Dominion Nuclear Connecticut, Inc.
Millstone Power Station
Rope Ferry Road
Waterford, CT 06385

Dominion

Impingement

February 26, 2002

D17305

Mr. James F. Grier
Supervising Sanitary Engineer
Permitting, Enforcement & Remediation Division, Water Management Bureau
Department of Environmental Protection
79 Elm Street
Hartford, CT 06106-5127

References:

1. Letter D16199, F.C. Rothen to M.J. Harder, dated August 30, 2000.
2. Letter C10566, M.J. Harder to F.C. Rothen, dated November 14, 2000
3. Letter D17249, W. Mathews to M.J. Harder, dated August 31, 2001.
4. Letter C10827, J.F. Grier to M. Keser, dated February 6, 2002.

Millstone Power Station
Comments on Scope of Study
<u>Cooling-Water System Technology Study</u>

Dear Mr. Grier:

By letter dated August 30, 2000 (Reference 1), a final Scope of Study (SoS) was submitted to the Connecticut Department of Environmental Protection (DEP), outlining alternative technologies which were to be examined to reduce entrainment of fish eggs and larvae from the use of once-through cooling water at Millstone Power Station (MPS). On November 14, 2000 (Reference 2), DEP in approving the SoS reserved the right "to modify and/or expand the [SoS]...based on the recommendation of independent expert/consultant review." The final report for the study, entitled "An Evaluation of Selected Cooling-Water System Alternatives for Millstone Power Station", was submitted by Dominion Nuclear Connecticut, Inc. (DNC) to DEP on August 31, 2001 (Reference 3).

Subsequent to the submittal of the final report on August 31, 2001, ESSA Technologies Ltd. was retained by DEP to perform reviews of both the SoS and the final report. Having reviewed the SoS, comments from both DEP and ESSA Technologies Ltd. were forwarded to DNC on February 6, 2002 (Reference 4).

Comments provided in Reference 4 are addressed by DNC in Enclosure 1 to this letter. If there are any further questions or comments regarding the SoS, DNC's responses to the comments of DEP and ESSA Technologies Ltd., or on other matters related to the MPS cooling-water study, please contact Dr. Milan Keser, Millstone Environmental Laboratory, at (860) 444-4238.

Very truly yours,

DOMINION NUCLEAR CONNECTICUT, INC.

Gary W. Johnson
Supervisor - Environmental Programs

Enclosure

cc: Mr. Ernest Beckwith
Connecticut Department of Environmental Protection
Marine Fisheries Office
PO Box 719
Old Lyme, CT 06371

Enclosure 1 to Letter No. D17305

RESPONSE TO COMMENTS MADE BY THE CONNECTICUT DEPARTMENT OF ENVIRONMENTAL PROTECTION AND ESSA TECHNOLOGIES LTD. REGARDING THE SCOPE OF STUDY FOR "COOLING WATER SYSTEM ALTERNATIVES TO REDUCE ENTRAINMENT AT MILLSTONE POWER STATION" SUBMITTED BY DOMINION NUCLEAR CONNECTICUT, INC. ON AUGUST 31, 2000

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION
NPDES PERMIT No. CT0003263

Dominion Nuclear Connecticut, Inc.
Millstone Environmental Laboratory
PO Box 128
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February 2002

RESPONSE TO COMMENTS MADE BY THE CONNECTICUT DEPARTMENT OF ENVIRONMENTAL PROTECTION AND ESSA TECHNOLOGIES LTD. REGARDING THE SCOPE OF STUDY FOR "COOLING WATER SYSTEM ALTERNATIVES TO REDUCE ENTRAINMENT AT MILLSTONE POWER STATION" SUBMITTED BY DOMINION NUCLEAR CONNECTICUT, INC. ON AUGUST 31, 2000

Introduction

Based upon its review of a report prepared by ESSA Technologies Ltd., which provides comments on the Scope of Study (SoS) submitted by NNECO (2000) for the project entitled "Cooling Water System Alternatives to Reduce Entrainment at Millstone Power Station" (DNC 2001a), the Connecticut Department of Environmental Protection (DEP) by letter dated February 6, 2002 (DEP 2002) requested comments on the following areas in reference to the SoS:

1. Potential structural modifications (e.g., extending jetties/groins, etc.);
2. Combinations of possible BTA;
3. Technologies which are usually applied to mitigate impingement were evaluated for the purpose of reducing entrainment; and
4. Impingement impacts and mitigation.

In providing comments, DEP noted that it had not required an evaluation of impingement impact in the cooling-water study because there was a general consensus that this impact was minor in comparison to entrainment. However, DEP further stated that it would be beneficial to compile for the record pertinent information regarding measures taken to reduce or mitigate impingement impact, such as with fish return systems, and to summarize the various monitoring and assessment studies undertaken over the years to address this issue.

In the following, Dominion Nuclear Connecticut, Inc. (DNC) addresses, in the order given above, each of the above comments resulting from the review of the SoS for Millstone Power Station (MPS) cooling water system alternatives by DEP and ESSA Technologies Ltd.

Item #1: Potential Structural Modifications to the MPS Intakes

Constructing a jetty or groin to reduce the entrainment of fish eggs and larvae was not considered in DNC (2001a) because the objective of the study was to evaluate measures that would minimize the use of once-through cooling water at MPS or otherwise reduce entrainment mortality. A structure such as a jetty or groin would not reduce the volume of water withdrawn by MPS and therefore would only reduce entrainment mortality if it could somehow result in the plant intakes withdrawing water having substantially lower egg and larval densities.

ESSA Technologies Ltd. noted in their review of the SoS that jetties extending from the present intakes could "reduce entrainment and impingement by changing the current patterns in the intake area." DNC respectfully differs with this view and believes that such structures may actually serve to increase both impingement and entrainment. The tidal flow in Long Island Sound (LIS) near MPS is substantial and local circulation patterns are described in DNC (2001a: Appendix B to Chapter 3 of Part II). For example, average tidal flow through Twotree Island Channel just off Millstone Point is nearly 900 thousand gallons per second and at maximum is about 2.2 million gallons per second. Extensive mixing of Niantic Bay and LIS waters occurs in the vicinity of the plant, with a mean tidal exchange of nearly 45 million gallons per minute. Vigorous tidal circulation also results in no vertical stratification of waters in inshore areas near MPS. This dynamic movement of water is also reflected by well-mixed distributions of organisms, such as winter flounder larvae and tautog eggs, as noted in DNC (2001a). Although some differences in densities may be found at inshore locations by tidal stage, the short temporal scales involved (tidal cycle of approximately 12.5 hours) mean less variation in densities over longer time scales. For example, densities of winter flounder larvae and tautog eggs only decrease much farther offshore than a jetty could be feasible. Even at the proposed location for an offshore intake in LIS (about 1 mile south of the present MPS intakes), the eggs and larvae of most fishes have similar or even higher densities than found in inshore areas near the present MPS intakes (DNC 2001a: Section 2.6, Chapter 2 of Part II). Thus, a jetty located near the intake structures would not alter flow patterns and ichthyoplankton densities enough to decrease entrainment as long as the same seawater volume is being entrained.

Evidence exists that a jetty-like structure, the Unit 3 intake construction cofferdam, may have contributed to increased impingement at MPS while it was in place. In effect, this structure, adjacent to Unit 2, created an embayment adjacent to the Unit 2 intake structure that likely funneled organisms towards that intake and, when it was in place, increased impingement relative to the period after its removal. This is analogous to power plants having intake canals, which tend to have higher impingement rates in comparison to stations with shoreline intakes. Following the removal of this cofferdam in 1983, impingement rates at Unit 2 significantly ($p < 0.01$) decreased (NUSCO 1987).

Structures such as jetties or groins may also act as an artificial reef in marine waters, attracting additional fish and invertebrates, which then become susceptible to impingement at any nearby intake. Although fish return systems have reduced impingement mortality for many species at MPS, potentially large increases in impingement due to the placement of a jetty or similar structure would result in additional incremental mortalities. Localized spawning of fish attracted to a jetty or groin, such as cunner, tautog, and rock gunnel, would also result in increased egg and possibly also larval entrainment at the nearby intakes.

The use of jetties or groins as envisioned would necessitate the placement of one or more massive structures into LIS. The impact of such large structures upon the benthic community of Niantic Bay could be considerable and would need to be further assessed.

Finally, neither jetties nor groins were listed as an existing or potential available technology for fish protection at power plants in extensive reviews performed by EPRI (1999) and Taft (2000). A jetty-like structure, a porous dike, however, was discussed in EPRI (1999) and this technology was included in the SoS (NNECO 2000) and evaluated for feasibility at MPS in DNC (2001a).

Item #2: Combinations of Possible BTA

DNC conducted a comprehensive evaluation of cooling water alternatives in its final report of August 31, 2001 (DNC 2001a). Each alternative was reviewed independently so that costs and resulting reductions in entrainment or entrainment mortality could be assessed for each. Some technologies examined clearly would not be combined (e.g., Gunderboom and cooling tower) because one technology would preclude the need for the other. In other instances, further review would be necessary to determine the feasibility of combining various intake technologies. If a combination of intake technologies is of interest, DNC would welcome the opportunity to perform any necessary analyses and supplement its final report upon a request of DEP. However, due to the potential for evaluating numerous technology combinations, DNC hereby proposes to meet with DEP subsequent to the review of the final cooling water alternatives report (DNC 2001a) to discuss this issue before any further evaluations are undertaken.

Item #3: Technologies Usually Applied to Mitigate Impingement Were Evaluated For Reducing Entrainment

ESSA Technologies Ltd. noted in DEP (2002) that "...behavioural barriers are impingement-reducing technologies that normally are not applied to reduce entrainment." DNC concurs with this comment and notes that behavioral barriers were only identified for consideration as part of the SoS because the present entrainment evaluation (DNC 2001a) was viewed as a continuation of the previous entrainment and cooling water alternatives study (NUSCO 1993a). Thus, an additional review was accomplished for completeness.

Prior to the 1993 study being performed, a series of meetings was held between DEP and Northeast Utilities Service Company (NUSCO), acting as agent for Northeast Nuclear Energy Company (NNECO), the then owner of MPS. These meetings and related correspondence resulted in a request from DEP that was reiterated in NUSCO (1992a) as follows: "[t]he proposed study...should review intake structure alternatives including screening devices and physical barriers such as sills, baffles, and curtain walls." At the time, behavioral barriers were viewed by Stone & Webster Engineering Corporation, NUSCO's contractor for the engineering portion of the 1993 study (and also for the present effort), as a potential intake screening technology that could reduce the entrance of larvae into a power plant intake structure. However, after performing a literature review of this technology, behavioral barriers were found not to have the ability to reduce larval fish entrainment (NUSCO 1993a).

Behavioral barriers were again reviewed in DNC (2001a) to see if any promising technologies had developed in the interim (e.g., air bubble flotation systems, which were once viewed as possibly having potential to reduce entrainment). However, no behavioral technologies to reduce entrainment were identified in a comprehensive industry review of fish protection at cooling water intakes (EPRI 1999; Taft 2000). As a result, these technologies were again found not to warrant further detailed evaluation.

Item #4: Impingement Impacts and Their Mitigation Were Not Addressed in the SoS

Introduction. As cited above, DEP in its letter of February 6, 2002 noted that DNC (or NNECO, as the former owner of MPS) was not required to formally evaluate impingement impacts in the 2001 study because a general consensus had been reached that potential impingement impacts were a minor concern in comparison to entrainment. This conclusion was the result of a series of evaluations and modifications (e.g., installation of fish returns; upgraded screen systems) to MPS intake structures made since 1980 to reduce impingement mortality. However, as ESSA Technologies Ltd. noted in their review, "[t]he SoS does not ... justify why impingement effects of the station will be excluded from the Study." Thus, DEP (2002) has now requested that DNC "compile, for the record, all pertinent information regarding measures taken to reduce/mitigate impingement (fish return systems, etc.), and the associated monitoring and assessment studies undertaken over the years to address this issue" (DEP 2002). The following provides the requested historical review. As part of the review, a list of selected reports and correspondence related to MPS impingement that were submitted mostly to DEP by NNECO or NUSCO is provided in Table 1. As indicated on the table, many of these documents are appended to this enclosure. These documents are the basis for much of the summary of impingement that follows; additional details may be found in the references themselves.

Brief Description of MPS Intakes. The MPS cooling water intake structures are typical of many coastal power plants. Briefly, Units 1 and 2 have four circulating water intake bays and Unit 3 has six located in separate shoreline intake structures on Niantic Bay. Each unit has a surface skimmer wall extending about 3-4 feet below the surface at mean low water to avoid withdrawing floating debris. The intake structures have coarse bar racks (2-inch gap) preceding vertical traveling screens to protect the plants from larger debris and help exclude larger aquatic organisms. Maximum intake approach velocities at the coarse bar racks are about 2, 1.5, and 1 foot per second for Units 1, 2, and 3, respectively. With MPS located in marine waters, considerable debris loading occasionally occurs. Common debris includes various seaweeds, detached eelgrass, and gelatinous zooplankton (jellyfish and ctenophores). Units 1 and 2 have always had 0.375-inch mesh conventional continuous belt traveling screens. Unit 3 originally had 0.1875-inch mesh screens, then a combination of 0.1875- and 0.375-inch mesh screens from early 1990 through summer 1992, and finally only 0.375-inch mesh screens since August 1992. Screens are rotated under differential pressure setpoints and screenwash frequencies vary from continuously during storms to a minimum of once per 8 hours. At both Units 1 and 2, all debris and organisms are washed off the traveling screens into a trough using a spraywash pressure of 85 psi. Originally, all debris and impinged organisms from Units 1 and 2 were retained in perforated baskets; screenwash water drained from the basket into LIS through a pipe. However, as noted below in the discussion of the history of impingement at MPS, a fish return system (also termed sluiceway) was retrofitted at each of these units. Unit 3 was built with a two-trough fish and trash return designed as an integral part of the intake screen system. The effectiveness of the Unit 3 fish return system is discussed in more detail below. For screenwashes at Unit 3, a low pressure (10 psi) spray is used to flush organisms off modified-lip fish baskets on the traveling screen panels into a lower fish sluiceway trough, which discharges into LIS along the seawall on the west side of the intake structure. Material remaining on the screens as they continue to rotate is washed off with a high (85 psi) pressure spray into an upper trash trough, which exits the screenhouse in the opposite direction as the fish return. Using a motorized conveyor system, this material empties into trash hoppers for disposal offsite.

Impingement Sampling. Impingement at MPS was initially intensively monitored to quantify losses and determine local species impacted. At Unit 1, mostly qualitative observations were made throughout 1971. Routine impingement monitoring began in 1972, when all impinged organisms were collected, identified, and counted daily over a 24-hour period. This process continued following the start-up of Unit 2 in 1975. However, in 1977 the collection frequency was reduced to three 24-hour samples per week and monthly impingement rates were estimated using sample count data and actual water volumes entrained at MPS. Within each month, an estimate for each day not sampled was calculated by multiplying the average impingement density (number per unit volume of cooling water used on days sampled) by the volume of cooling water on days not sampled. Monthly and annual impingement estimates were sums of daily impingement, either actual counts or estimated totals. A simulation data analysis showed that at this reduced level of effort, more than 85% of all impinged organisms were represented, but at levels of effort of less than three 24-hour samples per week, errors associated with the estimated monthly totals by species increased rapidly. Beginning in 1984, sampling effort was further stratified to increase the precision of impingement estimates for winter flounder and other fishes that were primarily taken during late winter, a period of high impingement. Sampling effort ranged from once weekly (April-November) to three (March) or four times per week (February). Routine impingement monitoring at MPS ceased in December 1987 and the reasons for this are discussed in more detail below in the narrative for Unit 2.

During the years when impingement sampling and fish return studies were conducted at MPS, more than 125 taxa of marine organisms were collected. A summary of impingement estimates at MPS for the most frequently taken fishes and macroinvertebrates is given in Table 2. Of note, two large impingement events occurred at MPS that involved schooling fishes. An estimated 50 million juvenile Atlantic menhaden and blueback herring were impinged at Unit 1 during August 10-20, 1971, causing screens to collapse and the unit to shut down. Since this event occurred prior to the advent of systematic impingement sampling at MPS, these totals do not appear on Table 2. No further impingement events of this magnitude or having such consequences to plant operations have occurred at MPS in the subsequent three decades. At Unit 2, an estimated 390,000 American sand lance were impinged during one 24-hour sampling period in July 1984; the weekly estimate was 480,000 and sand lance impingement during 1984 alone accounted for nearly half of the total estimated impingement of fish from 1976 through 1987 (Table 2). Excluding this mass impingement event, six fish taxa dominated impingement. These were the winter flounder, anchovies (mostly bay anchovy), grubby, silversides (mostly Atlantic silverside), Atlantic tomcod, and threespine and blackspotted sticklebacks. Among the invertebrates, Atlantic long-finned squid, various crabs, and American lobster were most numerous in impingement samples. Many of these species tended to have greatest impingement associated with storm events, particularly when water temperatures were cold or declining rapidly.

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TABLE 1. Summary of selected reports and correspondence submitted to CT DEP or other agencies which contain information on or assessed the effect of impingement at MPS. References indicated by a * are included in the Appendix to this document.

Description	Reference
Annual Reports to DEP containing information on MPS impingement monitoring from inception of sampling in 1972 to completion of sampling in 1987	NUSCO 1975-88[a]
MPS 316(b) demonstration	NUSCO 1976
Feasibility of modifying MPS Units 1 and 2 intake screenwash systems to improve the return of fish to LIS	NNECO 1981*
MPS Unit 3 Environmental Report (to the US Nuclear Regulatory Commission)	NUSCO 1983
Effectiveness of the MPS Unit 1 sluiceway in returning impinged organisms to LIS	NUSCO 1986*
Justification for discontinuing impingement monitoring at MPS Unit 2	NUSCO 1987*
Winter flounder impingement at MPS	NUSCO 1988a
The effectiveness of the MPS Unit 3 fish return system	NUSCO 1988b*
Progress reports on the MPS Units 1 and 3 fish return systems	NUSCO 1988c, 1989a,b, 1990a,c, 1991b, 1992b, 1993b[b], NNECO 1994*
Reassessment of impingement effects on winter flounder at MPS	NUSCO 1991a*
Aquatic organism return feasibility study for MPS Unit 2	NNECO 1999*
MPS Unit 2 aquatic organism return system survival study	DNC 2001b*

[a] Refers to successive Annual Report that were submitted by NUSCO on behalf of NNECO to DEP in April of each year; these reports were not included in the References Cited of this document.

[b] Progress reports were periodically sent to DEP related to work in improving the Unit 3 fish return system and on the operation of the Unit 1 sluiceway. Only the final report (NNECO 1994) is included in the Appendix.

Impingement

TABLE 2. Total and range of total annual impingement estimates of fishes and macroinvertebrates at MPS from 1976 through 1987 (Units 1 and 2 combined for 1976-83 and Unit 2 alone for 1984-87).

Taxon	Smallest annual estimate	Largest annual estimate	Total (1976-87)	% of total	[redacted]
Fishes:					
American sand lance	8	485,411	487,089[a]	46.9	[redacted]
Winter flounder	624	23,544	88,665	8.5	[redacted]
Anchovies	12	52,280	82,567	8.0	[redacted]
Grubby	647	14,634	61,984	6.0	[redacted]
Silversides	136	12,187	56,368	5.4	[redacted]
Atlantic tomcod	8	11,868	34,728	3.3	[redacted]
Gasterosteus spp. sticklebacks[b]	0	9,918	30,656	2.9	[redacted]
Threespine stickleback[b]	0	9,472	22,640	2.1	[redacted]
Blackspotted stickleback[b]	0	14,381	20,719	2.0	[redacted]
Cunner	57	3,851	20,131	1.9	[redacted]
Northern pipefish	384	6,572	17,478	1.7	[redacted]
Butterfish	135	4,061	17,415	1.7	[redacted]
Silver hake	41	9,419	15,944	1.5	[redacted]
Top thirteen taxa	6,404	506,492	956,384	92.1	
Others	2,039	20,992	82,086	7.9	
Total	8,560	511,387	1,038,470		
Macroinvertebrates:					
Atlantic long-finned squid	1,491	24,109	142,495	37.5	
Lady crab	1,343	31,952	120,460	31.7	
Rock crab	633	7,925	44,456	11.7	
Green crab	656	6,687	29,950	7.9	
Blue crab	437	1,963	14,317	3.8	
American lobster	501	1,967	11,900	3.1	
Spider crabs	119	1,598	8,517	2.2	
Top seven taxa	8,866	66,196	372,095	98.0	
Others	126	1,721	7,520	2.0	
Total	9,946	67,290	379,615		

[a] Approximately 480,000 American sand lance were estimated to have been impinged during the week of July 18, 1984 (98% of total sand lance impingement).

[b] Threespine (*G. aculeatus*) and blackspotted (*G. wheatlandi*) sticklebacks were not differentiated until 1981.

APPENDIX TO ENCLOSURE 1 OF LETTER D17305

D17305
Appendix 1

Feasibility of Modifying the Millstone Units 1 and 2 Cooling Water Intake Screen Wash System to Improve the Return of Fish to Long Island Sound

Submitted to the

State of Connecticut

Department of Environmental Protection

Prepared by

Northeast Utilities Service Company

for

Northeast Nuclear Energy Company

July 31, 1981

Summary

Estimates of the number of fish and macroinvertebrates impinged annually at Millstone Units 1 and 2 from 1976 through 1980 and their survival were calculated. Based on present operations, survival was relatively low for most fish. A special study was conducted from December 1980 through April 1981 to determine initial and extended survival of organisms collected immediately following screenwashes. The potential for a sluiceway to increase survival was good since survival of many species, including the commercial and recreationally important winter flounder, was high. Some smaller fishes, however, had poor survival. Few significant differences in survival were found among the four wash schedules examined.

Using the survival estimates, economic value was calculated for four abundant sport and commercial species impinged at Millstone. Adjusting for variable sport and commericial catches, value of the organisms presently removed by impingement ranged from $770 for the Atlantic long-finned squid to $4,787 for the winter flounder.

One potential terminus for a Unit 2 sluiceway is off the rock outcrop between Units 1 and 2. Results of various experiments were not conclusive as far as the potential for recirculation of organisms and other material from this location.

Present cooling water intake screenwash operations and maintenance requirements for trash handling were described. An engineering design study evaluated various alternatives for a sluiceway. Sluiceways discharging to Unit 3, barges, and to ponds were judged not feasible for construction. Cost estimates were prepared for three alternatives deemed practical at Millstone and these ranged from $342,000 to $580,000. The

alternatives included a combined discharge to the south, separate discharges to the west, and one where Unit 1 would discharge to the south and Unit 2 to the west. A cost benefit analysis of these three alternatives indicated that construction of sluiceways at both units was not feasible at this time because the high costs of construction far outweighted any benefits in maintenance savings, elimination of impingment sampling, and value of additional organisms saved. The only exception was modification of the present Unit 1 dewatering line to serve as a sluiceway and this option, which would cost $10,000, was recommended. It was further recommended that consideration of a Unit 2 sluiceway($332,000) be delayed until the actual costs, operation, and effectiveness of the Units 1 and 3 sluiceways could be evaluated and improvements over present financial conditions occur.

To ensure that the cooling water systems are not jeopardized during storms or other periods of high debris loading by modification of the present system, some operational latitude is essential. Therefore, it is also recommended that the plant superintendents have the discretion to temporarily return from a fish bypass mode to the present mode of operation when conditions demand such change.

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INTRODUCTION

In conjunction with the renewal of the NPDES permit for Millstone Nuclear Power Station Units 1 and 2, the United States Environmental Protection Agency acting through the Connecticut Department of Environmental Protection (CT DEP) requested that Northeast Utilities Service Company (NUSCo) perform a study to determine the feasibility of backfitting sluiceways to the intake screen wash troughs. The purpose of the sluiceways would be to direct fish and invertebrates back to Long Island Sound following impingement. A return system would reduce impingement mortality at Millstone since these organisms are presently collected in trash baskets where they may remain for periods of 24 h or greater. Relatively few specimens are released alive following collection during impingement sampling and handling in the laboratory.

An evaluation of the effectiveness of a sluiceway return system for increasing survival is given in the first section of this report. In order to estimate the potential for survival with a sluiceway, a field study to estimate immediate and delayed survival of impinged organisms took place from mid-December 1980 through early April 1981. Previous data collected during the regular impingement sampling program, which included estimates of the numbers, sizes, and survival rates of individual species impinged, were also used to calculate the economic value of organisms lost.

An engineering design study by the NUSCo Generation Civil Engineering group evaluated various sluiceway alternatives in terms of feasibility of construction, operations, and costs. Preliminary drawings of the various alternatives are given as well as some details concerning construction, operation, and maintenance. This material is presented in the second section of the report.

Finally, the economic savings of fish and shellfish potentially returned alive to Long Island Sound combined with maintenance and impingement monitoring savings were compared with the costs of construction and operation of various sluiceway alternatives. The results formed the basis of a cost-benefit analysis in which each alternative evaluated was accepted or rejected as a feasible backfit for Millstone Units 1 and 2.

SURVIVAL OF IMPINGED ORGANISMS

MATERIALS AND METHODS

Data were examined from the regular Millstone sampling program in order to determine the present biological and economic impact of impingement. During regular impingement sampling the collection baskets were emptied after a 24-h period. Screens were usually washed automatically depending upon a preset pressure differential caused by the accumulation of material on them. Screenwashes occurred from a few times daily to continuously during storms. Organisms were hand-picked from debris and returned to the laboratory in buckets. Species were separated, enumerated, measured, and classified as alive or dead. All live specimens were then released into Jordan Cove. The total man-power requirements for this sampling on an annual basis have been 0.7 man-year.

Initial impingement survival for each species was calculated as the percentage of live specimens of the total collected. This was determined for 1976 and 1978 through 1980 combined. In 1977 live specimens were also held for a 96-h period in the laboratory and extended survival as well as initial survival was calculated for each species:

$$\text{1977 extended survival} = \frac{A_{96}}{A_0}$$

where A_{96} = number of specimens alive at 96 h and A_0 = number of specimens at the start of the experiment.

A mean annual impingement estimate was calculated for each species taken at Millstone Units 1 and 2 combined for 1976 through 1980, the period of two-unit operation. Methodology for the calculation is given in NUSCo (1981). A length-frequency histogram was generated for the most abundant species to determine the sizes of fish or macroinvertebrates impinged.

Special samples for estimating immediate and extended impingement survival that would be expected for sluiceway operations were usually taken twice per week in mid-December 1980 and from late January through early April 1981 at Millstone Unit 2; no samples were taken at Unit 1 because of a refueling and repair outage. Sampling was conducted at night because significantly more organisms were impinged during the night at Millstone (NUSCo 1977). On each sampling date the screens were rotated and washed at 1400 h e.s.t. (eastern standard time). After an 8-h period they were washed at 2200 h to obtain the first sample. A second sample was taken at 0200 h (4-h hold) and a third at 0400 h (2-h hold). When high detritus loads occurred, usually due to high winds, the screens could not be held stationary and were operated continuously. At such times the normal sampling scheme was not accomplished and one or two collections were made during the night to evaluate the effects of continuous washes. On two occasions the initial hold was for 6 h instead of 8 h because the screens were not washed on time; these data were grouped with the 8-h washes for analyses.

Samples were taken from the screenwash trough of Unit 2 just before the trash baskets. Two 94 x 89 x 48-cm fish samplers (1.9-cm stretch nylon mesh) were rapidly alternated in the trough throughout the 10-min wash cycle so that the organisms retained were subjected to a minimum of collection stress. During continuous washes sampling occurred for about 1 to 1.5 h to obtain a number of specimens comparable to the standard samples. The samplers were emptied into a water-filled holding box and organisms were separated from macroalgae and detritus by dip nets or by hand. Specimens were placed into 72-liter insulated coolers and taken to the laboratory where they were counted and classified as live, dead, or stressed. The latter classification included fish that exhibited abnormal behavior, those with cuts, abrasions or other injuries, and crabs that were missing appendages. All live and stressed specimens were held under flow-through conditions in 141 x 81 x 22-cm or 122 x 61 x 30-cm holding tanks supplied with filtered salt water drawn from an undersand well in Jordan Cove. After the first week of sampling, predaceous fishes and large crabs were separated from the other specimens. Smaller stressed fish that were subject to predation were often kept in a floating screened box.

Observations of latent mortality were made at 6, 12, 36, and 60 h following collection. Dead specimens were removed and length and weight were recorded. The number of stressed individuals was also noted. At the 60-h observation all specimens were classified and measured (length and weight) and all those alive or stressed were released in Jordan Cove.

Survival estimates were determined by grouping the data by wash schedule (continuous; 2-, 4- or 8-h) and calculations were performed as follows:

$$\text{initial impingement survival} = \frac{A_0 + S_0}{A_0 + S_0 + D_0}$$

$$\text{extended impingement survival} = \frac{A_{6,12,36,\text{ or }60} + S_{6,12,36,\text{ or }60}}{A_0 + S_0}$$

$$\text{total impingement survival} = \frac{A_{60} + S_{60}}{A_0 + S_0 + D_0}$$

where $A_{0\ldots60}$, $S_{0\ldots60}$, and $D_{0\ldots60}$ represented the number of specimens of a species alive, stressed, or dead at initial and subsequent hours of observation. Differences in total survival of abundant species among the various screenwash schedules were examined with a G-test of independence at $P \leq 0.05$ (Sokal and Rohlf 1969).

The following procedure was used to calculate the economic loss of commercially important fishes and macroinvertebrates due to impingement under present operating and sampling regimes. The percent length frequency of the impingement catch of each species was multiplied by the mean annual impingement estimate to give the number per each 5 or 10-mm length group. Annual mortality estimates for each juvenile size class were applied to generate the numbers of equivalent adults and these were assigned to the size class at which commercial exploitation generally first takes place. Since impingement sampling currently takes place 3 times per week, the specimens not removed on the other 4 days were considered dead. The mean initial (from 1976 and 1978-80 data) and extended (from 1977 data) survival coefficients were used to determine the number of equivalent adults in each size group that were removed from the population by impingement each year; it was assumed that survival after impingement was not dependent upon size. Published length-weight relationships were used to calculate a mean weight for each of the size classes. The number of fish removed in each size class was multiplied by the average weight for that group and a summation over all size groups gave the total weight removed by impingement. Ex-vessel prices for commercially important species given by Coffey (1978) were adjusted upwards by 7% annually to obtain current estimated values. The weight was then multiplied by the estimated 1981 price to obtain a dollar value for the individuals lost to impingement. Sport fishing values were also calculated using data presented by the US Dept. of Commerce (1980). Total estimated expenditures by sports fishermen in Connecticut were divided by the total estimated finfish catch to give a dollar value per fish taken by sportsmen. For fishes taken by both the sport and commercial fisheries, the relative catch for each was determined by comparison of the landings. An adjusted total value based on these percentages was then computed. Similar calculations were made using immediate and delayed survival coefficients from the special sampling in 1980-81. The difference then would be the economic savings resulting from a sluiceway return system. These data, in conjunction with the construction, maintenance, and operational costs and savings estimated by the engineering study would demonstrate the feasibility of such a return system at Millstone.

A limited study was also conducted to evaluate a potential location for the terminus of Unit 2 sluiceway. On several occasions both live and dead winter flounder were marked by tagging or freeze branding and released approximately 30 ft in front of the rock outcrop between the intakes of Units 1 and 2 or by the Unit 1 bottom boom, located about 50 ft in front of the intake structure. The number of winter flounder recaptured during subsequent sampling at Unit 2 were noted. Results of similar experiments conducted in 1979 are also discussed.

RESULTS

The impingement catch at Millstone was dominated by a few fishes and macroinvertebrates (Table 1). Of these only some (e.g., winter flounder, northern lobster) have economic value in Connecticut. The winter flounder and Atlantic long-finned squid were most numerous; other abundant fishes impinged were small forage fishes such as silversides, sticklebacks, or anchovies (Table 2). The latter fishes and others such as the grubby or cunner have little or no sport or commercial value except as bait. Macroinvertebrates taken included various crabs and the commercially valuable northern lobster. Young or juveniles made up a large percentage of the catch (NUSCo 1981).

Initial survival of impinged organisms, as determined from the regular impingement monitoring program data from 1976 and 1978-80, ranged from 0 to 31.4% (Table 3). The winter flounder (31.4%), grubby (26.5%), tautog (24.6%), and skates (21.8%) had the greatest survival among fishes. Forage fishes such as silversides, anchovies, and rainbow smelt had little or no survival (0-0.2%). Initial survival of crabs and the northern lobster was high (73.8 - 88.0%) but very few (0.2%) of the Atlantic long-finned squid survived impingement.

The species with greatest survival were also examined monthly to see if any discernible seasonal differences occurred. Survival of winter flounder, grubby, and skates was greatest in winter and least in summer; tautog survived best in May and September. The northern lobster and blue crab had best survival in the summer and the lady crab in the fall.

During 1977 most specimens that were collected alive were held for 96 h to obtain an estimate of delayed mortality from stress or injuries

Table 1. Alphabetical listing by common name of all fishes and macroinvertebrates included in this report.

