NIAGARA MOHAWK POWER CORPORATION
Syracuse, New York

INTERIM PROGRESS REPORT, FISH GUIDANCE RESEARCH PROJECT No. EC 104
April 1981 - November 1982

FISH SURVIVAL SUBSEQUENT TO DIVERSION AT THE OSWEGO STEAM STATION UNIT 6

MAY 1983

Prepared By

LAWLER, MATUSKY & SKELLY ENGINEERS
Environmental Science & Engineering Consultants
One Blue Hill Plaza
Pearl River, New York 10965

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY

This report summarizes viability studies conducted by Lawler, Matusky & Skelly Engineers (LMS) for Niagara Mohawk Power Corporation (NMPC) on the fish diversion system at Oswego Steam Station Unit 6. The studies of the diversion system were initiated in April 1981 and were expanded in April 1982 to include the biological monitoring requirements of the draft SPDES permit. One of the permit conditions allows the permittee to request termination of viability studies on the fish diversion system after a report of one full year of studies is sent to the New York State Department of Conservation (NYSDEC). This report covers the viability data collected from April 1981 through November 1982 and specifically requests termination of any additional viability studies on the fish diversion system based on the 20 months of viability data collected to date and reported on herein. This data base is considered adequate to identify survival rates for the dominant species entrapped in the Unit 6 cooling water.

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 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 screens angled toward a bypass.

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 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 for this test program were collected from the sampling basin and from the traveling screens. The fish collections demonstrated a definite seasonal pattern. Spring collections were dominated by adult alewife and rainbow smelt; fall collections were dominated by juvenile rainbow smelt, alewife, and gizzard shad. While the same species dominated in both years, their absolute abundance differed widely. Adult alewife abundances were high (>118 fish/hr) in the spring of 1981 while adult rainbow smelt were low (<15 fish/hr). In the fall and early winter of 1981, juvenile 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 juvenile fish except smallmouth bass.

During the 20 months of sampling, a total of 984 viability collections and 430 diversion abundance collections were conducted. The fish present in each collection were classified as initially live, stunned, or dead. A significant proportion of some species were dead at initial sorting and classification.

Long-term survival observations (96-hr) were conducted on 7883 fish representing 34 species. Ten of these species were represented by more than 40 specimens. The dominant species, alewife and rainbow smelt, were represented by enough individuals to describe their survival by age class and season. Adult alewife survival varied from 11.7% during May to 75.0% during October. Adult rainbow smelt

survival also varied dramatically: from 100% during the period January through March to zero during May.

Sufficient numbers of white perch were collected and tested to identify two age classes with different seasonal distributions and survivals. Juvenile white perch dominated the collection during October and November and showed a survival of 68.1%. Adults of the same species were typically present during the spring (March through May) and showed a higher survival of 83.7%.

The remaining species were either tested in insufficient numbers to enable a 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).

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., juvenile 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 juveniles of the same species. Adult survival was highest immediately preceding the spawning activity and lowest immediately following spawning. This finding is important in light of the high natural mortality observed for juvenile alewife and rainbow smelt. The gravid, pre-spawn adults will have a greater influence on maintenance of natural stock densities than will a corresponding number of juvenile fish.

In general, the Oswego Steam Station Unit 6 diversion system is functioning as designed and sufficient information has been gathered to identify the survival rate for the dominant species present. This information coupled with the impingement and diversion abundance data will enable one to assess the effectiveness of the Oswego Unit 6 diversion system relative to the operation of the unit without the system. This assessment will be published in the fall of 1983.

CHAPTER 1.0

INTRODUCTION

The construction of Niagara Mohawk Power Corporation's (NMPC) Oswego Steam Electric Generating Station Unit 6 began in October 1972. Unit 6 began commercial operation in July of 1980 with a once-through cooling water system outfitted with a fish diversion and return system. The unit operates under the extended National Pollutant Discharge Elimination System (NPDES) permit while negotiations continue on the draft State Pollutant Discharge Elimination System (SPDES) permit.

The biological monitoring requirements of the most recent draft SPDES permit requires monitoring of impingement collections at Unit 6 for two years and larval entrainment monitoring for eight months (February-September). In addition, the permit requires investigation of fish survival subsequent to diversion.

In part, the draft SPDES permit specifies that:

> "The permittee may request termination of viability studies on the fish diversion system after a report on one (1) full year of studies is received."

A two-year biological testing program independent of SPDES monitoring requirements was designed to evaluate the performance of the Unit 6 angled screen diversion system. This program began in April 1981. With the initiation of the SPDES monitoring program in April 1982, the two programs complemented each other and provided an augmented data base. The two-year testing program contained three distinct study objectives, namely, to determine:

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

This report deals with the third objective, the viability of fish subsequent to their passage through the diversion system, and provides the results of 20 months (April 1981-November 1982) of survival information. Based on the results from these studies and the condition in the draft permit providing for the termination of the viability studies, the permittee (NMPC) requests termination of viability studies on the fish diversion system effective 31 March 1983. The viability results collected from April 1981-March 1983 will be integrated with the diversion efficiency and impingement data into the first annual SPDES monitoring report, to be completed in the fall of 1983.

Chapter 2.0 of this report describes the Unit 6 fish diversion system and its important hydraulic characteristics. Chapter 3.0 gives a description of the materials and methods employed during the studies, and Chapter 4.0 provides the results of the biological testing program.

CHAPTER 2.0

SYSTEM DESCRIPTION

The Oswego Unit 6 intake, screenwell, and associated fish guidance and transportation systems are shown in Figures 2.0-1 through 2.0-4. The design of this 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).

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 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/s (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 a single 11.2-m^2 (121-ft^2) tunnel. The design circulating water pump flow rate is 20.5 m^3/s (724 cfs). Since some of the pump flow is recirculated through the diversion system to the screenwell, the velocity in the

