 2°	GSD 1°	GSD 2°	STSH 1°	STSH 2°
Apr 1981	29	65	418	670	0	22	0	0	0	0	0	0
May	97	164	2,120	5,818	0	7	0	7	0	0	0	0
Jun	0	65	1,332	8,856	0	14	0	0	0	0	0	0
Jul	0	0	878	2,247	15	0	0	0	0	0	0	0
Aug	0	0	0	469	0	0	0	0	0	0	97	0
Sep	1,750	94	10,440	504	0	0	50	0	94	50	22	22
Oct	16,777	4,226	10,282	5,811	179	223	164	37	171	387	37	37
Nov	23,609	4,694	670	403	122	137	122	29	86	101	0	7
Dec	21,435	9,865	7	37	0	7	97	7	0	7	0	7
Jan 1982	7,380	2,946	372	7	7	15	52	22	149	7	67	22
Feb	2,137	134	54	0	7	0	128	27	54	7	0	0
Mar	1,830	119	126	0	112	0	260	0	97	0	45	0
Apr	8,899	547	23,479	36	353	7	180	14	58	0	79	0
May	112	67	3,616	156	7	0	0	0	7	7	0	0
Jun	353	684	1,051	389	0	0	7	0	0	0	0	0
Jul	30	30	1,994	1,235	0	0	0	0	0	0	0	0
Aug	439	30	670	179	387	7	15	0	0	0	52	15
Sep	763	576	2,981	1,037	14	29	7	29	0	0	187	58
Oct	231	193	655	774	0	37	7	30	0	0	37	119
Nov	511	122	50	101	0	0	0	0	14	7	0	0
Dec	156	97	15	15	7	7	0	0	0	0	0	0
Jan 1983	417	0	7	0	0	0	7	0	30	30	0	0
Feb	128	0	0	0	20	0	7	0	7	0	0	0
Mar	320	0	2,775	22	22	0	0	0	0	0	0	0
Total	87,403	24,718	63,992	28,766	1,252	512	1,103	202	767	603	623	287
SUM TOTAL	112,121		92,758		1,764		1,305		1,370		910	

[a]Based on monthly mean impingement rate (No./hr) from all impingement collections.

1° = Primary diversion system (screen 1-4)
2° = Secondary diversion system (screen 5)

AW - Alewife
RSM - Rainbow smelt
EMSH - Emerald shiner
GSD - Gizzard shad
WP - White perch

TABLE 3.0-13

LENGTH FREQUENCY OF RAINBOW SMELT IN IMPINGEMENT COLLECTIONS

Oswego Steam Station Unit 6 - April 1981-March 1982

SCREEN	LENGTH[a]	APR 1981	MAY 1981	JUN 1981	JUL 1981	AUG 1981	SEP 1981	OCT 1981	NOV 1981	DEC 1981	JAN 1982	FEB 1982	MAR 1982
		PERCENT OF TOTAL MEASURED WITHIN LENGTH INTERVAL											
Screens 1-4	3.0- 5.0	3	0				39	7	17	21	16	9	14
	5.1-10.0	27	30				57	92	82	79	81	89	76
	10.1-15.0	67	20				4	b	b	0	1	1	8
	15.1-20.0	3	50				0	1	0	0	1	1	3
	20.1-25.0	0	0				0	0	0	0	0	0	0
	Mean	10.7	13.4	-	-	-	5.5	6.2	5.8	5.6	5.9	5.9	6.8
	N	33	10	0	0	0	23	363	462	939	458	133	115
Screen 5	3.0- 5.0	0	0	0			0	27	13	12	4	0	10
	5.1-10.0	33	27	67			100	71	85	88	96	100	90
	10.1-15.0	33	27	0			0	2	2	0	0	0	0
	15.1-20.0	33	47	33			0	0	0	0	0	0	0
	20.1-25.0	0	0	0			0	0	0	0	0	0	0
	Mean	12.4	13.1	9.7	-	-	6.3	5.6	6.1	5.8	6.0	5.8	5.7
	N	3	15	3	0	0	1	66	109	660	275	2	10

[a] Total length in cm.

[b] Less than 0.5%

TABLE 3.0-14

LENGTH FREQUENCY OF ALEWIFE IN IMPINGEMENT COLLECTIONS

Oswego Steam Station Unit 6 - April 1981-March 1982

		PERCENT OF TOTAL MEASURED WITHIN LENGTH INTERVAL											
		1981									1982		
SCREEN	LENGTH[a]	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
Screen 1-4	3.1- 5.0	0	0	0	0		75	16	0				0
	5.1-10.0	12	31	9	25		25	83	100				0
	10.1-15.0	24	18	19	0		0	1	0				15
	15.0-20.1	62	50	68	75		0	0	0				85
	20.1-25.0	2	0	4	0		0	0	0				0
	Mean	15.4	14.0	16.1	15.0	-	4.9	5.9	6.8	-	-	-	16.8
	N	317	157	74	4	0	61	276	20	0	0	0	13
Screen 5	3.1- 5.0	0	0	b	0		0	24	0	0			
	5.1-10.0	13	41	14	0		100	70	100	100			
	10.1-15.0	13	16	11	13		0	6	0	0			
	15.1-20.0	73	43	74	87		0	0	0	0			
	20.1-25.0	0	b	1	0		0	0	0	0			
	Mean	15.6	13.1	15.7	16.7	-	5.2	6.4	6.8	6.9	-	-	-
	N	90	472	398	64	0	1	33	5	4	0	0	0

[a]Total length in cm.

[b]less than 0.5%

TABLE 3.0-15

LENGTH FREQUENCY OF WHITE PERCH IN IMPINGEMENT COLLECTIONS

Oswego Steam Station Unit 6 - April 1981-March 1982

		PERCENT OF TOTAL MEASURED WITHIN LENGTH INTERVAL											
		1981									1982		
SCREEN	LENGTH[a]	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
Screen 1-4	3.1- 5.0	0						21	0		0	0	0
	5.1-10.0	100						79	100		50	0	38
	10.1-15.0	0						0	0		0	0	15
	15.1-20.0	0						0	0		0	0	15
	> 20	0						0	0		50	100	31
	Mean	8.1	-	-	-	-	-	6.1	7.6	-	13.7	26.5	14.7
	N	17	0	0	0	0	0	19	4	0	2	1	13
Screen 5	3.1- 5.0	0	0	0				44	0	0	0		
	5.1-10.0	100	0	0				56	100	100	100		
	10.1-15.0	0	0	0				0	0	0	0		
	15.1-20.0	0	0	0				0	0	0	0		
	> 20	0	100	100				0	0	0	0		
	Mean	8.5	35.0	25.8	-	-	-	5.3	6.4	7.8	8.2	-	-
	N	1	1	1	0	0	0	25	6	1	3	0	0

[a]Total length in cm.

TABLE 3.0-16

TOTAL DIVERSION EFFICIENCY OF SELECTED SPECIES

Oswego Steam Station Unit 6 - April 1981 - March 1983

MONTH	AW	RSM	WP	GSD	EMSH	STSH	YP	SMB	TSB	MOTS
Apr 1981	97.8	98.8	88.1*	94.8*	92.3*	94.1*	92.6*	100*	70.4*	49.8*
May	91.0	91.8*								
Jun	75.7	91.8*								
Jul	83.6	91.8*								
Aug	36.7	91.8*								
Sep	49.1	76.7								
Oct	80.7	73.0								
Nov	85.6	64.3								
Dec	95.4	74.4								
Jan 1982	0	72.5								
Feb	40.9*	60.2								
Mar	40.9*	77.4								
Apr	40.9*	82.3*	84.4*	79.3*	71.9*	82.7*	83.3*	88.8*	80.1*	71.8*
May	80.3	82.3*								
Jun	87.6	43.8*								
Jul	88.6	43.8*								
Aug	66.9	55.4								
Sep	66.0	76.4								
Oct	72.2	82.5								
Nov	88.3*	87.7								
Dec	88.3*	85.5								
Jan 1983	88.3*	68.5*								
Feb	88.3*	68.5*								
Mar	65.6	77.2								
Program Mean	77.5*	74.2*	86.6*	94.4*	90.6*	90.8*	87.0*	92.0*	70.9*	53.4*

*Composited across month

AW - Alewife
RSM - Rainbow smelt
EWSH - Emerald shiner
GSD - Gizzard shad
WP - White perch
STSH - Spottail shiner
SMB - Smallmouth bass
TSB - Threespine stickleback
YP - Yellow perch
MOTS - Mottled sculpin

seasonal variations in diversion efficiency while the remaining species were presented as a yearly and program average.

Alewife diversion efficiency varied widely, from zero to 97.8%, with a program mean of 77.5%. The primary variable affecting alewife diversion was the condition of the population when entrapped. The difference between the 91.0-97.8% TDE in spring of 1981 and the 40.9-80.3% TDE in spring of 1982 can be attributed to the poor condition of the alewife stock (Section 3.4.1). Typically, the alewife TDE also dropped during the post-spawn period when the adults were emaciated and in poor condition.

Rainbow smelt TDE also varied over the duration of the study. The lowest TDE (43.8%) was reported in the summer of 1982, while the highest value was in the early spring of 1981 when the pre-spawn adults were diverted at a TDE of 98.8%. Like the alewife, rainbow smelt diversion was related to condition of the entrapped population.

Size or age of the entrapped fish also contributed to their ability to avoid impingement and divert through the system. Table 3.0-17 provides the total estimated alewife, rainbow smelt, and white perch entrapment over the two-year study period, the total number estimated to be diverted, and the total number estimated to be impinged, broken down by young-of-the-year and adult or subadult. These estimates are based on the average monthly impingement and diversion rates (No./hr) and are therefore subject to certain biases in sampling (see Section 3.3.1).

The majority of the entrapped alewife (68%) were subadult or adult (total length > 10 cm) while the majority of entrapped rainbow smelt (84%) were young-of-the-year. Diversion efficiency was greater for the larger size class of all three species reported in Table 3.0-17.

TABLE 3.0-17

ESTIMATED NUMBERS FOR ALEWIFE, RAINBOW SMELT, AND WHITE PERCH ENTRAPPED, IMPINGED, AND DIVERTED[a] BY SIZE CLASS[b]

Oswego Steam Station Unit 6 - April 1981 - March 1983

	ALEWIFE		RAINBOW SMELT		WHITE PERCH	
	≤10[b]	>10[b]	≤10[b]	>10[b]	≤13[b]	>13[b]
No. Entrapped	145,266	303,604	363,166	70,696	12,423	6,385
No. Impinged	39,686	53,072	107,741	4,380	1,319	445
No. Diverted	105,580	250,532	255,425	66,316	11,104	5,940
% Effective (TDE)	73	83	70	94	89	93

[a]Estimate based on average monthly collection rates (No./hr) over the period April 1981 through March 1983.