Fishes[a]

alewife - *Alosa pseudoharengus*
American eel - *Anguilla rostrata*
American sand lance - *Ammodytes americanus*
anchovies - *Anchoa* spp.
Atlantic menhaden - *Brevoortia tyrannus*
Atlantic silverside - *Menidia menidia*
Atlantic tomcod - *Microgadus tomcod*
bay anchovy - *Anchoa mitchilli*
blackspotted stickleback - *Gasterosteus wheatlandi*
blueback herring - *Alosa aestivalis*
butterfish - *Peprilus triacanthus*
codfishes - Gadidae
cunner - *Tautogolabrus adspersus*
fourspine stickleback - *Apeltes quadracus*
gasterostid sticklebacks - *Gasterosteus* spp.
grubby - *Myoxocephalus aenaeus*
inland silverside - *Menidia beryllina*
lumpfish - *Cyclopterus lumpus*
mummichog - *Fundulus heteroclitus*
ninespine stickleback - *Pungitius pungitius*
northern pipefish - *Syngnathus fuscus*
radiated shanny - *Ulvaria subbifurcata*
rainbow smelt - *Osmerus mordax*
red hake -*Urophycis chuss*
rock gunnel - *Pholis gunnellus*
sea raven - *Hemitripterus americanus*
silver hake - *Merluccius bilinearis*
silversides - *Menidia* spp.
skates - *Raja* spp.
snailfishes - *Liparis* spp.
striped killifish - *Fundulus majalis*
summer flounder - *Paralichthys dentatus*
tautog - *Tautoga onitis*
threespine stickleback - *Gasterosteus aculeatus*
white perch - *Morone americana*
windowpane - *Scophthalmus aquosus*
winter flounder - *Pseudopleuronectes americanus*

Macroinvertebrates[b]

Atlantic long-finned squid - *Loligo pealei*
blue crab - *Callinectes sapidus*
green crab - *Carcinus maenas*
lady crab - *Ovalipes ocellatus*
northern lobster - *Homarus americanus*
rock crab - *Cancer irroratus*

a from Robins et al. (1980)
b from Gosner (1971)

Table 2 Mean annual impingement estimate for the most abundant fishes and macroinvertebrates taken at Millstone Nuclear Power Station Units 1 and 2 from 1976 through 1980.

	Estimated Mean Annual Number Impinged
Fishes	
Pseudopleuronectes americanus	10,258
Menidia spp.	6,063
Gasterosteus spp.	5,208
Myoxocephalus aenaeus	3,812
Anchoa spp.	3,011
Merluccius bilinearis	1,860
Tautogolabrus adspersus	1,764
Microgadus tomcod	937
Syngnathus fuscus	933
Tautoga onitis	830
Scophthalmus aquosus	786
Cyclopterus lumpus	634
Peprilus triacanthus	551
Morone americana	491
Raja spp.	475
Osmerus mordax	401
Macroinvertebrates	
Loligo pealei	12,454
Ovalipes ocellatus	5,906
Callinectes sapidus	1,294
Cancer irroratus	873
Carcinus maenas	858
Homarus americanus	793

Table 3 Initial Survival of the most abundant fishes and macroinvertebrates impinged at Millstone Nuclear Power Station Units 1 and 2 during 1976 and 1978 through 1980.

	Total Examined	Percent Initial Survival
Fishes		
Pseudopleuronectes americanus	14,463	31.4
Myoxocephalus aenaeus	7,956	26.5
Tautoga onitis	1,816	24.6
Raja spp.	974	21.8
Gasterosteus spp.	6,720	7.0
Scophthalmus aquosus	1,726	6.9
Tautogolabrus adspersus	3,143	5.9
Cyclopterus lumpus	1,195	5.2
Microgadus tomcod	1,878	4.1
Syngnathus fuscus	1,999	1.6
Morone americana	1,055	0.6
Anchoa spp.	2,632	0.2
Peprilus triacanthus	1,383	0.1
Mendia spp.	7,080	0
Merluccius bilinearis	1,467	0
Osmerus mordax	889	0
Macroinvertebrates		
Callinectes sapidus	3,071	88.0
Carcinus maenas	1,833	79.7
Homarus americanus	2,016	75.8
Ovalipes ocellatus	9,492	73.9
Cancer irroratus	1,729	73.8
Loligo pealei	16,374	0.2

caused by impingement and subsequent handling (Table 4). Most of the species examined in 1977 had initial survival similar to those in 1976 and 1978-80. Differences in initial survival found for a few species could have been due to smaller sample size in 1977 than in the other 4 years. Extended survival after 96 h was approximately 80% for the commercially and recreationally important winter flounder, tautog, and northern lobster. Total survival for all fishes was 0 to 23.8%, 46.5 to 78.0% for the crabs and northern lobster, and 0.5% for the Atlantic long-finned squid.

Initial and 60-h extended survival for most fishes and macroinvertebrates taken during the special sampling in 1980-81 (Table 5; Figs. 1-5) was higher than that of organisms collected during normal impingement monitoring. Some of the above differences may be associated with sample size and the time of sampling, since samples were only taken during winter in 1980-81. Survival of the smaller forage fishes remained relatively poor and most mortality occurred within the first 36 h following impingement. The winter flounder and grubby had extended survival greater than 90% for all wash schedules. The sticklebacks (threespine and blackspotted sticklebacks were not differentiated) showed extended survival of 96% for continuous washes through 85% for an 8-h hold. Extended survival of the snailfishes ranged from 55 to 75%. Extended survival was lowest for the Atlantic silverside (13-25%).

Other species were collected in small numbers; of these, fishes such as lumpfish, skates, cunner, and striped killifish, and the rock crab showed good survival for all wash schedules whereas rainbow smelt, silver hake, and white perch had high mortality. The Atlantic tomcod, northern pipefish, and green crab had greater survival for the continuous through the 4-h screenwash intervals than for the 8-h interval.

Table 4. Initial and 96-h extended survival of the most abundant fishes and macroinvertebrates impinged at Millstone Nuclear Power Station Units 1 and 2 during 1977.

	Total Examined	Percent Initial Survival	Percent 96-h Extended Survival	Percent Total Survival
Fishes				
Pseudopleuronectes americanus	4,938	29.4	80.9	23.8
Myoxocephalus aenaeus	1,511	23.1	93.4	21.6
Gasterosteus spp.	3,727	19.3	81.7	15.8
Cyclopterus lumpus	426	15.5	93.9	14.5
Raja spp	498	19.5	63.8	12.4
Scophthalmus aquosus	269	18.2	63.3	11.5
Tautoga onitis	447	13.0	81.0	10.5
Tautogolabrus adspersus	829	4.6	94.7	4.3
Syngnathus fuscus	225	2.2	60.0	1.3
Microgadus tomcod	172	1.2	50.0	0.6
Morone americana	480	0.6	50.0	0.4
Anchoa spp.	449	0	--	0
Menidia spp.	822	0	--	0
Merluccius bilinearis	529	0	--	0
Osmerus mordax	223	0	--	0
Peprilus triacanthus	74	0	--	0
Macroinvertebrates				
Callinectes sapidus	236	82.2	94.8	78.0
Carcinus maenas	448	67.0	90.7	60.7
Ovalipes ocellatus	2,072	76.7	72.9	55.9
Cancer irroratus	405	56.8	94.8	53.8
Homarus americanus	299	57.9	80.3	46.5
Loligo pealei	2,267	0.5	--	0.5

Table 5 Initial and 60-h extended survival of fishes and macroinvertebrates impinged during various screenwash schedules at Millstone Nuclear Power Station Unit 2 from 15 December 1980 through 9 April 1981.

Continuous wash	Total examined	Percent Initial survival	Percent 60-h extended survival	Percent total survival
Fishes				
Cyclopterus lumpus	8	100.0	100.0	100.0
Apeltes quadracus	6	100.0	100.0	100.0
Raja spp.	4	100.0	100.0	100.0
Scophthalmus aquosus	3	100.0	100.0	100.0
Anguilla rostrata	1	100.0	100.0	100.0
Pholis gunnellus	1	100.0	100.0	100.0
Pseudopleuronectes americanus	133	97.0	100.0	97.0
Myoxocephalus aenaeus	56	100.0	94.6	94.6
Syngnathus fuscus	111	96.4	93.5	90.1
Gasterosteus spp.	180	91.7	95.8	87.8
Liparis spp.	8	100.0	75.0	75.0
Tautogolabrus adspersus	4	75.0	100.0	75.0
Microgadus tomcod	2	50.0	100.0	50.0
Morone americana	2	100.0	50.0	50.0
Osmerus mordax	24	58.3	35.7	20.8
Menidia menidia	32	62.5	25.0	15.6
Alosa aestivalis	2	50.0	0	0
Ammodytes americanus	2	0	-	0
Macroinvertebrates				
Cancer irroatus	4	100.0	75.0	75.0

Table (Cont'd)

2-h intermittant hold	Total examined	Percent initial survival	Percent 60-h extended survival	Percent total survival
Fishes				
Cyclopterus lumpus	7	100.0	100.0	100.0
Fundulus majalis	4	100.0	100.0	100.0
Pholis gunnellus	3	100.0	100.0	100.0
Syngnathus fuscus	3	100.0	100.0	100.0
Raja spp.	2	100.0	100.0	100.0
Apeltes quadracus	1	100.0	100.0	100.0
Tautogolabrus adspersus	1	100.0	100.0	100.0
Myoxocephalus aenaeus	178	96.6	95.9	92.7
Microgadus tomcod	27	96.3	96.2	92.6
Pseudopleuronectes americanus	146	97.9	93.7	91.8
Gasterosteus spp.	396	94.4	91.2	86.1
Scophthalmus aquosus	5	100.0	80.0	80.0
Morone americana	2	100.0	50.0	50.0
Liparis spp.	39	76.9	56.7	43.6
Ammodytes americanus	3	33.3	100.0	33.3
Mendia menidia	127	49.6	17.5	8.7
Osmerus mordax	15	26.7	0	0
Merluccius bilinearis	8	25.0	0	0
Mendia beryllina	3	0	–	0
Alosa aestivalis	1	0	–	0
Macroinvertebrates				
Cancer irrroratus	33	100.0	100.0	100.0
Carcinus maenas	5	80.0	100.0	80.0

Table (Cont'd)

4-h intermittant hold	Total examined	Percent initial survival	Percent 60-h extended survival	Percent total survival
Fishes				
Cyclopterus lumpus	17	100.0	100.0	100.0
Fundulus majalis	7	100.0	100.0	100.0
Apeltes quadracus	4	100.0	100.0	100.0
Ulvaria subbifurcata	2	100.0	100.0	100.0
Pungitius pungitius	1	100.0	100.0	100.0
Tautogolabrus adspersus	1	100.0	100.0	100.0
Microgadus tomcod	13	92.3	100.0	92.3
Myoxocephalus aenaeus	176	96.0	95.6	92.0
Pseudopleuronectes americanus	175	96.6	91.1	88.0
Raja spp.	7	85.7	100.0	85.7
Gasterosteus spp.	480	91.7	85.9	78.8
Syngnathus fuscus	12	91.7	81.8	75.0
Scophthalmus aquosus	4	100.0	75.0	75.0
Liparis spp.	51	80.4	73.2	58.8
Pholis gunnellus	2	50.0	100.0	50.0
Morone americana	12	91.7	9.1	8.3
Menidia menidia	297	30.0	15.7	4.4
Osmerus mordax	13	46.2	0	0
Merluccius bilinearis	8	0	-	0
Menidia beryllina	2	50.0	0	0
Ammodytes americanus	1	100.0	0	0
Anchoa mitchilli	1	0	-	0
Anguilla rostrata	1	100.0	0	0
Brevoortia tyrannus	1	100.0	0	0
Macroinvertebrates				
Cancer irroratus	29	96.6	92.9	89.7
Carcinus maenas	18	72.2	84.6	61.1

Tabl[illegible] (Cont'd)

8-h intermittant hold	Total examined	Percent initial survival	Percent 60-h extended survival	Percent total survival
Fishes				
Apeltes quadracus	4	100.0	100.0	100.0
Fundulus majalis	3	100.0	100.0	100.0
Pholis gunnellus	3	100.0	100.0	100.0
Raja spp.	2	100.0	100.0	100.0
Fundulus heteroclitus	1	100.0	100.0	100.0
Myoxocephalus aenaeus	233	97.9	96.5	94.4
Cyclopterus lumpus	27	100.0	92.6	92.6
Pseudopleuronectes americanus	164	96.3	94.9	91.5
Tautogolabrus adspersus	5	100.0	80.0	80.0
Gasterosteus spp.	398	92.7	84.8	78.6
Scophthalumus aquosus	6	83.3	80.0	66.7
Microgadus tomcod	19	89.5	70.6	63.2
Liparis spp.	30	80.0	66.7	53.3
Morone americana	15	60.0	77.8	46.7
Osmerus mordax	12	58.3	57.1	33.3
Ammodytes americanus	3	66.7	50.0	33.3
Syngnathus fuscus	6	100.0	16.7	16.7
Menidia menidia	330	20.6	13.2	2.7
Gadidae	4	0	-	0
Merluccius bilinearis	3	0	-	0
Alosa aestivalis	2	50.0	0	0
Menidia beryllina	2	0	-	0
Alosa pseudoharengus	1	0	-	0
Hemitripterus americanus	1	0	-	0
Urophycis chuss	1	100.0	0	0
Macroinvertebrates				
Homarus americanus	1	100.0	100.0	100.0
Cancer irroratus	41	97.6	92.5	90.2
Carcinus maenas	22	63.6	71.4	45.5

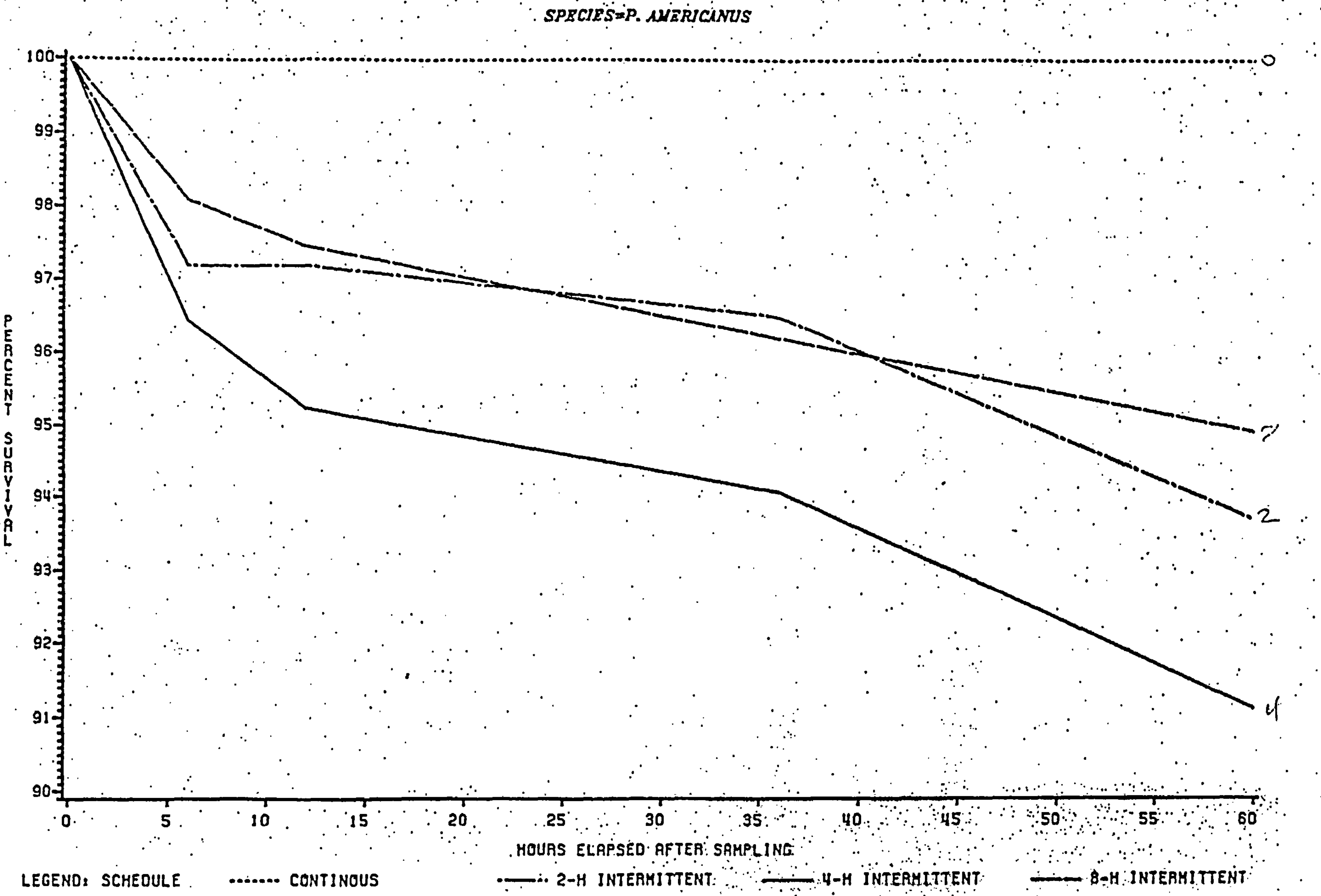


FIG 1. EXTENDED SURVIVAL OF FISH IMPINGED FROM VARIOUS WASH SCHEDULES

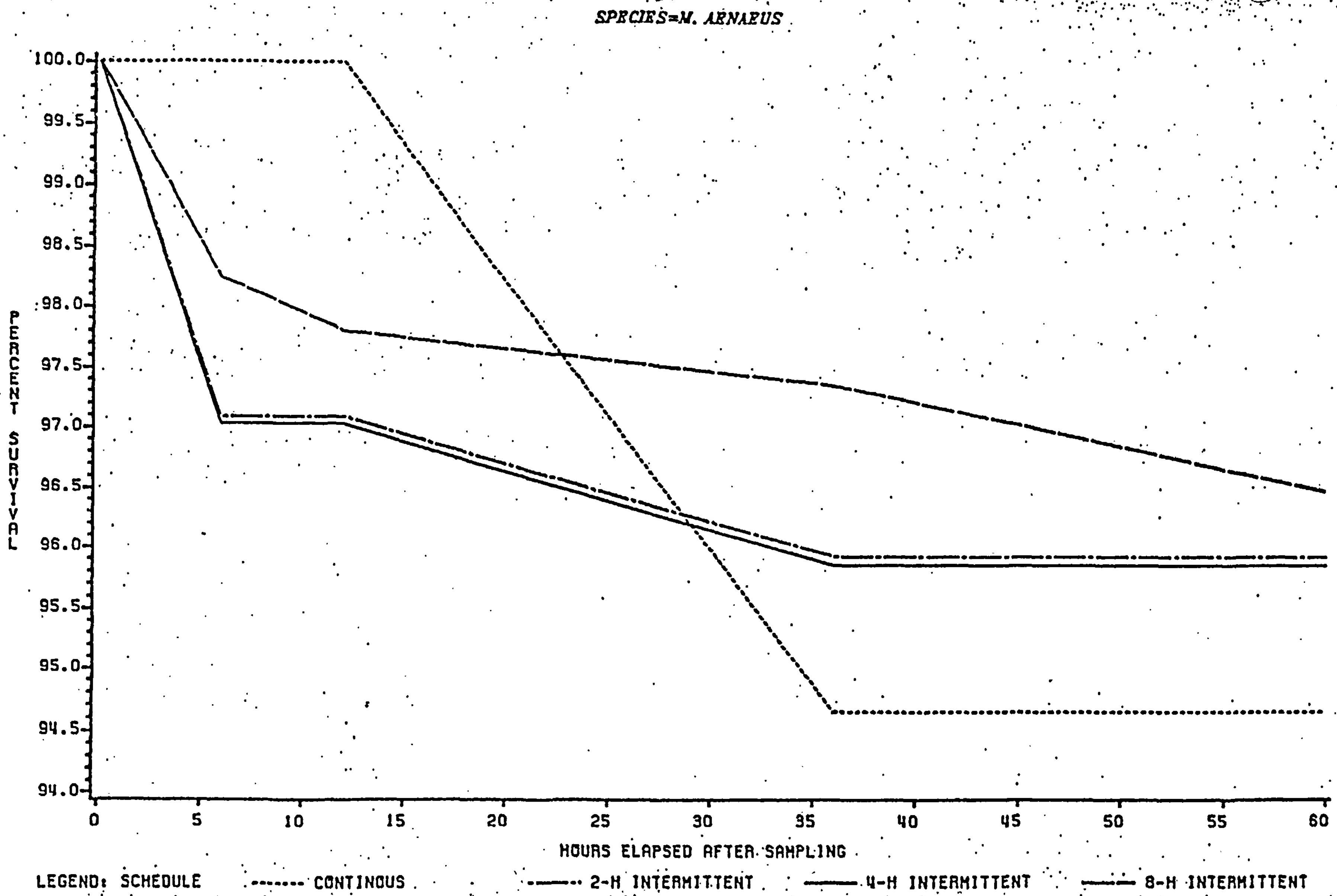


FIG 2 . EXTENDED SURVIVAL OF FISH IMPINGED FROM VARIOUS WASH SCHEDULES

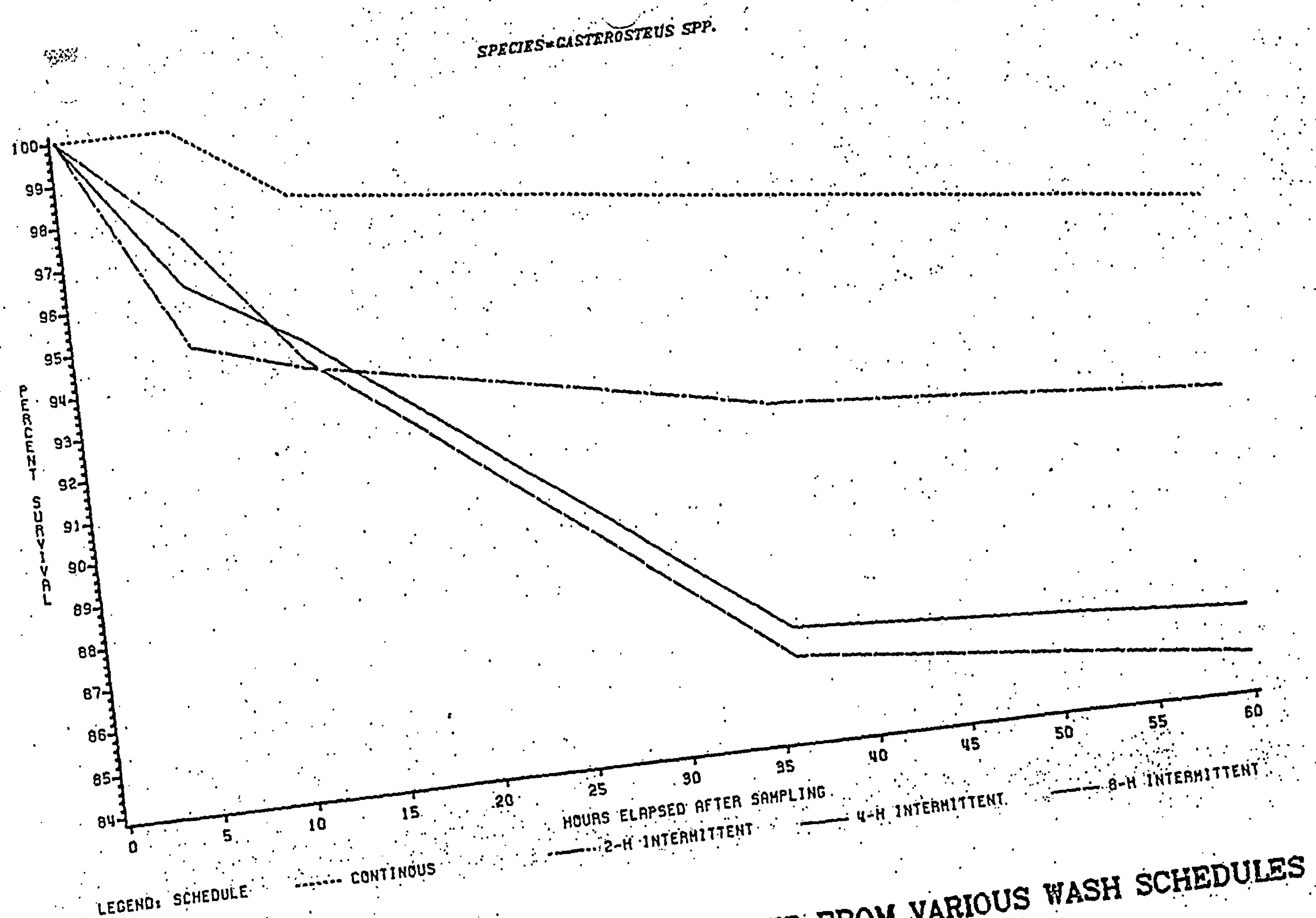


FIG 3. EXTENDED SURVIVAL OF FISH IMPINGED FROM VARIOUS WASH SCHEDULES

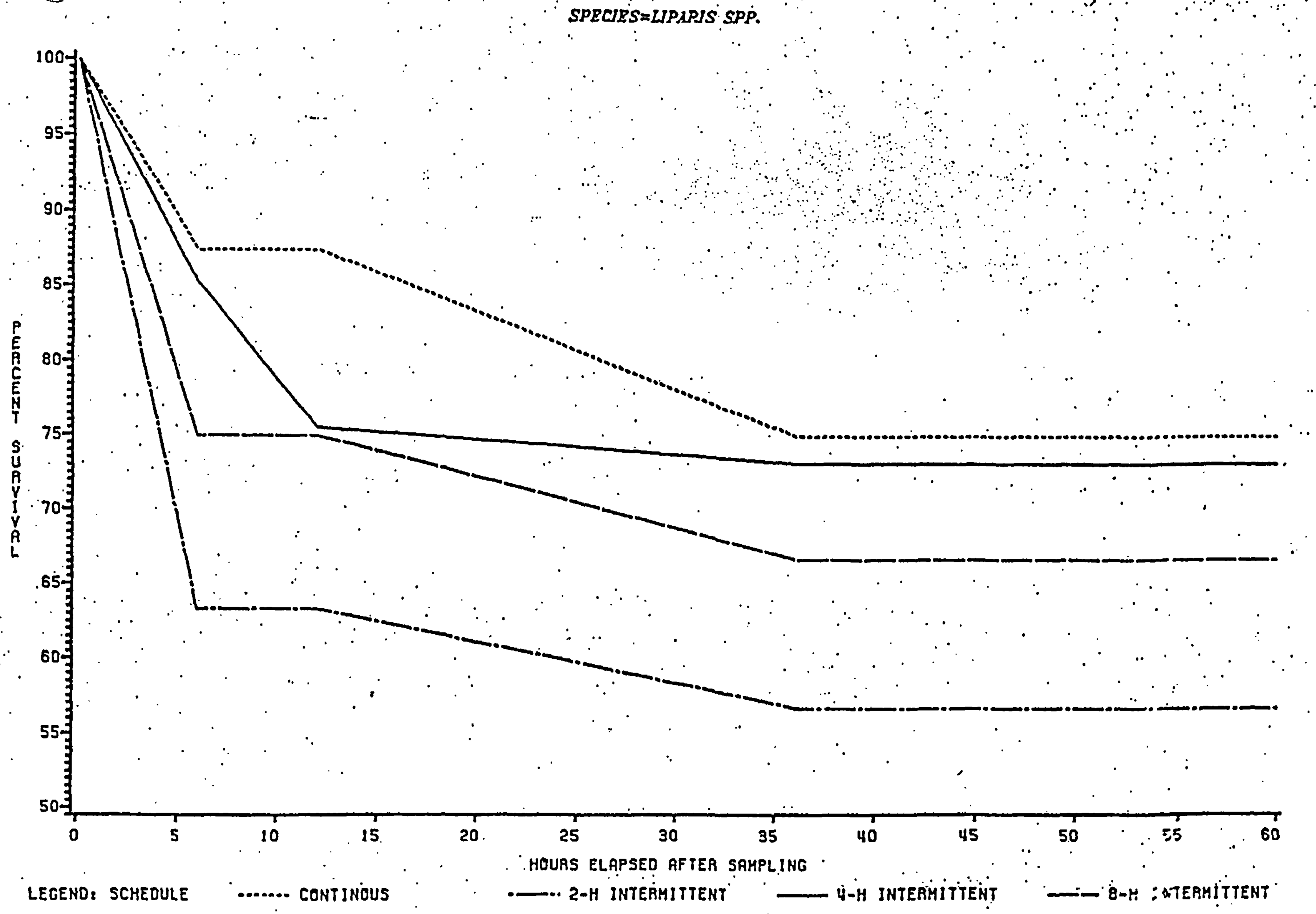


FIG 4. EXTENDED SURVIVAL OF FISH IMPINGED FROM VARIOUS WASH SCHEDULES

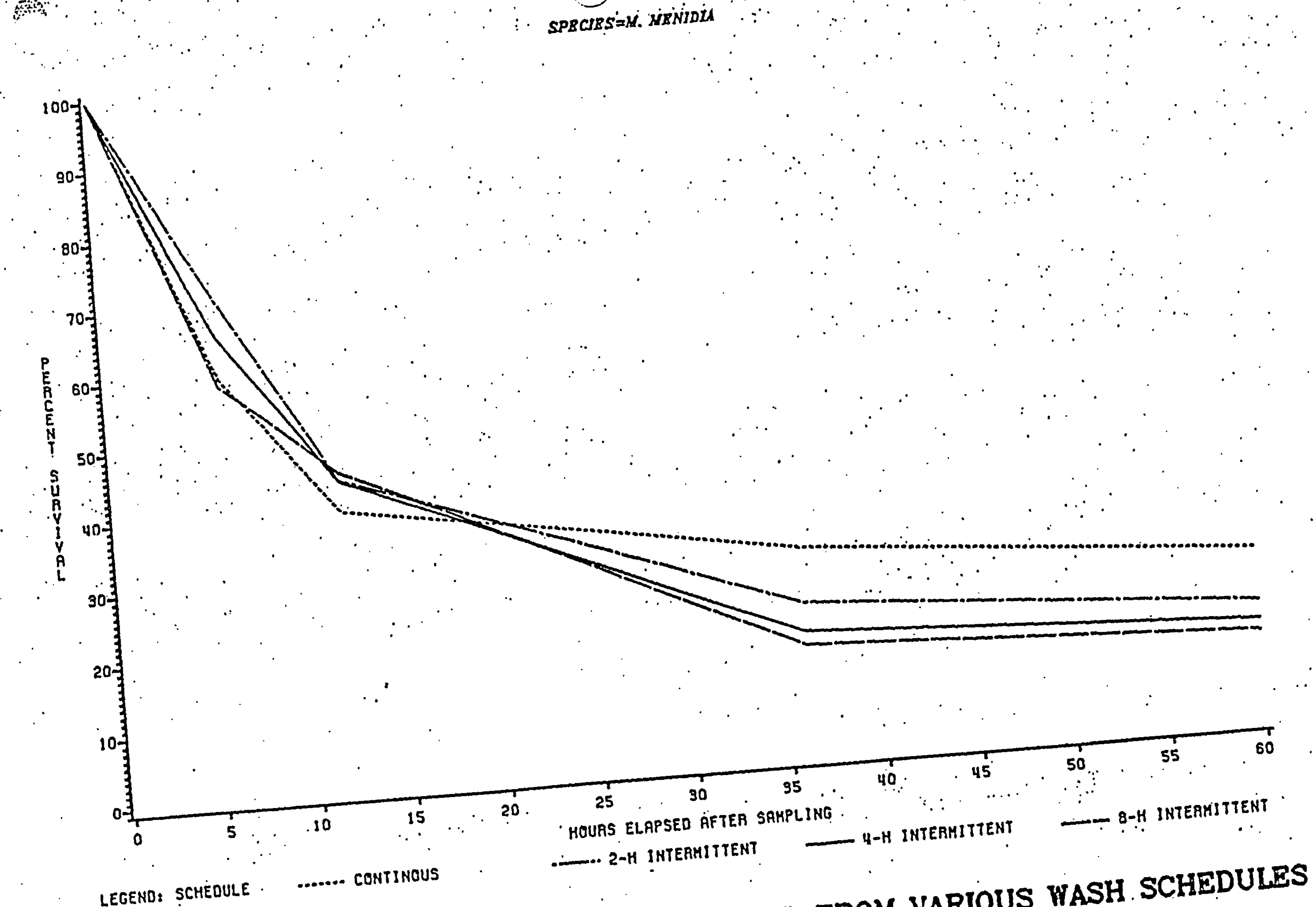


FIG 5 . EXTENDED SURVIVAL OF FISH IMPINGED FROM VARIOUS WASH SCHEDULES

The condition of specimens at 60 h following impingement for the five most abundant species collected was analyzed to determine the effect of wash schedule (Table 6). As expected, continuous washes generally produced the greatest survival but few significant differences were found among the various wash schedules. Differences that were found varied among the species examined.

The economic value of four commercially and recreationally important species (winter flounder, tautog, Atlantic long-finned squid, and northern lobster) removed by impingement at Millstone was computed using estimates of initial and extended survival. A total of 1,048 kg of winter flounder with an ex-vessel value of $1,038 was estimated to have been removed annually from the population by impingement at Millstone (Table 7). These fish also had a total estimated sport fishing value of $11,572. A comparison of the winter flounder sport (US Dept. of Commerce 1980) and commercial landings (CT DEP, unpublished) in Connecticut showed that about 65% of the total was landed by commercial fisherman. If the number of adult-equivalent winter flounder was adjusted to reflect these percentages, then the total value was $4,787. Similarly, tautog had a total commercial value of $43, a sport fishing value of $1,254, and an adjusted total value of $1,202 (Table 8).

The Atlantic long-finned squid removed by impingement had no sport value and a commercial value of $770 (Table 9). The northern lobster, because of its high ex-vessel value, was worth $1,073 (Table 10). Although also taken by non-commercial fishermen and divers, no data were available to assign these individuals a sport fishing value.