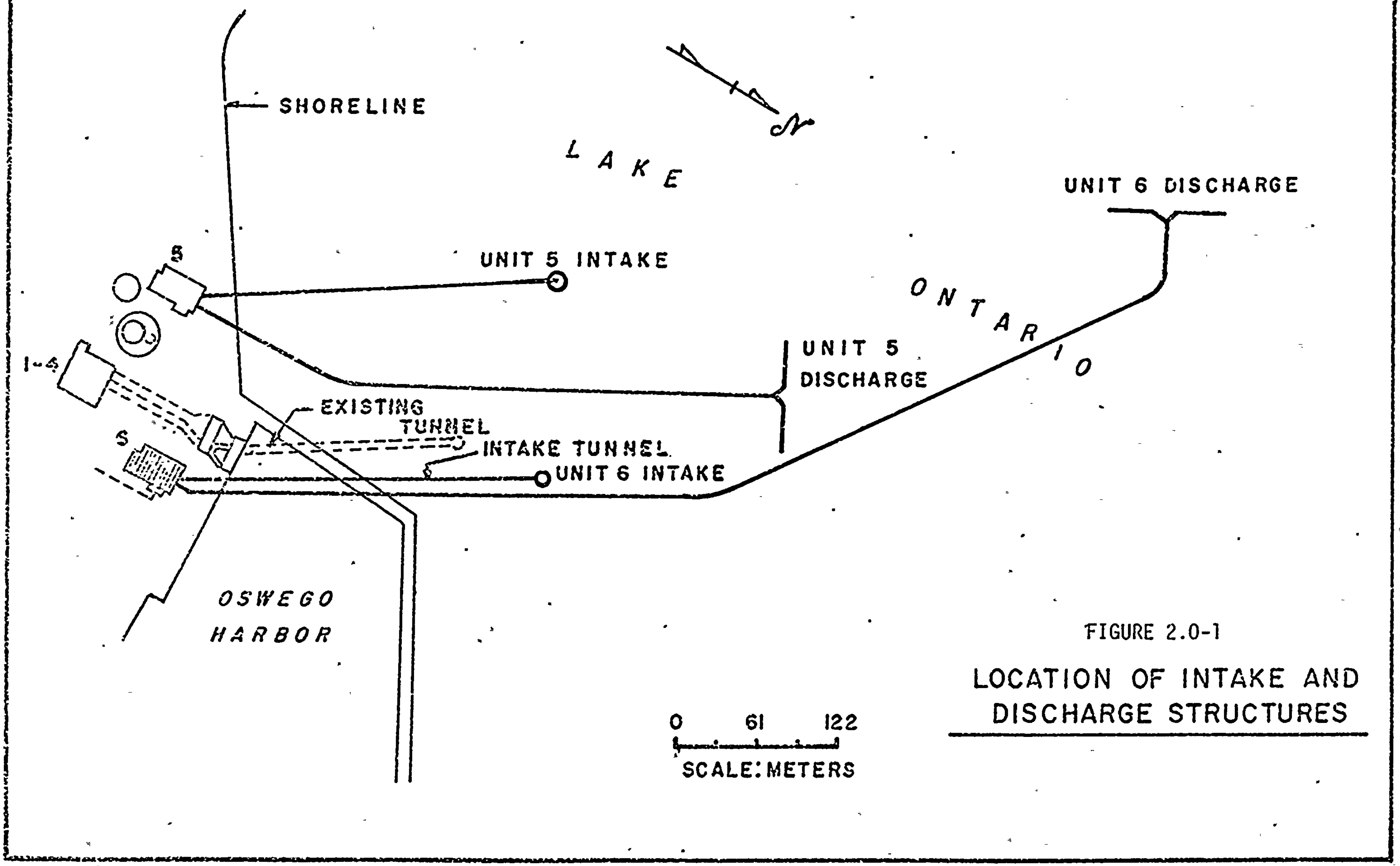


FIGURE 2.0-1

LOCATION OF INTAKE AND DISCHARGE STRUCTURES

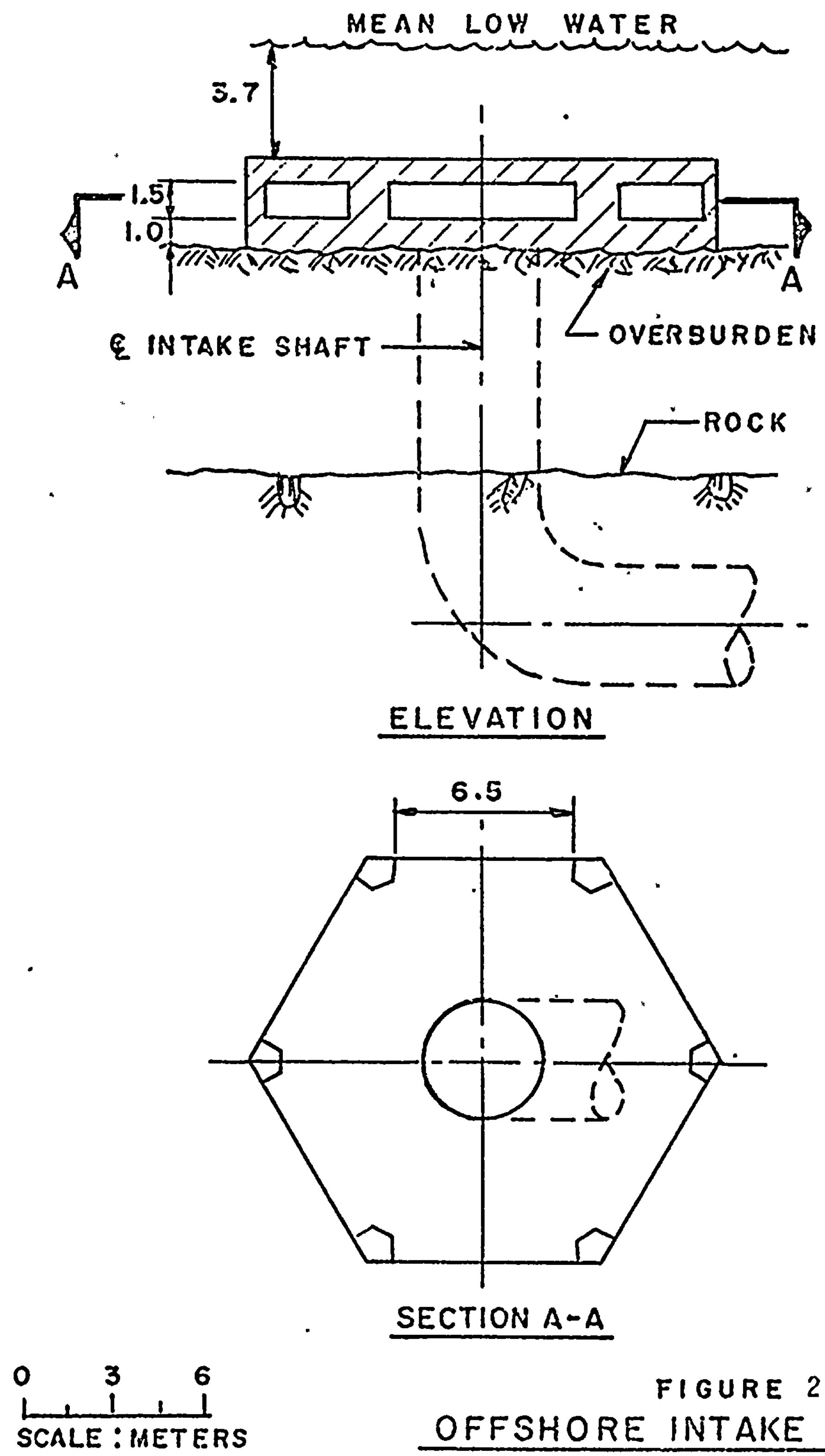


FIGURE 2.0-2
OFFSHORE INTAKE STRUCTURE
UNIT NO.6 OSWEGO STEAM STATION
NIAGARA MOHAWK POWER CORPORATION

ALL DIMENSIONS IN METERS

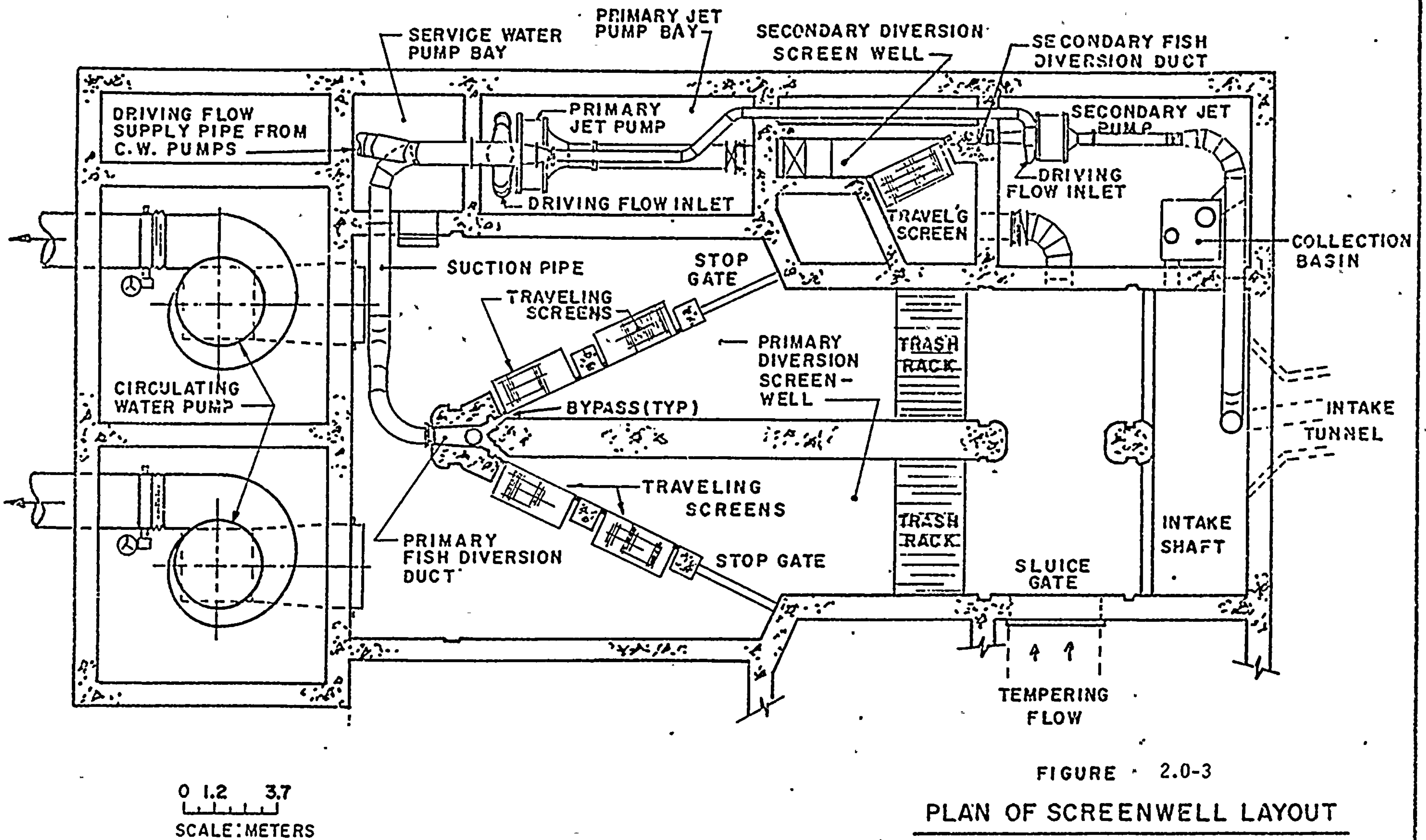
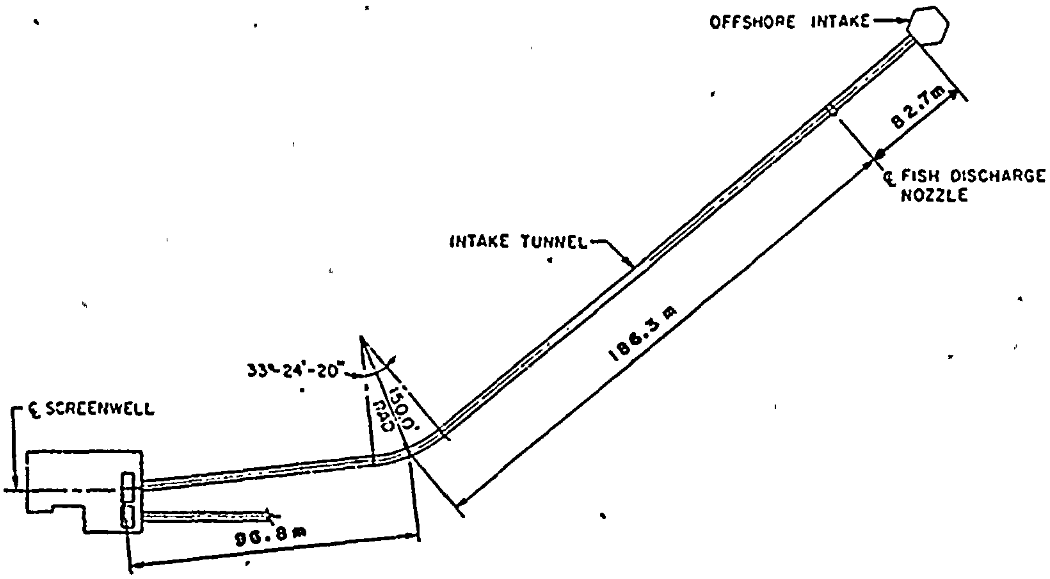