[b]Measured in centimeters.

Totals of 83, 94, and 93% of the entrapped adult alewife, rainbow smelt, and white perch were diverted through the system. Only 73, 70, and 89% of the young-of-the-year alewife, rainbow smelt, and white perch that were entrapped avoided impingement.

The remaining eight species presented on Table 3.0-16 showed program mean TDEs ranging from 53.4% for mottled sculpin to 94.4% for gizzard shad. Except for threespine stickleback and mottled sculpin, the TDEs were lower in the second year of the program than in the first.

CHAPTER 4.0

SURVIVAL SUBSEQUENT TO DIVERSION

4.1 SAMPLING PROCEDURE

Viability collections were made from the sampling basin located downstream of the screenwells and jet pumps and just prior to return offshore. Figure 2.0-5 provides a schematic of Unit 6.

The sampling basin consists of a 2.4 x 2.4 m (8 x 8 ft) pit in the northwest corner of the screenhous (Figure 2.0-3). A 76-cm (30-in.) intake pipe enters vertically through the floor of the pit (4.9 m [16 ft]) below screenhouse elevation. A 46-cm (18-in.) discharge pipe returns the flow to the primary screenwell. A hinged counter-weighted trap door over the inflow pipe opened when flow was diverted into the basin and closed when the flow ceased. The 46-cm (18-in.) exit port was covered by a 0.3-cm (0.13-in.) mesh screen of approximately 3.0-m^2 (32-ft^2) surface area inclined at a 45° angle to the wall and floor. A fish crowding device was used to facilitate fish sorting and reduce handling. It is designed to slide down the drain screen and across the basin floor, maintaining a tight seal with the basin wall, and was used to gently crowd the collected fish to one side of the basin to permit identification and sorting.

A sample was initiated by switching the lake discharge flow to the sampling basin by closing the gate valve on the discharge pipe and opening the gate valve on the sampling basin entrance pipe. Piezometer tubes on the discharge pipe were monitored to ensure that the water flow into the smapling basin equalled the previous lake discharge flow. At sample termination (after 15 okr 30 min), the gate valves were switched, returning the lfow to the lake, and the basin was slowly draiined to a depth of approximately 0.3 (1 ft).

The fish crowder was lowered along the inclined screen and manually slid across the basin floor. Live (swimming normally) and/or stunned (exhibiting some locomotion but not swimming normally) fish of the selected species were sorted into labeled transfer buckets full of ambient basin water and immediately transferred to numbered latent observation tanks. Sorting was conducted under subdued light and with minimal handling to reduce shock.

If large numbers of a select species were collected, random subsampling of both live and stunned fish was performed to select test organisms. Test fish were transferred to either 570-liter (150-gal) or 18-liter (5-gal) containers, depending on their size and numbers. Holding capacity of each tank was based on 5 g (0.01 lb) of fish weight per liter (1.0 qt) of water.

Test fish were segregated by life conditions (live or stunned) and by predators and prey. Initial chemistry parameters were determined for each holding tank. The fish not held for latent survival were recorded by species and life condition (live, stunned, or dead) and frozen for subsequent analysis.

Latent survival observations were conducted at 0, 12, 18, 36, 84, and 96 hrs following collection. At each observation, the holding tanks were checked for dead organisms. Any dead fish were removed, recorded, and frozen for subsequent analysis. At termination (96 hrs), all fish were sorted by life condition, recorded, bagged separately, and frozen. At the initial and final (96-hr) observations, temperature, dissolved oxygen, pH, and conductivity measurements in the holding tanks were recorded. At all other observations, temperature measurements were recorded.

All fish collected from the sample basin during a given survey and not tested for latent survival were identified to species, enumerated, and weighed. No damaged or decomposing fish were included in

biomass measurements. Individual length and weight measurements, a visual examination of sex and gonad development, and visual examination for parasites was performed on selected species. All fish that were tested for latent survival received individual length and weight measurements.

4.2 SAMPLING SCHEDULE

The April 1981-March 1982 sampling was the first year of the two-year program to evaluate the effectiveness of the angled screen diversion system. It included seasonal intensive sampling and routine sampling. At the beginning of the spring, fall, and winter seasons, an intensive three-day survey, including eighteen 15- or 30-min viability collections, was conducted. A routine survey was performed three times per week in the spring, fall, and winter and once per week in the summer. Each 8-hr routine survey consisted of six 15- or 30-min collections performed coincidently with the diel period of highest fish abundances (as determined from the intensive survey). Table 3.0-1 provides a summary of the scheduled sampling effort for each month.

The second year (April 1982-March 1983) of the evaluation of the diversion system was modified slightly based on the first year results and was conducted with the first year of the required SPDES monitoring program. Surveys were performed on a variable schedule, depending upon fish abundance. Three routine viability surveys were conducted per week during April, May, and October through December. One survey per week was conducted during the remaining seven months. Table 3.0-1 summarizes the sampling schedule.

4.3 EXPERIMENTAL DESIGN

One of the difficulties encountered in survival studies is the low concentration of test organisms. Many of the species enter the

intake at rates less than one fish per hour. The volume of water and the time sampled in a survival study are limited by the need to collect the organisms at low velocity and over a short duration to minimize organism stress in the collection area. To weight all collections equally when estimating survival is not advisable since proportions based on only a few fish are extremely variable. Therefore, where low numbers were collected, test organisms collected for each species (and age group) within a block were composited. The survival for any block or group of similar data are determined as follows:

$$P_S = \text{Proportion Surviving} = \frac{\sum_{i=1}^{K} \text{No. live* in ith sample}}{\sum_{i=1}^{K} \text{Total no. caught in ith sample}}$$

where K = No. of samples in the block (month, season, or year depending upon organism density);

$$95\%\ \text{CI for } P_S = P_S \pm 1.96 \sqrt{\frac{P_S(1-P_S)}{n}}$$

where n = No. of test fish in the block = $\sum_{i=1}^{K}$ Total no. caught in ith sample

When only a few organisms are collected, this formula is used to calculated the precision of the survival estimate; it also defines the maximum number of fish needed for any degree of precision in the survival estimate.

When sufficient numbers of test fish were present, a block was further described by the two variables: age or size class and time interval (month, season, or year). Some species demonstrated multiple age classes that were distinctly season-specific. Adult

*"Live" refers to those alive after 96 hrs.

alewife, rainbow smelt, and white perch predominated in the spring while juvenile alewife, rainbow smelt, gizzard shad, white perch, and smallmouth bass predominated in the fall. Emerald shiner, spottail shiner, threespine stickleback, mottled sculpin, and johnny darter showed seasonal distribution based on numbers, but were not distinct in their size class or age distribution. In some cases a block for juvenile fish extended over a different time frame than a corresponding block for the adults of the same species.

Since viability observations were conducted on live and stunned fish and since not all fish that diverted were alive, the results of the viability observations had to be adjusted for the proportion initally classified as live, stunned, or dead. The corrected survival was determined for alewife, rainbow smelt, white perch, emerald shiner, spottail shiner, and gizzard shad according to the following formulae:

$$SUR_c = (IL)\ (IL_{96}) + (IS)\ (IS_{96})$$

where

SUR_c = the corrected survival estimate

IL = the proportion initially classified as live

IL_{96} = the percent of the initially alive that survived through 96 hrs

IS = the proportion initially classified as stunned

IS_{96} = the percent of the initially stunned that survived through 96 hrs

Because of the smaller number of fish tested for the remaining species, the fish initially classified as live and stunned were combined into a single live classification. The corrected survival then was the proportion of the total initial alive (live and stunned) that survived for the 96-hr test period:

$$SURV_c = (TL)\ (TL_{96})$$

where

TL = the total proportion initially classified as live (live and stunned)

TL_{96} = the percent of the total alive that survived through 96 hrs

4.4 INITIAL SURVIVAL

The fish present in each viability or abundance collection were initially classified as live (swimming normally), stunned (exhibiting some locomotion but not swimming normally), or dead (exhibiting no locomotion even upon gentle prodding). Either all or a randomly selected portion of the live and stunned fish were then transferred to the holding facility and observed for latent mortality effects. Each life condition was maintained separately to identify differential mortality for the initially live vs the initially stunned fish. The dead fish were identified, enumerated, and saved for subsequent analysis.

Table 4.0-1 summarizes the results of the initial viability observation following diversion for six species. These results include all fish collected in the sampling basin, a total of 33,834 specimens for these six species.

As described in Section 4.3, sample blocks (a group of samples conducted over a defined interval of time) were used to describe survival of individual species. Since length-frequency analyses were not performed in conjunction with initial classification, the blocks could not be used to segregate by age class, but since

TABLE 4.0-1 (Page [illegible]2)

INITIAL VIABILITY CLASSIFICATION AS LIVE OR DEAD FOLLOWING DIVERSION

Oswego Steam Station Unit 6 - 1981-1983

	ALEWIFE				RAINBOW SMELT				WHITE PERCH			
MONTH	No. OBS	% LIVE	% STUNNED	% DEAD	No. OBS	% LIVE	% STUNNED	% DEAD	No. OBS	% LIVE	% STUNNED	% DEAD
Apr 1981	-				-				475	55.6	22.3	22.1
May	527	14.4	48.2	37.4	36	41.7	30.6	27.8	↓	↓	↓	↓
Jun	1166	33.2	28.5	38.3	↓				↓	↓	↓	↓
Jul	301	55.8	14.3	29.9	↓				↓	↓	↓	↓
Aug	171	12.3	2.3	85.4	0				↓	↓	↓	↓
Sep	↓				95	31.6	0	68.4	↓	↓	↓	↓
Oct	5,204	63.1	7.4	29.5	3,517	61.0	4.6	34.4	↓	↓	↓	↓
Nov	246	59.3	15.4	25.2	2,017	40.5	11.7	47.8	↓	↓	↓	↓
Dec	70	42.9	37.1	20.0	5,849	31.3	18.8	50.0	↓	↓	↓	↓
Jan 1982	↓				2,541	38.1	23.5	38.3	↓	↓	↓	↓
Feb	↓				270	16.3	47.4	36.3	↓	↓	↓	↓
Mar	↓				443	49.0	10.8	40.2	↓	↓	↓	↓
Apr	1,033	77.5	18.3	4.2	2,674	71.8	8.9	19.3	↓	↓	↓	↓
May	1,517	42.6	45.3	12.1	96	40.6	12.5	46.9	↓	↓	↓	↓
Jun	418	29.7	55.7	14.6	↓				↓	↓	↓	↓
Jul	1,086	41.5	40.5	18.0	↓				↓	↓	↓	↓
Aug	79	53.2	17.7	29.1	↓				↓	↓	↓	↓
Sep	392	45.4	8.2	46.4	180	20.6	5.0	74.4	↓	↓	↓	↓
Oct	151	19.2	17.9	62.9	81	24.7	3.7	71.6	↓	↓	↓	↓
Nov	84	73.8	9.5	16.7	286	32.9	13.6	53.5	↓	↓	↓	↓
Dec	51	52.9	33.3	13.7	79	62.0	7.6	30.4	↓	↓	↓	↓
Jan 1983	↓				51	21.6	13.7	64.7	↓	↓	↓	↓
Feb	↓				↓							
Mar	↓				↓							

- Not separated by initial life classification.