Table 6. Differences in impingement survival by wash schedule of the five most numerous fishes taken at Millstone Unit 2 from December 1980 through April 1981.

A. Winter flounder[a]

Wash schedule	Alive	Stressed	Dead	Total	% Dead
Continuous	127	2	4	133	3.0
2-h	124	10	12	146	8.2
8-h	144	6	14	164	8.5
4-h	144	10	21	175	12.0
Total	539	28	51	618	

$G = 16.034$ * ($\chi^2_{.05(6)} = 12.592$)

C 2 8 4

B. Grubby

Wash schedule	Alive	Dead	Total	% Dead
4-h	159	7	16	4.2
8-h	218	12	23	5.2
Continuous	53	3	56	5.4
2-h	164	13	17.	7.3
Total	594	35	629	

$G = 11.656$* ($\chi^2_{.05(3)} = 7.815$)

4 8 C 2

Table [illegible] (Cont'd)

C. Threespine and blackspotted sticklebacks

Wash Schedule	Alive	Stressed	Dead	Total	% Dead
Continuous	139	19	22	180	12.2
2-h	324	17	55	396	13.9
8-h	297	20	81	398	20.4
4-h	359	19	102	480	21.3
Total	1119	75	260	1454	

G = 23.262* $(\chi^2_{.05(6)} = 12.592)$

C 2 8 4

D. Snailfishes

Wash Schedule	Alive	Dead	Total	% Dead
4-h	30	21	51	41.2
8-h	16	14	30	46.7
2-h	17	22	39	56.4
Total	63	57	120	

G = 2.074 NS $(\chi^2_{.05(3)} = 7.815)$

4 8 2

Table (Cont'd)

E. Atlantic silverside

Wash schedule	Alive	Dead	Total	% Dead
Continuous	5	27	32	84.4
2-h	11	116	127	91.3
4-h	13	284	297	95.6
8-h	9	321	330	97.3
Total	38	748	786	

$G = 12.434^{*} \quad (\chi^2_{.05(3)} = 7.815)$

C 2 4 8

[a] Notes:

1. R X C test of independence using the G-test (Sokal and Rohlf 1969).
2. H_o: frequency of alive, stressed, and dead independent of wash schedule.

   H_A: frequency of alive, stressed, and dead dependent upon wash schedule.
3. Calculated G compared to table X^2 values with df = (Columns -1) (rows-1).
4. * = significant at $P \leq 0.05$; NS = not significant. Wash schedules arranged in ascending order of dead and those underlined are not significantly different.
5. Stressed specimens and those taken during continuous washes not included for some species where sample size was relatively small.

Table 7. Estimated value of winter flounder removed annually from population by impingement at Millstone Nuclear Power Station Units 1 and 2.

A. Adult- equivalent calculation

Length(mm)	age-class[a]	% total impingement	n[b]	Annual survival[c]	Adult-equivalents[d]
<130	0	33	3,385	0.145	162
130-230	1	35	3,590	0.333	1,185
>230	2+	32	3,283	---	3,283
				Total	4,630

B. Economic value calculation

length (mm)	%length frequency	Number of adult-equivalents impinged[e]	Mortality[f] S	I	E	Total	Mean Weight[g]	Total Weight
230	8.5	279	159	82	6	247	131	32.3
240	8.7	286	163	84	8	255	150	38.2
250	9.3	305	174	90	8	272	171	46.4
260	8.8	1636	935	481	44	1460	193	281.9
270	8.2	269	154	79	7	240	218	52.3
280	8.7	286	163	84	8	255	245	62.3
290	8.4	276	158	81	7	246	273	67.3
300	8.1	266	152	78	7	237	305	72.2
310	7.3	240	137	71	6	214	338	72.4
320	6.3	207	118	61	6	185	374	69.2
330	5.1	167	95	49	5	149	413	61.5
340	3.5	115	66	34	3	103	454	46.7
350	2.6	85	49	25	2	76	498	37.8
360	2.0	66	38	19	2	59	544	26.7
370	1.3	43	25	12	1	38	594	22.6
380	1.1	36	21	10	1	32	646	20.7
390	0.9	30	17	9	1	27	702	19.0
400	0.3	10	6	3	0	9	761	6.8
410	0.4	13	7	4	0	11	823	9.1
420	0.3	10	6	3	0	9	889	8.0
430	0.1	3	2	1	0	3	958	2.9
440-480	0.2	7	4	2	0	6	1107	6.6
Total	100.0	4,635	2,649	1,362	122	4,133	---	1,062.9 kg
Ex-vessel value[h]	($0.99/kg)							$1,052
Sport fishing value[i]	($2.80/fish)							$11,572
Adjusted total value[j]								$4,787

Table 7 (Cont'd)

a	NUSCo (1980)
b	% x annual impingement estimate of 10,258
c	Hess et al. (1975)
d	n x annual mortality rates to age-class 2+
e	3,283 adult-equivalents (age 2+) assigned sizes by length-frequency distribution; 1,347 assigned to 260 mm, approximate size of initial commercial exploitation (Saila et al. 1965)
f	S = sampling mortality : 57.1% of adult-equivalents not removed from Millstone I = initial impingement mortality : 68.6% of (total - S) E = extended impingement mortality : 19.9% of (total - S - I)
g	log (wt) = -5.401 + 3.183 log (l) (NUSCo 1978). Mean weight in g; total weight in kg
h	Value from Coffey (1978) adjusted upwards 7% per year to 1981
i	Calculated from US Dept. Commerce (1980)
j	65% of total catch calculated as commercial landings worth \$679 and 35% having sport fishing value worth \$4048

Tab   Estimated value of tautog removed annually from population   pingement at Millstone Nuclear Power Station Unit 1 and 2.

A. Adult - equivalent calculation

Length (mm)	Age-class[a]	% total impingement	n[b]	Annual survival[c]	Adult-equivalents[d]
<60	0	1.5	13	0.70	2
60-130	1	23.0	191	0.70	66
130-200	2	37.0	307	0.70	150
200-240	3	20.5	170	0.70	119
240+	4+	18.0	149	-	150
				Total	487

B. Economic Value Calculation

length (mm)	%length frequency	number of adult-equivalents impinged[e]	Mortality[f] S	I	E	Total	Mean Weight[g]	Total Weight
240	16.2	24	14	8	0	22	256	5.6
250	12.6	19	11	6	0	17	289	4.9
260	10.7	16	9	5	0	14	325	4.6
270	9.0	14	8	5	0	13	365	4.7
280	10.6	353	202	114	7	323	407	131.5
290	7.6	11	6	4	0	10	453	4.5
300	5.6	8	5	2	0	7	502	3.5
310	4.6	7	4	2	0	6	554	3.3
320	3.6	5	3	2	0	5	610	3.0
330	3.2	5	3	2	0	5	669	3.3
340	3.4	5	3	2	0	5	732	3.7
350	2.4	4	2	2	0	4	799	3.2
360	2.2	3	2	1	0	3	870	2.6
370	2.0	3	2	1	0	3	946	2.8
380	1.0	2	1	1	0	2	1025	2.0
390	0.6	1	1	0	0	1	1109	1.1
400	0.8	1	1	0	0	1	1197	1.2
410	1.0	2	1	1	0	2	1290	2.6
420-430	0.6	1	1	0	0	1	1438	1.4
440	1.0	2	1	1	0	2	1597	3.2
450-460	0.6	1	1	0	0	1	1767	1.8
480-500	0.6	1	1	0	0	1	2210	2.2
Total	100.0	488	282	159	7	448	--	196.7 kg

Ex-vessel value[h] ($0.22/kg)	$ 43
Sport fishing value[i] ($2.80/fish)	$1,254
Adjusted total value[j]	$1,202

a Cooper (1967)
b % x annual impingement estimate of 830
c estimated from Cooper (1964)
d n x annual survival rates to age-class 4+
e 150 adult-equivalents (age 4+) assigned sizes by length-frequency distribution; 337 arbitrarily assigned to 280 mm
f S = sampling mortality : 57.1% of adult-equivalents not removed from Millstone
I = initial impingement mortality : 75.4% of (total -S)

E = extended impingement mortality : 19.0% of (total-S-I)
g log (wt) = -4.788 + 3.023 log (TL) (NUSCo, unpublished)
Mean weight in g; total weight in kg
h value from Coffey (1978) adjusted upwards 7% per year to 1981
i calculated from US Dept. of Commerce (1980)
j 4% of total catch calculated as commercial landings worth $2 and 96% having sport fishing value worth $1200

T[illegible] 9. Estimated value of Atlantic long-finned squid removed [illegible]ually from population by impingement at Millstone Nuclear Power Station Units 1 and 2.

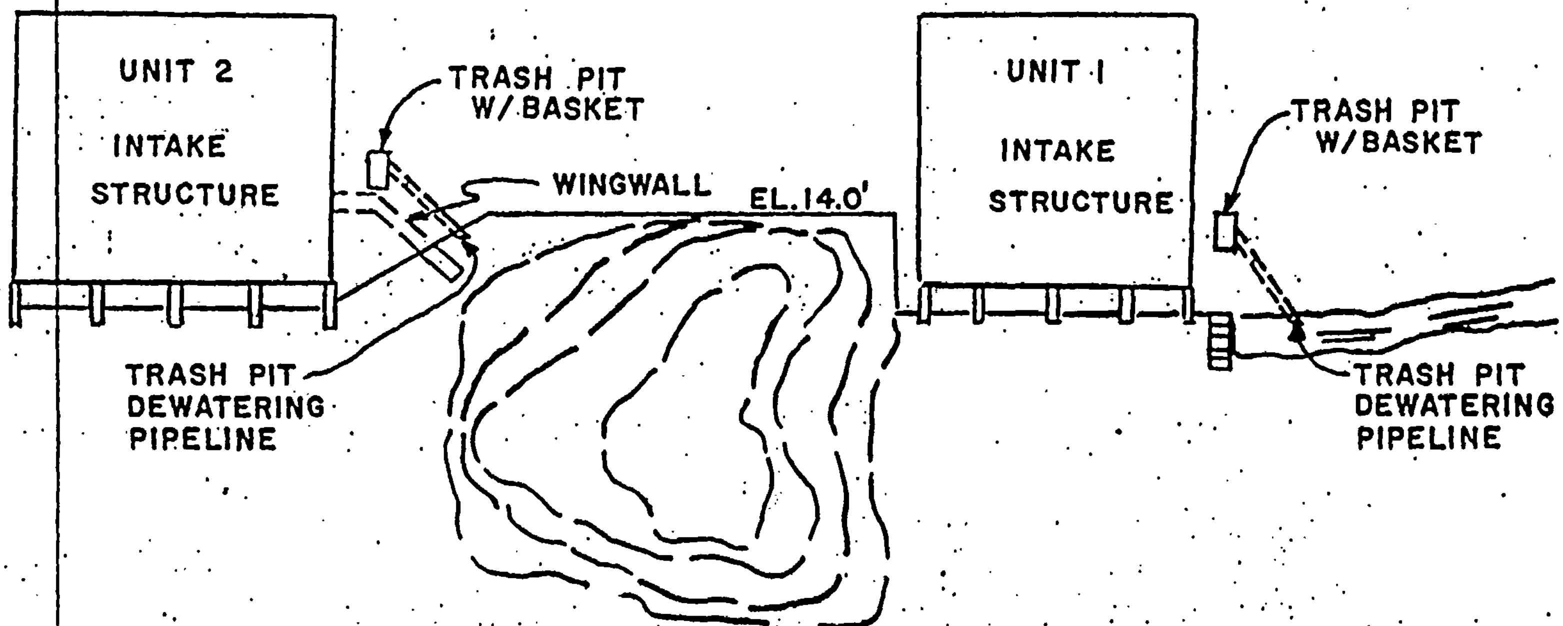
A. Adult- equivalent calculation

Length (mm)	age-class[a]	% total impingement	n^b	annual survival[c]	adult-equivalents[d]
<80	pre-recruit	33.6	4,185	0.05	209
>80	recruit	66.4	8,269	-	8,269
				Total	8,478

B. Economic value calculation

length (mm)	% length frequency	number of adult-equivalents impinged[e]	total mortality[f]	mean weight[g]	total weight
80	9.8	1019	1019	20	20.4
90	8.8	728	728	25	18.2
100	8.3	686	686	31	21.3
110	8.5	703	703	38	26.7
120	6.6	546	546	45	24.6
130	7.6	628	628	52	32.7
140	5.9	488	488	62	30.3
150	5.6	463	463	71	32.9
160	5.8	480	480	82	39.4
170	4.3	356	356	92	32.8
180	4.4	364	364	104	37.9
190	4.0	331	331	117	38.7
200	3.3	273	273	130	35.5
210	3.5	289	289	144	41.6
220	2.6	215	215	159	34.2
230	2.6	215	215	174	37.4
240	2.2	182	182	190	34.6
250	1.6	132	132	207	27.3
260	1.3	108	108	224	24.2
270	0.8	66	66	244	16.1
280	0.8	66	66	265	17.5
290	0.6	50	50	284	14.2
300	0.4	33	33	305	10.1
310	0.3	25	25	327	8.2
320	0.1	8	8	349	2.8
330	0.1	8	8	373	3.0
340-350	0.1	8	8	397	3.2
360-400	0.1	8	8	422	3.4
Total	100.0	8,478	8,478	-	669.2 kg
Ex-vessel value[h] ($1.15/kg)					$770

a Complex life cycle. Recruited to commercial fishery at 80 mm (MAFMC 1979)
b % x annual impingement estimate of 12,454
c Summers (1971)
d n x annual survival rate
e 8,269 recruits assigned sizes by length frequency distribution; 209 arbitarily assigned to 80 mm size class.
f assumed to be 100%
g males: log (w) = -2.2524 + 1.8635 log (mantle length) and females: log (w) = -3.031 + 2.2643 log (mantle length) (Tibbetts 1975). 1:1 sex ratio assumed. Mean weight in g; total weight in kg.
h Value from Coffey (1978) adjusted upwards 7% per year to 1981



NORTHEAST UTILITIES SERVICE CO.

Figure 6 Existing Conditions
Intake Structures

Table 10. Estimated value of northern lobster removed annually from population by impingement at Millstone Nuclear Power Station Units 1 and 2.

A. Adult- equivalent calculation

Length (mm)	age-class[a]	% total impingement	n[b]	Annual survival[c]	Adult-equivalents[d]
<81	pre-recruit	96.7	767	0.72	552
>81	recruit	3.3	26	-	26
				Total	578

B. Economic value calculation

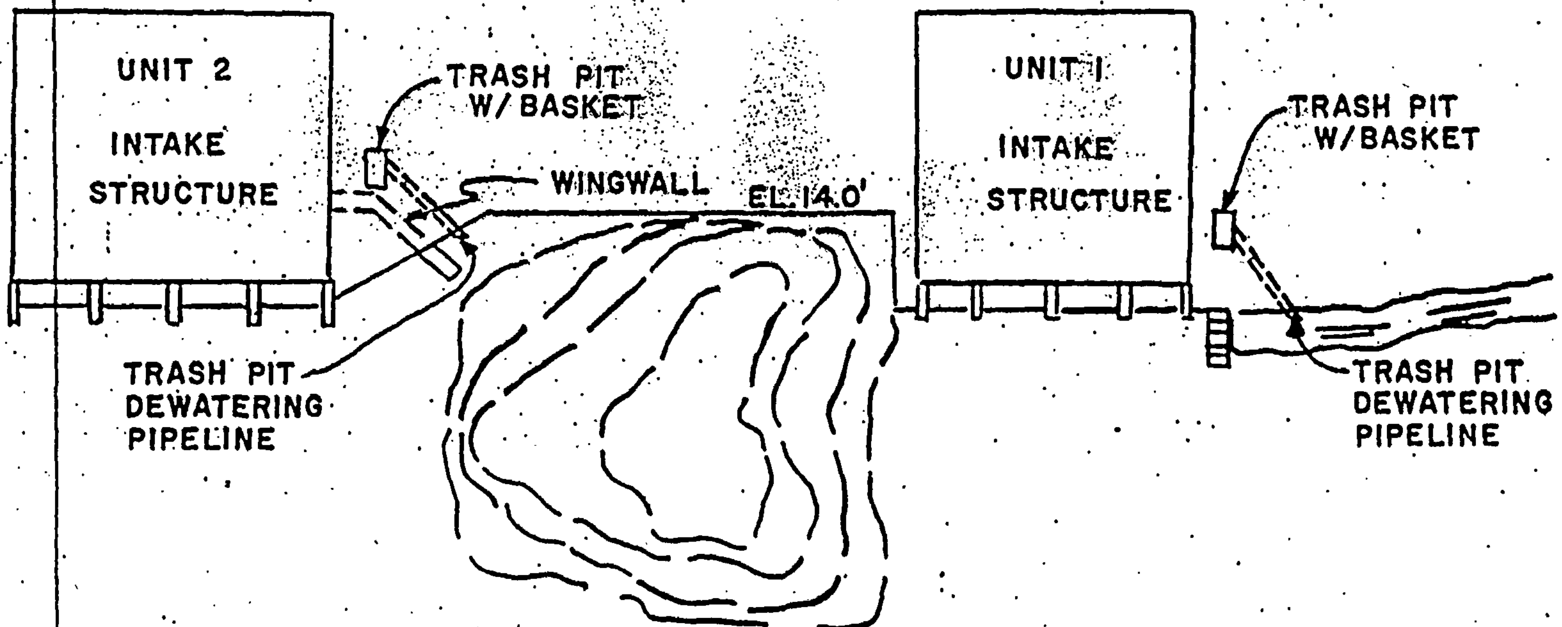
length (mm)	% length frequency	number of adult-equivalents impinged[e]	Mortality[f] S	I	E	Total	Mean weight[g]	Total weight
80	33.3	561	320	58	36	414	437	180.9
85	41.3	11	6	1	1	8	504	4.0
90	14.7	4	2	0	0	2	599	1.2
95-100	10.7	3	2	0	0	2	704	1.7
	100.0	579	330	59	37	426	-	187.5 kg

Ex-vessel value[h] ($5.72/kg) $1,073

a Assumed to be recruited to fishery at minimum legal carapace length.
b. % x total annual impingement estimate of 793
c. Dow (1964)
d. n x annual survival rate
e. 26 recruits assigned sizes by length frequency distribution; 552 arbitrarily assigned to 80 mm size class.
f. S = sampling mortality : 57.1% of adult-equivalents not removed from Millstone
   I = initial impingement mortality ; 24.2% of (total - S)
   E = extended impingement mortality : 19.7% of (total - S - I)
g. log (wt) = -3.0870 + 3.0008 log (carapace length) (Lund et al. 1973). Mean weight in g; total weight in kg.
h. value from Coffey (1978) adjusted upwards 7% per year to 1981.

Several other species impinged at Millstone, such as the silver hake, butterfish, white perch, and blue crab, have limited commercial or sport value in Connecticut. Most silver hake (99%) and butterfish (85%) were impinged as juveniles and the impingement estimates of butterfish and white perch were low. Although relatively abundant, the blue crab has demonstrated good survival following impingement. Therefore, neither adult-equivalent losses nor economic values were calculated for these species and their collective value was probably less than $100 annually.

A potential terminus for the Unit 2 sluiceway is off the rock outcrop between Units 1 and 2 (Fig. 6) and results of various mark and release studies conducted there are summarized in Table 11. Less than 10% of the marked live winter flounder released in nine trials were subsequently recaptured during impingement sampling. One exception was a 30% return following a storm in April 1979. No marked dead winter flounder were recovered in one experiment whereas 9% of the live fish released concurrently were recaptured. During another experiment only 2% of the winter flounder released during the day were impinged but 9% released the following night were retaken.



NORTHEAST UTILITIES SERVICE CO.

Figure 6 Existing Conditions
Intake Structures

Table 11. Results of mark and release studies conducted near a proposed terminus for the Unit 2 sluiceway during 1979 and 1981.

Date	Location released	Species[a]	Number marked	Number impinged	Comments
3-12-79	Inside Unit 1 bottom boom	*P. americanus*	23	0	Unit 2 Shutdown in spring 1979.
3-20-79	Inside Unit 1 bottom boom	*P. americanus*	17	1	
4-2-79	Outside Unit 1 bottom boom	*P. americanus*	54	16	High winds, stormy conditions
4-16-79	Inside Unit 1 bottom boom	*P. americanus*	37	3	
2-9-81	Off rocks between Units 1 and 2	*P. americanus*	76	7	Unit 1 shutdown in winter and spring 1981
"	" "	*P. americanus*	41	0	Specimens were dead
2-17-81	" "	*P. americanus*	64	1	
6-2-81	" "	*P. americanus*	109	2	
	" "	*P. dentatus*	4	1	
	" "	*T. adspersus*	5	0	
	" "	*H. americanus*	3	0	
	" "	*Raja* spp.	1	0	
	" "	*T. onitis*	1	0	
6-3-81	" "	*P. americanus*	92	8	Released at night

a Specimens alive and released during day except where noted

Table 11. Results of mark and release studies conducted near a proposed terminus for the Unit 2 sluiceway during 1979 and 1981.

Date	Location released	Species[a]	Number marked	Number impinged	Comments
3-12-79	Inside Unit 1 bottom boom	*P. americanus*	23	0	Unit 2 Shutdown in spring 1979.
3-20-79	Inside Unit 1 bottom boom	*P. americanus*	17	1	
4-2-79	Outside Unit 1 bottom boom	*P. americanus*	54	16	High winds, stormy conditions
4-16-79	Inside Unit 1 bottom boom	*P. americanus*	37	3	
2-9-81	Off rocks between Units 1 and 2	*P. americanus*	76	7	Unit 1 shutdown in winter and spring 1981
"	" "	*P. americanus*	41	0	Specimens were dead
2-17-81	" "	*P. americanus*	64	1	
6-2-81	" "	*P. americanus*	109	2	
	" "	*P. dentatus*	4	1	
	" "	*T. adspersus*	5	0	
	" "	*H. americanus*	3	0	
	" "	*Raja* spp.	1	0	
	" "	*T. onitis*	1	0	
6-3-81	" "	*P. americanus*	92	8	Released at night

a Specimens alive and released during day except where noted

DISCUSSION

The impingement operations presently at Millstone have resulted in relatively little overall survival for most species. However, the impingement survival study conducted during the winter and early spring of 1980-81 demonstrated that a large percentage of fish and macroinvertebrates can survive impingement if immediately returned to sea water. The extent of this increased survival has not been completely ascertained because of the limited seasonal nature of the sampling. Some mortalities in the laboratory, especially for cold-water forms such as the snailfishes, may have been due to the increased water temperature there due to the salt water well utilized and from the heated building where the holding tanks were located; temperatures were usually 5C or greater than ambient. Nevertheless, survival estimates in this study were generally similar to those recorded elsewhere (EAI 1977, 1979; Tatham et al. 1977, 1978). Benthic fishes (e.g., winter flounder, grubby), fishes with protective integument (e.g., sticklebacks, lumpfish), and the macroinvertebrates with a hard exoskeleton (crabs, northern lobster) had greater survival than smaller forage fishes (e.g., silversides, rainbow smelt). In addition, most dead crabs noted in this study had recently molted, which was also a major reason for impinged crab mortality reported by Tatham et al. (1978).

Studies at several power plants indicated that survival decreased from continuous screen washing through progressively longer intervals between washes (EAI 1977, 1979; Tatham et al. 1978). Differences among screenwash intervals at Millstone were less obvious. Our study indicated that screenwashes at 4 to 8-h intervals should be adequate in maintaining survival of commercially and recreationally important species. The interval time represented the maximum time an individual could have remained on a screen. Except for continous washes (about 10 min), the mean time period of impingement was not known.

Based on studies done at several other power plants (Tatham et al. 1977; MRI 1981), little or no additional mortality would be expected for most species following sluiceway passage. However, this could be dependent upon velocities, construction of bends, materials used, and the design of the exit terminus.

Experiments with marked winter flounder and other species that were released in the vicinity of the intakes were not conclusive as far as the suitability of this area for a sluiceway discharge. Most of the marked winter flounder were recaptured at night and during a storm, periods which also coincided with maximum impingement levels (NUSCo 1977, 1981). Therefore, the possibility exists that some organisms returned by a sluiceway could be reimpinged. A greater possibility may exist for the recirculation of small fish and invertebrates and algae and detritus, the extent of which is not presently known.

The calculation of commerical value of impinged organisms was dependent upon market conditions and fishing costs which included, but were not limited to boat operating expenses, seasonal availability, and abundance. Recent trends have indicated a continued annual increase in the value of most species landed in New England. Sport fishing value was more difficult to establish and total estimated expenditures made by Connecticut fishermen in 1979 were divided by the total sport catch, irrespective of species, to give an average cost per fish landed. This did not take into account the relative worth of the species and sizes sought by anglers. The sport fishing value of an individual fish to an individual fisherman is highly subjective and difficult to quantify and less confidence can be placed in these values.

ENGINEERING DESIGN STUDY

METHODS

Various sluiceway design alternatives were evaluated prior to the preparation of cost estimates. The ease of construction, maintenance, operations, and safety were among the factors considered in determining the technical feasibility of an alternative. Preliminary drawings and cost estimates were prepared only for those alternatives deemed practical at Millstone. Limitations of various pipeline materials (fiberglass, cement-lined ductile iron, reinforced concrete, and steel) were evaluated. Present as-constructed elevations, plant operating parameters, and projected design flows were all taken into consideration in preparation of preliminary designs.

DESCRIPTION OF PRESENT OPERATIONS

The traveling screen systems at the intake structures of Millstone Units 1 and 2 usually operate on a pressure differential (ΔP) system, although they may also be washed manually or by use of a timer. When a ΔP of 6 psi is reached due to the accumulation of material such as algae or fish on the 0.375-in wire mesh screens, the screens begin to rotate. The minimum number of daily screenwashes is three or four, with more frequent washes occurring when winds or tides load the screens with debris. During storms considerably more material is impinged and they are rotated continuously until the material decreases. Under usual conditions one pump at Unit 1 (1,050 gal/min) and one at Unit 2 (1,760 gal/min) each deliver an 80 psi spray which remove the organisms, macroalgae, and other debris retained on the screens. About 25% of this screenwash water is lost because of spray splashing, resulting in a gravity flow of 788 (Unit 1) and 1,320 gal/min (Unit 2) in the screen washwater troughs which carry the impinged material from the screenhouses.

At Unit 1 the material washed off the screens is transported in a trough that runs inside the structure to the south face where it exits the wall via an 18-in pipe. Washes from the traveling screens, service water pump strainers, and material periodically cleaned from the trash racks preceding the traveling screens use this pipe in common. This material drops into a trash pit which contains two baskets (one primary and one overflow) with 1-in drainage holes. The pit drains through a 15-in pipe buried in a trench which runs approximately 100 ft to the south of the intake structure and spills on the existing riprap shoreline protection (Fig. 6). A second overflow drainage line at a higher elevation drains the pit to near the southwest corner of the intake structure.

Full trash baskets are lifted out of the pit by truck-mounted crane, dumped, cleaned, and replaced. All detritus and organisms not removed by the impingement sampling program are hauled to a landfill for disposal. Presently this cleaning is done two or three times weekly and requires about 20 man-hours of labor per week (0.5 man-year), but following a storm as much as 48 man-hours may be required.

Material washed off the traveling screens at Unit 2 is carried in a trough exiting through the south wall of the screenhouse. This trough enters a larger one which also accepts material cleaned from the trash racks before emptying into the trash pit; service water strainer washes enter the pit through a separate trough. The pit contains a basket with 1-in perforations and drains from the bottom by a 24-in pipe. The pipe exits the seawall just south of the screenhouse and discharges into an area between the seawall and the rock outcrop between Units 1 and 2.

The trash basket is emptied, cleaned, and replaced usually five times a week by personnel conducting impingement sampling. In addition, it is emptied and cleaned by plant personnel when full at other times, especially during storms. The material is hauled to a landfill for disposal once a week. Routine maintenance requires about 8 man-hours per week (0.2 man-year) by plant personnel, but storms may necessitate up to 24 to 30 man-hours of work.

SLUICEWAY DESIGN ALTERNATIVES

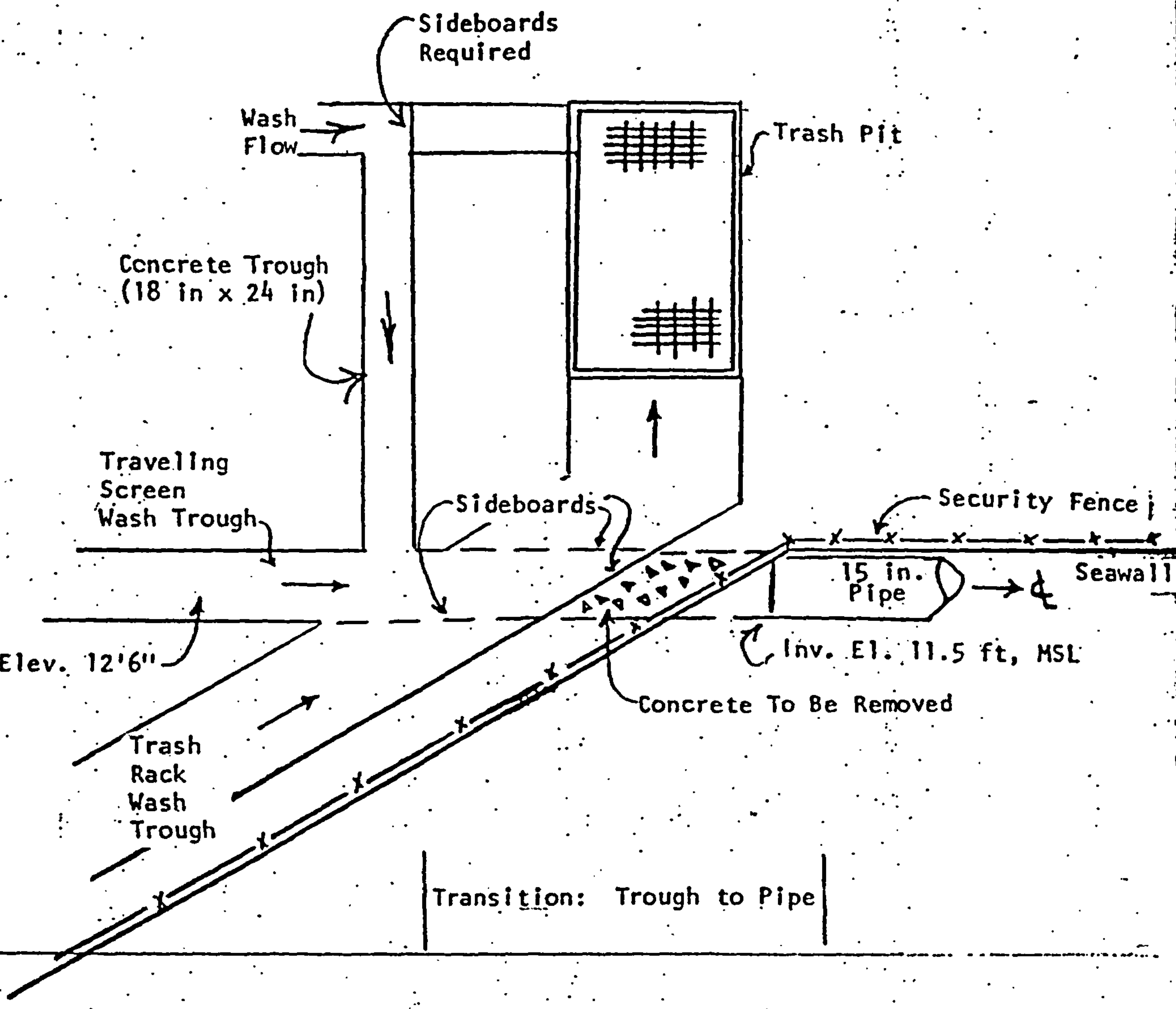
Alternative 1 - Discharges to the south

Unit 2

The Unit 2 trough exits the screenhouse at an invert elevation of 12.5 ft. To facilitate the return of organisms and other material to Long Island Sound, a flow bypass system using steel sideboards (Fig. 7) was designed to divert the flow into a pipeline mounted along the seawall between the intake structures of Units 2 and 1 and across the front face of the Unit 1 intake structure before terminating to the south (Fig. 8). A 15-in diameter reinforced concrete pipe would be needed to transfer the design flow of 1,320 gal/min and a slope of 0.004 ft/ft would keep the pipeline at a maximum elevation along the seawall and Unit 1 intake structure.

Flanged fittings and fabricated structural steel supports located approximately every 10 ft would be used to support the pipeline (Fig. 9). After an approximate pipe run of 125 ft, two 45° bends (with cleanouts) and a 25 ft section would be necessary to take the pipe from the seawall to the front face of the Unit 1 intake structure. There the pipe would be supported at each of the five concrete buttresses running down the west face (Fig. 10); trash rack removal or cleaning would not be impeded by this addition. Another 45° bend with cleanout would be used to bypass the stairway and trash pit overflow discharge near the southwest corner of the Unit 1 intake structure.

The pipeline would then enter a trench just inside the present security fence. Shortly thereafter a 45° wye connection would be used as a junction with the Unit 1 sluiceway (Fig. 11). The combined flow pipeline, constructed of 18-in reinforced concrete, would travel 350 ft



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TITLE

Figure 7. Alternatives 1-3.
Unit 2 trash pit modification.