FIGURE 2.0-3

PLAN OF SCREENWELL LAYOUT

UNIT NO.6—OSWEGO STEAM STATION



KEY PLAN
CIRC WATER INTAKE TUNNEL
NO SCALE

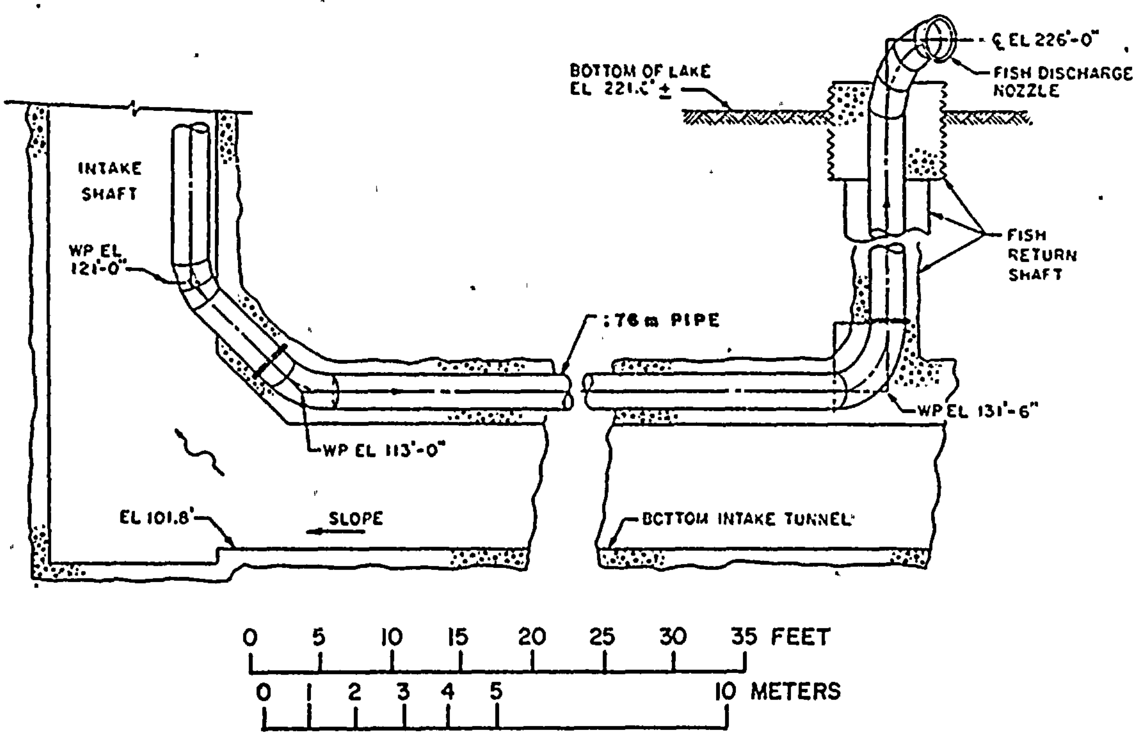


FIGURE 2.0-4
FISH RETURN PIPE
UNIT NO. 6 - OSWEGO STEAM STATION

tunnel is less than 182 cm/s (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 s. 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 while at the same time converging in the vertical plane at a 45° angle to two 0.6-m (24-in.) diameter pipes. The two pipes join into a single 0.8-m (32-in.) diameter pipe which 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.

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 screen-well 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) offshore 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 offshore during normal operation or into the basin during sampling. A description of the sampling basin is provided in Section 3.1.1.

CHAPTER 3.0

METHODS AND MATERIALS

3.1 FISH SAMPLING BASIN

Viability collections were made from the sampling basin located downstream of the screenwells and jet pumps and just prior to return offshore. Figure 3.0-1 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 screenhouse (Figure 3.0-2). 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. The fish sampling basin was modified to permit efficient sampling and to minimize fish handling. Since the basin could not be drained during certain pump operating conditions, a false floor was installed with a hinged counter-weighted trap door over the inflow pipe to allow more control in regulating the water depth for sample collection. 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 the false floor. A fish crowding device was used to facilitate fish sorting and reduce handling. This device consists of a 2.4 by 0.6 m (8 x 2 ft) metal frame covered with 0.3-cm (0.13-in.) nylon mesh that is designed to slide down the drain screen and across the basin floor, maintaining a tight seal with the basin wall. It was used to crowd the collected fish gently to one side of the basin to permit identification and sorting.

3.2 SAMPLING SCHEDULE

The April 1981-March 1982 sampling was conducted as the first year of a two-year program to evaluate the effectiveness of the angled