↓ Combined across months during periods of low abundance.

TABLE 4.0-1 (Page 2 of 2)

INITIAL VIABILITY CLASSIFICATION AS LIVE OR DEAD FOLLOWING DIVERSION

Oswego Steam Station Unit 6 - 1981-1983

	EMERALD SHINER				SPOTTAIL SHINER				GIZZARD SHAD			
MONTH	No. OBS	% LIVE	% STUNNED	% DEAD	No. OBS	% LIVE	% STUNNED	% DEAD	No. OBS	% LIVE	% STUNNED	% DEAD
Apr 1981	-				-				-			
May	0				0				0			
Jun	0				289	92.7	2.1	5.2	0			
Jul	0				↓				0			
Aug	0				↓				0			
Sep	83	92.8	0	7.2	↓				22	63.6	13.6	22.7
Oct	425	94.1	3.3	2.6	↓				1,043	80.9	9.6	9.5
Nov	106	86.8	6.6	6.6	57	86.0	5.3	8.8	188	59.6	27.7	12.8
Dec	51	74.5	17.6	7.8	↓				54	33.3	51.9	14.8
Jan 1982	35	71.4	17.1	11.4	↓				41	4.9	87.8	7.3
Feb	41	87.8	9.8	2.4	↓				↓			
Mar	20	65.0	20.0	15.0	↓				↓			
Apr	26	73.1	19.2	7.7	↓				0			
May	25	40.0	8.0	52.0	↓				0			
Jun	↓				0				0			
Jul	↓				21	71.4	9.5	19.0	0			
Aug	↓				↓				0			
Sep	↓				40	55.0	5.0	40.0	45	82.2	6.7	11.1
Oct	↓				36	77.8	0	22.2	↓			
Nov	↓				↓				↓			
Dec	↓				0				↓			
Jan 1983	↓				0				↓			
Feb	↓				0				↓			
Mar	↓				0				↓			

- Not separated by initial life classification.

↓ Combined across months during periods of low abundance.

seasonal trends were predominantly composed of single age groups, i.e., young-of-the-year (YOY) in the fall and adults in the spring, the blocks typically represent single age groups of fish.

As demonstrated by the data, a significant proportion of some species were dead at initial sorting and classification. During August 1981, 85% of the diverted alewives were dead at collection while during April 1982 only 4% were collected dead. The ranges for rainbow smelt, gizzard shad, and white perch were 19 to 74%, 7 to 23%, and 2 to 57%, respectively. In each case, the periods of highest initial mortality were associated with entrapment of YOY while the periods of lowest initial mortality were associated with entrapment of adults of the species. Control tests run in July 1982 on alewife (one of the most sensitive species) placed directly into the sampling basin during a collection indicated an initial mortality associated with the collection process of less than 4% (4 initially dead out of 110 test fish). Thus, the initial mortalities observed in the collection basin were most likely a manifestation of stresses that occurred before the fish reached the sampling basin rather than from stresses occurring during the collection process.

4.5 LONG-TERM SURVIVAL

Long-term survival observations (96-hr) were conducted on 7905 fish representing 34 species (Table 4.0-2). Ten of these species were represented by more than 40 specimens. Two species, alewife and rainbow smelt, were represented by enough individuals to describe their survival by age class and season, while white perch were described by age class (Table 4.0-3). When corrected for initial mortality (Section 4.3), the trends remained essentially the same but the final survivals seen through the system decreased (Table 4.0-4).

TABLE 4.0-2

VIABILITY TESTING

Oswego Steam Station Unit 6 - April 1981 - March 1983

SPECIES	SCIENTIFIC NAME	TOTAL TESTED[a]
Alewife	*Alosa pseudoharengus*	3599
Rainbow smelt	*Osmerus mordax*	2846
Emerald shiner	*Notropis atherinoides*	367
Gizzard shad	*Dorosoma cepedianum*	249
White perch	*Morone americana*	229
Mottled sculpin	*Cottus bairdi*	125
Spottail shiner	*Notropis hudsonius*	119
Smallmouth bass	*Micropterus dolomieui*	69
Threespine stickleback	*Gasterosteus aculeatus*	63
Yellow perch	*Perca flavescens*	43
Rock bass	*Ambloplites rupestris*	34
Logperch	*Percina caprodes*	31
Johnny darter	*Etheostoma nigrum*	23
Bluegill sunfish	*Lepomis macrochirus*	16
Trout-perch	*Percopsis omiscomaycus*	13
Brown trout	*Salmo trutta*	12
American burbot	*Lota lota*	11
White bass	*Morone chrysops*	8
Rainbow trout	*Salmo gairdneri*	8
Pumpkinseed	*Lepomis gibbosus*	6
Longnose dace	*Rhinichthys cataractae*	6
White sucker	*Catostomus commersoni*	4
Stonecat	*Noturus flavus*	4
Common shiner	*Notropis cornutus*	4
Lake trout	*Salvelinus namaycush*	3
Central mudminnow	*Umbra limi*	2
Lake chub	*Couesius plumbeus*	2
Brown bullhead	*Ictalurus nebulosus*	2
American eel	*Anguilla rostrata*	2
Largemouth bass	*Micropterus salmoides*	1
Chinook salmon	*Oncorhynchus tshawytscha*	1
Goldfish	*Carassius auratus*	1
Black bullhead	*Ictalurus melas*	1
Sea lamprey	*Petromyzon marinus*	1
Total		7905

[a]Includes initially stunned and initially live specimens.

TABLE 4.0-[illegible] 1 of 3)

ALEWIFE, RAINBOW SMELT, AND WHITE PERCH
LONG-TERM (96-hr) SURVIVAL[a] BY SIZE CLASS

Oswego Steam Station Unit 6 - 1981-1983

I. Alewife

	≤10cm				>10cm			
	LIVE		STUNNED		LIVE		STUNNED	
MONTH	No.	% SURV	No.	% SURV	No.	% SURV	No.	% SURV
Apr 1981	69	21.7	NT		805	36.9	NT	
May	201	7.5	17	0	525	12.6	14	0
Jun	↓		↓		160	28.8	142	0.7
Jul	NT		NT		80	55.0	17	0
Aug	NT		NT		↓		↓	
Sep	339	30.7	56	3.6	81	85.2	10	30.0
Oct	│		│		↓		↓	
Nov	│		│		65	49.2	11	18.2
Dec	↓		↓		↓		↓	
Jan 1982	NT		NT		NT		NT	
Feb	NT		NT		NT		NT	
Mar	NT		NT		116	19.0	4	0
Apr	9	0	1	0	↓		↓	
May	↓		↓		102	15.7	70	1.4
Jun	NT		NT		84	11.9	121	0
Jul	NT		NT		│		│	
Aug	65	3.1	9	0	↓		↓	
Sep	│		│		NT		NT	
Oct	│		│		7	85.7	4	0
Nov	│		│		↓		↓	
Dec	↓		↓		NT		NT	
Jan 1983	NT		NT		NT		NT	
Feb	NT		NT		NT		NT	
Mar	NT		NT		NT		NT	

[a]Percent alive at 96-hr observation.
NT = Not tested.

TABLE 4.0-3 (Page 2 of 3)

ALEWIFE, RAINBOW SMELT, AND WHITE PERCH
LONG-TERM (96-hr) SURVIVAL[a] BY SIZE CLASS

Oswego Steam Station Unit 6 - 1981-1983

II. Rainbow Smelt

	≤10cm				>10cm			
	LIVE		STUNNED		LIVE		STUNNED	
MONTH	No.	% SURV	No.	% SURV	No.	% SURV	No.	% SURV
Apr 1981	42	33.3	NT		199	90.4	NT	
May	↓		NT		25	0	NT	
Jun	↓		NT		NT		NT	
Jul	NT		NT		NT		NT	
Aug	NT		NT		NT		NT	
Sep	175	50.3	38	36.8	NT		NT	
Oct	↓		↓		64	70.3	13	30.8
Nov	157	35.0	23	34.8	↓		↓	
Dec	580	12.6	141	14.9	↓		↓	
Jan 1982	301	14.0	179	2.2	170	100	1	100
Feb	42	11.9	29	6.9	↓		↓	
Mar	↓		↓		↓		↓	
Apr	↓		↓		272	97.8	1	0
May	NT		NT		↓		↓	
Jun	NT		NT		↓		↓	
Jul	NT		NT		NT		NT	
Aug	NT		NT		NT		NT	
Sep	83	38.6	7	0	NT		NT	
Oct	↓		↓		3	100	1	0
Nov	↓		↓		NT		NT	
Dec	↓		↓		NT		NT	
Jan 1983	NT		NT		NT		NT	
Feb	NT		NT		NT		NT	
Mar	NT		NT		NT		NT	

[a]Percent alive at 96-hr observation
NT = Not tested.