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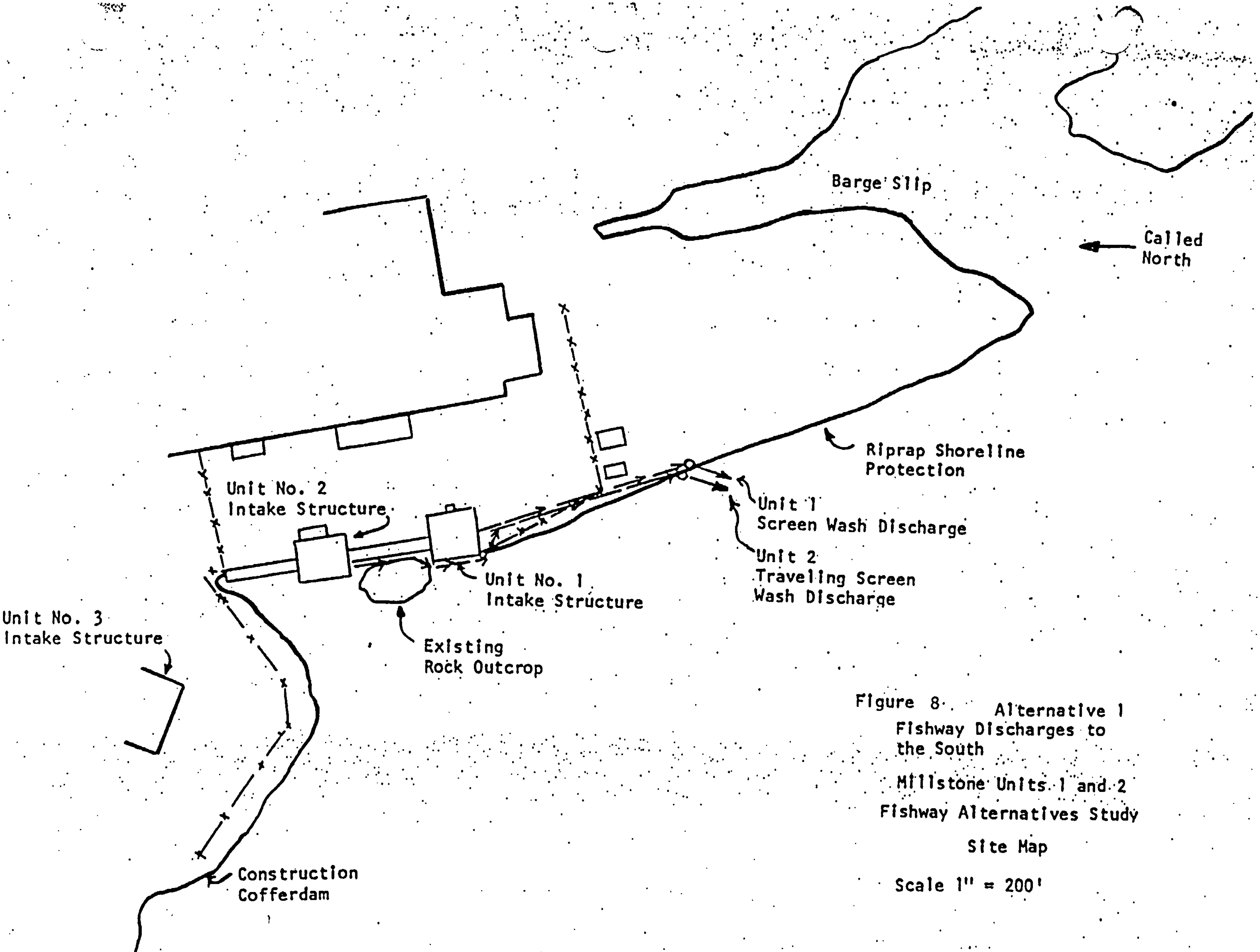

Figure 8 Alternative 1
Fishway Discharges to the South

Millstone Units 1 and 2
Fishway Alternatives Study
Site Map
Scale 1" = 200'

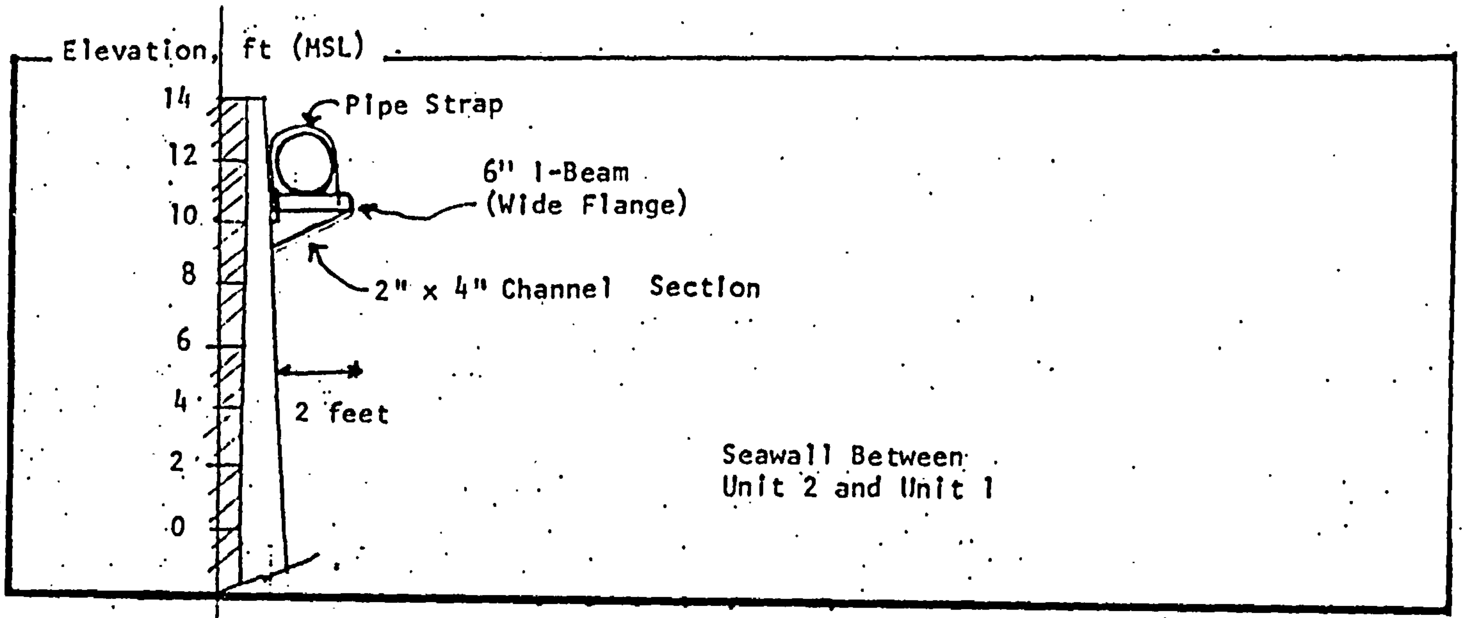

Figure 9
Profile
Alternative 1

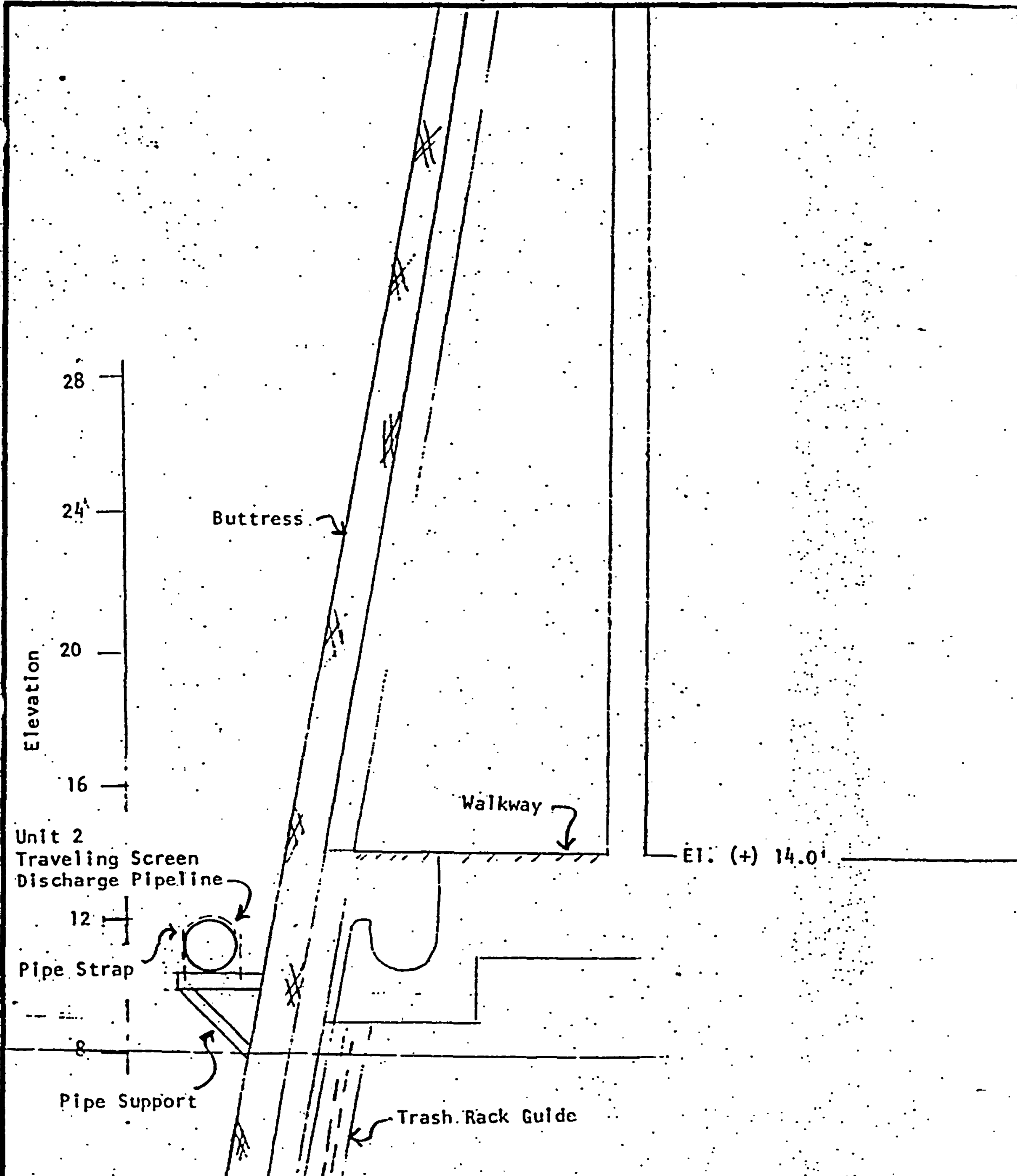

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Figure 10. Alternative 1. Unit 2 sluiceway typical profile, West face of Unit 1.

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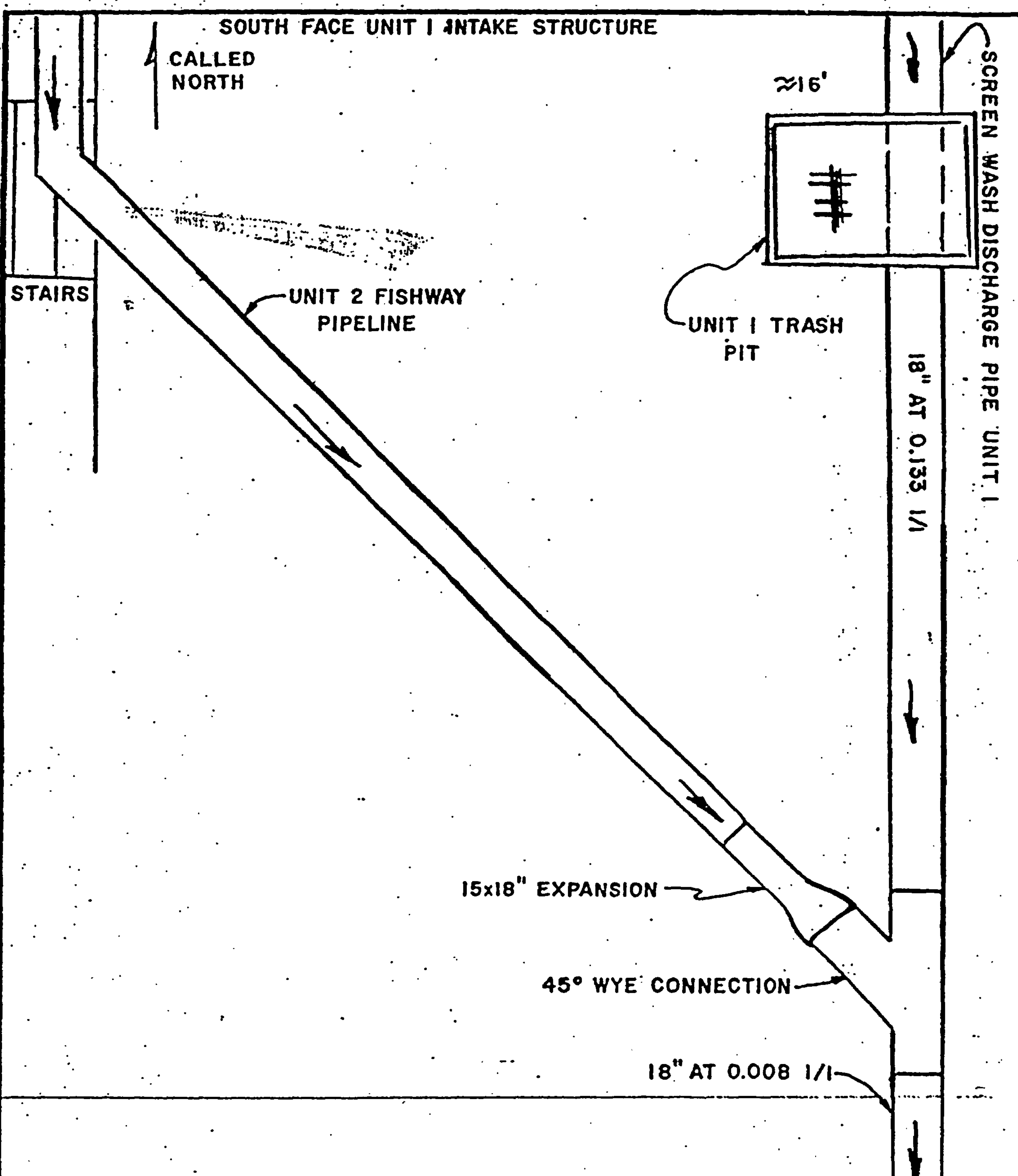

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TITLE Figure 11- Alternative 1. Unit 1 trash pit and junction with Unit 2

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at a 0.008 ft/ft slope to the south.

The line would exit the present riprap shoreline protection at an approximate invert elevation of 7.7 ft. The flow would then enter an open-channel chute down the riprap slope that would return material into the water (Fig. 12). The chute would be constructed of 18-in corrugated metal pipe and have a slope of 0.6 ft/ft.

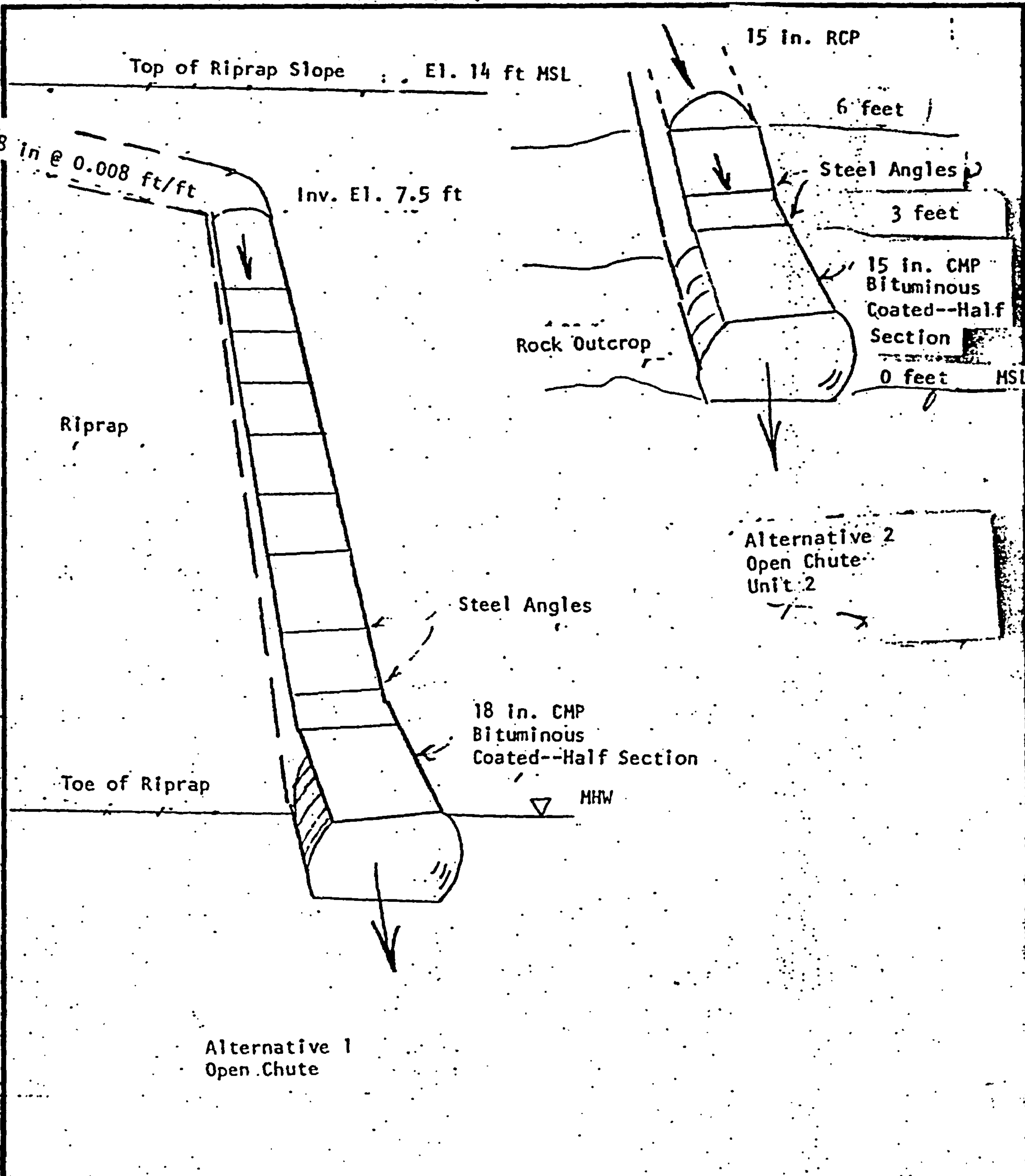
Unit 1

A removable 18-in pipe section or trough would be used to direct the traveling screen and service water strainer flows across the trash pit and into an 18-in pipeline. The pipeline would then join the Unit 2 sluiceway through a wye connection (Fig. 11).

Operations, maintenance, and estimated cost

Optimum operation of the traveling screen wash systems would be during ebb tide to facilitate removal of material away from the intakes. Screenwash pumps should remain on for at least 5 min following conclusion of screen rotation to insure pipe washout and help prevent blockages.

The trash pits would require cleaning only during trash rack cleaning operations or if the sluiceway was bypassed. The removable pipe section at Unit 1 and repositioning of sideboards at Unit 2 would allow trash rack material to drop into the pits for disposal rather than washing into Long Island Sound. In additon, the service water strainer flows at Unit 2 would enter the pipeline rather than draining to the area between the seawall and rock outcrop. This would help alleviate a persistent summer odor problem from this area. The sideboards and removal pipe



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FOR

TITLE Figure 12. Open Chute Discharge Alternative 1-3

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SCALE		DWG. NO.	

MF	P.A. #	NO	DATE	REVISIONS	BY	CHK

section would also allow bypass of the sluiceway and use of the trash pit as present during periods of maximum detrital loading of the screens. Since the extent of recirculation is unknown, this provision would be necessary so that plant operations are not encumbered.

The total estimated cost for Alternative 1 is estimated to be $580,000. This figure includes installation, escalation, and contingency. Maintenance of the system was estimated at 0.2 man-year (0.1 m-y per unit) to allow for cleaning, repairs, and other work. There is a net annual savings of 0.5 man-year for maintenance. Since operation during trash rack cleaning and most likely during major storm events would be similar to present, no net change in these hours would occur.

Alternative 2 - Discharges to the west

Unit 2

The flow bypass system designed for Alternative 1 (Fig. 7) would be used to direct the screenwash into a 15-in pipeline. This pipeline would run 40 ft to the south at a slope of 0.1 ft/ft and would be supported by fabricated structural steel supports approximately every 10 ft (Figs. 13 and 14). Two 45° bends incorporated in the pipeline would then direct the flow to the west and concrete piers would support the pipeline every 10 ft until it could be supported on the rock outcrop (Fig. 15). A 15-in open-channel chute would then discharge the material into the water (Fig. 12).

Unit 1

A removable pipe section would carry the flow exiting the screenhouse through the trash pit and join with a 15-in pipeline running to the west (Figs. 13 and 16). The pipe, mostly buried in a trench, would be supported at its terminus by riprap and discharge at mean sea level approximately 50 ft south of the Unit 1 intake structure (Fig. 15).

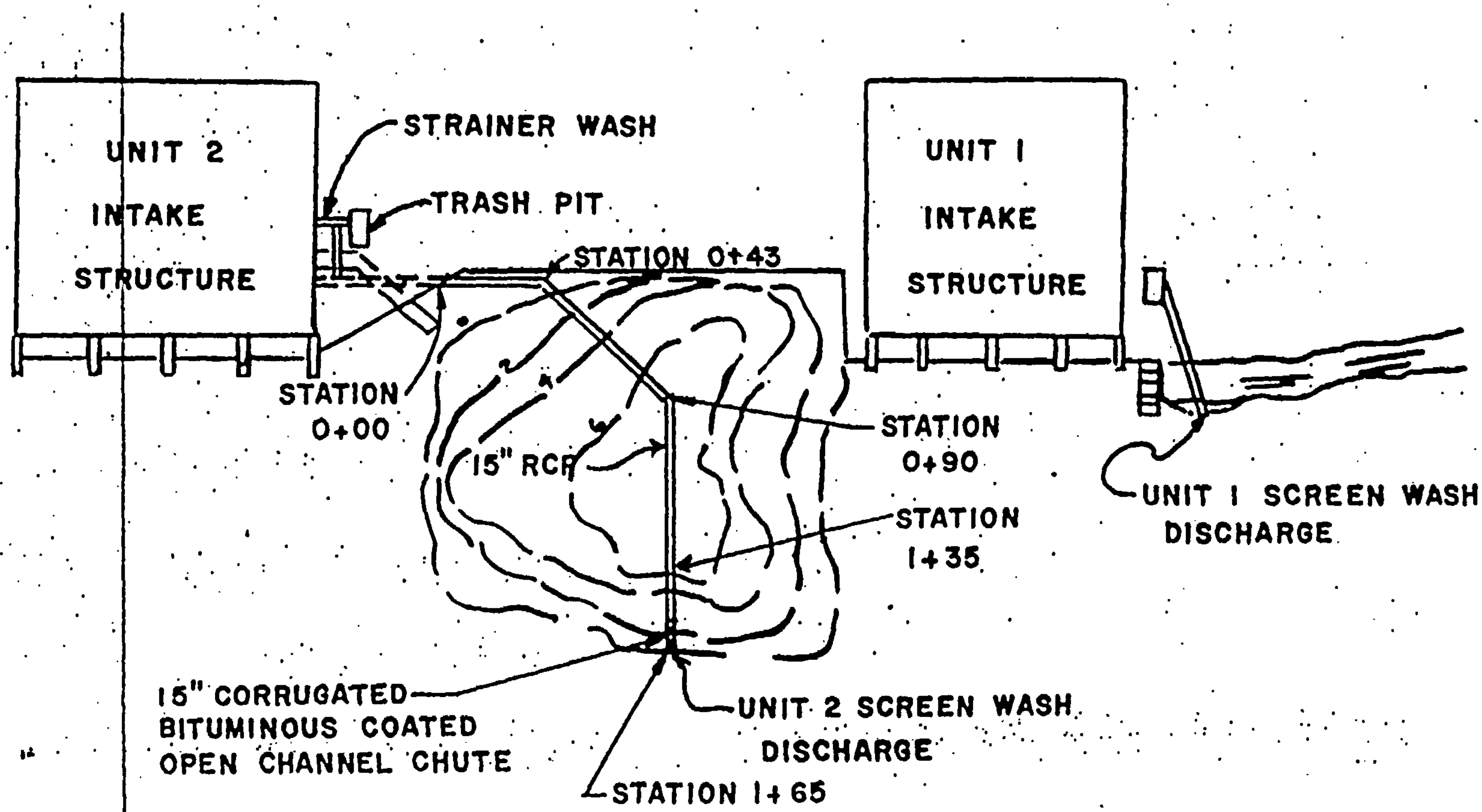

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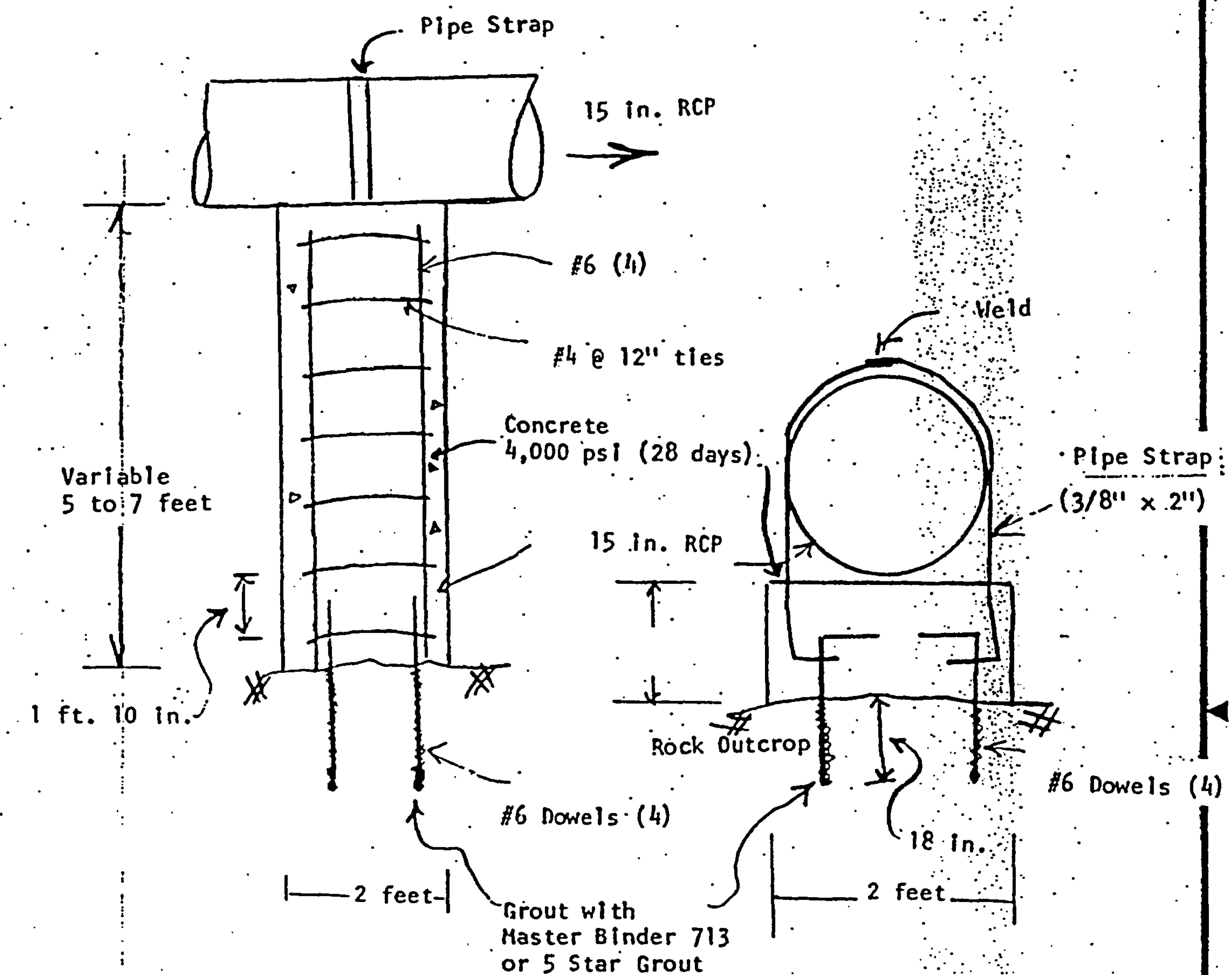
Figure 13. Alternative 2 and Alternative 3 for Unit 2



NORTHEAST UTILITIES SERVICE CO.

FOR

TITLE

Figure 14 Alternatives 2 and 3. Unit 2 concrete piers and pipe support.

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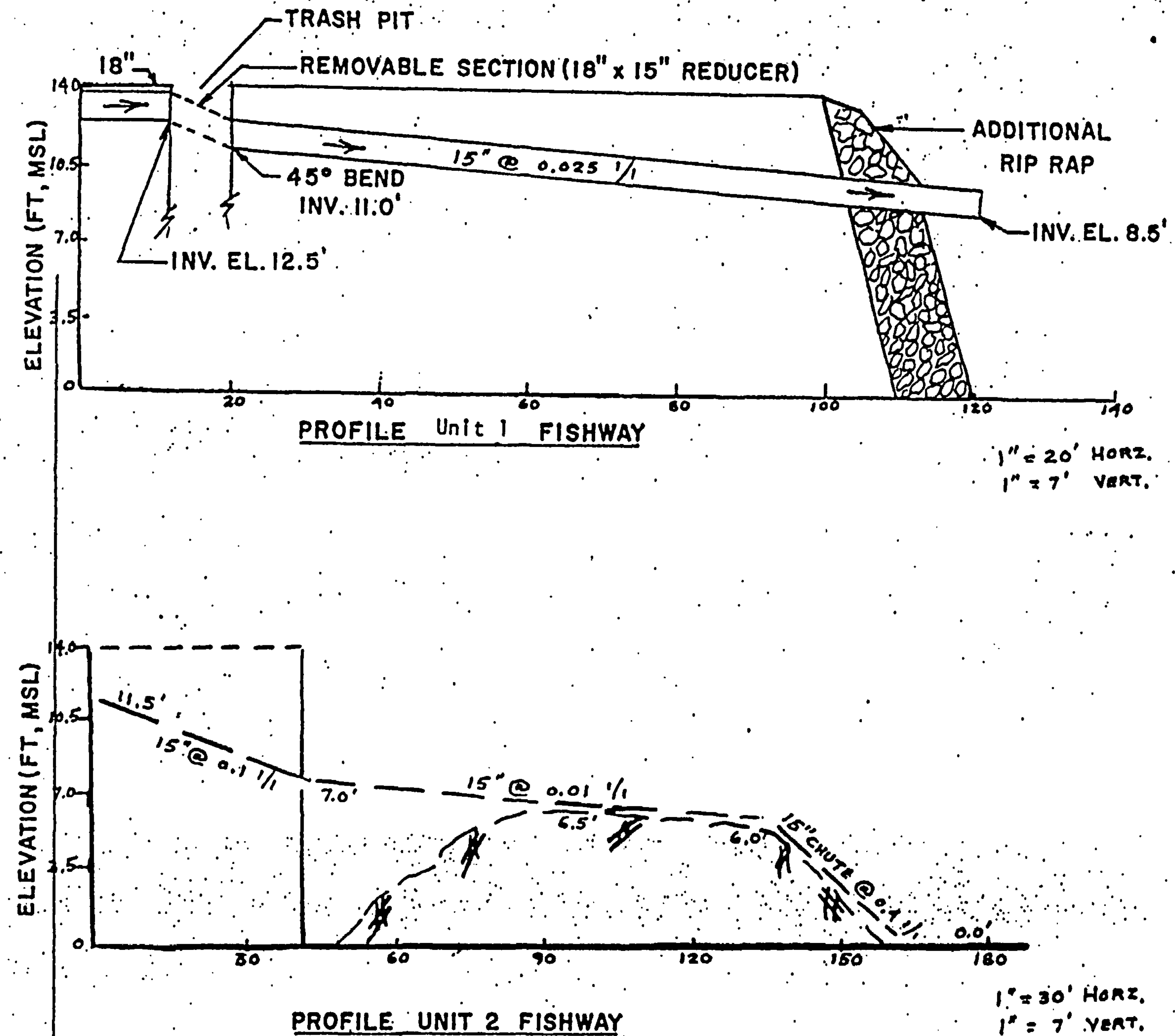

NORTHEAST UTILITIES SERVICE CO.

FOR

TITLE

Figure 15. Alternative 2. Profile of discharges.