FIGURE 3.0-1

OSWEGO STEAM STATION UNIT 6

Schematic

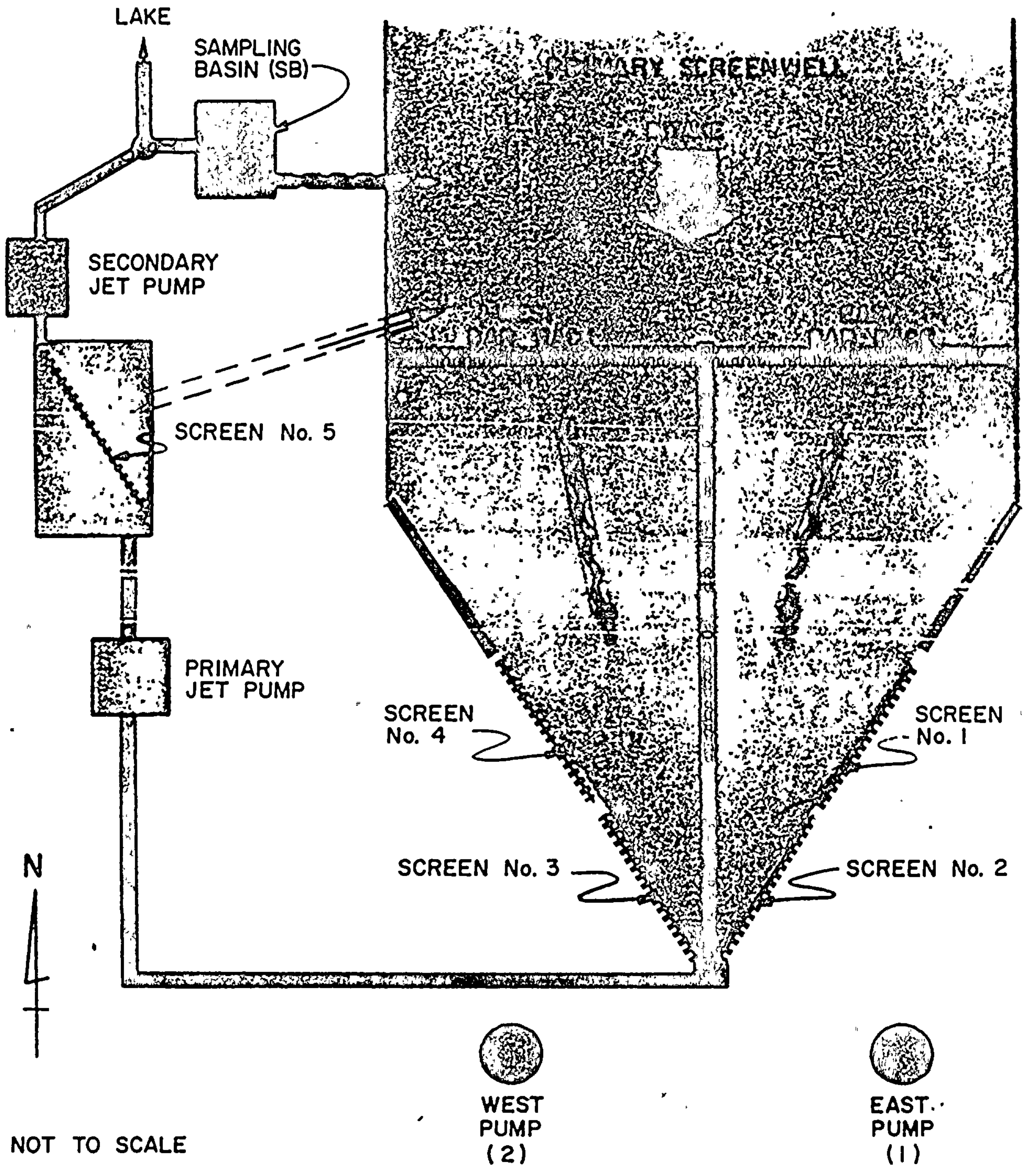
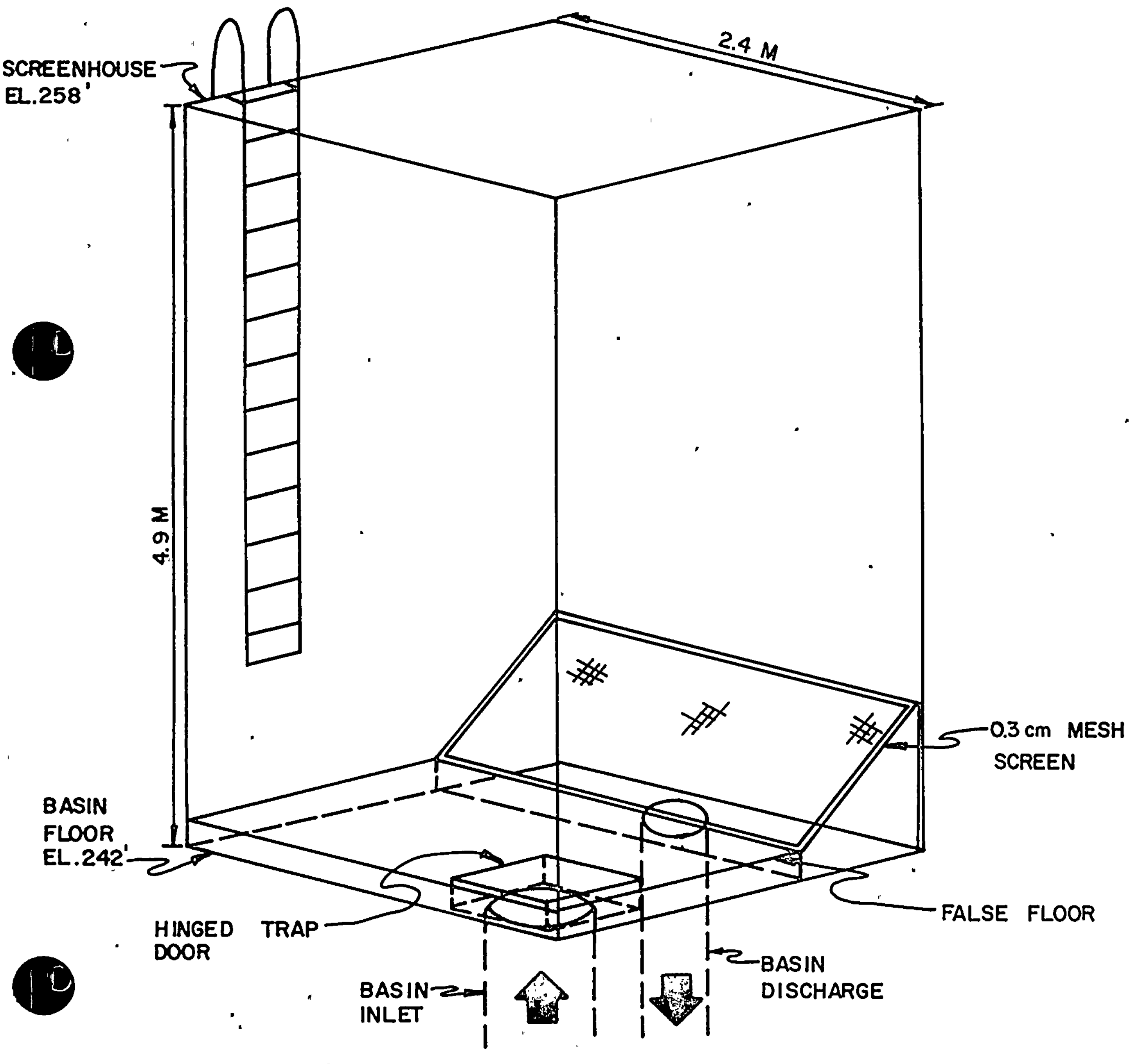


FIGURE 3.0-2

SAMPLING BASIN
OSWEGO STEAM STATION UNIT 6



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 consisted of an 8-hr survey 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 provides a summary of the scheduled sampling effort for each month. Because the sampling concentrated on the periods of highest abundances, caution should be used when evaluating the yearly estimates of impingement abundance based on this data.

The second year (April 1982-March 1983) of the evaluation of the diversion system is incorporated with the first year of the required SPDES monitoring program. Surveys are performed on a variable schedule, depending upon fish abundance. SPDES impingement sampling requires sixteen 24-hr impingement collections in April, twenty in May, six in August, and four in each of the remaining months. Diversion abundance is determined during each impingement survey and viability is evaluated weekly throughout the year. Additional viability sampling was conducted during April, May, October, and November 1982 as part of the evaluation of the diversion system. Table 3.0-1 summarizes the sampling schedule.

3.3 VIABILITY SAMPLING PROCEDURE

Prior to the initiation of a sample collection, the discharge pipe piezometer was read to determine the flow rate to the lake. A

TABLE 3.0-1

PROPOSED SAMPLING SCHEDULE: APRIL 1981 - NOVEMBER 1982

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
[illegible] 1982-Nov 1982	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	5 24-hr collections	1 survey[a] per impingement survey	1 survey[b] per week
	September	4 24-hr collections	1 survey[a] per impingement survey	1 survey[b] per week
	October - November	4 24-hr collections	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.

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. Once the flow was stabilized, the piezometer tubes were read again to ensure that the water flow into the sampling basin equaled the previous lake discharge flow. At sample termination (after 15 or 30 min), the gate valves were switched, returning the flow to the lake, and the basin was slowly drained to a depth of approximately 0.3 m (1 ft).

The fish crowder was lowered along the inclined screen and manually slid across the basin floor to crowd the collected fish gently to one side of the basin for sorting purposes. Live (swimming normally) and/or stunned (swimming erratically) fish of the selected dominant species were sorted into labeled transfer buckets full of ambient basin water and immediately transferred to numbered latent effects tanks. Sorting was conducted under subdued light and with minimal handling to reduce shock.