TABLE 4.0-3 (Page 3 of 3)

ALEWIFE, RAINBOW SMELT, AND WHITE PERCH
LONG-TERM (96-hr) SURVIVAL[a] BY SIZE CLASS

Oswego Steam Station Unit 6 - 1981-1983

III. White Perch

	<13cm				>13cm			
	LIVE		STUNNED		LIVE		STUNNED	
MONTH	No.	% SURV	No.	% SURV	No.	% SURV	No.	% SURV
Apr 1981	38	71.1	9	55.6	152	84.2	21	81.0
May								
Jun								
Jul								
Aug								
Sep								
Oct								
Nov								
Dec								
Jan 1982								
Feb								
Mar								
Apr								
May								
Jun								
Jul								
Aug								
Sep								
Oct								
Nov								
Dec								
Jan 1983								
Feb								
Mar								

[a]Percent alive at 96-hr observation

TABLE 4.0-4

ALEWIFE, RAINBOW SMELT, AND WHITE PERCH SURVIVAL[a] CORRECTED FOR INITIAL MORTALITY

Oswego Steam Station Unit 6 - 1981-1983

MONTH	ALEWIFE ≤10	ALEWIFE ≥10	RAINBOW SMELT ≤10	RAINBOW SMELT ≥10	WHITE PERCH ≤13	WHITE PERCH ≥13
Apr 1981	13.6	23.1	24.1	65.4	51.9	64.9
May	1.1	1.8	24.1	0	↓	↓
Jun	2.5	9.8	24.1	NT	↓	↓
Jul	NT	30.7	NT	NT	↓	↓
Aug	NT	6.8	NT	NT	↓	↓
Sep	3.9	11.2	15.9	NT	↓	↓
Oct	19.6	56.0	32.4	44.3	↓	↓
Nov	18.8	32.0	18.2	32.1	↓	↓
Dec	14.5	27.9	6.7	27.8	↓	↓
Jan 1982	NT	NT	5.8	61.6	↓	↓
Feb	NT	NT	5.2	63.7	↓	↓
Mar	NT	8.2	6.5	59.8	↓	↓
Apr	0	14.7	9.2	70.2	↓	↓
May	0	7.3	NT	39.7	↓	↓
Jun	NT	3.5	NT	39.7	↓	↓
Jul	NT	4.9	NT	NT	↓	↓
Aug	1.6	6.3	NT	NT	↓	↓
Sep	1.4	NT	8.0	NT	↓	↓
Oct	0.6	16.4	9.5	24.7	↓	↓
Nov	2.3	63.2	12.7	NT	↓	↓
Dec	1.6	NT	23.9	NT	↓	↓
Jan 1983	NT	NT	NT	NT	↓	↓
Feb	NT	NT	NT	NT	↓	↓
Mar	NT	NT	NT	NT	↓	↓

NT - None tested for latent survival observations.

[a]Percent surviving 96 hr (Section 4.3).

Alewife survival results varied widely throughout the year and across the two years of study. The two maximum periods of alewife entrapment at OSS-6 are the early spring-summer period when subadult and adult alewives (>10 cm) predominate and the fall period when the YOY (≤10 cm) alewives predominate. Survival of adult alewife following diversion typically exceeded that of YOY alewife.

During the first year of the study, adult alewife survival ranged from 2 to 56%, with the peak spring period ranging from 2 to 23% (Table 4.0-4). Survival during the second year ranged from 4 to 63%, with the peak spring period ranging from 7 to 15%.

At the beginning of their onshore migration (March-April), adult alewife survival through the system was as high as 23%, and dropped to 2-10% during their normal spawning period (May-June). This period was characterized by an increase in water temperature and an increase in the number of emaciated adult alewives collected. Most of the specimens collected during this period had varying degrees of fungal infestation (Saprolegnia sp.). The higher survival observed in July 1981 is most likely reflective of the post-spawn recovery that continues through early fall when the adults move offshore and the YOY predominate.

The low survival results reported during the spring and early summer of 1982 were coincident with a major alewife die-off observed in the vicinity (see Section 3.4). As the population recovered either from the stresses of spawning or environmental conditions (temperature, low iodine levels, etc.) contributing to their observed die-off, adult alewife survival increased. Only a few adults were collected in the fall, but a survival of 56% was observed in October 1981 and 63% in November 1982. The reduction in survival in November and December 1981 could be related to the decreased water temperatures with the onset of winter and/or the effect of tempering that was also initiated during this period.

YOY alewife demonstrated similar seasonal responses. YOY alewife were first observed in the cooling water system in late August when the organisms were 2.5 to 3.5 cm in total length. By October the young had grown to 5.0 to 6.5 cm in total length. Survival during October 1981, when most of the entrapment occurred, was 20%. Survival for the yearlings (8.0-9.0 cm) through May and June (1981) was lower than that reported for YOY in the fall. This pattern agrees with the adult survival and suggests that the late spring mortality commonly observed in alewife populations under natural conditions is not related solely to stresses associated with spawning. Numerous causes for the periodic midwinter, early spring, and summer massive mortalities of alewives have been hypothesized. They range from failure to adjust to temperature extremes and fluctuations on the Great Lakes, exhaustion of the food supply, failure to osmoregulate, failure to extract sufficient iodine from the iodine-poor Great Lakes, or a combination of one or more of these causes (Brown 1968).

Rainbow smelt survival also varied dramatically by age class and season. Adult (>10 cm) rainbow smelt survival subsequent to diversion was closely related to their spawning condition. Throughout the late winter and early spring, rainbow smelt survival ranged between 60 to 70%. By completion of spawning in May, their survival had dropped. Only a few specimens were collected during the summer, and these were typically emaciated and infected with fungus. Numbers of adults remained low throughout the fall, but those collected were in better condition.

YOY (≤10 cm) rainbow smelt survival during the fall was higher than the corresponding alewife YOY survival. Survivals decreased during December and remained low throughout the winter (January-March). The increased survival observed for the smelt yearlings for the spring-summer period (1981) relative to that observed during the winter period (1982) was expected because of the moderating water

temperatures, the termination of tempering, and an increase in planktonic food. It was, however, in contrast to the observed trend for yearling alewife.

White perch were not collected in sufficient abundance to permit breakdown by year, but a difference in survival subsequent to diversion was evident between YOY and adult white perch. YOY white perch ($\leq$13 cm) were primarily collected during October 1981 and showed a survival of 52%, while adult white perch (>13 cm) were primarily collected during April 1982 and showed a significantly higher survival of 65% (Table 4.0-4).

The remaining species were either tested in insufficient numbers to enable similar breakdown (gizzard shad, threespine stickleback) or survival across all conditions was so high that further breakdown was unwarranted (emerald shiner, spottail shiner, smallmouth bass, and yellow perch). Table 4.0-5 provides a summary of these species. Of the 31 species, only four, gizzard shad, trout-perch, threespine stickleback, and central mudminnow, demonstrated a survival of less than 75%. Two of these species, trout-perch and central mudminnow, were tested in insufficient numbers to evaluate their survival results. Since gizzard shad and threespine stickleback are considered fragile species, the results are not surprising.

Overall, survival of fish specimens following passage through the diversion system is highly species-, age-, and season-specific. Species can be classified as hardy, intermediate, or fragile based on their ability to survive the stresses associated with passage through the diversion system. In some cases, survival of individual species may vary widely, depending upon age, i.e., YOY vs adult rainbow smelt, or upon season, i.e., early spring vs late spring rainbow smelt. Typically, adult survival was higher than survival of the YOY of the same species. Adult survival was highest immediately preceding the spawning activity and lowest immediately following.

TABLE 4.0-5

SURVIVAL SUBSEQUENT TO PASSAGE THROUGH THE DIVERSION SYSTEM

Oswego Steam Station Unit 6 - April 1981 - March 1983

TAXON	LONG-TERM VIABILITY RESULTS No. TESTED	No. ALIVE AT 96 hr	% SURVIVING	% INITIAL SURVIVAL[a]	% SYSTEM SURVIVAL
American burbot	11	11	100	100	100
American eel	2	2	100	100	100
Black bullhead	1	1	100	100	100
Brown bullhead	2	2	100	100	100
Brown trout	12	12	100	100	100
Bluegill sunfish	16	16	100	87.5	87.5
Chinook salmon	1	1	100	100	100
Central mudminnow	2	1	50.0	100	50.0
Common shiner	4	4	100	100	100
Emerald shiner	367	341	92.8	93.5	86.8
Gizzard shad	249	152	61.0	90.0	54.9
Goldfish	1	1	100	100	100
Johnny darter	23	22	95.6	94.7	90.5
Lake chub	2	2	100	100	100
Largemouth bass	1	1	100	100	100
Longnose dace	6	6	100	100	100
Logperch	31	31	100	100	100
Lake trout	3	3	100	100	100
Mottled sculpin	125	117	93.6	81.5	76.3
Pumpkinseed	6	5	83.3	100	83.3
Rock bass	34	32	94.1	94.9	89.3
Rainbow trout	8	7	87.5	100	87.5
Sea lamprey	1	1	100	100	100
Smallmouth bass	69	64	92.8	95.1	88.2
Spottail shiner	119	108	90.8	89.4	81.2
Stonecat	4	3	75.0	100	75.0
Threespine stickleback	63	9	14.3	65.4	9.4
Trout-perch	13	11	84.6	83.9	71.0
White bass	8	6	75.0	100	75.0
White sucker	4	3	75.0	100	75.0
Yellow perch	43	42	97.7	100	97.7

[a] Live and stunned fish combined because of the low numbers of fish in one or both categories.

4.6 OFFSHORE SURVIVAL

4.6.1 Sampling Procedure

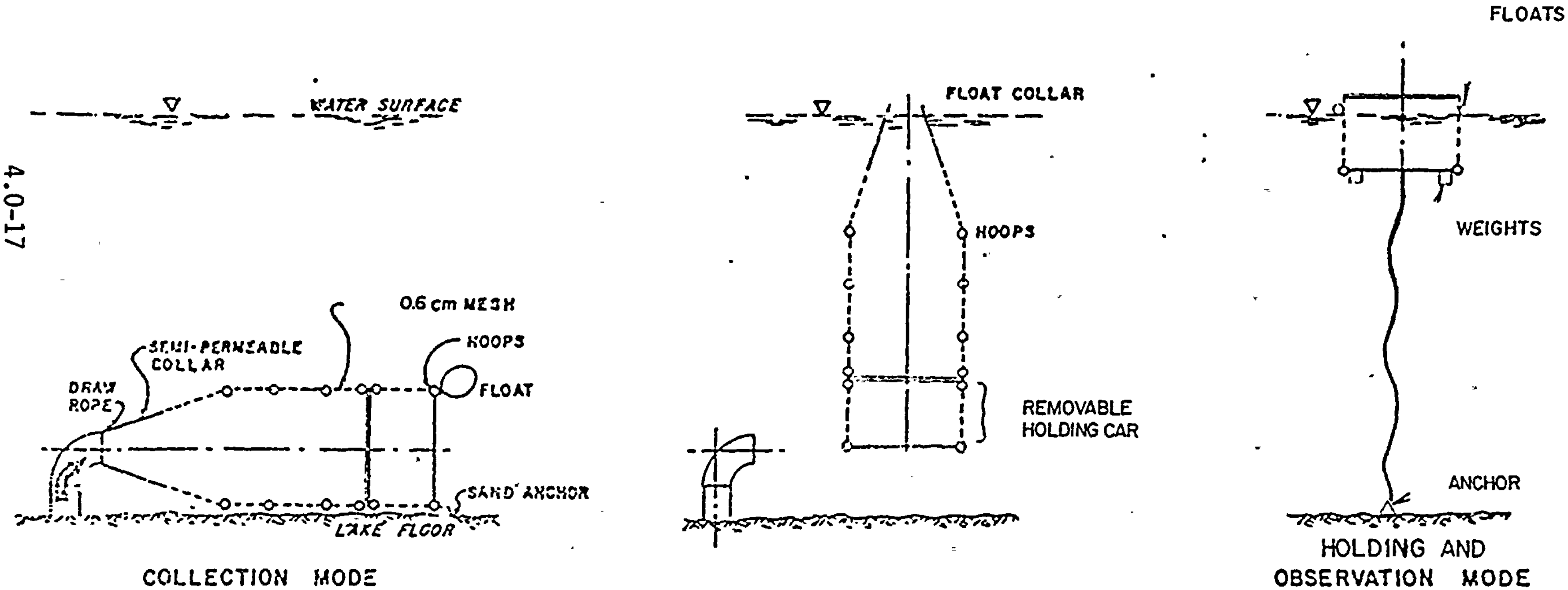
A specially designed net consisting of an attachment cone and holding car was constructed and deployed offshore to collect the fish as they were discharged from the diversion return conduit. The net consisted of a 5.2 m (17 ft) long, 1.8 m (6 ft) diameter, modified hoop net that attached by drawstring over the flange on the discharge conduit (Figure 4.0-1). When in the collection mode, the net was oriented horizontally with its apex (attachment cone) attached to the discharge port and the base (holding car) anchored approximately 6.1 m (20 ft) away. The densely woven base produced a stagnant area where fish could reside during the collection period. Small buoys attached directly to the fiberglass support rings and anchor lines attached to the base of the net were used to maintain its shape and orientation along the axis of discharge flow.