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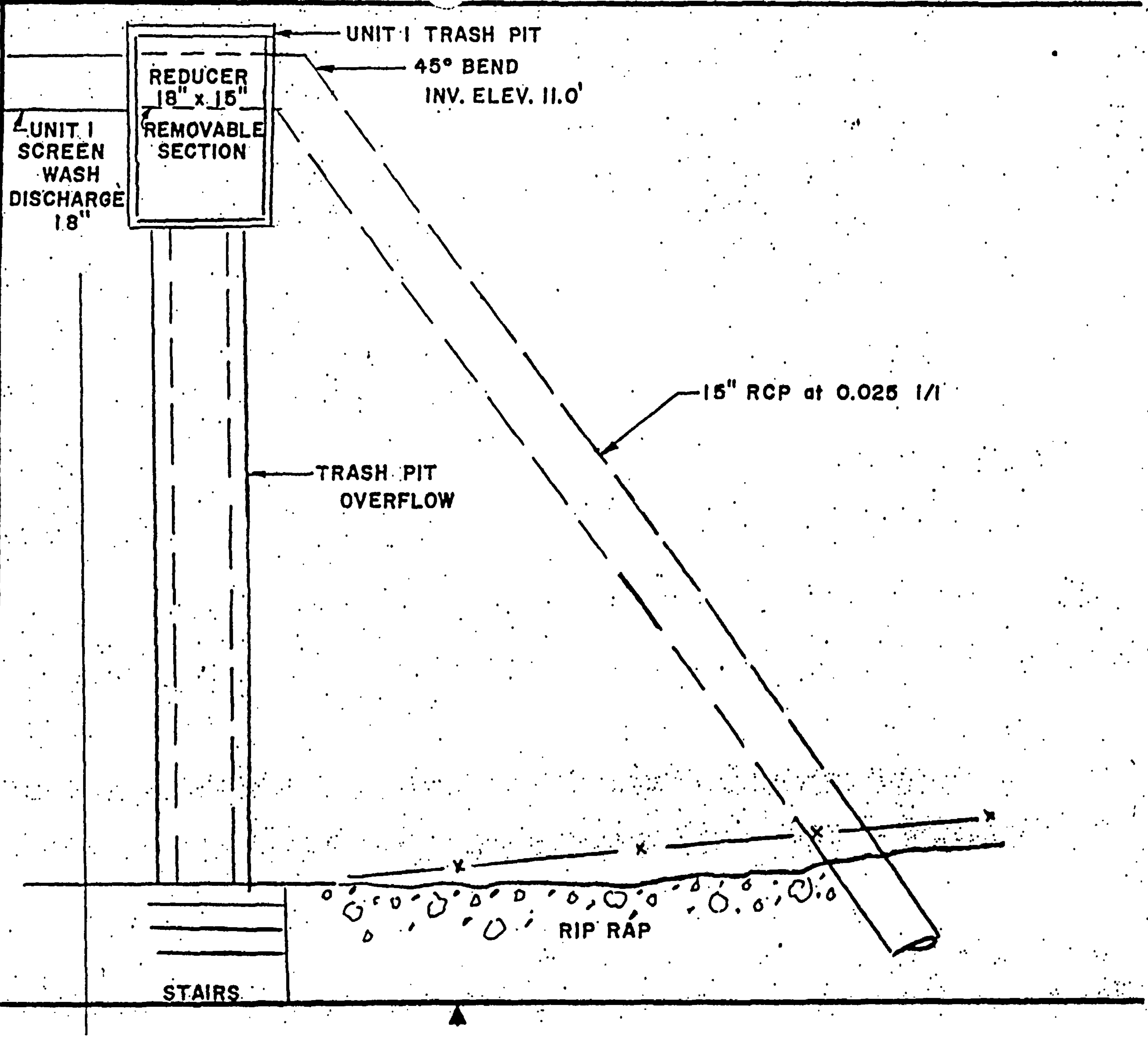

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Figure 16. Alternative 2. Unit 1 discharge.

Operations, maintenance, and estimated cost

Benefits similar to Alternative 1 would occur with this option, such as increased fish survival and decreased maintenance costs. Since the screenwash material would be discharged much closer to the intake structures, similar provisions for a bypass are necessary. The total estimated cost for the sluiceways is $480,000 and 0.2 man-years was allocated for maintenance and repairs.

Alternative 3 - Unit 1 discharge to south, Unit 2 to west

Unit 2

The Alternative 2 sluiceway to the west (Figs. 7 and 12-15) would also be used as the system for this particular option.

Unit 1

The existing 15-in dewatering line which drains the trash pit would be used as a fish return line. A modified basket or chute would be used to guide the material from the 18-in line exiting the screenhouse through a drop of 6 ft in the trash pit to the 15-in pipeline. The pipeline runs approximately 100 ft from the intake structure and presently spills on the riprap shore protection (Fig. 6). Another pipe section would return the material into the water.

Operations, maintenance, and estimated cost

Benefits similar to Alternative 1 would occur, although material would be discharged much closer to the intake structures, especially at Unit 2. This makes a bypass necessary to prevent recirculation of impinged material under unfavorable conditons. The total estimated cost for both sluiceways is $342,000. However, since the Unit 1 sluiceway would consist mostly of an extant system, its cost is estimated at $10,000 as compared to $332,000 for Unit 2. Because of the large difference, this alternative will be evaluated for the concurrent construction of a sluiceway at both units (Alt. 3A) and for independent construction at Unit 1 (3B) and Unit 2 (3C).

Alternative 4 - Discharge to Unit 3

The traveling screen wash from Unit 1 would enter a 15-in pipeline and two 90^{o} bends would be incorporated in the line so that flow can be directed north across the west face of Unit 1. Two 45^{o} bends would be used to bring the line to the seawall north of Unit 1 (Fig. 17). The line would run the length of the seawall to the south face of Unit 2. The flow from Unit 2 would join this pipeline and the junction would require 45^{o} and 90^{o} bends as well as a 45^{o} lateral connection. An 18-in pipeline would then proceed north across the west face of Unit 2 and two 45^{o} bends would be used to bring the line towards the seawall north of Unit 2. This seawall mounted line would run north and then bend west to connect with the proposed Unit 3 sluiceway.

Many 45^{o} and 90^{o} bends are required for this alternative and to ensure hydraulic pipeline stability their radii should be greater than 1.5 times the pipe diameter. Plans for the proposed Unit 3 sluiceway have not been finalized and its operation will not commence until 1986 or later. The engineering and costs to construct a sluiceway linking Units 1 and 2 with 3 are not deemed feasible and no further analysis has been undertaken for this alternative.

Alternative 5 - Discharge to barges

The traveling screen washes from both units would be directed to the west and would discharge into bottom-dump hopper barges moored offshore of the intake structures (Fig. 18). Periodically the barges would have to be transported away from the units and emptied.

Pipelines similar to Alternatives 1 or 2 would have to be constructed as well as the purchase of rental of barges. Company-owned boats or rented tugs would be required to transport the barges. During adverse

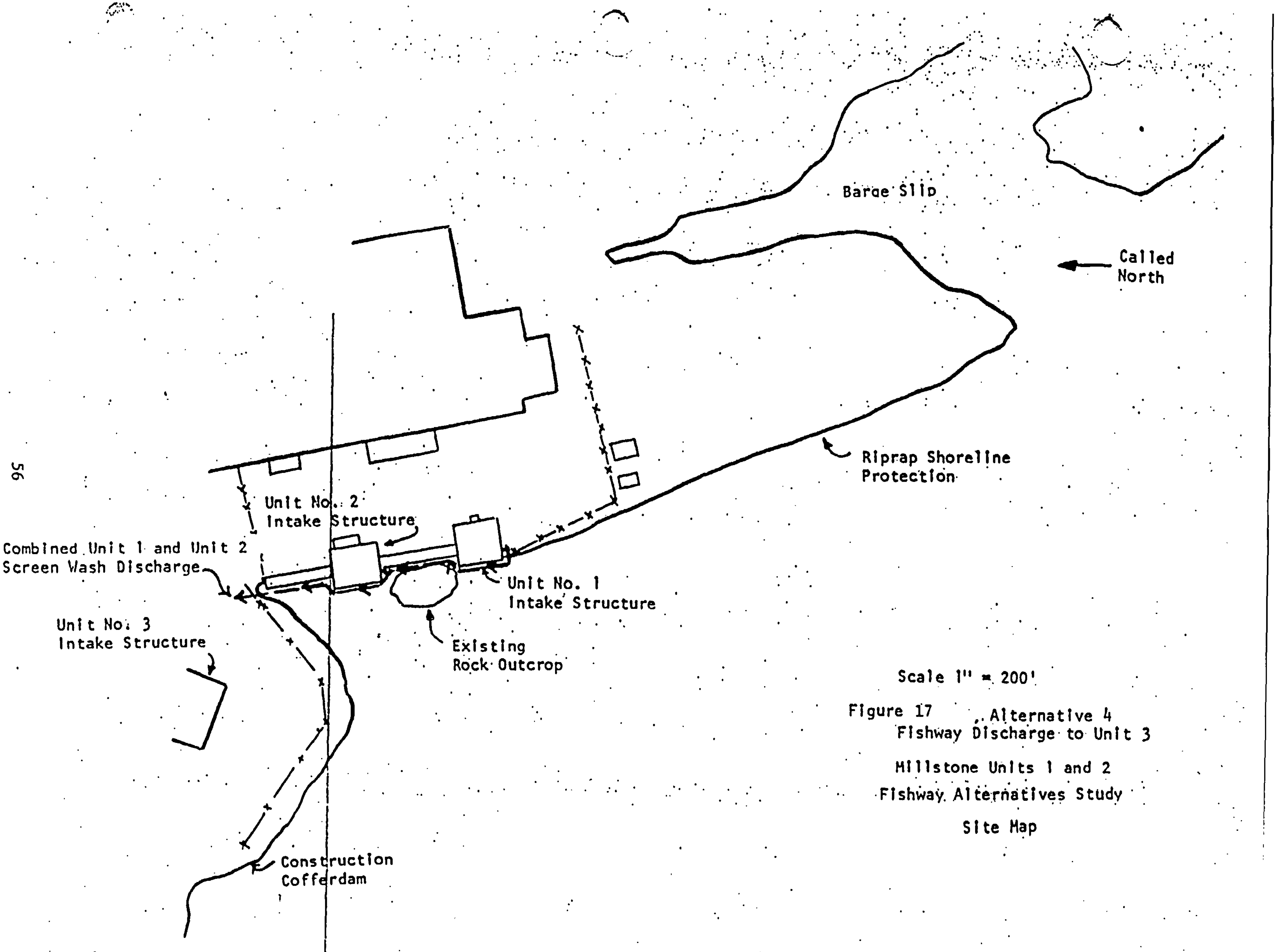

Figure 17 Alternative 4 Fishway Discharge to Unit 3

Millstone Units 1 and 2

Fishway Alternatives Study

Site Map

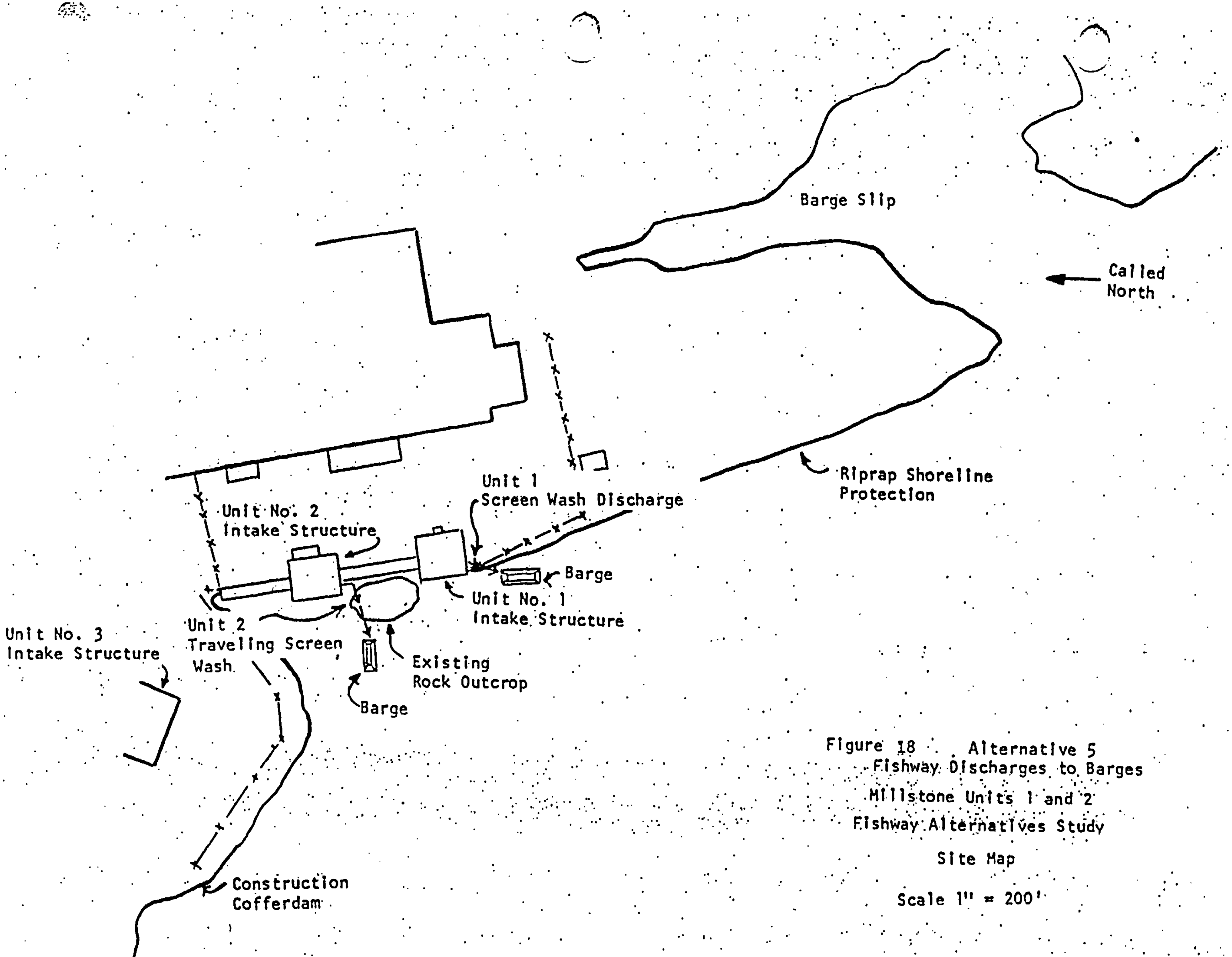

Figure 18 Alternative 5
Fishway Discharges to Barges

Millstone Units 1 and 2
Fishway Alternatives Study

Site Map

Scale 1" = 200'

weather conditions the proximity of the barges to the intake structures could be hazardous. The effects of holding organisms in the barges is not known. Cost estimates for this alternative have not been completed because the feasibility of this system is questionable for the reasons noted above.

Alternative 6 - Discharge to ponds

The traveling screen washes from both units, including all organisms and detritus, would enter on-site holding ponds (Fig. 19). The ponds would have an overflow capability and would be constructed near the south face of each intake structure. Periodically material would be loaded into tank trucks and discharged into Long Island Sound at a suitable location.

The construction of ponds and sluiceways would require removal of significant amounts of rock, concrete, and earth. Considerable underground electrical lines, conduit, and security systems exist in the proximity of the intake structures and much vehicle traffic occurs in this area as well. Ponds would require frequent cleaning and considerable labor as well as specialized equipment for fish removal and transport. The effects of severely warm or cold weather on survival of held organisms are also not known. Anticipated high costs and engineering impracticalities have made this alternative not feasible and no further study has been undertaken.

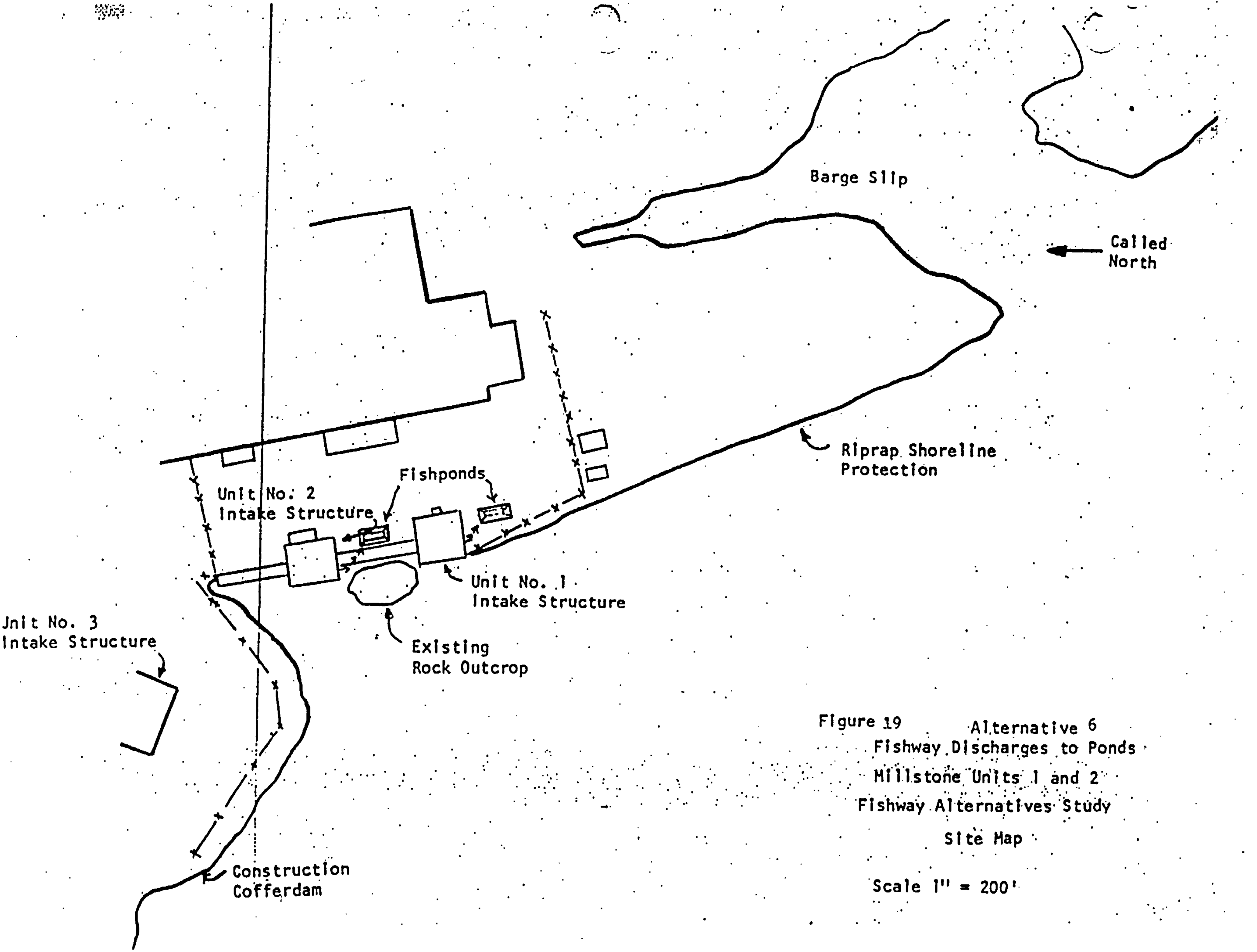

Figure 19 Alternative 6
Fishway Discharges to Ponds
Millstone Units 1 and 2
Fishway Alternatives Study
Site Map

Scale 1" = 200'

COST BENEFIT ANALYSIS

METHODS

Three sluiceway design alternatives (Table 12) were selected for cost benefit analysis. The NUSCo financial carrying charge model (Table 13) with parameters adjusted as of 6 July 1981 was used to compute annual capital costs based on the estimated construction cost of each alternative. Each alternative was estimated to have a 15 year life and the carrying charges, costs, and savings were computed over this period. Calculations based on manpower and value of impinged organisms saved were adjusted upwards 7% per year.

Maintenance and impingement personnel base salaries ($20,000) and overhead ($10,800) totaled $30,800 per man-year (m-y). Maintenance costs were based on 0.2 m-y for Alternatives 1 through 3A but on 0.1 m-y for 3B and 3C, since the latter two alternatives considered only a single unit. Maintenance savings were based on 0.7 m-y (Alt. 1-3A), 0.5 m-y (3B), and 0.2 m-y (3C); about 70% of the present routine maintenance expenditures for man power occur at Unit 1.

It was assumed that with a sluiceway in place impingement monitoring would no longer be required, but a 1 year study to determine the effectiveness of the sluiceway in reducing mortality would commence following construction. The total cost of the study at both units was estimated at $20,400. Impingement monitoring savings would be 0.7 m-y for Alternatives 1 through 3A, based on program deletion. If Alternative 3B is chosen, however, savings would be only 0.125 m-y, which represents the time needed to sample at Unit 1 alone. It was assumed that sampling would continue at Unit 2 and the associated laboratory work, data analysis, and report preparation would continue as present. The remaining 0.575 m-y was therefore allocated to Alternative 3C, assuming that a Unit 2 sluiceway could potentially be constructed at a later date, if feasible.

Table _2. Summary of sluiceway design alternatives and estimated costs used for cost benefit analysis.

Alternative	Description	Cost
1	Separate pipelines join near Unit 1 and discharge 350 ft to south	$580,000
2	Separate pipelines discharge to west of each unit	$480,000
3A	Use of existing dewatering line at Unit 1, Unit 2 discharge to west	$342,000
3B	Use of existing dewatering line at Unit 1 only	$ 10,000
3C	Unit 2 discharge to west only	$332,000

Table 13. NUSCo financial carrying charges model input parameters (6 July 1981)

Construction period is 1 year starting in 1982

Effective property tax rate = 0.0%

Effective Rate for other taxes = 7.00%

AFUDC rate = 0.0% not compounded

Construction period debt portion of plant account = 48.0%

Preferred stock portion of plant account = 12.0%

Construction period bond interest rate = 13.00%

Preferred stock interest rates = 12.50%

Cost of common equity rate = 19.00%

Present/future worth rate = 15.34%

Book depreciation is calculated by straight line method

Conn state income tax rate = 10.00%

Federal income tax rate = 46.0%

There are income taxes on equity return

Investment tax credit rate after 1980 = 10.0%

Normalization charge due to investment tax credit is deducted from book value

6 months in last year of construction

6 months in first year in service

Book life = 15 years

ADR tax life = 16.0 years

In service period rate of return = 15.30%

In service period debt portion of plant account = 48.0%

In service period bond interest rate = 13.00%

Sum of the years digits method used for tax depreciation

Tax depreciation over ½ year

Net Book salvage rate = 0.0%

Gross tax salvage rate = 0.0%

Gross tax cost of ...

Values of impinged organisms saved by construction of a sluiceway were computed. Estimated weight and number and commercial and sport values of important species reported previously in this report were used in the calculations. A 90% increase in survival over present operations was estimated for winter flounder, tautog, and northern lobster and a 20% increase in survival was estimated for the Atlantic long-finned squid. Total savings were divided in half for single unit analysis of Alternatives 3B and 3C.

The present/future worth values were used for the determination of cost benefit. These values represent the amount that money at some future date is worth in present dollars and take into account the costs that Northeast Utilities must bear in borrowing funds. Present/future worth was calculated as:

$$\frac{\text{total dollars per year}}{1.1534^n}$$

where n is the year. The total present/future worth dollars computed for costs and savings associated with each year of sluiceway operation were summed over the 15 year period. Costs were compared to savings for each alternative and the net difference indicated the cost benefit of construction.

RESULTS AND DISCUSSION

The cost benefit analysis showed that construction of sluiceways at both units (Alts. 1-3A) is not feasible at this time because the high costs associated with financing construction far outweigh any benefits gained in maintenance savings, elimination of impingement sampling, and value of additional organisms saved (Table 14). Deficits at the end of the 15-year period ranged from \$273,695 for Alternative 1 to \$24,135 for Alternative 3A. Consequently, it is not justifiable for the Northeast Utilities ratepayers to assume the costs of construction and maintenance of these alternatives.

The construction and operation of Alternative 3B, the modification of the existing Unit 1 trash pit dewatering line, is currently feasible and the net benefits for this option are \$138,032 if upon completion impingement sampling is not required at this unit. However, the construction of an accompanying sluiceway at Unit 2 (Alt. 3C) is not warranted, with costs exceeding savings by \$162,101. Periodic resumption of the present system of operations would also be necessary at the discretion of the plant superintendent at Unit 1 during some trash rack cleaning operations and whenever deemed necessary to prevent accumulation and recirculation of material from interfering with plant operations. Present screenwash operations and impingement sampling at Unit 2 would continue. Unit 3, presently under construction and with an estimated completion date of 1986, will have a sluiceway return system in operation. Therefore, it is strongly recommended that further consideration of a Unit 2 sluiceway be delayed until the actual costs, operation, and effectiveness of the Units 1 and 3 sluiceways have been evaluated. Improvements over Northeast Utilities' present financial conditions will also undoubtedly be necessary to make a Unit 2 sluiceway cost effective.

Table 14. Summary of cost benefit analysis over a 15 year service life period for various sluiceway design alternatives.

	TOTAL COSTS					TOTAL SAVINGS					NET
Alternative	Financial Carrying Charges	Maintenance	Sluiceway Monitoring	Total	Present/ future worth	Maintenance	Impingement Monitoring	Survival of impinged organisms	Total	Percent/ future worth	
1	1,586,841	154,760	20,400	1,762,001	675,746	541,784	541,784	163,590	1,247,158	402,051	- 273,695
2	1,313,247	154,760	20,400	1,488,407	570,888	541,784	541,784	163,590	1,247,158	402,051	-168,837
3A	935,688	154,760	20,400	1,110,848	426,186	541,784	541,784	163,590	1,247,158	402,051	- 24,135
3B	27,360	77,397	10,200	114,957	44,280	386,986	96,748	81,795	565,529	182,312	138,032
3C	908,331	77,397	10,200	995,928	382,328	154,760	445,034	81,795	681,589	220,227	-162,101

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NORTHEAST UTILITIES

THE CONNECTICUT LIGHT AND POWER COMPANY
THE HARTFORD ELECTRIC LIGHT COMPANY
WESTERN MASSACHUSETTS ELECTRIC COMPANY
HOLYOKE WATER POWER COMPANY
NORTHEAST UTILITIES SERVICE COMPANY
NORTHEAST NUCLEAR ENERGY COMPANY

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July 31, 1981

Mr. Stanley J. Pac
Commissioner
Department of Environmental Protection
State Office Building
Hartford, CT 06115

Reference: NPDES Permit No. CT0003263 (DEP Order No. 2859), dated July 2, 1980.

Dear Mr. Commissioner:

Millstone Nuclear Power Station
<u>Cooling Water Intake Screen Wash System</u>

In Reference (1) Paragraph 14, it was ordered by the Commissioner that the Northeast Nuclear Energy Company (NNECO), Millstone Nuclear Power Station, take such action as necessary to submit on or before July 31, 1981, for the review and approval of the Commissioner of Environmental Protection, an engineering report studying the feasibility of modifying the cooling water intake screen wash system to improve the return of fish back to Long Island Sound.

NNECO hereby submits such a report prepared by Northeast Utilities Service Company entitled, "Feasibility of Modifying the Millstone Units 1 and 2 Cooling Water Intake Screen Wash System to Improve the Return of Fish to Long Island Sound." The report considers various alternatives which would improve survival of organisms subsequent to their impingement on the traveling screens of Millstone Units 1 and 2 and combines both engineering and biological design criteria. Recommendations are made on the basis of a cost-benefit analysis, which compares the economic value of fish and invertebrates saved to the costs of construction and maintenance for each alternative.

Briefly, results show that the costs of those alternatives which require major new construction far exceed the anticipated savings and that the expenditures are, therefore, unwarranted. Such is the case of alternatives considered for Millstone Unit 2. However, the presence of an existing dewatering line at Unit 1 provides for an alternative at this unit which is cost effective and currently feasible (See alternative 3B).

On the basis of report findings, NNECO is prepared to implement the latter alternative (3B) for Millstone Unit 1. Part of the savings from this option accrue from the proposed discontinuance of impingement monitoring during operation of the fish return system. Once the return system is put into service, therefore, we would recommend that the current requirement to monitor impingement at Unit 1 be deleted.

We recommend further that consideration of a Unit 2 backfit be postponed. As you know, Millstone Unit 3, presently under construction and with an estimated completion date of 1986, will have a sluiceway return system. It is suggested that consideration of a Unit 2 sluiceway be delayed until costs, operation and effectiveness of the Units 1 and 3 sluiceways have been evaluated. Improvement over present financial conditions of Northeast Utilities will also be necessary to make a sluiceway cost effective.

It is important to note that during periods of high debris loadings, storms, or other times the fish bypass system might adversely affect operation of the plant cooling water systems. For this reason, it is strongly recommended that the Plant Superintendents be given the operational flexibility of temporarily returning to the present mode of operation when such high debris conditions occur.

If after reviewing the report and its recommendations, you have further questions or wish to discuss the options, please contact Dr. William C. Renfro, Director of Environmental Programs, at (203) 666-6911, Extension 3240.

Very truly yours,

NORTHEAST NUCLEAR ENERGY COMPANY

W. G. Counsil

W. G. Counsil
Senior Vice President

Enclosure - w/2 copies

cc: W. L. Winterbottom - w/enclosure
Dept. of Environmental Quality
Water Compliance Unit
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Appendix 2

The Effectiveness of the Millstone Unit 1 Sluiceway in Returning Impinged Organisms to Long Island Sound

Submitted to the

State of Connecticut

Department of Environmental Protection

Prepared by

Northeast Utilities Service Company

for

Northeast Nuclear Energy Company

May 31, 1986

The Effectiveness of the Millstone Unit 1 Sluiceway in Returning Impinged Organisms to Long Island Sound

INTRODUCTION

Under NPDES Permit No. CT0003263 (DEP Order No. 2859) issued July 2, 1980 by the Commissioner of the Connecticut Department of Environmental Protection (DEP) to Northeast Nuclear Energy Company (NNECo), an engineering report was required which addressed the feasibility of modifying the cooling-water intake systems of Millstone Nuclear Power Station (MNPS) Units 1 and 2 to improve the return of fish and shellfish back to Long Island Sound (LIS). A report (NUSCo 1981) was submitted to the DEP on July 31, 1981 which demonstrated that backfitting a fish return sluiceway at MNPS Unit 1 was cost-effective. With the concurrence of the DEP, the Unit 1 sluiceway was fabricated, installed, and put into operation in mid-December of 1983. A study to examine the mortality of fishes and invertebrates impinged at Unit 1 and returned to the source water body via the sluiceway was initiated in January 1984 and continued through July 1985. This report presents the results of that study and discusses the effectiveness of the Unit 1 sluiceway in returning aquatic organisms back to LIS.

MATERIALS AND METHODS

The MNPS Unit 1 screenwash system was modified in several ways to return aquatic organisms (see NUSCo 1981). A trash basket placed in a pit adjacent to the intake structure formerly intercepted all material washed from the four traveling screens preceding the circulating and service water pumps. This was replaced by a stainless steel trough that carried material from the screenhouse into a buried 38.1-cm (15-in) concrete pipe. If necessary, this portion of the sluiceway may be removed and the original trash basket put back into place. The pipe dewatering the pit had emptied onto the rock rip-rap along the west shoreline of MNPS. A 45.7-cm

(18-in) galvanized pipe was joined onto this line. After continuing about 4 m, the sluiceway pipe bends to the right approximately 45° and continues for about 8 m where it is anchored to a rock outcrop just offshore of the rip-rap. The upper half of approximately the last 6 m of the sluiceway was removed and thus resembles a trough entering the water; much of this portion is underwater at high tide. The upper half of a 2-m section of the sluiceway pipe about midway up the rip-rap and near where it exits the ground was also removed to provide access for sampling.

Twenty-three samples were taken in the sluiceway when Unit 1 was in operation from January 1984 through July 1985 to examine the survival of impinged fish and macroinvertebrates. The normal complement of at least four circulating and two or three service water pumps were online during each collection. Because most impingement usually occurs at night and for ease of sampling, it was most practical to sample in early morning and during low tide. Therefore, collections were made approximately every other week in 1984 when an ebbing tide occurred during the morning. Samples were taken once a month in 1985 under the same conditions.

Before a sample was collected, the traveling screens were first washed during the middle of the night to clean them of previously accumulated debris and organisms and then were not allowed to rotate or wash for approximately 6 h. Following this period, the sampler, a 45.7-cm diameter by 61-cm long stainless steel mesh cylinder with approximately 2 m of 4.88-mm netting attached, was placed into the sluiceway at the sampling access area and held in place by ropes. The screens were then rotated and cleaned and as material collected during the 20-min wash cycle, the net was periodically emptied. All organisms were picked from the debris by hand and placed into an insulated cooler or bucket containing seawater. The specimens were returned to the laboratory and held in tanks with running seawater; crabs and predatory fish were kept separate from other species. Dead organisms were removed, identified, and measured following the initial collection and after periods of 6 and 24 h. At 72 h following collection, the remaining live and dead organisms were removed. At this time, individuals that were stressed (i.e., showing obvious injury or abnormal behavior) were recorded as dead because they probably would have been preyed upon by larger fish or birds. Total length of fish, carapace width of crabs, carapace length of lobsters, and mantle length of squid were recorded to the nearest mm.

Survival of each species was calculated based on the proportion of specimens alive at the initial, 6-, 24-, and 72-h observations. For some survival estimates species were placed into three groups, termed "pelagic" (total of 18 fish species), "demersal" (27 fishes), and "crustaceans" (8 decapods). These groupings generally reflected habits and body type. Free-swimming fishes such as herrings, Atlantic silverside, and butterfish were considered pelagic whereas bottom-dwelling forms such as sculpins and flounders as well as those with armored or hard integuments such as sticklebacks and northern pipefish were classified as demersal. The crustacean group was comprised of various crabs and the northern lobster. The Atlantic long-finned squid was not placed into any group for reasons to be discussed below.

Water temperatures at the intake and in laboratory holding tanks were recorded. Temperatures during sampling ranged from 3.0 to 20.0 C and the samples were assigned to three approximately equal-sized seasonal groups for some of the survival calculations. These were cold-water (2.0-5.6 C; 8 collections), cool-water (7.0-15.0 C; 7), and warm-water (16.7-20.0 C; 8).

Winter flounder were used in a number of experiments designed to examine their potential for re-impingement after return to LIS via the sluiceway. Adults larger than 20 cm were tagged using Petersen discs (see NUSCo 1985b for methods) and released near the intake structures of Units 1 and 2 on seven occasions during 1981 to 1983. Several experiments conducted in 1979 and reported in NUSCo (1981) are also summarized in this report. These winter flounder were marked by freeze branding (NUSCo 1985b) and released near a bottom boom formerly in place near the Unit 1 intake.