If large numbers of a 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 or 18-liter containers, depending on their size and numbers. Holding capacity of each tank was based on 5 g of fish weight per liter 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 with the remainder of the sample.

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.

3.4 SCREENHOUSE HOLDING FACILITIES

The holding and latent survival observations of diverted organisms were conducted in a wet laboratory constructed in the screenhouse of Unit 6. The space is divided into two areas: a holding tank area and an ancillary storage and work area. Ambient water from the screenwell is supplied to a sand filter in the holding area by the service water pumps. The Airquatic Model FG24-FCA fiberglass sand filter with a filtration rate of 4 l/s (63 gpm) and filter area of 0.3 m^2 (3.1 ft^2) processes the entire flow prior to use. The filtered water flows through PVC pipes to valved attachment points at each 570-liter (150-gal) plastic holding tank. Each tank is operated on a flow-through system with adjustable standpipe (variable water depth). When needed to hold juveniles or small species, 18-liter flow-through containers were arranged within the 570-liter tanks (Figure 3.0-3). A Schramm Model 3/4 JS-B compressor supplies air to the holding facility.

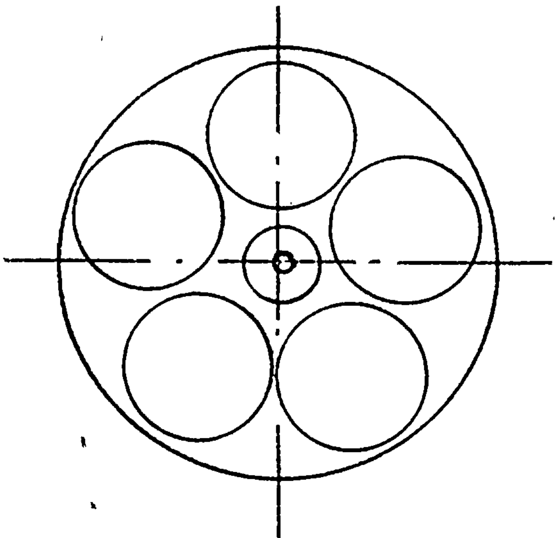
3.5 ANALYSIS PROCEDURE

3.5.1 Equipment

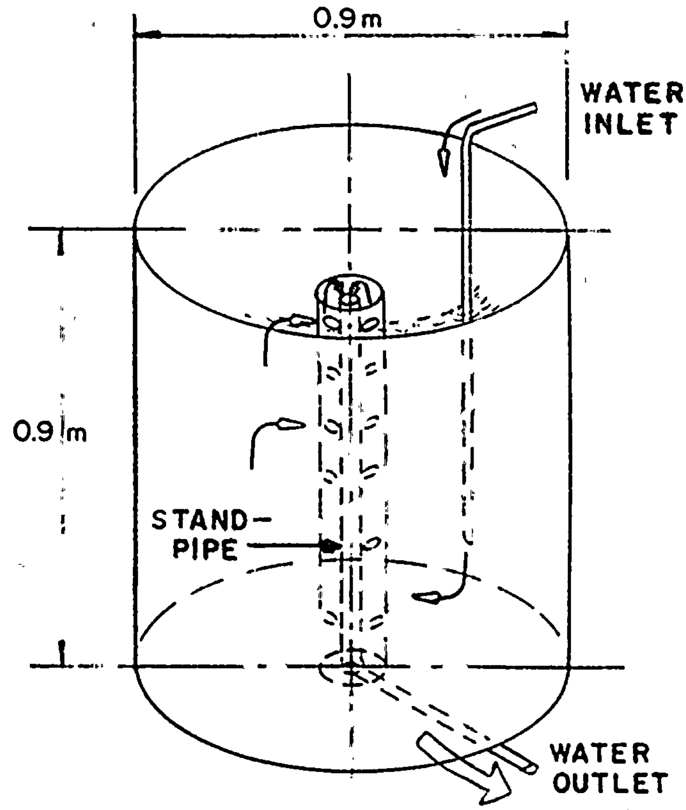
All fish length measurements were performed on standard fish measuring boards to 0.1-cm accuracy. Fish weights less than 250 g were measured on a Fisher Model XS-250 digital analytical balance to

FIGURE 3.0-3

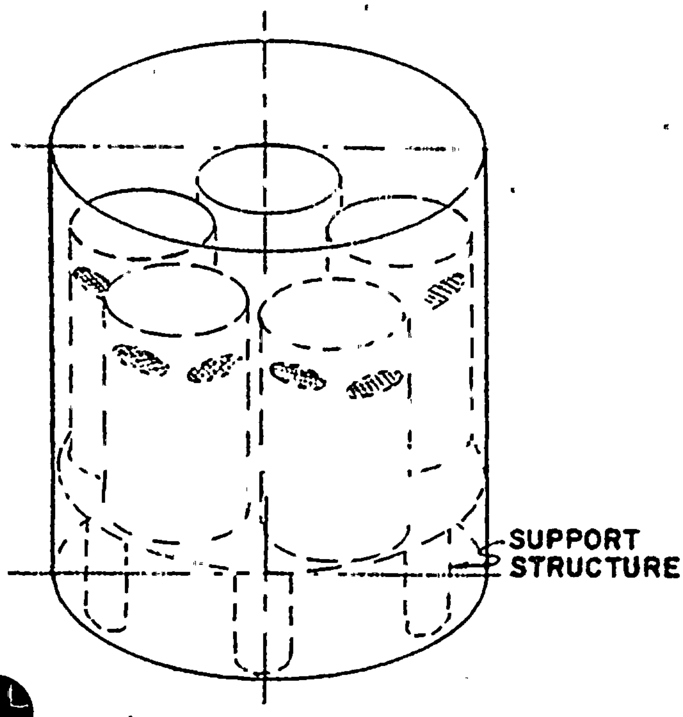
LATENT SURVIVAL HOLDING CONTAINERS



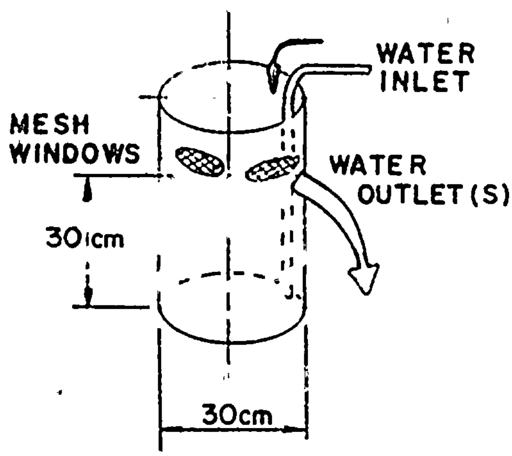
TOP VIEW



570 LITER TANK



SIDE VIEW



18 Liter TANK

ARRANGEMENT OF 18 Liter TANKS
IN 570 LITER TANK

0.1-g accuracy. Fish weights in excess of 250 g were measured on a Fisher countertop balance to 1.0-g accuracy. All weights were determined on thawed fish that were blotted dry.

3.5.2 Methods

All fish collected from the sample basin during a given 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. Following preliminary analysis, all fish were composited for secondary analysis.

Secondary analysis consisted of individual length and weight measurements, a visual examination of gonad development and sex, and visual examination for parasites. If a composite contained more than 100 individuals per species, a random numbers table was used to generate a subsample.

All viability fish that were tested for latent survival received complete secondary analysis.

CHAPTER 4.0

RESULTS AND DISCUSSION

4.1 COMMUNITY STRUCTURE

Viability testing was conducted on those fish entrapped at the offshore intake and diverted through the angled screen diversion system. The total entrapped population is determined by the sum of fish impinged (No./hr) on either the primary or secondary diversion screens and the number of fish diverted (No./hr) based on the sample basin collections (abundance and viability). This number is defined as the total entrapment rate. In this report, these numbers are used only to identify the dominant species for viability testing purposes. In the year-end report, the survival results will be adjusted for the proportion initially alive and then applied to the impingement and diversion rates to assess the effectiveness of the diversion system in returning alive to the lake the fish entrapped in the cooling water flow.

The fish collections demonstrated a definite seasonal pattern (Table 4.0-1). Spring collections were dominated by adult alewife and rainbow smelt; fall collections were dominated by juvenile rainbow smelt, alewife, and gizzard shad. While the same species dominated in both years, their absolute abundance differed widely. Adult alewife abundances were high (>118 fish/hr) in the spring of 1981 while adult rainbow smelt were low (<15 fish/hr). In the fall and early winter of 1981, juvenile 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 juvenile fish except smallmouth bass.