The net was set and retrieved by scuba divers. A 6-8 m (20-25 ft) boat, modified with a boom and gunwale struts designed to hold the net vertically at the water surface, was used as the crew boat. At the designated sample end time, the attachment cone was removed from the discharge port, tied shut, and the net rotated from its horizontal orientation to a vertical orientation with the apex end being taken to the crew boat. The net was then raised slowly to enable initial observation of the number of fish and their general condition. Initially dead fish were removed and bagged for later analysis. No effort was made to separate initially stunned from initially live fish (Section 4.1).

The holding car was then separated from the attachment cone and attached to a flotation platform that allowed in situ holding for between 48 and 96 hrs depending upon weather conditions. Viability observations and removal of dead fish were conducted every

FIGURE 4.0-1

LAKE COLLECTION AND HOLDING NETS



24 hrs. Fish were classified as either initially dead, dead at one of the observations, or alive-at-termination.

4.6.2 Sampling Schedule

Lake discharge collections were collected during April, May, June, September, October, and November 1982 coincident with the periods of highest entrapment. During each sampling month 48 to 120 hrs of sampling was conducted depending upon the numbers of fish and weather conditions. During periods of high abundance, the net was deployed for 1- or 2-hr durations; during the periods of lower abundance, the net was deployed for a 24-hr duration.

4.6.3 Survival Results

A total of 10,699 fish representing 23 species were collected in the offshore sampling effort (Table 4.0-6). The majority (81%) of those were alewife, collected during the three-month period from April through June 1982. The majority of these fish were classified as dead-on-collection. As discussed in earlier sections of this report (Section 3.4 and 4.4), this period was characterized by a massive die-off of subadult and adult alewife in the site vicinity. Offshore survival of alewife during this period was below 1% (Table 4.0-6) as compared to 4 to 15% survival based on collections from the sampling basin (Table 4.0-4). Both the offshore and plant collections were dominated by subadult and adult alewives (>10 cm). Offshore alewife survival in the late fall increased to 7% while concurrent in-plant sampling provided a 63% survival for adult alewives (Table 4.0-4).

Rainbow smelt survival, based on April 1982 offshore sampling, was 85% as compared to 70% based on in-plant sampling. The 8 to 13%

TABLE 4.0-6

SURVIVAL RESULTS OF FISH COLLECTED AT THE OFFSHORE DISCHARGE

Oswego Steam Station Unit 6 - April 1981-March 1983

	APR		MAY		JUN		SEP		OCT		NOV		GRAND TOTAL	
SPECIES	TOTAL TESTED[a]	% ALIVE @ TERM.	TOTAL TESTED	% ALIVE @ TERM.	TOTAL TESTED	% ALIVE @ TERM.	TOTAL TESTED	% ALIVE @ TERM.	TOTAL TESTED	% ALIVE @ TERM.	TOTAL TESTED	% ALIVE @ TERM.	TOTAL TESTED	% ALIVE @ TERM.
AW	343	0	5,587	1.0	2,785	1.0	44	2.0	511	1.0	44	6.8	9,314	1.0
RSM	33	84.8	137	3.6	322	1.0	3	0	42	0	39	0	576	6.1
EMSH	3	66.7	1	0	97	40.2	-	-	6	16.7	-	-	107	40.2
MOTS	7	0	25	68.0	7	71.4	5	0	36	77.8	27	92.6	107	70.1
RB	1	100	87	98.8	4	50.0	13	92.3	-	-	1	100	106	96.2
YP	5	100	17	76.5	57	73.7	13	53.8	-	-	-	-	92	72.8
JD	-	-	24	79.2	63	84.1	-	-	-	-	-	-	87	82.8
GSD	-	-	-	-	-	-	-	-	11	9.1	65	26.2	76	23.7
STSH	6	100	3	33.3	8	75.0	4	75.0	37	89.2	2	50.0	60	83.3
SMB	2	100	-	-	1	100	13	84.6	34	82.4	8	87.5	58	84.5
TPER	2	50.0	13	69.2	16	87.5	-	-	-	-	-	-	31	77.4
WP	8	37.5	3	66.7	9	55.6	4	0	-	-	1	0	25	40.0
AE	1	100	9	100	4	100	5	100	1	100	-	-	20	100
BSF	-	-	-	-	4	75.0	10	60.0	-	-	-	-	14	64.3
PS	-	-	-	-	-	-	11	90.9	1	100	-	-	12	91.7
BNB	-	-	-	-	1	100	3	66.7	-	-	-	-	4	75.0
ABUR	1	100	1	100	1	100	-	-	-	-	-	-	3	100
CHIN	-	-	-	-	2	100	-	-	-	-	-	-	2	100
BNT	-	-	1	100	-	-	-	-	-	-	-	-	1	100
CSH	-	-	1	0	-	-	-	-	-	-	-	-	1	0
LMB	-	-	-	-	-	-	1	100	-	-	-	-	1	100
LP	1	100	-	-	-	-	-	-	-	-	-	-	1	100
WS	-	-	-	-	-	-	-	-	1	100	-	-	1	100

[a]Includes initial dead.
- None tested.

reported for YOY survival in-plant during the fall sampling (September-November) was not reflected in the offshore survival results. No survival was reported for the 84 rainbow smelt (predominantly YOY) collected offshore in the fall of 1982.

At 40%, white perch survival (predominantly adult), based on offshore sampling, was substantially lower than the 65% based on in-plant sampling. Insufficient numbers of YOY white perch were collected offshore to enable any type of comparison.

Of the seven remaining species represented by at least 20 organisms from in-plant and offshore sampling, three (spottail shiner, smallmouth bass, and Mottled sculpin) demonstrated similar survival at both locations; three (yellow perch, emerald shiner, and gizzard shad) had higher survival in-plant than offshore; and one (rock bass) demonstrated higher survival offshore than in-plant. Observation of both in-plant and offshore collection procedures suggests that the offshore procedures place a slightly higher stress on the test organism than do the in-plant procedures. Also, predator and prey were not always able to be separated and some mortality was undoubtedly the results of predation. For the hardier species, such as the salmonids, smallmouth bass, and rock bass, the added stress had a minimal effect on the final data. However, the more fragile species such as alewife, gizzard shad, and YOY rainbow smelt did exhibit lower survivals based on the offshore collection.

The incremental increases in stress applied to the organism as it passes through the diversion system will have a cumulative effect until the organism either returns to the lake or succumbs. The transport offshore through the discharge conduit is the last stress applied before the organism is released to the source water body. This additional stress appears to have minimal effect on the hardy sport fish: smallmouth bass, salmonids, and rock bass.

These species are capable of passing through the entire diversion system, including the discharge conduit, with survivals in excess of 80%. For the more fragile forage species, namely, alewife, gizzard shad, and YOY rainbow smelt, the additional stress associated with the offshore transport appears to have reduced their survivals slightly. Based on the low in-plant survivals, however, the observed reduction is not surprising.

In general, the survival results obtained in-plant provide a good indication of the ultimate survival to be observed offshore. While some additional mortality can be expected to result from the offshore transport, the magnitude of this mortality will vary by species and age or size.

4.7 DARK-INDUCED DIVERSION

4.7.1 Methods and Materials

In preliminary studies performed during 1981, it was observed that a sudden reduction of ambient light level in the screenwell to virtual darkness produced a rapid increase in the number of diverted fish. The actual mechanics of the phenomenon are unknown, but it is most likely related to a disorientation in the fish caused by a physiological change from photopic vision (daylight vision that primarily uses the cones of the retina) to scotopic vision (night vision that primarily uses the rods). With this disorientation, it is believed that the fish are displaced downstream in the current and into the bypass. Momentary contact with the screen may occur but increased impingement was not observed concomitant with the increased diversion.

Based on these preliminary observations, a 13-month study was conducted from March 1982 to March 1983. Light entered the screenwell

primarily through the steel access grating that made up a considerable portion of the screenhouse floor. Since the screenhouse was under constant illumination, the screenwell below was also constantly illuminated. In order to control the light level within the screenwell, four 100-watt incandescent lights were positioned under the grating; one each on the east and west side of the screenwell just upstream of the bypass and one each on the east and west side of the screenwell just upstream of the bar racks. Each light was controlled by a rheostat and could be turned off simultaneously.

To eliminate background light entering through the grating, heavy gauge black plastic was laid over all the grating and covered by sheets of plywood. Black plastic was also wrapped around the screen housings and any location through which light might penetrate to the screenwell. Thus, the screenwell light condition was controlled solely by the four lamps.

The experimental design required a weekly collection of fish induced to divert by darkening the screenwell (turning off the four lights). This collection immediately followed the regular diversion abundance and survival collections and thereby enabled comparison of fish survival subsequent to diversion under both normal light conditions and the experimental or "dark-induced" diversion. Sampling was conducted throughout the day to avoid possible diel behavioral cycles that may affect diversion or survival following diversion. Impingement was monitored throughout the period to identify any effects resulting from the dark cycle.

A dark collection was of 15- or 30-min duration depending upon the numbers of fish present. The same procedures were followed for the dark viability collections as were previously outlined for the standard (light) collections (Section 4.1). As soon as flow into the sampling basin was stabilized, the light in the screenwell was turned off and remained off until this sample was complete. Once

the bypass flow was returned offshore and the basin was closed, the lights were turned on and remained on until the next dark collection (typically, one week).