Data from regular impingement collections made at Unit 1 (see NUSCo 1984 for methods) from October 1976 through December 1983 were used to obtain estimates of total impingement during that period. These estimates were used to determine the effect of the Unit 1 sluiceway on the biota found in the vicinity of MNPS. Data recorded on the molting status of lobsters impinged at MNPS from 1982 through 1985 were also used to help assess lobster survival in the sluiceway.

RESULTS

The Unit 1 sluiceway went into operation on December 17, 1983 and stayed in service until Unit 1 was shutdown from April 13 through July 3, 1984. Although no records of its operation are available for the remainder of 1984, the dates of the sluiceway sampling were such that it could not have been out of service for an extended period, if at all. The screenhouse and trash racks were cleaned once during the fall and the sluiceway was not operated for about 5 to 7 d during this procedure. NU agreed to maintain records of sluiceway operations beginning in 1985; the number of days the sluiceway was removed is given in Appendix 1.

Forty-five species of fish and nine macroinvertebrates were found in the sluiceway samples (Tables 1 and 2). Cold-water collections tended to have more species and specimens than the other two groups. However, an exception was the warm-water sample of July 8, 1985, when 349 specimens and 20 species were taken. Numerically, the 1,356 specimens collected during the study were dominated by eight species which comprised 83% of the total: the Atlantic long-finned squid (416), threespine stickleback (217), blackspotted stickleback (184), butterfish (104), grubby (74), northern pipefish (49), winter flounder (44), and green crab (39). Relatively few specimens of other species were taken. However, when species were collectively grouped, distinctly different rates of mortality were found due to impingement and passage through the sluiceway. A discussion of the survival of each species group, the eight most abundant species, and the locally important northern lobster follows.

Table 1. Summary of collections taken in the MNPS Unit 1 sluiceway from January 1984 through July 1985.

Collection number	Date	Water temperature (°C)	Temperature group	Number of species	Number of specimens
1	25 Jan 84	3.0	Cold	6	30
2	7 Feb 84	3.0	Cold	12	55
3	21 Feb 84	4.0	Cold	8	39
4	6 Mar 84	4.0	Cold	11	53
5	19 Mar 84	4.0	Cold	11	150
6	2 Apr 84	4.0	Cold	12	165
7	7 Aug 84	20.0	Warm	6	11
8	20 Aug 84	20.0	Warm	5	11
9	10 Sep 84	20.0	Warm	8	24
10	24 Sep 84	20.0	Warm	5	15
11	9 Oct 84	17.0	Warm	7	42
12	22 Oct 84	16.7	Warm	8	56
13	6 Nov 84	15.0	Cool	15	41
14	19 Nov 84	13.1	Cool	10	29
15	3 Dec 84	9.0	Cool	6	7
16	18 Dec 84	9.2	Cool	10	19
17	31 Dec 84	8.5	Cool	8	21
18	15 Jan 85	2.0	Cold	3	9
19	10 Apr 85	5.6	Cold	13	67
20	7 May 85	7.0	Cool	15	63
21	10 Jun 85	13.4	Cool	12	28
22	8 Jul 85	19.8	Warm	20	349
23	29 Jul 85	19.6	Warm	9	72

The demersal fish and crustacean groups had the greatest survival in the sluiceway with overall rates of 77 and 71%, respectively (Table 3). Survival of demersal fish was best when water temperatures were cold (83%) and decreased during cool- (53%) and warm-water (36%) periods. However, more than 80% of these fish were taken during the colder months. Survival of crustaceans was also greatest during the colder months (92%), and was similar during cool (71%) and warm (65%) months. Few pelagic fish survived impingement and sluiceway passage; most individuals collected alive died during the 3-d holding period. Most of these species were taken during months with warm water temperatures. More than half of these were butterfish and most others were small forage fish or

Table 2. Percent initial and extended survival and species groups of fishes and macroinvertebrates taken in the MNPS Unit 1 sluiceway from January 1984 through July 1985.

Species	Common name[a]	Species group[b]	Number examined	Initial survival	Survival at 6 h	Survival at 24 h	Survival at 72 h
Alosa aestivalis	blueback herring	P	6	0	0	0	0
Alosa pseudoharengus	alewife	P	8	0	0	0	0
Ammodytes spp.	sand lance	P	2	0	0	0	0
Anchoa mitchilli	bay anchovy	P	28	0	0	0	0
Anguilla rostrata	American eel	D	1	100	100	100	100
Astroscopus guttatus	northern stargazer	D	1	100	100	100	100
Brevoortia tyrannus	Atlantic menhaden	P	4	100	75	25	0
Callinectes sapidus	blue crab	C	7	86	86	86	86
Cancer irroratus	rock crab	C	12	92	92	92	92
Caranx hippos	crevalle jack	P	1	0	0	0	0
Carcinus maenus	green crab	C	39	82	77	67	62
Centropristis striata	black sea bass	D	1	100	0	0	0
Clupea harengus	Atlantic herring	P	1	0	0	0	0
Cyclopterus lumpus	lumpfish	D	9	89	67	56	56
Dorosoma cepedianum	gizzard shad	P	1	0	0	0	0
Enchelyopus cimbrius	fourbeard rockling	D	1	0	0	0	0
Etropus microstomus	smallmouth flounder	D	2	50	50	50	50
Fundulus heteroclitus	mummichog	D	3	100	100	67	67
Gasterosteus aculeatus	threespine stickleback	D	217	95	93	92	91
Gasterosteus wheatlandi	blackspotted stickleback	D	184	91	90	89	86
Homarus americanus	northern lobster	C	28	38	38	38	38
Lactophrys spp.	trunkfish	D	1	100	100	100	100
Libinia spp.	spider crab	C	7	71	71	71	71
Liparis spp.	snailfish	D	1	100	100	100	100
Loligo pealei	Atlantic long-finned squid	-[c]	416	0	0	0	0
Lophius americanus	goosefish	P[d]	9	0	0	0	0
Menidia menidia	Atlantic silverside	P	13	54	15	8	0
Merluccius bilinearis	silver hake	P	6	0	0	0	0
Microgadus tomcod	Atlantic tomcod	D	26	35	35	27	27
Morone americana	white perch	P	1	0	0	0	0
Mugil cephalus	striped mullet	P	1	0	0	0	0
Myoxocephalus aenaeus	grubby	D	74	87	78	76	74
Neopanope texana	mud crab	C	3	100	100	100	100
Ophidion marginatum	striped cusk-eel	D	2	100	50	50	50
Opsanus tau	oyster toadfish	D	2	100	100	100	100
Osmerus mordax	rainbow smelt	P	3	33	0	0	0
Ovalipes ocellatus	lady crab	C	21	95	91	86	81
Pagurus pollicaris	hermit crab	C	1	100	100	100	100
Peprilus triacanthus	butterfish	P	104	1	0	0	0
Pholis gunnellus	rock gunnel	D	1	100	100	100	100
Pollachius virens	pollock	D	1	0	0	0	0
Pomatomus saltatrix	bluefish	P	3	33	33	0	0
Prionotus carolinus	northern searobin	D	1	0	0	0	0
Prionotus evolans	striped searobin	D	1	100	100	100	100
Pseudopleuronectes americanus	winter flounder	D	44	93	91	89	86
Pungitius pungitius	ninespine stickleback	D	1	100	100	100	100
Raja spp.	skate	D	11	100	100	100	82
Scophthalmus aquosus	windowpane	D	3	100	100	100	100
Selene vomer	lookdown	P	4	0	0	0	0
Sphyraena borealis	northern sennet	P	1	0	0	0	0
Sphoeroides maculatus	northern puffer	D	3	100	100	100	67
Syngnathus fuscus	northern pipefish	D	49	55	45	33	16
Tautogolabrus adspersus	cunner	D	5	20	20	20	20
Urophycis tenuis	white hake	D	1	0	0	0	0

a Fishes from Robins et al. (1980) and invertebrates from Gosner (1971)
b C indicates crustaceans, D demersal fishes, and P pelagic fishes
c Treated separately during analyses
d Pelagic prejuvenile stage of development

Table 3. Percent initial and extended survival by species and water temperature groups for fishes and invertebrates taken in the MNPS Unit 1 sluiceway from January 1984 through July 1985.

Species group	Temperature group	Number examined	Initial survival	Survival at 6 h	Survival at 24 h	Survival at 72 h
demersal	cold	536	90	88	85	83
	cool	88	71	64	58	53
	warm	22	41	36	36	36
	total	646	86	83	80	77
crustaceans	cold	13	92	92	92	92
	cool	42	81	76	74	71
	warm	43	81	79	70	65
	total	98	83	80	75	71
pelagic	cold	19	32	11	5	0
	cool	27	22	11	4	0
	warm	150	1	1	0	0
	total	196	7	3	1	0

small juveniles of larger predatory species. The slender bodies of some pelagic species allowed many individuals to become wedged in the 9.5-mm mesh of the traveling screens, which increased impingement mortality.

No Atlantic long-finned squid survived impingement (Table 4). This species is fragile and difficult to keep alive following collection. Furthermore, it has a relatively short (12-18 mo) life span and dies after spawning (Arnold and Williams-Arnold 1977). Most of the squid taken during this study were immature and relatively few post-spawning adults were collected. However, based on squid egg masses picked up during trawl studies in Niantic Bay, considerable spawning occurs locally. Post-spawning, moribund adults have been observed in regular impingement collections at MNPS. Thus, some mortality attributed to impingement is actually due to natural events. Because of their abundance in impingement collections at MNPS, fragility, and particular life history, this species was not grouped with any others.

Table 4. Percent initial and extended survival by water temperature for the most abundant species taken in the MNPS Unit 1 sluiceway from January 1984 through July 1985.

Species group	Temperature group	Number examined	Initial survival	Survival at 6 h	Survival at 24 h	Survival at 72 h
Atlantic long-finned squid	cool	51	0	0	0	0
	warm	365	0	0	0	0
threespine stickleback	cold	207	95	93	93	92
	cool	10	90	80	80	70
blackspotted stickleback	cold	178	90	90	89	87
	cool	6	100	83	83	83
butterfish	cool	1	0	0	0	0
	warm	103	1	0	0	0
grubby	cold	56	89	84	80	79
	cool	17	82	65	65	65
	warm	1	0	0	0	0
northern pipefish	cold	35	57	46	34	17
	cool	11	55	46	27	9
	warm	3	33	33	33	33
winter flounder	cold	29	100	97	97	93
	cool	9	89	89	78	78
	warm	6	67	67	67	67
green crab	cold	2	100	100	100	100
	cool	17	88	82	77	71
	warm	20	75	70	55	50
northern lobster	cold	2	50	50	50	50
	cool	5	20	20	20	20
	warm	1	100	100	100	100

The threespine and blackspotted sticklebacks both had similar high (greater than 85%) survival in the MNPS Unit 1 sluiceway. These species are small (mean lengths of 59 and 45 mm, respectively) and most were taken when water temperatures were cold. A number of sticklebacks collected during the first few samples were noted to have symptoms of gas bubble disease in the laboratory holding tanks. This may have contributed to some of the mortality observed and was not noted in subsequent collections.

Almost all butterfish were taken during the summer (about half in one collection) and none survived 6 h following collection. Most (97%) of them were small young under 65 mm in length. According to Mansueti (1963), most small butterfish are either commensal or parasitic on jellyfish. Many butterfish were probably impinged as they remained with host jellyfish which passively drifted into the Unit 1 intake. Mortality was due to the fragile nature of these small fish impinged simultaneously with large masses of jellyfish. Although closely associated with jellyfish, small butterfish are apparently like other fish in not being immune to nematocysts and can be injured or killed if they become entangled in the tentacles (Mansueti 1963).

The grubby, a small sculpin (mean length of 77 mm), was taken during cold and cool periods. Like most of the demersal fishes, survival was relatively good, with two-thirds to three-quarters of them surviving impingement after 3 d.

Despite having an integument armed with bony rings, the northern pipefish suffered relatively high mortality (about 84% overall). Unlike most species, mortality increased steadily over time during the 3-d holding period. It is a year-round resident and was taken during all three water temperature periods, although predominantly during colder weather.

The winter flounder is one of the most abundant and important finfishes found in the vicinity of MNPS (NUSCo 1985b). Although a year-round resident, adults are primarily impinged during winter and spring and mostly juveniles are taken during summer. The winter flounder demonstrated good survival, with an overall rate of 86%. Only 7% mortality occurred during periods of cold water temperatures, when most are impinged. Little mortality occurred after 6 h.

From 1981 to 1983, 299 tagged winter flounder were released near a large rock outcrop between the intake structures of Units 1 and 2 (Table 5). Of these, 198 were fish that had been captured by trawl and 101 were fish that had been collected alive in impingement samples. Fifteen fish were impinged (80% within 3 d of release), whereas 17 were recaptured by the sport and commercial fisheries (4 to 735 d after release). On only one occasion were more than two tagged fish impinged. This occurred after the June 3, 1981 release, when seven of the nine recaptures were made within 2 d. These were the only fish that had been released during the night.

Table 5. Summary of winter flounder tagged and released near MNPS Units 1 and 2 intakes.

Date of release	Source of fish	Number released	Number recaptured: Impinged	Sport fishery	Commercial fishery	NUSCo trawling[a]	% impinged	% recaptured
2 June 1981	Trawling	109	1	7	1	7	0.9	14.7
3 June 1981	Trawling	89	9	1	1	0	10.1	12.4
29 March 1982	Impingement	15	0	3	1	1	0	33.3
5 April 1982	Impingement	18	1	0	0	0	5.6	5.6
12 April 1982	Impingement	8	1	0	0	0	12.5	12.5
26 April 1982	Impingement	20	1	2	1	0	5.0	20.0
7 March 1983	Impingement	40	2	0	0	2	5.0	10.0
Total		299	15	13	4	10	5.0	14.0

[a] All released alive; 3 subsequently recaptured a second time and included in above totals

Twenty of 131 (15%) winter flounder released near the Unit 1 bottom boom during 1979 were subsequently impinged (NUSCo 1981). However, 16 of these (30% of those released that day) were taken following a storm with high winds on April 2, 1979. The estimated total impingement at MNPS that week was 1,152, the ninth highest weekly estimate since October 1972. High impingement of winter flounder has been associated with the passage of storms with strong winds blowing towards the intakes during periods of low water temperatures (NUSCo 1983).

The green crab was primarily taken during cool and warm periods. It was the most numerous of the crustaceans taken during the study and also had the highest mortality (40%) of this group; other crabs suffered mortality of 20% or less. Most mortality occurred during summer. Some of the green crab mortality may be due to individuals molting and some may be size-related; the mean length of live green crabs (30 mm) exceeded that of dead ones (21 mm).

Although only eight northern lobster were taken during the study, they are undoubtedly the most commercially important invertebrate found in local waters (NUSCo 1985a). Survival following sluiceway passage was apparently poor (38%). However, at least four of the five dead specimens were in the process of molting when collected, resulting in an overestimate of mortality. Additional data from regular MNPS impingement studies were examined to help assess lobster survival. From 1982 through 1985, only 21 (1%) of 1,643 northern lobster examined had recently molted and were soft-shelled; another 41 (3%) were classified as near-molting. Of the remaining 1,601 hard-shelled lobsters observed, 76% were alive when collected. This is actually a highly conservative estimate. Lobsters in regular impingement collections may have been held for up to 24 h in the trash baskets, often mixed with considerable amounts of macroalgae, detritus, and jellyfish and, depending upon the season, exposed to long periods of desiccation and extreme temperatures. Thus, survival of non-molting lobsters is probably much greater than indicated by this study and probably equals or exceeds that of other crustaceans impinged (overall survival of 71%).

Historical impingement data from Unit 1 were examined in order to assess the mitigating effects of the sluiceway. From October 1976 through December 1983, an estimated 236,629 fish, 71,726 crustaceans, and 64,360 squid were impinged (Table 6). Most (56%) of the fish were in the demersal species group and 44% were in the pelagic group (Table 7). Demersal fish dominated during cold and cool periods, whereas pelagic fish were most abundant during the warm months. About two-thirds of the squid were taken during the summer. Most crustaceans were impinged during the warm (53% of total) and cool (35%) periods.

DISCUSSION

Under terms for its installation, the Unit 1 sluiceway can be taken out of service when high debris loading or similar conditions occur that would adversely affect plant cooling water system operations. Such conditions occurred frequently during the fall of 1985. Loading of the traveling screens that might be caused by recirculation of algae and detritus will be evaluated by NNECo during 1986 and potential remedies will be examined.

The results of the sluiceway survival study were conservative in that no control specimens were used to ascertain mortality due to collection, handling, and holding in the laboratory. Furthermore, all injured specimens were considered dead, although some of them might have recovered in the wild. Thus, actual mortality for most

Table 6. Estimated total number of fish and invertebrates impinged at MNPS Unit 1 from October 1976 through December 1983.

Species	Species group[e]	Number impinged	% of total
Fishes			
anchovies[a]	P	44,300	18.7
winter flounder	D	40,902	17.3
silversides[b]	P	29,775	12.6
grubby	D	22,392	9.5
sticklebacks[c]	D	22,952	9.7
silver hake	P	10,722	4.5
cunner	D	9,218	3.9
Atlantic tomcod	D	8,364	3.5
butterfish	P	5,621	2.4
northern pipefish	D	5,500	2.3
others	D	22,146	9.3
others	P	13,249	5.6
Invertebrates			
squid[d]	-	64,260	47.3
lady crab	C	44,605	32.9
rock crab	C	8,315	6.5
green crab	C	6,349	4.4
blue crab	C	4,907	3.6
northern lobster	C	3,323	2.8
others	-	3,450	2.5

[a] Includes mostly bay and some striped anchovy
[b] Includes mostly Atlantic and some inland silverside
[c] Includes threespine and blackspotted stickleback
[d] Includes mostly Atlantic long-finned and some short-finned squid
[e] P indicates pelagic, D demersal, and C crustacean

Table 7. Estimated total number of fish and invertebrates impinged at MNPS Unit 1 by species group and time period from October 1976 through December 1983.

Species group	Cold[a]	%	Cool	%	Warm	%
Demersal fish	75,997	57	36,853	28	19,939	15
Pelgic fish	42,315	41	15,642	15	45,885	44
Squid and other mollusks	2,169	3	20,699	32	41,514	65
Crustaceans	8,282	12	25,407	35	38,039	53

[a] Cold period is December through March
Cool period is April, May, October, and November
Warm period is June through September

species at Unit 1 is probably less than reported. Survival of most fish classified as demersal and most non-molting crustaceans exceeded 70%. These groups include the commercially and recreationally important winter flounder and northern lobster as well as others such as tautog and blue crab. The demersal fish are primarily impinged during periods of cold and cool water temperatures, which also enhances their survival.

Pelagic fishes, which includes mostly herrings, small forage fishes, and small young of certain predatory species, and the squids suffered almost complete mortality. Most of these species are impinged more frequently during the summer, when warmer water temperatures and large volumes of jellyfish impinged concurrently also tend to reduce survival. The process of impingement alone probably causes most mortalities and the addition of a sluiceway did not increase survival. However, many of these species (e.g., Atlantic silverside and bay anchovy) are far more abundant locally than their numbers impinged would indicate and impingement impact is most likely minor.

The recirculation and re-impingement of species other than the winter flounder is unknown. The number of winter flounder re-impinged was probably overestimated as the marked fish were released directly between the Unit 1 and 2 intakes, much closer to the Unit 1 intake than the sluiceway terminus. Susceptibility to re-impingement would depend upon species-specific behavior, condition of individuals, water temperature, and time of day. On ebb tides, water flow is to the east and away from the MNPS intakes. If individuals returned from the sluiceway either swim with the current or are passively carried by it, then they would not be brought back into the vicinity of the Unit 1 intake for more than half of the time. Except for storms with strong winds blowing towards the intakes, recirculation of fish returned to LIS via the Unit 1 sluiceway is probably minimal. The re-impingement of fish during storms would be mitigated by continuous screenwashes which reduce impingement mortality. Most pelagic fish and squid do not normally survive the first impingement episode so re-impingement of these species would not contribute to increased mortality.

The rates of survival found for various species and groups during this study were very similar to those reported in NUSCo (1981) and probably realistically reflect the survival attainable with the present screenwash system at Unit 1. Data from impingement survival studies at other northeastern Atlantic coastal or estuarine power stations are summarized in Table 8. Although sampling methodologies and plant operational characteristics differed among the studies, the findings were similar. In general, pelagic fishes had relatively high mortality whereas demersal fishes and crustaceans had good survival following impingement and return to the source water body. Some studies also showed that decreasing the time between washes improved survival. Survival of fish from MNPS Unit 1 is similar to that found at Brayton Point, MA and appears to be greater than at Pilgrim, MA for comparable wash cycles.

In conclusion, the MNPS Unit 1 sluiceway has worked as designed in successfully returning most aquatic organisms back to LIS. Based on the numbers and types of aquatic organisms impinged, survival of a large majority of demersal fish and non-molting crustaceans has occurred due to the installation and operation of the sluiceway. The projected survival of important fishes and invertebrates, such as the winter flounder and the northern lobster, has lessened the impact of impingement on the local aquatic community.

Table 8. Comparison of data from impingement survival studies at other northeastern power stations.

Power Station	Species	Species group[a]	Wash cycle(h)	Holding period(h)	% Survival	Remarks	Reference
Bowline, NY	white perch	P	0[b]	96	56	Not adjusted for	King et al.
	white perch	P	4	96	19	control mortality,	1977
						which was high.	
Brayton Point, MA	Atlantic silverside	P	0	24	47		MRI 1982
	Atlantic silverside	P	2-12	24	1-10		
	windowpane	D	0	24	83		
	windowpane	D	8	24	66		
	winter flounder	D	0-8	24	90-94		
	winter flounder	D	12	24	83		
Danskammer Point, NY	white perch	P	0	84	40-61	Adjusted for	King et al.
	white perch	P	4	84	9	control mortality.	1977
	Atlantic tomcod	D	0	84	83		
	Atlantic tomcod	D	2	84	87		
Oyster Creek, NJ	blueback herring	P	2	None[c]	17	Only included	Tatham et al.
	Atlantic herring	P	2	None[c]	8	number of live	1977
	bay anchovy	P	2	None[c]	7	specimens reported	
	Atlantic silverside	P	2	None[c]	34	for P group, since	
	northern pipefish	D	2	None[c]	90	most damaged indivi-	
	striped searobin	D	2	None[c]	82	duals apparently	
	smallmouth flounder	D	2	None[c]	74	were in poor condition.	
	winter flounder	D	2	None[c]	85	For D and C groups,	
	blue crab	C	2	None[c]	93	combined number of	
						live and damaged since	
						latter was minor and	
						did not affect survival.	
Pilgrim, MA	herrings	P	8	56	0		MRI 1984
	Atlantic silverside	P	8	56	0		
	rainbow smelt	P	8	56	0		
	threespine stickleback	D	8	56	2		
	cunner	D	8	56	1		
	grubby	D	8	56	38		
	winter flounder	D	8	56	15		
	northern puffer	D	8	56	6		
Pilgrim, MA	Atlantic silverside	P	8	56	3	Data combined for	Anderson
	grubby	D	8	56	30	1984-85 studies.	1985a,b
	winter flounder	D	8	56	33		
Roseton, NY	white perch	P	0	84	29-60	Adjusted for	King et al.
	white perch	P	4	84	23-36	control mortality.	1977
	Atlantic tomcod	D	0	84	81		
	Atlantic tomcod	D	2	84	72		

[a] P indicates pelagic, D demersal, and C crustacean

[b] 0 indicates continuous wash

[c] Immediate survival estimates given as relatively few specimens held for delayed mortality

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NORTHEAST UTILITIES

THE CONNECTICUT LIGHT AND POWER COMPANY
WESTERN MASSACHUSETTS ELECTRIC COMPANY
HOLYOKE WATER POWER COMPANY
NORTHEAST UTILITIES SERVICE COMPANY
NORTHEAST NUCLEAR ENERGY COMPANY

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May 27, 1986

D01185

Mr. Stanley J. Pac, Commissioner
Department of Environmental Protection
State Office Building
165 Capitol Avenue
Hartford, Connecticut 06115

References:

1. NPDES Permit No. CT0003263 (DEP Order No. 2859), dated July 2, 1980.
2. Letter, W. G. Counsil to S. J. Pac, with report entitled "Feasibility of Modifying the Millstone Units 1 and 2 Cooling Water Intake Screen Wash System to Improve the Return of Fish to Long Island Sound." Letter dated July 31, 1981.
3. Letter (DGP/WPC 152-001), R. E. Moore to W. G. Counsil, dated April 14, 1982.
4. Letter (F1079B), W. G. Counsil to S. J. Pac, dated July 20, 1982.

Dear Mr. Pac:

Millstone Nuclear Power Station, Unit 1
Cooling Water Intake Screenwash System

Pursuant to NPDES Permit No. CT0003263, Reference 1, Paragraph 14, Northeast Nuclear Energy Company (NNECO) was ordered by the Department of Environmental Protection (DEP) to submit an engineering report studying the feasibility of modifying the cooling water intake screenwash systems of Millstone Nuclear Power Station (MNPS) Units 1 and 2 to improve the return of organisms impinged on the traveling screens back to Long Island Sound. A report was prepared by Northeast Utilities Service Company (NUSCO) for NNECO and submitted on July 31, 1981, Reference 2. This report considered various alternatives and combined both engineering and biological criteria as well as cost-benefit analyses. As a result, NUSCO indicated that a sluiceway was cost effective and could be installed at Unit 1.

The above recommendation was approved by the DEP, Reference 3, and the construction and installation of a fish return sluiceway at Unit 1 was initiated.

In addition, a one-year study was proposed to examine the operation of the sluiceway to ensure that the objective of reduced impingement mortality was met, Reference (4). Accordingly, NUSCO, on behalf of NNECO, hereby submits a report entitled "The Effectiveness of the Millstone Unit 1 Sluiceway in Returning Impinged Organisms to Long Island Sound." This report examines the survival of fish and invertebrates in the sluiceway subsequent to their impingement at Unit 1. Briefly, the report shows that the survival and successful return of many impinged individuals to Long Island Sound has lessened the impact of MNPS operations on the local aquatic community.

If you have any questions after reviewing the report, please call Dr. William C. Renfro, Director, NUSCO Environmental Programs, at (203) 665-3240.

Very truly yours,

NORTHEAST UTILITIES SERVICE COMPANY
As Agent for Northeast Nuclear Energy Company

R. A. Reckert

R. A. Reckert
Vice President

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D17305

Appendix 3

Enclosure 2 to Letter No. D01595

JUSTIFICATION FOR DISCONTINUING IMPINGEMENT MONITORING
AT MILLSTONE UNIT 2

NORTHEAST NUCLEAR ENERGY COMPANY

MILLSTONE NUCLEAR POWER STATION

NPDES PERMIT NO. CT0003263

by

Northeast Utilities Service Company

P.O. Box 270

Hartford, Connecticut 06141-0270

June 1987

Introduction

Impingement occurs when young and adult fish and invertebrates are trapped on the intake screens of the cooling-water system. The intake screen system at Millsone Unit 2 usually operates when a specific pressure differential is exceeded, although it may be washed manually or by use of a timer. When a pressure differential of 6 psi is reached as a result of material (i.e., algae or fish) accumulated on the 9.5 mm mesh screen, the screens are automatically rotated. The minimum number of daily washes is three, with more frequent washes occurring when winds or tides load the screens with debris. Under usual conditions an 80 psi spray removes organisms, algae and other debris from the screens. Material washed off the intake screens is carried in a trough exiting through the south wall of the intake structure and empties into a trash pit. The pit contains a basket with 2.45 cm perforations in which all material is collected. Impingement sampling is done by sorting fish and macroinvertebrates from all the material washed from the screens during a 24-h period, usually beginning and ending at 0800. Collected aquatic organisms are identified to the lowest possible taxon, counted, and up to 50 specimens of each species are measured. Catch is recorded as number impinged per 24-hr period.

Impingement at Millstone Unit 2 is monitored as a requirement of NPDES Permit No. CT0003263. Sampling was initiated in September 1975. The objective of impingement monitoring has been to quanify total annual species-specific mortality. Complementray sampling programs were established to monitor the abundance of potentially impinged species in the Millstone area.

Throughout the design, construction and operation of Millstone Nuclear Power Station consideration has been given to ways of reducing mortality of marine organisms resulting from impingement. While the best available technology was incorporated during the design and construction of the unit, additional measures have been investigated and tested in an attempt to further reduce impingement losses.

Because total species-specific impingement mortality has been quantified and was found not to affect the abundance of potentially impinged taxa and possible mitigation measures to reduce impingement losses have been evaluated and incorporated when possible, we propose to discontinue impingement monitoring at Unit 2. This report presents the results of 11 years of monitoring data, a review of diversion measures which were tested in an attempt to reduce impingement losses, and a summary of the engineering report which addressed backfitting sluiceways to Units 1 and 2.

Impingement Estimates

Monthly impingement estimates were based on extrapolating actual counts using a volumetric ratio. This method was developed to account for the fact that impingement rates are directly influenced by cooling-water flow (Con Ed and PASNY 1977; Lawler, Matusky and Skelly Engineers 1980; NUSCO 1987). Cooling-water volume estimates corresponding to the actual 24-h impingement period of each sample were used. Within each month, an estimate for every day not sampled was calculated by multiplying the average impingement density (number of organisms per m^3 of cooling water) based on the days sampled in that month times the volume of cooling water on each day not sampled. All of these daily estimates were then added to the sum of the actual sample counts to arrive at the monthly totals for each species. Annual impingement estimates were calculated by summing the monthly estimates.

Annual impingement estimates were calculated from January 1976-December 1986 (Tables 1 and 2). Over 100 species of fish and invertebrates have been impinged over the past 11 years. Sand lance, *Ammodytes americanus*, accounted for almost 60% of the impinged fish taxa. Prior to 1984, sand lance accounted for less than 1% of the species composition (NUSCO 1984). However, in 1984, an estimated 480,000 sand lance were impinged at Unit 2 during the week of July 18th. This estimate was based on a single 24-h sample, but qualitative observations made during the remainder of the week indicated that the numbers of impinged sand lance decreased rapidly. The sand lance is a schooling species (Leim and Scott 1966) and a large school probably encountered the intake structures. A similar short-term large impingement of a schooling species, Atlantic menhaden, *Brevoortia tyrannus*, occurred in 1971 (NUSCo 1982). At this time, an estimated 50 million juvenile menhaden were impinged in August at Unit 1 (the only unit operating then). Prior to the mass impingement of sand lance, six fish species dominated the impingement collections at Unit 2 and accounted for over 70% of the fish impinged there. These included winter flounder; *Pseudopleuronectes americanus*, grubby; *Myoxocephalus aenaeus*, anchovies; *Anchoa* spp. , silversides; *Menidia* spp. , Atlantic tomcod; *Microgadus tomcod*, and sticklebacks; *Gasterosteus* spp. . Except for anchovies, these taxa were mostly impinged in the winter months (December through March).

Winter flounder was the most abundant accounting for approximately 15% of the impingement catch. Among the impinged macroinvertebrates, lady crab; *Ovalipes ocellatus*, and Atlantic long-finned squid; *Loligo pealei*, were the most abundant and together accounted for over 60% of the impinged invertebrates. Cancer crab; *Cancer irroratus*, green crab; *Carcinus maenus*, blue crab; *Callinectes sapidus*, spider crab; *Libinia emarginata*, and lobster; *Homarus americanus*, accounted for an additional 30% of the impinged invertebrates.

Complementry sampling programs were established to monitor the abundance of potentially impinged species in the Millstone area (NUSCO 1987). Although the data were highly variable, no long-term changes in abundance were found. The life history and population dynamics of the commercially important winter flounder and lobster in the Millstone area have been studied intensively (NUSCO 1987). There is no evidence that the operation of the Millstone Nuclear Power Station has affected either population. Variability in annual abundance estimates appear to be related to natural fluctuations and increases in commercial fishing.

Fish diversion studies

Although intake structures at the Millstone Station were constructed using the best available technology for minimizing environmental impact, additional measures were investigated in an attempt to further reduce impingement losses. This section details these efforts.

A number of devices were tested at Millstone in an attempt to divert fish from the intakes (NUSCO 1976). These include: electric fish screens, acoustic sounding devices, underwater lights,and surface and bottom fish barriers. In 1973, a study was initiated to evaluate the feasibility of an electrified guidance device that would prevent fish and invertebrates from being entrapped. Studies were conducted at the University of Rhode Island in continuous flow-through electified maze tanks. The response of winter flounder and lobsters were tested using various electrical combinations. Results indicated that different electrical parameters would be needed for fish and invertebrates. Because of power requirements and associated safety hazards it was concluded that such an electrical device to divert marine organisms from the intakes was not a feasible alternative.

A sparker-type geophysical sounding device was tested at Millstone. Measurements indicated the noise level producted by a maximum sound input of 2000 volts to the sparker was 130 dB. Behavioral response of winter flounder to the sparker was observed by placing 35 winter flounder of various size in a net covered cage and energizing the sparker at a distance of 15 feet and less. Results indicated that regardless of power level or distance there was no visible response. Based on results no further testing was done.

Ten 1000 watt lights were mounted on the Unit 1 trashracks approximately four feet from the ocean bottom, with two lights per intake bay. The lights were positioned to illuminate the bottom area immediately in front of the trash racks. The lights were operated on a two-day-on, two-day-off schedule from 1800 to 0600. The time period, water temperature, lights on or off and the number of organisms impinged by species were recorded. Results of analysis of covariance indicated that there was no significant difference in light effect on the impingement rate of three species: blue crab, lady crab and squid. No further attempts to use underwater lights was undertaken.