TABLE 4.0-1

MONTHLY MEAN ENTRAPMENT RATE[a]

Oswego Steam Station Unit 6 - 1981-1982

MONTH	SELECTED SPECIES									GRAND TOTAL[b]
	AW	RSM	EMSH	GSD	WP	STSH	SMB	TSB	YP	
Apr 1981	74.5	12.5	0.4	1.2	1.0	0.5	-	-	0.4	94.0
May	118.7	4.5	0.1	-	1.0	0.4	-	-	0.4	128.9
Jun	58.3	0.8	0.3	0.3	0.2	0.3	-	-	0.3	63.6
Jul	25.6	0.3	-	-	0.1	0.7	0.3	0.1	-	27.4
Aug	1.5	-	-	-	-	2.0	1.6	-	0.4	5.6
Sep	29.9	16.6	10.0	3.0	-	0.5	-	-	0.2	62.5
Oct	112.1	104.7	8.3	19.3	8.9	5.5	0.2	-	0.5	267.9
Nov	10.4	110.1	3.6	6.6	2.6	0.7	-	2.4	0.3	141.7
Dec	2.0	164.1	1.1	1.2	0.2	0.3	-	6.3	-	178.7
Jan 1982	2.8	50.4	0.7	0.8	0.4	0.6	0.2	0.2	0.5	64.4
Feb	0.4	8.5	1.4	0.2	0.4	-	0.4	0.1	-	12.9
Mar	0.4	11.6	0.9	0.4	2.5	0.2	0.2	0.2	0.2	19.4
Apr	55.3	74.9	1.1	0.2	4.3	0.8	c	0.4	0.6	143.6
May	25.7	0.8	0.5	c	0.1	0.2	0.2	-	0.2	29.8
Jun	16.1	2.2	0.1	-	0.2	-	-	-	0.2	20.9
Jul	38.0	0.9	0.4	-	0.4	0.4	0.4	-	0.2	42.2
Aug	3.0	1.5	0.2	-	1.6	0.6	1.6	c	0.5	11.4
Sep	15.5	9.7	1.0	0.3	0.4	2.5	0.3	-	-	30.9
Oct	6.1	3.5	0.4	0.4	0.1	1.0	1.7	-	-	14.6
Nov	1.0	3.4	-	0.6	0.1	0.2	0.3	-	0.1	7.1

[a]No./hr (sum total of impingement, diversion, and viability studies).
[b]All species collected; includes small numbers of other species.
[c]<0.1.
- Not collected.

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

The dominant species for survival testing purposes were alewife, rainbow smelt, emerald shiner, gizzard shad, and white perch. Several other species were also collected in lesser numbers (Table 4.0-1).

4.2 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 densities of much 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 samples equally when estimating survival is not advisable since proportions based on only a few fish are extremely variable. Therefore, where sample size was small (<30 organisms), samples 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);

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

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

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 calculate the precision of the survival estimate; it also defines the maximum number of fish needed for any degree of precision in the survival estimate.

A block was described by 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 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. A minimum of 30 test organisms was used to define a block, but in most cases a block was represented by at least 100 test organisms.

4.3 SURVIVAL RESULTS

During the 20 months of sampling, a total of 984 viability collections (15 or 30-min sample duration) and 430 diversion abundance collections were conducted (Table 4.0-2). 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

TABLE 4.0-2

SAMPLING SUMMARY APRIL 1981-NOVEMBER 1982

Oswego Steam Station Unit 6

MONTH	No. IMPINGEMENT SURVEYS 8-hr	No. IMPINGEMENT SURVEYS 24-hr	No. DIVERSION ABUNDANCE COLLECTIONS	No. VIABILITY COLLECTIONS
Apr 1981[a]	7	3	32	72
May[a]	12		24	72
Jun[a]	8		16	48
Jul[a]	4		8	24
Aug[a]	3		6	18
Sep[a]	3		6	12
Oct[a]	10	3	38	78
Nov[a]	10		20	60
Dec[a]	14		28	84
Jan 1982[a]	7	3	32	66
Feb[a]	13		26	54
Mar[a]	12		24	60
Apr[b]		16	32	72
May[b]	1	20	42	66
Jun[b]	1	4	14	36
Jul[b]	1	4	14	30
Aug[b]		6	18	24
Sep[b]	1	4	14	24
Oct[b]	1	4	14	42
Nov[b]	5	4	22	42
TOTAL	113	71	430	984

[a]Work effort performed as part of Unit 6 evaluation.
[b]Work effort performed as part of Unit 6 evaluation and SPDES permit requirements.

initially live vs the initially stunned fish. The dead fish were identified, enumerated and saved for subsequent analysis.

Table 4.0-3 summarizes the results of the initial viability observation following diversion for eight species. These results include all fish collected in the sampling basin, a total of 33,827 specimens. To facilitate evaluation of survival, the stunned and live classifications were combined to provide a live vs dead comparison. The initial classification of live and stunned was highly dependent upon individual species behavior and water temperature and to a lesser degree the judgment of the technician. The absolute determinant of ultimate survival was the final condition 96 hrs after collection. Thus these numbers were the ones used in the overall assessment of system effectiveness.

As described in Section 4.2, 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 are not performed in conjunction with initial classification, the blocks could not be used to segregate by age class, but since seasonal trends were predominantly composed of single age groups, i.e., juveniles 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. From 4 to 58% of the alewives that were collected from the sample basin were initially classified as dead. The ranges for rainbow smelt, gizzard shad, and white perch were 19 to 72%, 7 to 15%, and 1 to 53%, respectively. 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

TABLE 4.0-3

INITIAL CLASSIFICATION AS LIVE OR DEAD FOLLOWING DIVERSION

Oswego Steam Station Unit 6

SPECIES		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Alewife	No. Obs.	-	→	→	1038	2044	1584	1387	81	561	5355	330	65
	% Live	NA			96	81	68	79	70	42	70	77	82
	% Dead	NA			4	19	32	21	30	58	30	23	18
Rainbow smelt	No. Obs.	2541	270	443	2674	62	→	70	←	275	3598	2303	5849
	% Live	62	64	60	81	61		56		28	65	51	50
	% Dead	38	36	40	19	39		44		72	35	49	50
White perch	No. Obs.	→	→	63	134	→	→	→	→	→	208	66	←
	% Live			94	99						70	47	
	% Dead			6	1						30	53	
Gizzard shad	No. Obs.	41	←	←	-	-	-	-	-	→	1073	221	54
	% Live	93			NA	NA	NA	NA	NA		90	88	85
	% Dead	7			NA	NA	NA	NA	NA		10	12	15
Emerald shiner	No. Obs.	35	41	→	54	←	←	→	→	92	433	106	51
	% Live	89	98		81					88	97	93	92
	% Dead	11	2		19					12	3	7	8
Spottail shiner	No. Obs.	→	→	43	←	→	→	→	→	74	326	←	←
	% Live			88						68	94		
	% Dead			12						32	6		
Smallmouth bass	No. Obs.	←	←	←	-	→	→	→	64	←	78	←	←
	% Live				NA				89		100		
	% Dead				NA				11		0		
Yellow perch	No. Obs.	→	→	→	→	→	40	←	←	←	←	←	←
	% Live						100						
	% Dead						0						

- None collected.
NA - Not applicable.
→ X ← Combined across months during periods of low abundance.

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.

Long-term survival observations (96-hr) were conducted on 7881 fish representing 34 species (Table 4.0-4). 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. Survival for these two species was described by a total of 21 blocks (Table 4.0-5). Adult alewife survival varied from 11.7% during May to 75.0% during October. Adult rainbow smelt survival also varied dramatically: from 100% during the period January through March to zero during May. These results are graphically presented in Figures 4.0-1 and 4.0-2.

Survival of adult alewife during the spring, at the beginning of their onshore spawning migration (March-April), was 34.5% and dropped to less than 15% 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. Most of the specimens collected during this period had various degrees of fungal infestation (Saprolegnia sp.). The low survival results reported during May and June 1982 were coincident with a major alewife die-off observed in the vicinity. As the population recovered either from the stresses of spawning or other environmental conditions (temperature, low iodine levels, etc.[1]) contributing to their observed die-off, adult alewife survival increased. A maximum survival of 75% was observed during the early fall. The reduction in survival occurring in November and December 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.