4.7.2 Results

A total of 54 collections were conducted simultaneously with the screenwell darkening. Typically, the diversion rate (number of fish collected/hr) measured during the dark collection was 5 to 10 times greater than the diversion rate measured during the preceding light collections. This was most evident during periods when alewife or rainbow smelt were abundant.

Table 4.0-7 provides the survival results for alewife and rainbow smelt subsequent to dark-induced diversion. Adult alewife survival in the spring (March-May) of 1982 under light conditions ranged from 7.3 to 14.7%, while under dark conditions the range was 27.4 to 48.7% (Table 4.0-7). Likewise, YOY alewife dark-induced survival during late summer-fall ranged from 0 to 40.5% as compared to the 0.6 to 2.3% range observed under light conditions. Survival of adult alewives following dark-induced diversion during this period was also higher than the corresponding diversion under light conditions.

Rainbow smelt survival following dark-induced diversion reflected the same improvement in survival as observed for alewife.

Table 4.0-8 provides the results of the remaining seven species that were represented by a minimum of 20 test organisms. In each case, survival following dark-induced diversion was higher than under the light conditions. The more hardy the species or the higher the survival under light conditions, the less the observed improvement. The fragile species, alewife, gizzard shad, and juvenile rainbow

TABLE

ALEWIFE AND RAINBOW SMELT SURVIVAL SUBSEQUENT TO DARK-INDUCED PASSAGE THROUGH THE DIVERSION SYSTEM

Oswego Steam Station Unit 6

MONTH	<10 cm No.	<10 cm % SURVIVAL	<10 cm % INITIAL SURVIVAL	<10 cm DARK SYSTEM SURVIVAL[a]	<10 cm LIGHT SYSTEM SURVIVAL[b]	>10 cm No.	>10 cm % SURVIVAL	>10 cm % INITIAL SURVIVAL	>10 cm DARK SYSTEM SURVIVAL[a]	>10 cm LIGHT SYSTEM SURVIVAL[b]
ALEWIFE										
Mar 1982	0					0				
Apr	0					155	27.7	98.8	27.4	14.7
May	1				0	76	48.7	100	48.7	7.3
Jun	1				NT	118	31.4	95.9	30.1	3.5
Jul	1				NT	372	28.0	98.6	27.6	4.9
Aug	39	40.5	100	40.5	1.6	179	36.3	100	36.3	6.3
Sep	52	0	89.7	0	1.4	62	17.7	89.7	15.9	NT
Oct	340	8.3	97.1	8.1	0.6	179	48.4	97.1	47.0	16.4
Nov	5				2.3	10				63.2
Dec	3				1.6	1				NT
Jan 1983	0					0				
Feb	0					0				
Mar	0					0				
RAINBOW SMELT										
Mar 1982	0					23				59.8
Apr	0					77	100	92.9	92.9	70.2
May	0					0				
Jun	0					0				
Jul	0					0				
Aug	74	12.2	96.7	11.8	NT	1				NT
Sep	53	58.5	84.8	49.6	8.0	1				NT
Oct	1				9.5	50	67.8	96.2	65.2	24.7
Nov	8				12.7	5				NT
Dec	18	42.9	57.9	24.8	23.8	0				NT
Jan 1983	1				NT	1				NT
Feb	0					1				NT
Mar	0					0				

[a] Corrected for initial mortality.

⊢⊣ Composited over interval due to low abundance.

[b] Taken from Table 4.0-4.

NT - None tested

TABLE 4.0-8

SURVIVAL SUBSEQUENT TO "DARK-INDUCED" PASSAGE THROUGH THE DIVERSION SYSTEM

Oswego Steam Station Unit 6

SPECIES	LONG-TERM VIABILITY RESULTS No. TESTED	No. ALIVE @ 96 hr	% SURVIVING	% INITIAL SURVIVAL	DARK SYSTEM SURVIVAL[a]	LIGHT SYSTEM SURVIVAL[b]
Spottail shiner	439	396	90.2	99.2	89.5	81.2
Emerald shiner	63	57	90.5	100	90.5	86.8
Trout-perch	44	37	84.1	97.8	82.2	71.0
Johnny darter	39	37	94.9	100	94.9	90.5
Gizzard shad	32	28	87.5	100	87.5	54.9
Rock bass	29	29	100	100	100	89.3
Mottled sculpin	23	23	100	96.0	96.0	76.3

[a]Corrected for initial mortality.

[b]Taken from Table 4.0-5.

smelt, showed the most marked increase in survival as a result of dark-induced diversion.

The most obvious effect of the dark diversion is the significant reduction in initial mortality at collection. In general, the fish in the sampling basin during the initial classification (see Section 4.1) appeared much more lively and fewer stunned and dead fish were recovered following a dark-induced diversion than during the previous regular collections. Initial alewife survivals for dark-induced diversion ranged from 89.7 to 100% (Table 4.0-7) while the initial survivals for the corresponding regular diversion ranged from 37 to 96% (Table 4.0-1). Rainbow smelt ranges were 57.9 to 96.5% (Table 4.0-7) and 26 to 81% (Table 4.0-1) respectively for dark-induced and regular light diversion.

The increased survival observed subsequent to dark-induced diversion relative to that observed under continuous light conditions could be the result of a decrease in residence time within the screenwell. Schools of alewife have been observed to swim in the screenwell for up to several weeks at a time. It is anticipated that weaker members of the school break off, are swept downstream, and are either impinged or (more likely) diverted into the bypass. Since the size of the school (or at least that part of the school observed from the surface) appears to remain fairly stable over the period, entrapment into the screenwell must approach or equal the number diverted. If in fact the weaker fish are the ones diverted, then survival of these fish would be expected to be lower than for fish diverted in good condition. By shutting off the lights, the integrity of the school is lost and a portion of these fish are displaced downstream and induced to divert. Thus, a regular routine of light and dark cycles may reduce the potential for the formation of schools and thereby reduce fish residence within the screenwell.

CHAPTER 5.0

TOTAL PLANT EFFICIENCY

Total plant efficiency (TPE) is a function of the TDE and the long-term survival. The total efficiency by month was determined for the 10 prevalent species according to the following formula (Table 5.0-1):

$$TPE = (TDE) \times (SURV_c)$$

where

TDE = proportion diverting

$SURV_c$ = 96-hr survival corrected for initial mortality

TPE for alewife and rainbow smelt are presented by size class and month, white perch by size class for each year, and the remaining seven species for each year only. The TPE values varied widely by species, size, and season or month. TPE for juvenile and adult alewife ranged from 0 to 16% and 0 to 56%, respectively, while juvenile and adult rainbow smelt ranges were slightly higher (3 to 24% juveniles, 0 to 65% adults).

Table 5.0-2 integrates the monthly TPE values and the estimated entrapment rates (Table 3.0-9) over the two-year study period to provide an estimate of the number of fish, by species, returned alive to the source water body. This number then, when compared to the total number of fish entrapped, indicates the total system effectiveness for each particular species.

A further breakdown of these data (Table 5.0-3) indicates that for some species, particularly rainbow smelt, the degree of effectiveness differed significantly for different size classes. The Oswego

TABLE 5.0-1

MONTHLY TOTAL PLANT EFFICIENCY BY SPECIES

Oswego Steam Station Unit 6 - April 1981 - March 1983

MONTH	AW ≤10 cm	AW >10 cm	RSM ≤10 cm	RSM >10 cm	WP ≤13 cm	WP >13 cm	EMSH	STSH	GSD	YP	SMB	TSB	MOTS
Apr 1981	13.3	22.6	23.8	64.6	45.7	57.2	80.1	76.4	52.0	90.5	88.2	6.6	38.0
May	1.0	1.6	22.1	0	↓	↓	↓	↓	↓	↓	↓	↓	↓
Jun	1.9	7.4	22.1	20.4	↓	↓	↓	↓	↓	↓	↓	↓	↓
Jul	2.7	25.7	18.4	20.4	↓	↓	↓	↓	↓	↓	↓	↓	↓
Aug	1.2	2.5	18.4	20.4	↓	↓	↓	↓	↓	↓	↓	↓	↓
Sep	1.9	5.5	12.2	17.0	↓	↓	↓	↓	↓	↓	↓	↓	↓
Oct	15.8	45.2	23.7	32.3	↓	↓	↓	↓	↓	↓	↓	↓	↓
Nov	16.1	27.4	11.7	20.6	↓	↓	↓	↓	↓	↓	↓	↓	↓
Dec	13.8	26.6	5.0	20.7	↓	↓	↓	↓	↓	↓	↓	↓	↓
Jan 1982	0	0	4.2	44.7	↓	↓	↓	↓	↓	↓	↓	↓	↓
Feb	3.0	7.4	3.1	38.3	↓	↓	↓	↓	↓	↓	↓	↓	↓
Mar	3.0	3.4	5.0	46.3	45.7	57.2	80.1	76.4	52.0	90.5	88.2	6.6	38.0
Apr	0	6.0	7.6	57.8	43.8	54.8	62.4	67.2	43.5	81.4	78.3	7.5	54.8
May	0	5.9	7.1	32.7	↓	↓	↓	↓	↓	↓	↓	↓	↓
Jun	0.7	3.1	3.8	17.4	↓	↓	↓	↓	↓	↓	↓	↓	↓
Jul	0.7	4.3	3.8	14.1	↓	↓	↓	↓	↓	↓	↓	↓	↓
Aug	1.1	4.2	4.8	17.8	↓	↓	↓	↓	↓	↓	↓	↓	↓
Sep	0.9	7.5	6.1	24.6	↓	↓	↓	↓	↓	↓	↓	↓	↓
Oct	0.4	11.8	7.8	20.4	↓	↓	↓	↓	↓	↓	↓	↓	↓
Nov	2.0	55.8	11.1	21.7	↓	↓	↓	↓	↓	↓	↓	↓	↓
Dec	1.4	55.8	20.4	21.1	↓	↓	↓	↓	↓	↓	↓	↓	↓
Jan 1983	1.4	55.8	16.4	16.9	↓	↓	↓	↓	↓	↓	↓	↓	↓
Feb	1.4	55.8	16.4	16.9	↓	↓	↓	↓	↓	↓	↓	↓	↓
Mar	1.0	41.5	18.5	19.1	43.8	54.8	62.4	67.2	43.5	81.4	78.3	7.5	54.8

AW - Alewife
RSM - Rainbow smelt
WP - White perch
EMSH - Emerald shiner
STSH - Spottail shiner
GSD - Gizzard shad
YP - Yellow perch
SMB - Smallmouth bass
TSB - Threespine stickleback
MOTS - Mottled sculpin

X· ►Combined across months during periods of low abundance.