Both surface and bottom fish barriers were placed at the Unit 1 intake. A comparison of impingement rates at Units 1 and 2 was done to determine if a significant reduction occurred as a result of placing these barriers at the intakes. No reduction in impingement was observed and the barriers were removed.

Sluiceway studies

As a condition of the renewal of the NPDES permit for Millstone Nuclear Power Station Units 1 and 2, the United States Environmental Protection Agency acting through the Connecticut Department of Environmental Protection requested Northeast Utilities Service Company (NUSCO) perform a study to determine the feasibility of backfitting sluiceways to the intake screen wash troughs. The purpose of these sluiceways would be to direct fish and invertebrates back to Long Island Sound following impingement. The NUSCO Generation Civil Engineering group evaluated various sluiceway alternatives in terms of operations, costs and the feasibility of construction. Drawings of various alternatives as well as details concerning construction, operation and maintenance are documented in NUSCO (1981). The economic savings of fish and invertebrates potentially returned alive to Long Island Sound combined with maintenance and impingement monitoring savings were compared with the costs of construction and operation of various sluiceway alternatives. The results formed the basis of a cost-benefit analysis in which each alternative was evaluated (NUSCO 1981).

After evaluating six sluiceway designs for Unit 1 the modification of an existing dewatering line was found to be a feasible alternative. A sluiceway was constructed and placed in operation December 1983. The effectiveness of this sluiceway was evaluated and was found to work as designed in returning most aquatic organisms back to Long Island Sound (NUSCO 1986). Based on the numbers and types of aquatic organisms impinged, survival of a majority of demersal fish and non-molting crustaceans has occurred due to the installation and operation of the sluiceway. The projected survival of important fishes and invertebrates (i.e. winter flounder and lobsters) has lessened the impacts of impingement on the local aquatic community.

Six alternatives were designed to returned impinged fish to Long Island Sound at Unit 2. Alternatives included discharging a sluiceway to the south or the west, through the existing dewatering line, to Unit 3, to a barge, or to holding ponds. Because of the location of the intake structure between Units 1 and 3, various engineering difficulties and problems associated with expected recirculation of impinged organisms if discharged close to the intakes, all six designs were not practical or cost effective. The Connecticut Department of Environmental Protection reviewed and concurred with our recommendation to construct a sluiceway only at Unit 1 and found that the proposed action was consistent with applicable policies of Connecticut Coastal Mangement Act (Section 22a-92 of the Connecticut General Statutes as amended by Section 2 of P.A. 535). Since no sluiceway was constructed at Unit 2, routine sampling has continued there through the present.

Coffer Dam Removal

There was a noticable reduction in daily impingement at Unit 2 after the removal of a coffer dam surrounding the Unit 3 intake in June 1984. The coffer dam existed when Unit 2 began operating and it provided an ideal reef-like habitat close to the Unit 2 intake. Monitoring data were analyzed to investigate if the removal of this dam resulted in a significant reduction of the average number of organisms impinged daily at Unit 2. The data used were 24-hr impingement counts on the days sampled from January 1976 through April 1987. Sand lance counts were not used in this analysis because the unusually large impingement of sand lance in 1984 would have biased the results. All data were log-transformed to reduce skewness and kurtosis and to stabilize variance prior to testing for impingement differences before and after June 1984. Because the impingement rates are known to be influenced by cooling water flow rates, we used a variance-covariance model to adjust the impingement counts for daily differences in cooling water flows. The adjusted least-squares means (LSMEANS) for the groups "before" (January 1976 through May 1984) and "after" (June 1984 through April 1987) and the results of t-tests conducted to compare these two group means are presented in Table 3. These results are presented for total impingement counts ignoring phylum, and for the separate impingement counts for the fish and invertebrate phyla. In all cases the mean impingement after removal of the dam was significantly ($P < 0.01$) lower than during the period when the coffer dam was in place.

Conclusions

Impingement has been monitored at Millstone Unit 2 for 11 years. Complementary sampling programs were established to monitor the abundance of potentially impacted taxa in the Millstone area. Mitigation measures to reduce impingement losses at the Millstone Nuclear Power Station have been evaluated and incorporated, when possible. The addition of sluiceways at Units 1 and 3 have lessened the impacts of impingement on the local aquatic community. Since the removal of a coffer dam surrounding Unit 3 in 1984, impingement losses at Unit 2 have been significantly reduced. Since impingement losses at Unit 2 have been well documented and possible mitigation measures have been incorporated, we feel the continuation of impingement monitoring would no longer serve any practical purpose and recommend deletion of this monitoring as of December 31, 1987. Provisions will exist to examine and report large impingement events, such as previously mentioned for Atlantic menhaden and sand lance. Observations of unually large impingement events made during regular routine daily inspections by Unit 2 operations and maintenance personnel shall be reported to and investigated by Northeast Utilities Environmental Laboratory, and communicated to the Connecticut Department of Environmental Protection as soon as possible.

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Table 1. Annual impingement estimates for all finfish taxa impinged at Millstone Unit 2 from January 1976 through December 1986.

Fish Taxa	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Total
Ammodytes spp.	46	20	239	59	168	223	81	161	485411	73	42	486523
Pseudopleuronectes americanus	2783	4604	3184	10077	3576	6207	2735	6213	2542	2769	1049	45739
Myoxocephalus aenaeus	1027	1299	3980	1721	9167	3262	2671	7023	2359	4621	1427	38557
Anchoa spp.	848	177	774	2508	4073	3722	4085	12726	4200	342	38	33493
Menidia spp.	853	503	2292	3319	8676	2769	800	3759	1042	1484	511	26008
Microgadus tomcod	45	86	1956	768	1213	2809	10302	2264	4938	1130	8	25519
Gasterosteus spp.	1533	3609	3480	2241	6710	.	.	.	.	.	.	17573
Gasterosteus wheatlandi	.	.	.	.	.	580	1090	11691	702	21	1799	15883
Gasterosteus aculeatus	.	.	.	.	.	5883	1188	4638	1055	859	921	14544
Syngnathus fuscus	559	260	875	425	766	1417	557	3503	1467	460	858	11147
Peprilus triacanthus	114	122	233	1091	781	1416	2414	465	1455	1337	1406	10834
Tautogolabrus adspersus	357	598	1399	1656	751	883	1787	694	1188	466	57	9836
Merluccius bilinearis	586	304	282	361	1659	277	422	998	133	106	44	5172
Scophthalmus aquosus	434	188	243	503	570	367	354	1241	569	174	292	4935
Morone americana	136	260	458	230	489	491	1340	476	375	48	19	4322
Tautoga onitis	464	98	731	578	106	434	397	168	664	122	96	3858
Cyclopterus lumpus	26	265	209	248	689	329	9	499	120	1010	128	3532
Raja spp.	292	165	133	170	231	464	274	626	275	99	285	3014
Osmerus mordax	282	204	390	62	101	283	184	897	71	99	105	2678
Paralichthys dentatus	230	17	59	7	27	261	88	72	646	29	377	1813
Brevoortia tyrannus	177	50	62	135	154	101	247	311	167	242	55	1701
Prionotus spp.	364	112	63	49	61	242	147	86	49	72	142	1387
Cynoscion regalis	26	568	70	4	7	466	40	38	34	14	8	1275
Alosa pseudoharengus	48	274	26	92	118	128	203	192	79	59	32	1251
Alosa aestivalis	86	125	88	140	94	121	63	234	91	51	42	1135
Liparis spp.	6	208	86	11	25	371	19	155	39	66	0	986
Sphoeroides maculatus	165	4	17	49	12	80	126	166	174	86	81	960
Stenotomus chrysops	114	76	19	87	35	78	115	95	53	105	23	800
Anguilla rostrata	60	25	56	84	73	66	207	104	60	48	10	793
Opsanus tau	69	27	77	96	49	123	55	67	98	28	23	712
Pomatomus saltatrix	23	44	9	47	27	81	40	108	110	46	34	569
Pholis gunnellus	48	28	39	86	28	88	42	121	49	12	24	565
Pollachius virens	5	6	2	2	71	55	41	41	253	0	37	513
Trinectes maculatus	20	6	14	53	35	21	75	29	194	21	21	489
Fundulus spp.	12	16	91	14	75	99	33	13	20	8	0	381
Urophycis chuss	3	17	0	80	19	42	26	41	71	13	0	312
Hemitripterus americanus	9	2	5	2	25	64	51	94	22	6	12	292
Urophycis regia	5	0	0	3	14	12	19	187	7	0	13	260
Clupea harengus	33	114	0	5	2	35	9	16	12	12	5	243
Caranx hippos	5	0	2	4	2	47	91	9	21	34	8	223
Gadus morhua	0	0	0	0	0	10	24	2	142	7	16	201
Urophycis spp.	0	29	124	0	2	2	0	0	0	0	0	157
Centropristis striata	22	2	0	0	7	0	2	6	74	0	28	141
Mugil cephalus	3	4	10	4	18	5	7	17	39	4	19	130
Sphyraena borealis	12	4	10	0	0	25	63	0	12	0	0	126
Leiostomus xanthurus	12	2	83	0	0	0	2	16	0	0	8	123
Monacanthus hispidus	5	0	34	45	8	4	4	7	3	9	0	119
Ophidion marginatum	16	0	0	10	0	0	7	4	50	6	17	110
Apeltes quadracus	2	4	2	2	31	45	12	3	2	0	6	109
Etropus microstomus	2	0	0	0	0	5	4	41	20	10	22	104

Table 1. (Continued).

Fish Taxa	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Total
Alosa sapidissima	12	1	0	2	33	16	6	17	16	0	0	103
Melanogrammus aeglefinus	0	0	4	88	3	0	0	0	0	0	0	95
Selene setapinnis	30	0	0	0	0	0	2	2	20	34	7	95
Urophycis tenuis	0	1	4	0	4	17	13	2	45	0	0	86
Pungitius pungitius	0	0	2	0	0	4	19	17	5	10	19	76
Scomber scombrus	0	4	0	4	0	12	46	2	0	0	0	68
Selene vomer	0	22	0	0	5	0	2	0	14	22	0	65
Aluterus schoepfi	1	36	4	0	3	0	9	0	6	0	0	59
Caranx crysos	0	9	7	0	0	5	14	0	24	0	0	59
Paralichthys oblongus	16	0	4	7	4	16	2	4	0	6	0	59
Alectis ciliaris	1	7	2	0	0	28	2	0	6	7	0	53
Mugil curema	0	0	0	0	0	10	0	3	27	8	4	52
Mustelis canis	2	6	18	2	0	6	4	0	0	8	6	52
Fistularia tabacaria	3	4	5	0	10	2	5	0	0	6	0	35
Myoxocephalus spp.	1	31	0	0	0	0	0	0	0	0	0	32
Squalus acanthias	2	0	0	0	6	0	0	21	0	0	2	31
Morone saxatilis	0	0	3	2	0	0	13	5	0	7	0	30
Ulvaria subbifurcata	2	1	3	2	0	7	2	0	6	4	0	27
Conger oceanicus	13	4	0	0	0	2	5	2	0	0	0	26
Myoxocephalus octodecemspinosus	0	0	0	5	5	2	4	8	0	0	0	24
Hippocampus erectus	2	0	0	0	0	0	0	4	0	3	13	22
Myoxocephalus scorpius	0	16	6	0	0	0	0	0	0	0	0	22
Ophidiidae	17	0	0	0	0	0	5	0	0	0	0	22
Trachurus lathami	0	0	0	16	0	4	0	0	0	0	0	20
Chaetodon ocellatus	0	0	2	0	0	2	7	0	0	7	0	18
Gadidae	0	0	5	0	0	0	13	0	0	0	0	18
Decapterus macarellus	0	0	0	0	0	0	0	0	15	0	0	15
Pristigenys alta	0	0	0	0	0	0	2	0	12	0	0	14
Dactylopterus volitans	0	2	0	0	0	0	4	0	0	7	0	13
Cyprinodon variegatus	0	0	4	0	4	2	2	0	0	0	0	12
Chilomycterus schoepfi	0	0	0	0	0	0	2	0	8	0	0	10
Macrozoarces americanus	0	0	0	2	0	0	0	2	0	6	0	10
Etrumeus teres	0	2	0	5	0	0	2	0	0	0	0	9
Lophius americanus	0	0	0	0	0	0	2	0	0	7	0	9
Enchelyopus cimbrius	0	0	0	0	0	0	0	0	8	0	0	8
Priacanthus arenatus	0	0	0	0	0	0	2	0	6	0	0	8
Clupeidae	0	0	0	0	0	0	0	0	3	4	0	7
Menticirrhus saxatilis	0	0	2	3	0	0	2	0	0	0	0	7
Alosa spp.	0	0	0	0	0	0	0	0	6	0	0	6
Hippocampus spp.	0	0	0	0	0	0	0	0	0	6	0	6
Priacanthus cruentatus	0	0	0	0	0	2	0	4	0	0	0	6
Selar crumenopthalmus	3	0	0	0	0	2	0	0	0	0	0	5
Seriola zonata	0	5	0	0	0	0	0	0	0	0	0	5
Aulostomus maculatus	3	0	0	0	0	0	0	0	0	0	0	3
Monocanthus spp.	0	0	0	0	0	0	0	0	3	0	0	3
Alosa mediocris	0	0	0	0	0	0	2	0	0	0	0	2
Decapterus punctatus	0	0	0	0	0	2	0	0	0	0	0	2
Ictalurus catus	2	0	0	0	0	0	0	0	0	0	0	2
Rhinoptera bonasus	0	0	0	0	0	2	0	0	0	0	0	2
Salmo trutta	0	0	0	2	0	0	0	0	0	0	0	2
Total	12077	14677	21981	27268	40822	34636	32745	60410	511387	16360	10199	782562

Table 2. Annual impingement estimates for all invertebrate taxa impinged at Millstone Unit 2 from January 1976 through December 1986.

Invertebrate Taxa	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Total
Ovalipes ocellatus	1402	2289	1831	4708	14224	13054	23194	4876	4118	2838	1552	74086
Loligo pealei	5095	1257	2430	10763	11083	7895	6846	2779	14748	3298	1912	68106
Cancer irroratus	457	389	442	438	560	3919	5179	4036	6680	4456	6264	32820
Carcinus maenus	425	408	368	408	670	2339	1532	4311	5647	2727	2960	21795
Callinectes sapidus	564	193	499	945	927	964	1120	468	1020	733	621	8054
Homarus americanus	663	308	261	402	392	1043	1032	458	1167	505	549	6780
Libinia spp.	1244	205	93	91	124	516	475	887	1484	407	689	6215
Neopanope texana	0	13	16	13	18	104	362	288	1496	244	373	2927
Limulus polyphemus	281	11	17	54	46	152	86	10	164	0	41	862
Pagurus spp.	227	37	8	4	88	38	14	11	12	7	83	529
Squilla empusa	52	38	4	2	193	23	20	25	3	3	0	363
Cancer borealis	12	4	5	77	9	10	11	12	2	0	0	142
Argopecten irradians	0	0	0	0	0	2	2	37	38	0	0	79
Penaeus aztecus	0	0	0	0	2	2	45	0	0	7	7	63
Upogebia affinis	0	0	0	0	0	0	14	39	0	0	0	53
Illex illecebrosus	0	5	6	0	0	9	0	0	6	0	0	26
Callinectes similis	0	0	0	0	0	0	14	0	0	0	0	14
Lunatia heros	0	0	0	0	2	0	2	0	0	0	0	4
Aplysia wilcoxi	0	0	0	0	2	0	0	0	0	0	0	2
Hexapanopeus angustifrons	1	0	0	0	0	0	0	0	0	0	0	1
Total	10423	5157	5980	17905	28340	30070	39948	18237	36585	15225	15051	222921

Table 3. Summary statistics of log-transformed impingement monitoring data (daily total counts) and results of t-tests comprising mean daily impingement rates before and after May 1984.

ALL ORGANISMS:

Monitoring Period	n	Mean	Range	LSMEAN[a]	Std. Error	t-test[b] for equality of LSMEANS: t	Prob > t
(1) Jan. 1976-May 1984	1549	4.071	0 to 8.08	4.072	0.03196	5.28	<0.01
(2) June 1984-April 1987	240	3.664	0 to 6.55	3.613	0.08085		
	1,789						

FISH ONLY:

Monitoring Period	n	Mean	Range	LSMEAN[a]	Std. Error	t-test[b] for equality of LSMEANS: t	Prob > t
(1) Jan. 1976-May 1984	1456	3.466	0.69 to 8.07	3.479	0.03456	5.10	<0.01
(2) June 1984-April 1987	223	3.078	0.69 to 6.52	2.996	0.08823		
	1,679						

INVERTEBRATES ONLY:

Monitoring Period	n	Mean	Range	LSMEAN[a]	Std. Error	t-test[b] for equality of LSMEANS: t	Prob > t
(1) Jan. 1976-May 1984	1383	3.077	0.69 to 7.30	3.065	0.037061	2.81	<0.01
(2) June 1984-April 1987	213	2.789	0.69 to 6.21	2.781	0.093965		
	1,596						

(a) Least-square means adjusted for daily cooling water flow variability.

(b) One-tail t-test. Alternative hypothesis: LSMEANS (1) > LSMEANS (2).

NORTHEAST UTILITIES

THE CONNECTICUT LIGHT AND POWER COMPANY
WESTERN MASSACHUSETTS ELECTRIC COMPANY
HOLYOKE WATER POWER COMPANY
NORTHEAST UTILITIES SERVICE COMPANY
NORTHEAST NUCLEAR ENERGY COMPANY

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P.O. BOX 270
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July 31, 1987

D01595

Ms. Leslie Carruthers, Commissioner
Department of Environmental Protection
State Office Building
165 Capitol Avenue
Hartford, Connecticut 06115

References: (1) NPDES Permit No. CT0003263 (Order No. 2859), Northeast Nuclear Energy Company, Millstone Nuclear Power Station, Unit Nos. 1, 2 and 3.

(2) Letter (D01237), J. F. Opeka to S. J. Pac, dated July 28, 1986.

Dear Commissioner Carruthers:

Millstone Nuclear Power Station
Modification of Environmental Impact Monitoring Studies

Paragraph 12 of the above-referenced NPDES permit requires that, on or before July 31, 1985, and annually thereafter, a study proposal be submitted to the Commissioner of Environmental Protection covering biological studies, entrainment studies and impingement monitoring as required by paragraph 5 of the NPDES permit. The enclosed proposals (Enclosures 1 and 2), outlining the 1988 program, fulfill this requirement. Please note that reference to specific numbers of replicate samples has been omitted in certain programs to provide flexibility in the event Northeast Utilities (NU) current resource optimization efforts necessitate reductions in the scope of ecological monitoring at Millstone.

A report entitled "Survey of Bivalve Molluscs in Jordan Cove and Outer Jordan Cove, Waterford, Connecticut," is also being provided for your information and use (Enclosure 3). This report provides densities of recreational shellfish in Jordan Cove and updates the Coastal Area Shellfish Concentration Map published in 1979. These data were collected by Northeast Utilities Service Company, on behalf of Northeast Nuclear Energy Company, to establish a baseline of shellfish concentrations prior to 3-unit operation at Millstone.

Also enclosed is the proposed scope of work for the 3-unit thermal plume study planned for August 21 - 28, 1987 (Enclosure 4). This study satisfies commitments made in Reference 2 (Proposed Ecological Studies for 1987) submitted July 28, 1986. The thermal plume will be mapped by measuring Rhodamine WT dye concentrations and water temperatures in the waters off Millstone Point. The dye will be injected into the Unit 3 cooling water at the discharge into the quarry. The dye concentrations will be 1.5 ppb at the quarry discharge, and no coloration should be visible beyond the discharge. The schedule may be modified if simultaneous 3-unit operation can not be achieved during the study period. The DEP will be informed of such changes.

If after reviewing this report you have further questions, please contact Mr. Paul M. Jacobson, Manager, NU Environmental Laboratory, at (203) 444-4239.

Very truly yours,

NORTHEAST UTILITIES SERVICE COMPANY
As Agent for Northeast Nuclear Energy Company

E. J. Mroczka
Senior Vice President

Appendix 1 to Enclosure 3
of letter D 01830
dated January 29, 1988

D17305
appendix 4

The Effectiveness of the Millstone Unit 3 Fish Return System

Northeast Nuclear Energy Company

Millstone Nuclear Power Station

NPDES Permit No. CT0003263

December 31, 1987

Northeast Utilities Service Company

PO Box 270

Hartford, CT 06141-0270

Introduction

The design of the Millstone Nuclear Power Station (MNPS) Unit 3 intake structure incorporated a system to return fish and invertebrates impinged on the traveling screens back to Long Island Sound. The fish return system consists of fine mesh screens (3/16"), fish trays on each screen panel, and low and high pressure nozzles that direct material accumulated on the screens into a sluiceway and a debris trough, respectively. Fish and invertebrates are removed by a low pressure wash and returned to Long Island Sound through the fish sluiceway. To prevent debris recirculation, the material washed into the debris trough is accumulated into a trash hopper and removed. The system was operational when MNPS Unit 3 began commercial generation in April 1986.

In April 1987, in accordance with Paragraph 5 of NPDES Permit No. CT0003263, Northeast Utilities Service Company (NUSCO) completed a one-year evaluation of the efficiency of the system in separating fish from debris and a study to examine the mortality of returned fishes and invertebrates. This report presents the results of that study.

The Intake Structure and Fish Return System

The Unit 3 intake structure is divided into six bays and contains six circulating, four service water and two screenwash pumps (NUSCO 1983). At full capacity, about 56.6 m^3/sec of water is pumped through the entire structure. Water to each bay passes through a trash rack followed by a traveling screen. During normal operation, the average water velocity through each bay is 0.24 m/sec. The trash racks are 4.9 m wide and consist of 1.3 cm thick by 8.9 cm deep vertical steel bars installed 6.4 cm apart at a slope of 5 to 1. The traveling screens, located upstream of the circulating water pumps, consist of an endless band of screening panels 4.3 m wide by 0.61 m high constructed of 4.76-mm mesh copper cloth. The traveling screens rotate according to the differential water level across each screen. The screens automatically rotate when the difference in the water elevation reaches 100 mm.

After screen rotation is initiated, screen-wash water is directed through the low pressure spray header (10 psi) to flush aquatic organisms off the fish trays on the screen panels into the lower fish sluiceway trough, and also through a high pressure spray (85 psi) to clean debris off the screens into an upper trash trough. The 70-cm diameter lower trough exits the west wall of the intake structure and connects to a 30-cm diameter pipe, which runs down along a seawall about 22 m to the north. A 76-cm section of the sluiceway pipe about 30 cm to the west of the intake structure is open to allow for sampling. The sluiceway ends about 10 m from rock rip-rap along the shore. There was concern that organisms exiting the sluiceway might hit the seawall. To prevent this, a 30° elbow was added to the terminus of the sluiceway to direct fish away from the seawall. The debris trough exits the intake structure through the east wall and material is removed from the trough by a motorized conveyor system and deposited in a trash hopper for removal offsite.

Materials and Methods

Samples were taken weekly from May 1986 though October 1986 and at least monthly thereafter, except during March 1987 when no samples were taken due to operational problems. Because most impingement occurs after dark, most sampling was done at least one hour after sunset. Several hours before a sample was collected, the traveling screens were washed to clean them of previously accumulated debris and organisms and then were not allowed to rotate or wash for about 3 h. On six occasions, high differential water level due to debris loading caused the screens to run continously. On December 16 and 22, 1986 the debris conveyor system was not operational and samples were collected only from the sluiceway trough. Data from these two collections was not used to determine efficiency.

Organisms were simultaneously collected from both the sluiceway and debris troughs. To collect organisms from the sluiceway, a 34 cm wide by 38 cm high by 50 cm long stainless steel sampler with about 2 m of 4.88-mm netting attached was placed in the sluiceway sampling area. The screens were rotated and cleaned and, as material accumulated in the sampler during the approximate 45 min wash cycle, the net was removed every 1 to 3 min and emptied. Total sampling time and the time the sampler was out of the water to remove organisms were recorded. All organisms were separated from algae and jellyfish by hand and placed into an insulated cooler or bucket containing seawater. During the same time, a screen was placed at the discharge of the debris conveyor system on top of the trash hopper. All organisms were removed from the debris and no attempt was made to keep these specimens alive.

Specimens collected from both the debris hopper and the sluiceway were returned to the laboratory. Live organisms collected from the sluiceway were held in tanks with running seawater; crabs and predatory fish were kept separate from other species. Dead organisms from the sluiceway and all organisms collected from the debris trough were identified and measured following the initial collection. Dead organisms were also removed, identified and measured after periods of 6 and 24 h. At 72 h, the remaining organisms were removed. At this time, animals that were stressed (i.e. injured or behaving abnormally) were recorded as dead. Total length of fish, carapace width of crabs, carapace length of lobster and mantle length of squid were recorded to the nearest mm. Water temperatures at the intake and the laboratory holding tanks were recorded.

The number of organisms collected in the sluiceway was adjusted based on the percentage of time the sampler was out of the water. For example, if the sampler was out of the water for 10% of the sample duration, the sluiceway catch was adjusted upwards by 10%. Efficiency of the sluiceway was expressed as the ratio of the adjusted sluiceway catch to the total (sluiceway and debris trough) catch.

Survival estimates were calculated for individual species as well as for groups of organisms classified by body type and season of occurrence based on water temperature. Survival was calculated from the proportion of total numbers of specimens alive at the initial, 6-, 24-, and 72-h observations. The four body-type groups were "pelagic", "demersal", "crustaceans" and "squid". Free-swimming fishes (e.g., herrings, silversides, butterfish) were considered pelagic, whereas bottom dwellers (e.g., sculpins, flounders) as well as those with hard integuments (e.g., sticklebacks, pipefish) were classified as demersal. The crustacean group was comprised of crabs and the American lobster. The Atlantic long-finned squid was considered as a separate group. For some survival calculations, samples were assigned to three temperature groups: "cold", "cool" and "warm". The temperatures ranged from 3.5 to 7.0°C (cold), 8.0 to 15.0°C (cool) and 16.0 to 22.0°C (warm).

Results

A total of 32 samples was taken during the study period and 55 species of fish and 15 macroinvertebrates were taken in sluiceway and debris trough collections (Table 1). Warm-water collections tended to contain more species and specimens than the other two groups. The 3,355 specimens collected during the study were dominated by 10 species and these comprised 85% of the total: rock crab (579), northern pipefish (402), butterfish (372), Atlantic long-finned squid (341), spider crab (226), lady crab (212), bay anchovy (181), green crab (149), Atlantic silverside (124), and threespine stickleback (109).

The numbers of fish and macroinvertebrates collected from the sluiceway trough were compared to the numbers collected from the debris trough to determine the efficiency of the sluiceway. The percent efficiency was calculated for each species (Table 2) and averaged 41% for all specimens collected. Only one or two specimens of some species were collected, which accounted for the extreme range of percentages of 0 to 100%. Because of this, the rates of return of the ten most abundant fish and the eight most abundant macroinvertebrates were determined (Table 3). The percent efficiency averaged 49% for the most abundant fishes and 45% for the macroinvertebrates.

The mean lengths of the most abundant organisms collected in the sluiceway were compared to those found in the debris trough to determine if the size of an organism influenced its entry into the sluiceway (Table 4). The mean length of fish collected in the sluiceway was not significantly different ($p > 0.05$) from those in the debris. For all species except the cunner, the mean lengths of fish found in the debris were larger than those in the sluiceway. Mean lengths of bay anchovy, winter flounder and northern pipefish collected in the debris were significantly larger ($p < 0.05$) than those found in the sluiceway.

Table 1. Summary of samples collected at the Unit 3 fish return system.

Date	Water Temperature	Temperature Group[a]	Number of Species	Number of Specimens
05-13-86	10.0	cool	12	43
05-19-86	13.0	cool	14	53
05-27-86	13.0	cool	13	40
06-02-86	14.1	cool	19	72
06-09-86	14.5	cool	9	31
06-16-86	18.0	warm	21	98
06-23-86	17.0	warm	12	76
06-30-86	19.0	warm	9	83
07-07-86	20.0	warm	13	128
07-14-86	19.0	warm	9	22
07-21-86	19.5	warm	16	86
07-28-86	22.0	warm	16	68
08-04-86	21.0	warm	12	217
08-11-86	22.0	warm	20	512
08-25-86	20.5	warm	19	267
09-02-86	21.0	warm	21	144
09-08-86	19.0	warm	19	174
09-15-86	20.0	warm	3	3
09-22-86	18.2	warm	3	4
09-29-86	19.7	warm	12	130
10-06-86	17.3	warm	15	264
10-14-86	18.0	warm	9	83
10-20-86	15.0	cool	13	51
10-27-86	15.0	cool	7	45
11-10-86	14.0	cool	13	48
11-17-86	11.5	cool	16	30
12-16-86	10.0	cool	12	51[b]
12-22-86	7.0	cold	11	115[b]
01-06-87	5.0	cold	8	25
01-12-87	7.0	cold	18	68
02-10-87	3.5	cold	22	95
04-21-87	10.5	cool	14	155

[a] cold 3.5 to 7.0°C

cool 8.5 to 15.0°C

warm 16.0 to 22.0°C

[b] no debris-trough collections

Table 2. Species specific efficiency of the Unit 3 Fish Return System in separating fish and invertebrates from debris.

Species	Common Name	Numbers collected Sluiceway Trough	Debris Trough	Percent Efficiency
Alosa aestivalis	blueback herring	0	1	0
Alosa pseudoharengus	alewife	0	1	0
Alosa sapidissima	American shad	0	1	0
Aluterus schoepfi	orange filefish	1	0	100
Ammodytes spp.	sand lance	3	2	60
Anchoa mitchilli	bay anchovy	81	100	45
Anguilla rostrata	American eel	0	1	0
Apeltes quadracus	fourspine stickleback	1	2	33
Argopecten irradians	bay scallop	0	1	0
Brevoortia tyrannus	Atlantic menhaden	61	27	69
Callinectes sapidus	blue crab	3	15	17
Cancer irroratus	rock crab	286	289	50
Carcinus maenus	green crab	36	107	25
Centropristis striata	black sea bass	1	0	100
Chaetodon capistratus	foureye butterflyfish	0	1	0
Chaetodon ocellatus	spotfin butterflyfish	0	1	0
Clupeidae	herring	0	1	0
Clupea harengus	Atlantic herring	1	2	33
Conger oceanicus	conger eel	2	0	100
Cyclopterus lumpus	lumpfish	1	1	50
Cynoscion regalis	weakfish	3	2	60
Decapterus punctatus	round scad	0	1	0
Enchelyopus cimbrius	fourbeard rockling	4	1	80
Engraulis eurystole	silver anchovy	1	0	100
Etrumeus teres	round herring	1	0	100
Gadidae	codfishes	1	0	100
Gadus morhua	Atlantic cod	1	4	20
Gasterosteus aculeatus	threespine stickleback	14	14	50
Gasterosteus wheatlandi	blackspotted stickleback	8	13	38
Hippocampus erectus	lined seahorse	0	1	0
Homarus americanus	American lobster	13	32	29
Libinia spp.	spider crab	56	170	25
Limulus polyphemus	horseshoe crab	0	1	0
Loligo pealei	Atlantic long-finned squid	170	171	50
Menidia menidia	Atlantic silverside	49	40	55
Merluccius bilinearis	silver hake	5	4	56

Table 2. (continued)

Species	Common Name	Numbers collected Sluiceway Trough	Debris Trough	Percent Efficiency
Microgadus tomcod	Atlantic tomcod	3	4	43
Monacanthus hispidus	planehead filefish	2	0	100
Morone americana	white perch	0	1	0
Myoxocephalus aenaeus	grubby	23	27	46
Myoxocephalus octodecemspinosus	longhorn sculpin	0	1	0
Neopanope texana	mud crab	27	38	41
Ophidion marginatum	striped cusk-eel	1	2	33
Opsanus tau	oyster toadfish	0	1	0
Osmerus mordax	rainbow smelt	7	16	30
Ovalipes ocellatus	lady crab	134	77	64
Pagurus longicarpus	hermit crab (small)	2	3	40
Pagurus pollicaris	hermit crab (large)	1	6	14
Paralichthys dentatus	summer flounder	1	11	8
Penaeus aztecus	brown shrimp	1	2	33
Peprilus triacanthus	butterfish	112	260	30
Pholis gunnellus	rock gunnel	4	2	67
Pinnotheres maculatus	pea crab	5	0	100
Polinices duplicata	Atlantic moon snail	0	2	0
Pollachius virens	pollock	3	1	75
Pomatomus saltatrix	bluefish	18	37	33
Prionotus carolinus	northern searobin	2	0	100
Prionotus evolans	striped searobin	9	7	56
Pseudopleuronectes americanus	winter flounder	7	29	19
Raja spp.	skate	0	2	0
Scophthalmus aquosus	windowpane	5	18	22
Sphoeroides maculatus	northern puffer	1	1	50
Stenotomus chrysops	scup	0	2	0
Syngnathus fuscus	northern pipefish	264	138	66
Tautogolabrus adspersus	cunner	32	16	66
Tautoga onitis	tautog	10	4	71
Trachurus lathami	rough scad	2	3	40
Trinectes maculatus	hogchocker	0	2	0
Urophycis regia	spotted hake	1	0	100
Urophycis tenuis	white hake	2	1	67

Table 3. Millstone Unit 3 sluiceway efficiency for the ten most abundant fish and the eight most abundant invertebrate species.