TABLE 4.0-4

VIABILITY TESTING

Oswego Steam Station Unit 6

SPECIES	SCIENTIFIC NAME	TOTAL TESTED[a]
Alewife	*Alosa pseudoharengus*	3596
Rainbow smelt	*Osmerus mordax*	2830
Emerald shiner	*Notropis atherinoides*	367
Gizzard shad	*Dorosoma cepedianum*	248
White perch	*Morone americana*	228
Mottled sculpin	*Cottus bairdi*	123
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*	7
Pumpkinseed	*Lepomis gibbosus*	6
Longnose dace	*Rhinichthys cataractae*	6
White sucker	*Catostomus commersoni*	4
Stone cat	*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 nebulosa*	2
American eel	*Anguilla rostrata*	2
Largemouth bass	*Micropterus salmoides*	1
Chinook salmon	*Oncorhynchus tshawytscha*	1
Gold fish	*Carassius auratus*	1
Black bullhead	*Ictalurus melas*	1
Sea lamprey	*Petromyzon marinus*	1
Total		7881

[a]Includes initially stunned and initially live specimens.

TABLE

LONG-TERM (96-hr) SURVIVAL[a] BY SPECIES

Oswego Steam Station Unit 6

SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Alewife												
≤ 10 cm	NT	NT	NT	19.7 ± 9.0	6.8 ± 3.3	←	NT	→	4.1 ± 5.5	26.6 ± 4.4	11.8 ± 10.8	←
> 10 cm	NT	NT	→	34.5 ± 3.1	11.7 ± 2.4	12.6 ± 3.4	23.3 ± 5.4	←	→	75.0 ± 8.7	48.8 ± 10.8	←
Rainbow smelt												
≤ 10 cm	9.6 ± 2.6	9.3 ± 7.7	→	27.1 ± 11.3	←	←	NT	NT	→	45.6 ± 6.4	37.1 ± 6.2	13.0 ± 2.5
> 10 cm	→	→	100.0 ± 0	95.5 ± 1.9	0.0	←	NT	NT	NT	64.2 ± 10.4	←	←
White perch												
≤ 13 cm	→	→	→	→	→	→	→	→	→	68.1 ± 13.3	←	←
> 13 cm	→	→	→	83.7 ± 5.5	←	←	←	←	←	←	←	←
Gizzard shad												
< 48 cm	→	→	→	→	→	→	→	→	→	60.9 ± 6.1	←	←
Emerald shiner												
< 10 cm	→	→	→	→	→	→	→	→	→	92.9 ± 2.6	←	←
Spottail shiner												
< 14 cm	→	→	→	→	→	→	→	→	→	90.8 ± 5.2	←	←
Smallmouth bass												
< 40.9 cm	→	→	→	→	→	→	→	→	→	92.8 ± 6.1	←	←
Yellow perch												
< 26.2 cm	→	→	→	→	→	97.7 ± 4.5	←	←	←	←	←	←
Threespine stickle-back												
< 7.0 cm	→	→	→	→	→	→	→	→	→	→	→	14.3 ± 8.6

[a]Percent alive at 96-hr observation ± 95% Confidence Interval.
NT = None Tested.
—▷X◁— Combined across months during periods of low abundance.

FIGURE 4.0-1

ALEWIFE SURVIVAL SUBSEQUENT TO DIVERSION

Oswego Steam Station Unit 6

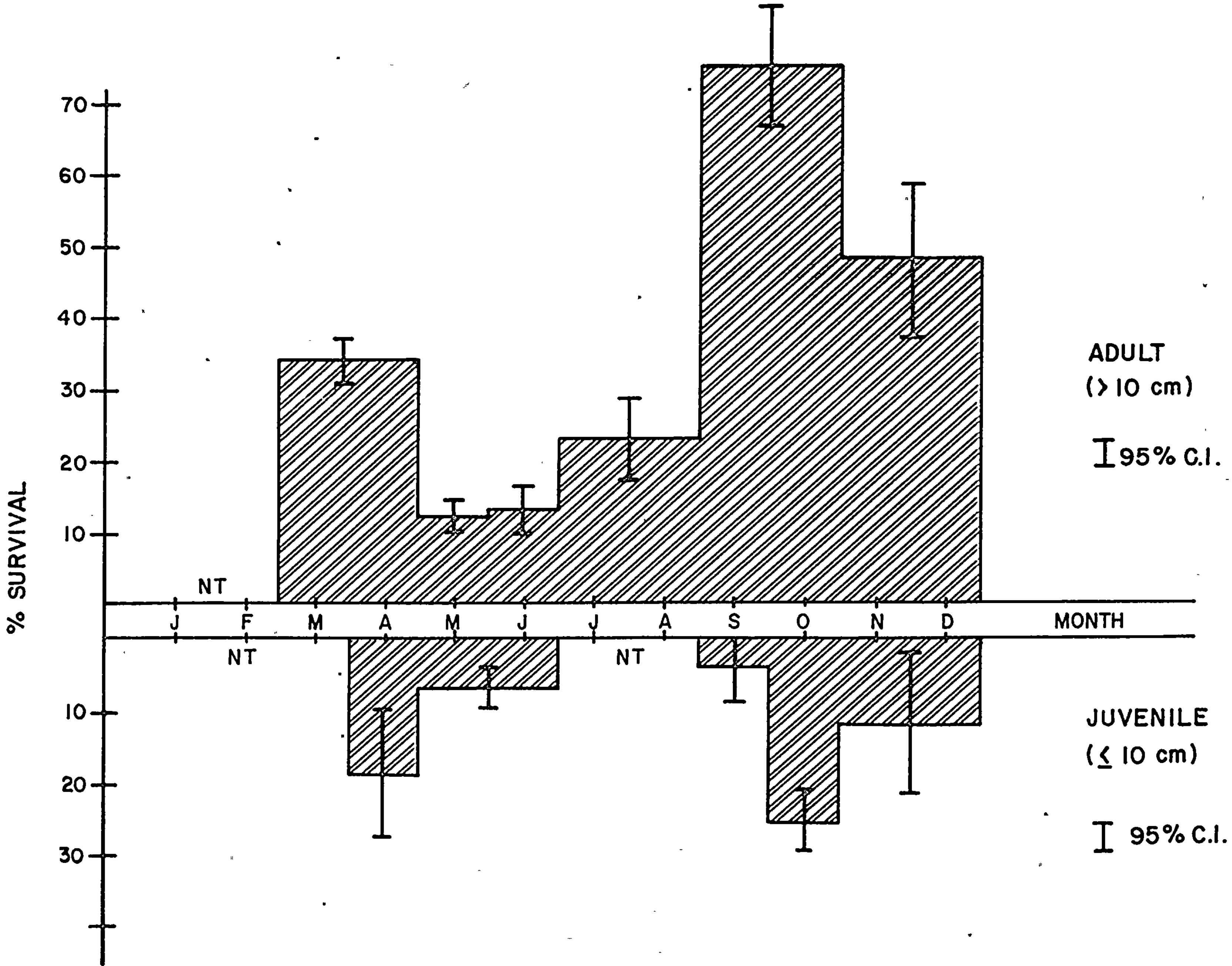
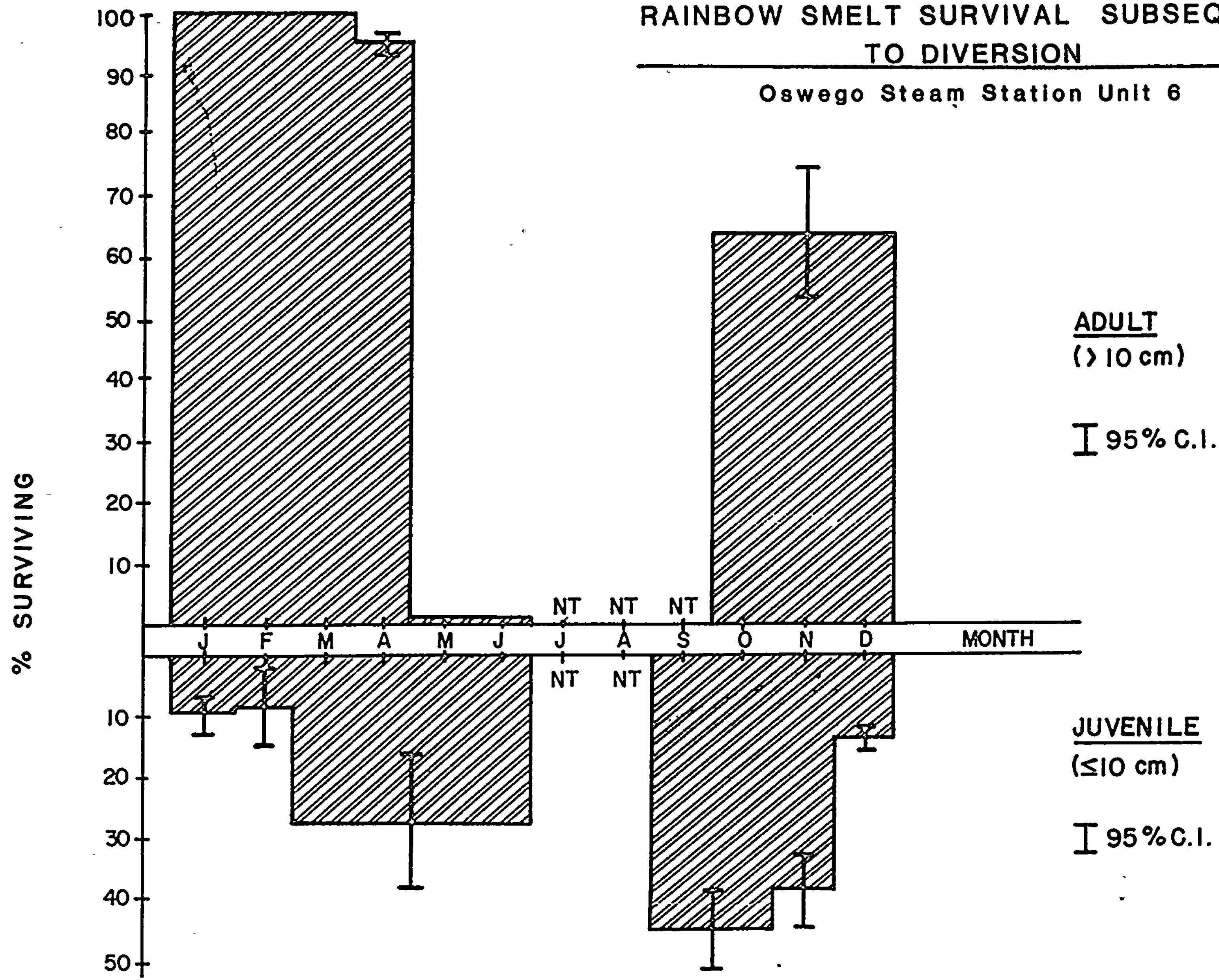