TABLE 5.0-2

ESTIMATED NUMBERS OF FISH RETURNED ALIVE TO LAKE ONTARIO

Oswego Steam Station Unit 6 - April 1981 - March 1983

MONTH	AW	RSM	WP	EWSH	STSH	GSD	YP	SMB	TSB	MOTS
Apr 1981	11732	5265	364	231	292	449	261	0	0	57
May	1269	124	368	59	228	0	235	0	0	175
Jun	2975	127	71	173	165	112	195	0	0	27
Jul	4895	41	37	0	398	0	0	197	5	0
Aug	28	0	0	0	1137	0	270	1050	0	0
Sep	581	1454	0	5767	275	1142	130	0	0	274
Oct	17961	19764	3033	4941	3126	7479	357	111	0	608
Nov	1852	9883	912	2087	396	2482	195	0	112	309
Dec	361	6371	70	650	142	452	0	0	311	116
Jan 1982	0	1789	129	423	358	306	303	131	12	1419
Feb	21	213	138	775	0	63	0	237	4	181
Mar	10	2319	1050	537	125	155	135	131	12	113
Apr	2262	24987	1699	490	372	60	346	23	24	225
May	1113	106	37	232	100	13	121	117	0	98
Jun	358	125	79	67	0	0	117	0	0	47
Jul	1216	34	163	186	175	0	121	233	0	114
Aug	84	61	544	93	340	0	321	1118	2	163
Sep	137	432	126	467	1016	94	0	208	0	59
Oct	131	222	36	158	525	113	0	49	0	367
Nov	113	584	113	0	194	335	117	16	0	205
Dec	4	357	117	93	0	65	0	0	0	135
Jan 1983	3	252	0	19	0	55	24	23	0	16
Feb	0	34	88	17	0	12	0	0	0	15
Mar	3375	263	32	93	0	65	0	0	0	306
No. Returned Alive	50481	74807	9206	17558	9364	13452	3248	3644	482	5029
Total Estimated Entrapment	448870	433862	18808	22598	12744	26173	3735	4389	7262	11827
Percent Returned Alive	11.2	17.2	48.9	77.7	73.5	51.4	87.0	83.0	6.6	42.5

AW - Alewife
RSM - Rainbow smelt
WP - White perch
EWSH - Emerald shiner
STSH - Spottail shiner
GSD - Gizzard shad
YP - Yellow perch
SMB - Smallmouth bass
TSB - Threespine stickleback
MOTS - Mottled sculpin

diversion system effectively returned 54% of the rainbow smelt greater than 10 cm while only 10% of those 10 cm or less were returned alive to the lake. Individual size or age class was of less importance to the ultimate effectiveness of the system on alewife and white perch (Table 5.0-3).

Section 4.5 indicates that the system effectiveness could be improved by using a light/dark cycle to induce fish diversion and reduce fish residence in the screenwell. Table 5.0-4 provides the estimated results that would be expected from such a dark-induced diversion scheme. Using a study period from March 1982 through March 1983, the system effectiveness for alewife would be improved from 7 to 20% while rainbow smelt system effectiveness would be increased from 34 to 49%. Table 5.0-5 indicates that the dark-induced diversion is especially effective for adult rainbow smelt, providing a system effectiveness for this species/life stage of 84%.

Thus, the use of a light/dark cycle to induce fish diversion appears to improve the effectiveness of the diversion system, especially for the adults of a given species.

TABLE 5.0-3

DIVERSION SYSTEM EFFECTIVENESS[a] FOR ALEWIFE, RAINBOW SMELT, AND WHITE PERCH BY SIZE CLASS[b]

Oswego Steam Station Unit 6 - April 1981 - March 1983

	ALEWIFE		RAINBOW SMELT		WHITE PERCH	
	<10[b]	>10[b]	<10[b]	>10[b]	<13[b]	>13[b]
No. Entrapped	145,266	303,604	363,166	70,696	12,423	6,385
No. Impinged	39,686	53,072	107,741	4,380	1,319	445
No. Diverted	105,580	250,532	255,425	66,316	11,104	5,940
No. Surviving	12,240	38,241	36,442	38,365	5,584	3,622
% Effective (TPE)	8.4	12.6	10.0	54.3	50.0	56.7

[a]Estimate based on average monthly collection rates (No./hr) over the period April 1981 through March 1983.

[b]Measured in centimeters.

TABLE 5.0-4

ESTIMATED NUMBERS OF FISH RETURNED ALIVE TO LAKE ONTARIO USING DARK-INDUCED DIVERSION

Oswego Steam Station Unit 6 - March 1982 - March 1983

MONTH	ALEWIFE LIGHT[a]	ALEWIFE DARK[b]	RAINBOW SMELT LIGHT[a]	RAINBOW SMELT DARK[b]
Mar 1982	10	32	2319	3652
Apr	2262	4579	24987	32986
May	1113	7452	106	168
Jun	358	3067	125	196
Jul	1216	6930	34	55
Aug	84	643	61	82
Sep	137	50	432	2685
Oct	131	569	222	529
Nov	113	153	584	1137
Dec	4	20	357	394
Jan 1983	3	13	252	283
Feb	0	0	34	39
Mar	3375	2505	263	290
No. Returned Alive	8806	26013	29776	42496
Total Estimated Entrapment	128574	128574	86265	86265
Percent Returned Alive	6.8	20.2	34.5	49.3

[a] Taken from Table 5.0-2.
[b] Estimated numbers of fish returned alive using dark-induced diversion system.

TABLE 5.0-5

DIVERSION SYSTEM EFFECTIVENESS[a] FOR ALEWIFE AND RAINBOW SMELT BY SIZE CLASS USING DARK-INDUCED DIVERSION

Oswego Steam Station Unit 6 - April 1981 - March 1983

	ALEWIFE		RAINBOW SMELT	
	<10[b]	>10[b]	<10[b]	>10[b]
No. Entrapped	20,349	108,225	43,557	42,708
No. Impinged	6,729	34,634	13,031	3,623
No. Diverted	13,620	73,591	30,526	39,085
No. Surviving	1,021	24,992	6,816	35,680
% Effective (TPE)	5.0	23.1	15.6	83.5

[a]Estimate based on average monthly collection rates (No./hr) over the period March 1983.

[b]Measured in centimeters.

CHAPTER 6.0

POTENTIAL FOR RECIRCULATION

A special study was conducted from 14-21 April 1982 to evaluate the potential for recirculation of fish from the offshore discharge to the offshore intake. The proximity of the discharge to the intake (82.7 m; 271 ft) makes it feasible that a portion of the discharged fish are re-entrained at the intake, thereby affecting the estimated numbers impacted and the anticipated survival for fish subjected to multiple passes through the system.

To evaluate the degree of recirculation, 1103 live tagged adult rainbow smelt were released into the bypass slot of the secondary screenwell on 14 April 1982 coincident with high, naturally occurring smelt abundances. Impingement and bypass fish were then monitored continuously at Unit 6 for the next seven days. Impingement at Units 1-4 and Unit 5 was also continuously monitored for tagged smelt.

A summary of the release and recovery results is presented in Table 6.0-1. Of the 1103 live tagged smelt that were released only three (<1%) were recovered in Unit 6. None were recovered in Units 1-4 or Unit 5. Since all the recoveries were made within five days of the release (two of the three within the first 29 hours) it is unlikely that additional smelt would recirculate after seven days had elapsed.

The degree of recirculation of adult rainbow smelt from the offshore fish discharge to the offshore intake appears negligible. This is probably the case with other commonly entrapped species, but the lack of sufficient numbers for testing precludes analysis of other species.

TABLE 6.0-1

RAINBOW SMELT RECIRCULATION STUDY

Oswego Steam Station Unit 6 - 14-21 April 1982

DATE RELEASED	TIME RELEASED	NUMBER RELEASED	RECAPTURE LOCATION	NUMBER	DATE RECAPTURED	TIME RECAPTURED	ELAPSED TIME
14 Apr 1982	1245	1103	Unit 4 Impingement	0			
			Unit 5 Impingement	0			
			Unit 6 Impingement	1	15 Apr 1982	1739	28.9 hr
			Unit 6 Sample Basin	1	15 Apr 1982	1329	24.7 hr
			Unit 6 Sample Basin	1	19 Apr 1982	0000	107.2 hr

CHAPTER 7.0

ASSESSMENT OF PREDATOR POPULATION

From April through November 1982, 13 gill net surveys were performed to assess the potential for predation of fish exiting the Unit 6 diversion system (Table 7.0-1). In order to observe the maximum potential for predator attraction, the surveys were scheduled to coincide with periods of high fish diversion. Thus, the major sampling effort was expended during the spring of 1982 with lesser effort expended during the subsequent fall.

Gill net samples were collected at the fish discharge nozzle located approximately 300 m (1000 ft) northwest of the Unit 6 screenhouse and at a control site approximately 0.8 km (0.5 mi) west of the fish discharge and 300 m (1000 ft) offshore north of S.U.N.Y. Oswego. All samples were collected with a 30.8 x 3.1-m (100 x 10 ft) multifilament gill net with 12.7-cm (5 in.) stretch mesh deployed on the bottom along the 8 m (25 ft) depth contour. The net was set parallel to shore at each station. Predation surveys were normally overnight sets of 12- to 24-hr duration. When weather conditions on Lake Ontario prevented safe sample retrieval, the collections exceeded 24 hours.

Upon removal from the net, each potential predator was identified, its condition noted, and it was placed on ice in a labeled cooler for subsequent analysis. All predator species captured received individual length and weight measurements and examination for general body condition and tags.

The most abundant predator species in the collections were lake trout, Salvelinus namaycush (59 captured), followed by smallmouth bass, Micropterus dolemieui (20), and brown trout, Salmo trutta

TABLE 7.0-1

PREDATION SURVEY SAMPLE DATES FOR 1982

Oswego Steam Station Vicinity

28 April
30 April
19 May
24 May
25 May
26 May
15 June
27 June
28 July
9 September
21 September
6 October
17 November

(14). The remaining species (walleye, Stizostedion vitreum; American burbot, Lota lota; Rainbow trout, Salmo gairdneri; chinook salmon, Oncorhynchus tschawytscha; and Coho salmon, Oncorhynchus kisutch) were represented by fewer than five individuals each (Table 7.0-2). Salmonids were present in every collection but most abundant in late spring and late fall with a peak in May. Smallmouth bass were present from April through October but most abundant in May and September. American burbot were captured only in May and walleye were collected intermittently from April through September.

The total number of predators captured at each site was almost equal (Control-54, Discharge-52). Of the most frequently encountered predator species, only smallmouth bass seemed to have any preference between sites. In May, six bass were captured at the control site and none at the discharge. This may be more closely related to pre-spawning movements than to feeding habits. There is no evidence of greater predator abundance in the vicinity of the fish discharge than in similar nearby habitats.

TABLE 7.0-2

FISH COLLECTED IN 12.7-cm (5-in.) STRETCH-MESH GILL NET

Oswego Steam Station Vicinity - 1982

SPECIES	APR		MAY		JUN		JUL		SEP		OCT		NOV		TOTAL	
	CONTROL	EXP	CONTROL	EXP	CONTROL	EXP	CONTROL	EXP	CONTROL	EXP	CONTROL	EXP	CONTROL	EXP	CONTROL	EXP
Smallmouth bass	1	1	6		1		1	2	3	4		1			12	8
Brown trout	3				1	2	1			6	1				6	8
Walleye	1						1	1		1				2	2	2
Chinook salmon		1	1												1	1
Lake trout			15	15	11	10							3	5	29	30
American burbot			3												3	0
Coho salmon				1											0	1
Rainbow trout				1	1									1	1	2
Total	5	2	25	17	14	12	3	3	3	11	1	1	3	6	54	52
Mean Temp. (surface) (°C)	7.2	7.7	7.4	7.2	11.5	12.1	22.2	22.1	17.1	17.0	15.8	15.8	8.2	8.4		

CHAPTER 8.0

DISCUSSION

The objective of the two-year research program was to assess:

1. The efficiency of the angled screen
2. The effectiveness of the fish bypass
3. The viability of any organism that successfully enters the bypass system and eventually returns to Lake Ontario

The efficiency of the angled screens and the effectiveness of the fish bypass is discussed in detail in Chapter 3.0. In general, the angled screen system is effective in diverting fish from the primary screenwell, through the secondary screenwell, and back out to the lake. Degree of effectiveness varied widely by species, size class or age, and season, but overall effectiveness (composite across entire project duration, i.e., size class and season) for the 10 dominant species ranged from 53% for mottled sculpin to 94% for gizzard shad (Table 3.0-16). The distinctive behavior of the mottled sculpin contributed to its low diversion efficiency. Because of its poor swimming ability and demersal preference, this species typically seek out the bottom or other substrate upon which to rest. In the lake, mottled sculpin were never observed swimming in the water column. Once in the screenwell, this species rested on the vertical traveling screens and was removed from the water column as the screens were rotated and washed.

At 78 and 74%, respectively, alewife and rainbow smelt diversion efficiencies appeared low. Studies conducted by Taft and Mussalli (1978) upon which the Oswego diversion system was designed, indicate

that alewife and rainbow smelt diversion efficiencies in their test flume were typically at or near 100%. However, assuming the laboratory tests used only hardy test specimens under controlled conditions, then the laboratory results could legitimately be compared with the upper portion of the range observed in the test results; i.e., 98% for alewife and 99% for rainbow smelt (Table 3.0-16).

The results described in Chapter 3.0 indicate that, depending upon the condition of the entrapped population and their age or size, the range of observed diversion efficiencies can approach the range represented by the laboratory study.

Adult alewife in good condition (April 1981) demonstrated a 98% diversion efficiency, while the same age class one year later (coincident with a substantial local alewife die-off) demonstrated only a 41% diversion efficiency (Table 3.0-16). Although condition factor analysis (Everhart et al. 1975) indicated no significant difference in condition (as described by a length-weight relationship) between the two populations, the presence of the massive mortality in 1982 (not observed in 1981) indicates that the April 1982 population was, in fact, responding adversely to an environmental stress.

An equally important variable in assessing diversion effectiveness was age class. The adults, which typically dominated the spring collections, provided higher diversion efficiencies (83% for alewife and 94% for smelt) than the YOY fish which dominated the fall and early winter collections (73% for alewife and 70% for smelt) (Table 3.0-17).

The other objective of the study was to identify the viability of the fish following diversion and upon return to the lake. Sampling was conducted primarily in-plant from a sampling point just prior to

final transport offshore (Section 4.1). Additional collections were made offshore to determine if there was any major source of mortality associated with the transport process.

As demonstrated in the diversion efficiency results, variability in the survival results was related primarily to condition of the population and secondarily to the age or size class of the individuals. In turn, condition of the entrapped population was dictated by natural environmental conditions (i.e., water temperature, food availability) and reproductive state (i.e., sexual maturity). Viability results for the two dominant species, alewife and rainbow smelt, are presented and discussed in detail in Chapter 4.0 (Table 4.0-4). Seasonal trends were related to reproductive state with the highest survivals occurring just prior to spawning and the lowest survivals occurring just after spawning. Adult alewife survivals ranged from 2 to 63%, with YOY survival substantially lower, 0 to 20%. Rainbow smelt fared better, with adult survivals ranging from 0 to 70% and YOY smelt survival falling between 5 and 32%. Taft and Mussalli (1978) reported a mean differential mortality of 35.7 ± 13.5% (survival = 64.3%) for alewife and attributed the low survival to difficulty in handling this fragile species in the model facility. When they combined the diversion test apparatus with the transport system and thereby reduced the handling, their mortality decreased to only 4% (survival = 96%).

Several factors might have contributed to the differences between their laboratory results and the actual findings in the operating system. Based on the results of this study, the condition of the fish at diversion is a primary factor in determining whether or not the test organism will survive passage through the diversion system. In the study reported by Taft and Mussalli, the test fish were collected, transported, and acclimated to the holding apparatus. Mortality resulting from this handling culled the weaker individuals from the test population. Testing was conducted

primarily on subadult and adult alewife rather than on the more sensitive YOY. Because of time constraints, flume experiments were limited in duration, and the effect of long-term residency was not evaluated.

In contrast, the fish tested in this study are those that were entrapped at the offshore velocity cap intake and transported through the turbulent intake tunnel, approximately 370 m (1200 ft) to the primary screenwell where the flow enters the screenwell through a vertical intake shaft rising approximately 30 m (100 ft) in 20 sec. The fish then encounter the vertical bar racks and the angled screen diversion system. During the period November through April, the organisms also encounter tempering in the primary screenwell, which subjects them to a turbulent boil and an immediate increase in temperatures of from 2 to 8°C.

Thus, while the diversion system may provide high survival results under laboratory conditions for alewives that are in good condition, the components associated with an offshore cooling water intake system may not transport the test specimens to the diversion system in the best of condition. This factor is evident in the results of the fragile species; alewife, gizzard shad, juvenile rainbow smelt, and threespine stickleback. The hardy species, the salmonids, smallmouth bass, and rock bass, appear to be less affected by the intake system and are capable of handling the cumulative stress of the transport to, and the passage through, the diversion system with minimal mortality.

In terms of overall system effectiveness, only 17 and 11%, respectively, of the rainbow smelt and alewife entrapped in the OSS-6 cooling water system were returned to the lake and were expected to survive. In contrast, 87 and 83%, respectively, of the yellow perch and smallmouth bass were effectively returned to the source

water body (Table 5.0-2). Upon further breakdown, 54% of the adult smelt were estimated as survivors but only 10% of the YOY would pass through the system and return offshore in any condition to survive. Alewife survival of the two size classes differed much less (13% for subadult/adults and 8% for YOY). Fifty-seven percent of the adult white perch survived the diversion system vs 50% of the YOY (Table 5.0-3). These findings are important in terms of impact assessment or differential cropping of various age classes and the effect on reproductive capacity. They are also critical for estimating potential effectiveness of the angle screen diversion system at other sites.

The total estimated entrapment for the two-year study period is 1,026,812 fish. The 10 species presented in Table 5.0-2 account for 990,268 fish or 96% of the total estimated entrapment at Oswego Unit 6. Of these, 187,271 fish or 18% were returned alive to the lake and were expected to survive. Thus, in the most basic terms, the OSS-6 angled screen fish diversion system is reducing the total plant cropping and thus its impact by approximately 18%.

The overall effectiveness of the system on the game species (white perch, rock bass, yellow perch, smallmouth bass, brown trout, white bass, chinook salmon, rainbow trout, and largemouth bass) was approximately 65%. Of the 34,200 estimated game fish entrapped over the two-year period, 18,808 (55%) were white perch with a 49% recovery rate. The remaining 15,392 were primarily smallmouth bass and yellow perch with 83 and 87% recovery rates, respectively.

Based on the findings of increased survival subsequent to dark-induced diversion (Section 4.7), the overall efficiency of the diversion system can be increased appreciably through regulation of a light and dark cycle. An estimate of 128,574 alewives were entrapped during the 13-month period from March 1982 to March

1983. Under normal light diversion conditions 8806 (7%) of the entrapped alewife were returned offshore and were expected to survive. Based on the dark-induced survival results, the same period would return 26,013 (20%) of the entrapped alewives safely (Table 5.0-4).

Results for rainbow smelt were not as dramatic. Total plant efficiency for smelt, based on light diversion, was 34% as compared to 49% using a dark-induced diversion. Additional investigations into the use of a light/dark regime for improvement of alewife and rainbow smelt diversion and subsequent survival is currently being conducted and will be reported in a later report.

The investigations conducted on the Oswego Steam Station Unit 6 angled screen diversion system can be summarized as follows:

1. Mechanically and hydraulically, the system is functioning as designed with minimal operational problems.
2. Diversion of fish across the angled screens is highly dependent upon species, their condition (i.e., physiological and/or reproductive state), and their age or size class.
3. The fragile species (alewife, gizzard shad, juvenile smelt) are more susceptible to impingement than are the hardy species (salmonids, smallmouth bass, rock bass, yellow perch).
4. Unless weakened by recent spawning activities, adults of a species typically exhibit a higher diversion efficiency than the young.
5. Survival following diversion was also dependent upon species, their condition, and their age or size class.
6. Survival results based on offshore collections indicated that in-plant collections provided a good estimate of ultimate survival upon discharge offshore.

7. The condition of the alewife population at the time of entrapment and the stresses applied to the population upon transport to the screenwell most likely account for the substantial differences in survival results observed in laboratory studies and the actual installation.

8. Overall TPE varied from 6.6 to 17.8% for the fragile species (threespine stickleback, alewife, and rainbow smelt) to 73.5 to 87.0% for the hardy species (spottail shiner, emerald shiner, smallmouth bass, and yellow perch).

9. The angled screen diversion system is an applicable and proven technology that will operate with minimal additional maintenance beyond that required for the traditional vertical traveling screens. Its effectiveness as a mitigation device will depend upon the species of interest, their age or size class, and the condition in which the individuals are delivered to the system.

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