FIGURE 4.0-2

RAINBOW SMELT SURVIVAL SUBSEQUENT TO DIVERSION

Oswego Steam Station Unit 6



Juvenile alewife demonstrated similar seasonal responses. Presence of young alewife in the cooling water system occurred in late August when the organisms were approximately 2.5 to 3.5 cm in total length. By October these young had grown to 5.0 to 6.5 cm in total length and survival increased from less than 5% to in excess of 25%. With the colder temperatures and tempering occurring in November and December, survival dropped to less than 15%. By the following spring (April) the young had grown to approximately 7.5 to 8.5 cm, with a survival of close to 20%. Survival for the yearlings (8.0-9.0 cm) dropped significantly through May and June. 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 different 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, to failure to extract sufficient iodine from the iodine-poor Great Lakes, or a combination of one or more of these causes(1).

To keep the alewife survival information in proper perspective, natural mortality of this species should be considered in conjunction with the observed diversion survival. As demonstrated in the data, adult survival was significantly higher than juvenile survival. Likewise, natural mortality of juvenile alewife is higher than adult mortality (aside from the periodic catastrophic mortalities that affect primarily adult alewife(2)). The average monthly instantaneous mortality for young-of-year alewife in the Hudson River was estimated at 0.125(3). Hence, the survival fraction corresponding to the nine-month (September-May) period from young-of-year to Age I is given by

$$S = e^{-0.125(9)} = 0.325$$

The same data provided an instantaneous mortality rate from Age I to Age II (sexual maturity for most alewife[4]) of 0.056, giving a survival fraction for the corresponding 12-month period equal to

$$S = e^{-0.056(12)} = 0.511$$

Since alewife become mature at Age II, through-plant mortality of organisms less than Age II could be converted to Age II fish through a computation of equivalent adults. Survival estimates to Age II can be obtained by consecutively multiplying the individual life stage survival rates. Thus, the survival rate for young-of-year fish (juveniles) is 0.166 (17%), and Age I fish (subadults) is 0.511 (51%). These values will be applied to the impingement and diversion mortality to estimate the plant cropping in terms of equivalent adults. This assessment will be published in the fall of 1983.

The higher survival of the adult alewife relative to the lower juvenile alewife survival is a major factor in overall impact assessment.

Adult rainbow smelt survival subsequent to diversion was closely related to their spawning condition. Throughout the late winter and early spring, rainbow smelt survival remained very high (95-100%). By completion of spawning in May, their survival had dropped to zero. 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 that were collected were in better condition and demonstrated good survival (64%).

Juvenile rainbow smelt survival during the fall was significantly higher than the corresponding alewife juvenile survival. As seen with the alewife, survivals decreased during December and remained low throughout the winter (January and February). The increased survival observed for the smelt yearlings for the period March through June relative to that observed during the previous winter 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.

Although no published survival estimate for rainbow smelt have been located, they can be estimated from results from other species to be between 5 and 15% for young-of-year and 40 to 60% for subadults (Age I). Based on the high survival of adults through the system in early spring and the high natural mortality of the juvenile (young-of-year) through their first year (concomitant with low diversion survival), it is anticipated that impact to the rainbow smelt population from the operation of Unit 6 will be minimal.

Sufficient numbers of white perch were collected and tested to identify two age classes with different seasonal distribution and survival. Juvenile white perch predominated during October and November and showed an overall survival of 68.1%. Adults of the same species were typically present during the spring (March through May) and showed a higher overall survival of 83.7% (Table 4.0-5).

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 4.0-6 provides a summary of the remaining species which occasionally occurred in collections and did not show a specific seasonal trend. Of the 25 species, only one, central mudminnow, demonstrated a survival of less than 75%. Of the 318 specimens reported in Table 4.0-6, a total of 300 (94.3%) survived passage through the diversion system.

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., juvenile 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 juvenile of the same species. Adult survival was highest immediately preceding the spawning activity and lowest immediately following.

In general, the Oswego Steam Station Unit 6 diversion system is functioning as designed and sufficient information has been gathered to identify the survival rate for the dominant species present. This survival information and impingement and diversion abundance data, coupled with the comprehensive historical data base assembled since 1970 regarding fish impingement and populations in this area of Lake Ontario, is sufficient for an adequate assessment of the aquatic impact associated with the operation of the Unit 6 once-through cooling water system. This assessment will be published in the fall of 1983.

TABLE 4.0-6

SURVIVAL SUBSEQUENT TO PASSAGE THROUGH THE DIVERSION SYSTEM

Oswego Steam Station Unit 6

	No. TESTED	No. ALIVE AT 96 hr	% SURVIVING
American burbot	11	11	100
American eel	2	2	100
Black bullhead	1	1	100
Brown bullhead	2	2	100
Brown trout	12	12	100
Bluegill sunfish	16	16	100
Chinook salmon	1	1	100
Central mudminnow	2	1	50.0
Common shiner	4	4	100
Goldfish	1	1	100
Johnny darter	23	22	95.6
Lake chub	2	2	100
Largemouth bass	1	1	100
Longnose dace	6	6	100
Logperch	31	31	100
Lake trout	3	3	100
Mottled sculpin	123	117	95.1
Pumpkinseed	6	5	83.3
Rock bass	34	32	94.1
Rainbow trout	7	6	85.7
Sea lamprey	1	1	100
Stone cat	4	3	75.0
Trout perch	13	11	84.6
White bass	8	6	75.0
White sucker	4	3	75.0
TOTAL	318	300	94.3

REFERENCES CITED

1. Colby, P.J. 1971. Alewife dieoffs: why do they occur? Limnos 4:2: 18-27.

2. Brown, E.H. Jr. 1968. Population characteristics and physical condition of alewives, Alosa pseudoharengus in a massive dieoff in Lake Michigan. Great Lakes Fishery Commission Tech. Rept. No. 13.

3. Barnthouse, L.W. et. al. 1982. The impact of entrainment and impingement on fish populations in the Hudson River estuary. Vol. II. Oak Ridge National Laboratory, Environ. Sci. Div. Publ. 1791. [NUREG/CR-2220, Vol. II, ORNL/NUREG/TM-385/V2.]

4. Scott, W.B., and E.J. Crossman. 1973. Alewife, p. 120-127. In Freshwater fishes of Canada. Fish. Res. Bd. Can. Bull.