Species	Common Name	Sluiceway Trough	Debris Trough	Percent Efficiency
Fishes				
Syngnathus fuscus	northern pipefish	264	138	66
Peprilus triacanthus	butterfish	112	260	30
Anchoa mitchilli	bay anchovy	81	100	45
Menidia menidia	Atlantic silverside	49	40	55
Gasterosteus aculeatus	threespine stickleback	14	14	50
Brevoortia tyrannus	Atlantic menhaden	61	27	69
Myoxocephalus aenaeus	grubby	23	27	46
Pomatomus saltatrix	bluefish	18	37	33
Tautogolabrus adspersus	cunner	32	16	66
Pseudopleuronectes americanus	winter flounder	7	29	19
All abundant fishes combined		661	688	49
Invertebrates				
Cancer irroratus	rock crab	286	289	50
Libinia spp.	spider crab	56	170	25
Ovalipes ocellatus	lady crab	134	77	64
Carcinus maenus	green crab	36	107	25
Neopanope texana	mud crab	27	38	41
Homarus americanus	American lobster	13	32	33
Callinectes sapidus	blue crab	3	15	17
Loligo pealei	Atlantic long-finned squid	170	171	50
All abundant invertebrates combined		725	899	45

Table 4. Comparison of mean lengths of organisms collected from the sluiceway and debris at Millstone Unit 3 from May 86-April 87.

		SLUICEWAY		DEBRIS		
		Fishes				
Species	Common name	Number measured	Mean length (mm)	Number measured	Mean length (mm)	t
Syngnathus fuscus	northern pipefish	189	142	118	154	0.0007 **
Peprilus triacanthus	butterfish	82	53	243	58	0.1886 ns
Anchoa mitchilli	bay anchovy	44	40	73	52	0.0001 **
Menidia menidia	Atlantic silverside	58	82	34	83	0.8975 ns
Gasterosteus aculeatus	threespined stickleback	68	48	13	50	0.5131 ns
Brevoortia tyrannus	Atlantic menhaden	38	34	26	46	0.1656 ns
Myoxocephalus aenaeus	grubby	34	72	26	76	0.3668 ns
Pomatomus saltatrix	bluefish	12	53	25	54	0.8243 ns
Tautogolabrus adspersus	cunner	29	50	15	40	0.0725 ns
Pseudopleuronectes americanus	winter flounder	6	133	29	201	0.0282 *
all abundant fishes combined		558	85	602	83	0.6300 ns
		Invertebrates				
Cancer irroratus	rock crab	212	17	185	22	0.0001 **
Libinia emarginata	spider crab	47	21	168	36	0.0001 **
Ovalipes ocellatus	lady crab	101	14	77	27	0.0001 **
Carcinus maenus	green crab	33	23	108	30	0.0126 *
Neopanope texana	mud crab	20	16	38	18	0.1365 ns
Homarus americanus	American lobster	14	57	32	59	0.4873 ns
Callinectes sapidus	blue crab	3	138	15	119	0.4910 ns
all abundant crustaceans combined		430	19	623	31	0.0001 **
Loligo pealei	long-finned squid	122	55	166	69	0.0163 *

ns - no significant difference

* - significant difference ($p < 0.05$)

** - highly significant difference ($p < 0.001$)

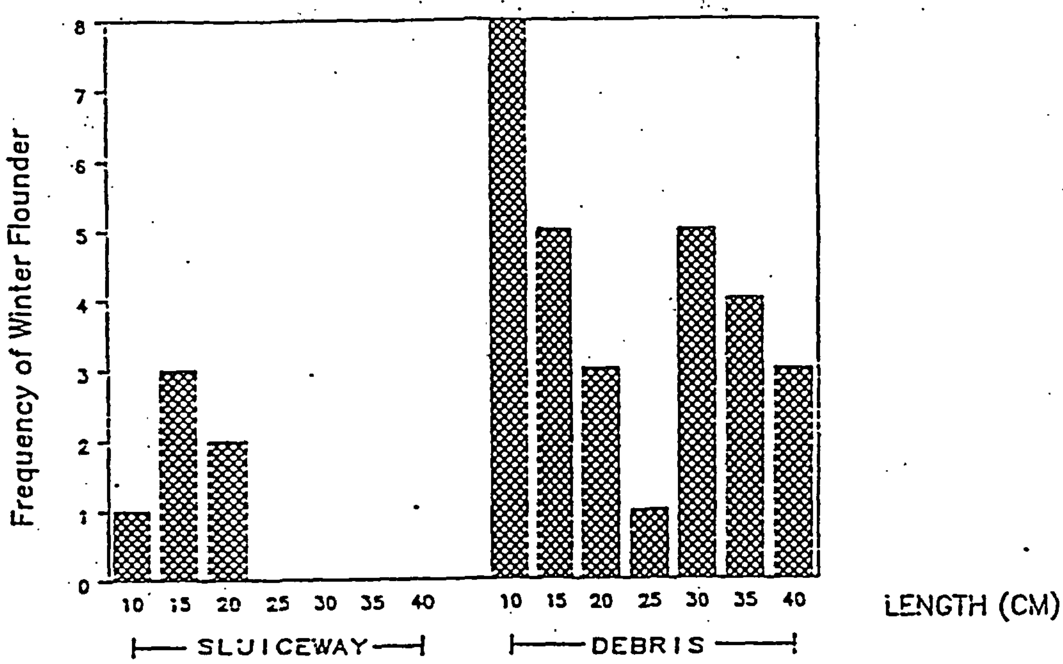

Figure 1. The length frequency of winter flounder collected from the Millstone Unit 3 sluiceway and the debris hopper from May 1986 through April 1987.

Because of the wide size range in the winter flounder lengths, data was separated by size class (Fig. 1). Only small immature winter flounder were collected in the sluiceway trough, while all size classes were found in the debris.

A significant difference ($p < 0.001$) in the mean size of all crustaceans was found between those collected from the sluiceway and debris. The American lobster and mud and blue crabs were the only crustaceans for which the mean length of those found in the debris was not different from those in the sluiceway. Except for the blue crab, the mean lengths of crustaceans found in the debris were larger than those in the sluiceway. Crustaceans probably used their appendages to hold onto the traveling screens, so that more smaller crabs were washed off the screens by the low pressure spray than larger ones. Squid found in the debris samples were signficantly larger than those found in the sluiceway samples.

Organisms collected from the sluiceway were held in the laboratory for 72 h to determine their survival. In general, demersal fish and crustacean groups had the greatest survival (Table 5). Survival of demersal fish was best when water temperatures were cool (88%) or warm (85%) and was somewhat less during cold (73%) periods. Survival of crustaceans did not vary with temperature (86-88%). Few pelagic fish or squid survived impingement and sluiceway passage; most of these organisms died within the 72-h holding period. Most of the pelagic fish were collected during the warm-water period.

The ten most abundant fish collected in the study had various rates of survival depending on whether they were demersal or pelagic (Table 6). Northern pipefish had high initial (>95%) and three-day survival (>90%). These fish have an integument armed with rings which probably enhanced survival. The threespine stickleback, a small species with hard body plates, also had high (>70%) survival in the sluiceway. All grubbies survived impingement and only one died after the three-day holding period. The cunner had a high rate of initial survival (>90%) and most survived the holding period (>85%). All the winter flounder were collected alive and survived through the holding period (100%). Few butterfish survived impingement (16%) and almost none (2%) survived past 72 h. Most butterfish collected were small and according to Mansueti (1963), small butterfish are commensal with jellyfish. Many of the butterfish were impinged along with host jellyfish which drifted into the intake. Mortality was probably due to the fragile nature of these small fish simultaneously impinged with large masses of jellyfish. The survival of other species may also have been affected by the large masses of jellyfish impinged during May through July and in October during this study. The remaining fish that dominated the collections, (bay

Table 5. Percent initial and extended survival for groups (body type and water temperature) of organisms taken in the Millstone Unit 3 sluiceway from May 86-April 87.

Body type group	Temperature group	Number examined	Initial survival (%)	Survival at 6 h (%)	Survival at 24 h (%)	Survival at 72 h (%)
crustacean	cold	8	87	87	87	87
	cool	33	91	91	88	88
	warm	446	90	89	87	86
demersal	cold	94	79	77	74	73
	cool	131	92	91	90	88
	warm	191	92	87	85	85
pelagic	cold	50	12	8	4	2
	cool	44	18	4	4	2
	warm	216	12	2	1	1
squid	cool	11	9	0	0	0
	warm	124	9	6	2	0

Table 6. Millstone Unit 3 sluiceway survival by species following various holding periods.

Species	Common Name	Body Type Group[a]	Number Examined	(%) Initial Survival	(%) Survival at 6h	(%) Survival at 24h	(%) Survival at 72h
Alosa pseudoharengus	alewife	P	1	0.0	0.0	0.0	0.0
Aluterus schoepfi	orange filefish	P	1	100.0	100.0	0.0	0.0
Ammodytes spp.	sand lance	P	6	33.3	33.3	33.3	16.7
Anchoa mitchilli	bay anchovy	P	62	1.6	0.0	0.0	0.0
Apeltes quadracus	fourspine stickleback	D	1	0.0	0.0	0.0	0.0
Brevoortia tyrannus	Atlantic menhaden	P	54	0.0	0.0	0.0	0.0
Callinectes sapidus	blue crab	C	2	100.0	100.0	100.0	100.0
Cancer irroratus	rock crab	C	246	87.0	85.8	83.7	82.9
Carcinus maenus	green crab	C	35	80.0	77.1	77.1	77.1
Centropristis striata	black sea bass	D	1	100.0	100.0	100.0	100.0
Clupea harengus	Atlantic herring	P	1	0.0	0.0	0.0	0.0
Conger oceanicus	conger eel	D	2	100.0	100.0	0.0	0.0
Cyclopterus lumpus	lumpfish	D	1	0.0	0.0	0.0	0.0
Cynoscion regalis	weakfish	P	3	0.0	0.0	0.0	0.0
Enchelyopus cimbrius	fourbeard rockling	D	3	66.7	66.7	66.7	66.7
Engraulis eurystole	silver anchovy	P	1	0.0	0.0	0.0	0.0
Etrumeus teres	round herring	P	1	0.0	0.0	0.0	0.0
Gadidae	codfish	P	1	0.0	0.0	0.0	0.0
Gadus morhua	Atlantic cod	P	1	0.0	0.0	0.0	0.0
Gasterosteus aculeatus	threespined stickleback	D	74	73.0	71.6	71.6	71.6
Gasterosteus wheatlandi	blackspotted stickleback	D	9	100.0	100.0	100.0	100.0
Homarus americanus	American lobster	C	14	92.9	92.9	85.7	85.7
Libinia spp.	spider crab	C	47	97.9	97.9	95.7	93.6
Loligo pealei	Atlantic long-finned squid	S	135	8.9	5.9	2.2	0.0
Menidia menidia	Atlantic silverside	P	68	22.1	2.9	1.5	0.0
Merluccius bilinearis	silver hake	P	3	33.3	0.0	0.0	0.0
Microgadus tomcod	Atlantic tomcod	D	4	75.0	50.0	25.0	0.0
Monacanthus hispidus	planehead filefish	P	1	100.0	100.0	100.0	100.0
Myoxocephalus aenaeus	grubby	D	34	100.0	100.0	100.0	97.1
Neopanope texana	mud crab	D	22	86.4	86.4	86.4	86.4
Ophidion marginatum	striped cusk-eel	D	2	100.0	100.0	100.0	100.0
Osmerus mordax	rainbow smelt	P	8	25.0	25.0	12.5	12.5
Ovalipes ocellatus	lady crab	C	113	96.5	93.8	92.9	90.3
Pagurus longicarpus	hermit crab (small)	C	2	100.0	100.0	100.0	100.0
Pagurus pollicaris	hermit crab (large)	C	1	100.0	100.0	100.0	100.0
Paralichthys dentatus	summer flounder	D	1	100.0	100.0	100.0	100.0
Penaeus aztecus	brown shrimp	C	1	100.0	100.0	100.0	100.0
Peprilus triacanthus	butterfish	P	87	16.1	3.4	3.4	2.3
Pholis gunnellus	rock gunnel	D	5	80.0	80.0	80.0	80.0
Pinnotheres maculatus	pea crab	C	4	100.0	100.0	100.0	100.0
Pollachius virens	pollock	P	3	33.3	33.3	33.3	33.3
Pomatomus saltatrix	bluefish	P	14	42.9	7.1	0.0	0.0
Prionotus carolinus	northern searobin	D	1	100.0	0.0	0.0	0.0
Prionotus evolans	striped searobin	D	9	88.9	77.8	66.7	66.7
Pseudopleuronectes americanus	winter flounder	D	6	100.0	100.0	100.0	100.0
Scophthalmus aquosus	windowpane	D	5	80.0	80.0	80.0	80.0
Sphoeroides maculatus	northern puffer	D	2	50.0	0.0	0.0	0.0
Syngnathus fuscus	northern pipefish	D	210	95.2	92.4	91.4	91.0
Tautogolabrus adspersus	cunner	D	28	92.9	92.9	92.9	85.7
Tautoga onitis	tautog	D	8	100.0	100.0	100.0	100.0
Trachurus lathami	rough scad	P	1	0.0	0.0	0.0	0.0
Urophycis regia	spotted hake	P	1	0.0	0.0	0.0	0.0
Urophycis tenuis	white hake	P	1	0.0	0.0	0.0	0.0

[a] P = pelagic
D = demersal
C = crustacean
S = squid

anchovy, Atlantic silverside, Atlantic menhaden and small juvenile bluefish), are pelagic species and none of these individuals survived the three-day holding period.

Of the eight dominant macroinvertebrates collected, all of the crustaceans had high survival rates while no squid survived the holding period (Table 6). Survival rates ranged from 77% for the green crab to 100% for the blue crab. The American lobster, the most commerially important invertebrate found in local waters, had a high three-day sürvival (86%). In general, crustaceans that were molting when impinged suffered high mortality. A few Atlantic long-finned squid survived impingement, but none survived the three-day holding period. This species is fragile and based on laboratory observations, some latent mortality of squid, particularly larger ones taken in the fall, may have been due to stress imposed during the holding period.

Discussion

The Unit 3 fish return system is a complex two-trough system. The low pressure spray wash should be set to maximize the return of aquatic organisms and minimize the flow of debris back to Long Island Sound. A 100% return of all aquatic organisms would be unrealistic, but the calculated 41% return rate revealed that the system may need adjustment. In general, the size of aquatic organisms returned in the sluiceway trough was smaller than that of those entering the debris hopper. This indicated that larger organisms were not being effectively washed off the screens by the low pressure spray. The spray headers may have to be realigned or the pressure increased to improve the efficiency of removal.

Results of the sluiceway survival study were encouraging. These findings were conservative in that no control specimens were used to ascertain mortality due to handling and holding in the laboratory. In addition, all injured specimens were considered dead, although some may have recovered if released immediately. Thus, actual survival for most species is probably greater than reported. Survival of most organisms classified as demersal and as crustaceans exceeded 80%. These groups include the commercically and recreationally important winter flounder and American lobster.

Pelagic fishes, which include herrings, small forage fishes, and young of predatory species, and squid suffered almost complete mortality. Most of these species were impinged during the summer, when warm water temperatures and concurrent impingement of large masses of jellyfish tended to reduce survival. Many years of impingement data collected at MNPS Units 1 and 2 indicated that these species rarely survived the impingement process (NUSCO 1983).

The rates of survival found for various species and groups during this study were similar to those reported for the MNPS Unit 1 sluiceway (NUSCO 1986). Survival rates of the more abundant species collected at Unit 3 were the same or higher than found at Unit 1, except for the threespine stickleback and rock and mud crabs, which had slightly lower rates (Table 7). The survival rates for American lobster, northern pipefish, and cunner were much higher at Unit 3 than at Unit 1. A high proportion of molting lobsters was collected during the Unit 1 sluiceway study (NUSCO 1986), which could have accounted for the difference in the survival rates for that species. At Unit 1, impinged organisms are washed from the screens using a high pressure spray (80 psi), while those at Unit 3 are washed with a low pressure spray (10 psi). As many survival rates were similar at different pressures, this indicated that the process of impingement on the traveling screens alone may have caused much of the mortality.

Table 7. Comparison of extended percent survival of aquatic organisms returned at Millstone Unit 3 and Unit 1.

Species	Common Name	Percent Extended Survival Unit 3	Unit 1
Anchoa mitchilli	bay anchovy	0	0
Brevoortia tyrannus	Atlantic menhaden	0	0
Callinectes sapidus	blue crab	100	86
Cancer irroratus	rock crab	83	92
Carcinus maenus	green crab	77	62
Gasterosteus aculeatus	threespine stickleback	72	91
Homarus americanus	American lobster	86	38
Libinia spp.	spider crab	94	71
Loligo pealei	Atlantic long-finned squid	0	0
Menidia menidia	Atlantic silverside	0	0
Myoxocephalus aenaeus	grubby	97	74
Neopanope texana	mud crab	86	100
Ovalipes ocellatus	lady crab	90	81
Peprilus triacanthus	butterfish	2	0
Pomatomus saltatrix	bluefish	0	0
Pseudopleuronectes americanus	winter flounder	100	86
Syngnathus fuscus	northern pipefish	91	16
Tautogolabrus adspersus	cunner	86	20

Results of impingement survival studies at other northeastern Atlantic coastal and estuarine power stations were summarized on Table 8 and compared to results of this study. Findings were similar even though sampling methods and plant operations differed among the studies. Generally, pelagic fishes had high mortality rates and demersal fishes and crustaceans had good survival. Survival of fish from MNPS Unit 3 appears to be similar to that found at Brayton Point, MA and greater than at Pilgrim, MA for similar wash cycles. Initial survival for demersal species was similar to that at Oyster Creek, NJ, even though less time elapsed between screen washes there.

Conclusion

Further work is needed to improve the efficiency of the fish return sluiceway system. If feasible, the low pressure spray wash system may require adjustments to wash more organisms into the sluiceway while at the same time preventing the recirculation of excess debris. Although work is needed to improve efficiency, survival of those organisms returned was high, especially for demersal fish and crustaceans. Following improvements to the MNPS system, the projected survival of important fishes and invertebrates would further decrease the impact of impingement on the local aquatic community.

Table 8. Comparison of data from impingement survival studies at other northeastern power stations.

Power Station	Species	Species group[a]	Wash cycle(h)	Holding period(h)	% Survival	Remarks	Reference
Bowline, NY	white perch	P	0[b]	96	56	Not adjusted for control mortality, which was high.	King et al. 1977
	white perch	P	4	96	19		
Brayton Point, MA	Atlantic silverside	P	0	24	47		MRI 1982
	Atlantic silverside	P	2-12	24	1-10		
	windowpane	D	0	24	83		
	windowpane	D	8	24	66		
	winter flounder	D	0-8	24	90-94		
	winter flounder	D	12	24	83		
Danskammer Point, NY	white perch	P	0	84	40-51	Adjusted for control mortality.	King et al. 1977
	white perch	P	4	84	9		
	Atlantic tomcod	D	0	84	83		
	Atlantic tomcod	D	2	84	87		
Oyster Creek, NJ	blueback herring	P	2	None[c]	17	Only included number of live specimens reported for P group, since most damaged individuals apparently were in poor condition. For D and C groups, combined number of live and damaged since latter was minor and did not affect survival.	Tatham et al. 1977
	Atlantic herring	P	2	None[c]	8		
	bay anchovy	P	2	None[c]	7		
	Atlantic silverside	P	2	None[c]	34		
	northern pipefish	D	2	None[c]	90		
	striped searobin	D	2	None[c]	82		
	smallmouth flounder	D	2	None[c]	74		
	winter flounder	D	2	None[c]	85		
	blue crab	C	2	None[c]	93		
Pilgrim, MA	herrings	P	8	56	0		MRI 1984
	Atlantic silverside	P	8	56	0		
	rainbow smelt	P	8	56	0		
	threespine stickleback	D	8	56	2		
	cunner	D	8	56	1		
	grubby	D	8	56	38		
	winter flounder	D	8	56	15		
	northern puffer	D	8	56	6		
Pilgrim, MA	Atlantic silverside	P	8	56	3	Data combined for 1984-85 studies.	Anderson 1985a,b
	grubby	D	8	56	30		
	winter flounder	D	8	56	33		
Roseton, NY	white perch	P	0	84	29-60	Adjusted for control mortality.	King et al. 1977
	white perch	P	4	84	23-36		
	Atlantic tomcod	D	0	84	81		
	Atlantic tomcod	D	2	84	72		

[a] P indicates pelagic, D demersal, and C crustacean

[b] 0 indicates continuous wash

[c] Immediate survival estimates given as relatively few specimens held for delayed mortality

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January 29, 1988

D01830

Ms. Leslie Carothers, Commissioner
Department of Environmental Protection
State Office Building
165 Capitol Avenue
Hartford, Connecticut 06115

References:

1. NPDES Permit No. CT0003263 (Order No. 2859), Northeast Nuclear Energy Company, Millstone Nuclear Power Station, Units 1, 2 and 3.
2. Letter (D01595), E. J. Mroczka to L. Carothers, dated July 31, 1987.
3. Letter (C01588) from R. J. Barlow to J. F. Opeka, dated November 23, 1987.

Dear Commissioner Carothers:

Millstone Nuclear Power Station
Modified Ecological Monitoring Program for 1988

Paragraph 12 of the Millstone Nuclear Power Station NPDES permit, Reference 1, requires that on or before July 31, 1985, and annually thereafter, Northeast Nuclear Energy Company (NNECO), submit to the Commissioner of the Department of Environmental Protection (DEP), a study proposal covering biological studies, entrainment studies and impingement monitoring as directed in paragraph 5 of the NPDES permit. Accordingly, Northeast Utilities Service Company (NUSCO), as agent for NNECO, submitted a proposal in fulfillment of this requirement, Reference 2. Upon review, the DEP requested that the ecological monitoring effort be maintained at 1987 levels but agrees that impingement monitoring at Unit 2 can be discontinued, Reference 3. In addition, the DEP requested that new studies on the impacts on winter flounder and other fishes be included in the proposal.

In response to DEP's requests, NUSCO hereby submits on behalf of NNECO, a modified proposal (Enclosure 1) and a justification for the additional studies proposed to satisfy DEP concerns (Enclosure 2). Also included (Enclosure 3) is the information DEP requested covering Unit 3 impingement monitoring.

Ms. Leslie Carothers, Commissioner
D01830/Page 2
January 29, 1988

If after reviewing the submittals you have further questions, please call Mr. Paul M. Jacobson, Manager, NU Environmental Laboratory, at (203) 444-4239.

Very truly yours,

NORTHEAST UTILITIES SERVICE COMPANY
As Agent for Northeast Nuclear
Energy Company

E. J. Mroczka
Senior Vice President

D 17305
Appendix 5

Enclosure 1 to Letter No. D04716

REASSESSMENT OF IMPINGEMENT EFFECTS ON WINTER FLOUNDER AT MILLSTONE NUCLEAR POWER STATION

NORTHEAST NUCLEAR ENERGY COMPANY
MILLSTONE NUCLEAR POWER STATION
NPDES PERMIT No. CT0003263

Northeast Utilities Service Company
PO Box 270
Hartford, Connecticut 06141-0270
June 1991

Background

The output from a stochastic model to determine the effect of the three-unit Millstone Nuclear Power Station (MNPS) operation on the local Niantic River population of winter flounder was recently provided in NUSCO (1991a) with several other impact assessment results to the Connecticut Department of Environmental Protection (CT DEP). The conditions for the model termed "Simulation A" were similar to the deterministic model used in the MNPS 316(b) demonstration (NUSCO 1976), except that the recent modeling efforts were only concerned with the impact of larval winter flounder entrainment at MNPS. The deterministic model in the 316(b) demonstration included both the effects of entrainment and impingement on the local Niantic River winter flounder stock and attributed a considerable amount of the predicted impact to impingement. As more recent information on impingement at MNPS was deemed necessary by CT DEP, annual estimates of winter flounder impingement were re-examined to provide information necessary to further update the impact assessment models. The objectives were to provide current estimates of impingement, taking into account past records, more recent changes in MNPS operation, and varying abundance of winter flounder. Realistic estimates of age- and gender-specific impingement mortality allocated to the Niantic River stock were calculated and incorporated into Simulation A and other assessment models.

Conceptual Approach and Sources of Information

Impingement is presently not being monitored at any of the three MNPS units. Sampling at Unit 1 was discontinued following the installation of a fish return sluiceway in December 1983. Because impingement losses were well-documented and feasible mitigation measures were incorporated, monitoring at Unit 2 no longer served a practical purpose and sampling at Unit 2 ended in December 1987. The final 2 years of sampling at Unit 2 resulted in relatively low impingement estimates for many species, which was attributed, in part, to the start-up of Unit 3 in early 1986. Historical winter flounder impingement data (see NUSCO 1987b for a summary of sampling methodologies and estimation procedures) were reviewed to determine what factors may have been important in influencing impingement and whether predictive regression models could be constructed to estimate present levels of impingement at all three units. Impingement estimates had been made for Unit 1 from 1973 through 1983 and for Unit 2 from fall 1975 through 1987 and length-frequency data of impinged fish were recorded from 1976 through 1987. Data on cooling-water flow used by each unit were available for 1976 through 1990. For this report, impingement estimates for Units 1 and 2 were also generated for each quarter (winter: January-March; spring: April-June; summer: July-September; fall: October-December) of every year.

Impingement of winter flounder was previously shown to have been highly seasonal (NUSCO 1987a: Table 29), size-specific (NUSCO 1987a: Table 31), dependent upon plant operations, and greatly affected by environmental variables such as water temperature and wind velocity (NUSCO 1987a: Table 30). Despite the many factors affecting impingement, the number of fish impinged has to be related in some way to the number of fish available in the vicinity of a power plant. In other words, the numbers of winter flounder impinged must be related to the annual relative abundance of their population in the area. Preliminary analyses indicated that impingement of winter flounder at MNPS was perhaps related to their annual trawl catch in Niantic Bay (Fig. 1). Therefore, data from the two-unit operational period (1976-85) were examined to determine if trawl catches could reliably be used to predict estimates of impingement. Information on the abundance of winter flounder near MNPS was provided by a long-term trawl monitoring study

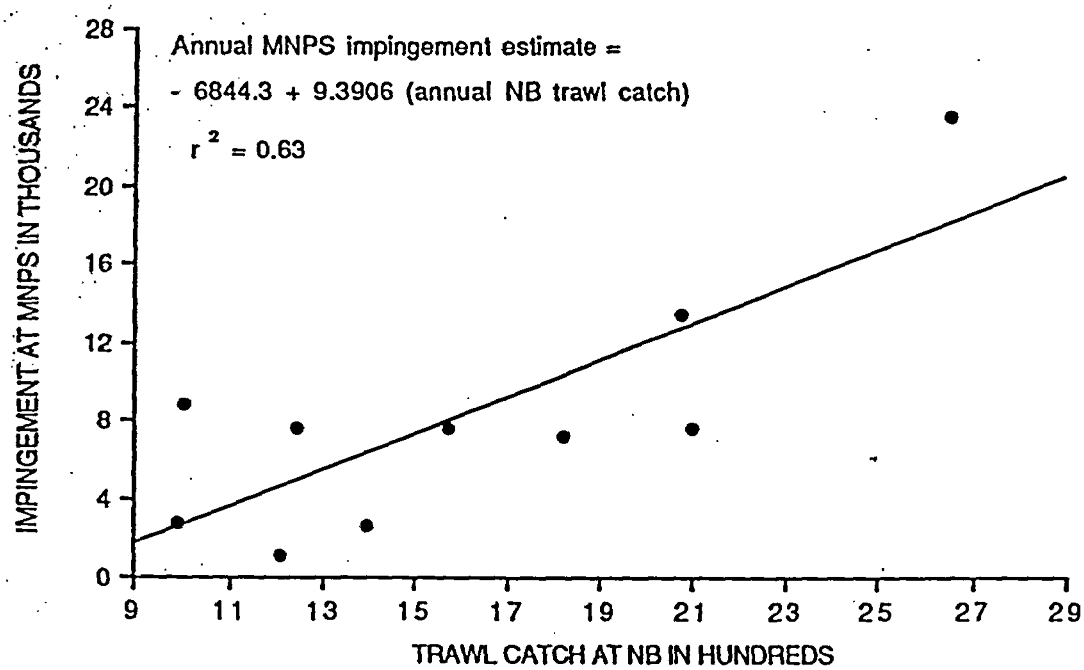

Fig. 1. Relationship between the estimated annual impingement of winter flounder at MNPS Units 1 and 2 with the total annual catch of winter flounder at trawl station NB for 1976 through 1985.

(see NUSCO 1991c for methods), which has remained unchanged since 1976. As trawl sampling effort was nearly the same for all years, annual and within-year quarterly sums of winter flounder catches were computed for each trawl station and for various combinations of stations. The relationship between annual and quarterly trawl catches and corresponding annual and quarterly impingement estimates were then investigated using linear regression analysis.

Once historical estimates of impingement were summarized and predictions of impingement in more recent years were obtained using the best regression models, mortality estimates were made using information on the effectiveness of fish return sluiceways at Units 1 and 3 (NUSCO 1981, 1986, 1988b). Mortalities were allocated to age and sex groups by using available information on the gender and length-frequency composition of the impingement catches. The risk of impingement for winter flounder spawning in the Niantic River was evaluated using information provided by the recapture of fish tagged with Peterson discs, summarized in NUSCO (1987a) and from female spawning population abundance estimates given in NUSCO (1991b). Annual mortality rates as a result of impingement were determined for female winter flounder of ages 0 through 4+; these values were converted to equivalent instantaneous rates for use in simulation models. The effect of both larval entrainment and impingement of juveniles and adults as a result of MNPS operation were assessed using the Simulation A modeling scenario as outlined in NUSCO (1991a).

Estimates of Impingement and Impingement Mortality

Unit 2

Estimation of current impingement at Unit 2 was the first priority, because it was the only unit at which sampling took place after Unit 3 began operating (1986-87). Thus, regression model predictions could be compared with estimates actually generated from sampling under present operating conditions. Furthermore, the only concurrent impingement data for Unit 3 were available from Unit 2 from a comparative impingement study done in 1987 (NUSCO 1988a). These data would enable the prediction of impingement at Unit 3, based on estimates made for Unit 2.

A preliminary examination of the impingement catch of winter flounder at Unit 2 showed that following the start-up of Unit 3, a significant ($p<0.0001$; adjusted least-squares means t-test) decrease occurred in impingement. As a preliminary analysis showed that the total annual catch of winter flounder at the Niantic Bay (NB) trawl station appeared to be correlated with impingement (Fig. 1), it was also assumed that the annual impingement estimates at Unit 2 from 1976 through 1985 (prior to Unit 3 operation) were dependent upon the corresponding annual catch of winter flounder at the NB trawl station. For the regression model, impingement was found to be significantly related to the catch of winter flounder at NB (Fig. 2):

Annual Unit 2 impingement estimate = -1347 + 3.6844(annual NB trawl catch).

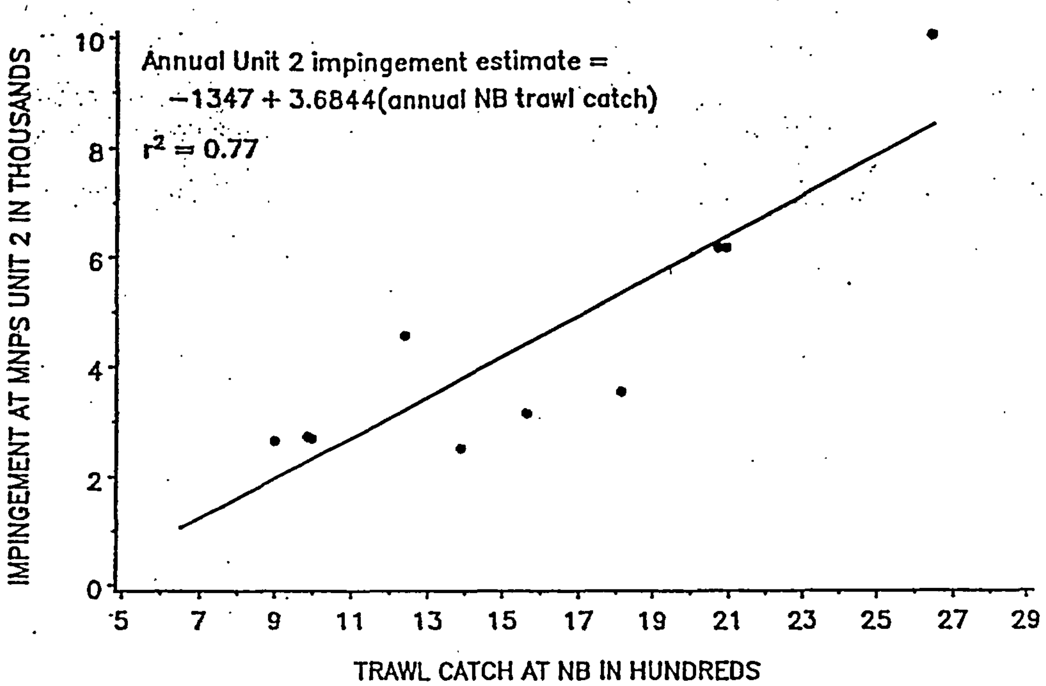

Fig. 2. Regression model illustrating the prediction of impingement at MNPS Unit 2 from the catch of winter flounder at trawl station NB from 1976 through 1985. Actual values are shown by the filled circles and the predictive linear regression by the solid line.

In an attempt to refine the regression model, quarterly impingement estimates were used with quarterly trawl catches for NB and other trawl stations alone or in various combinations. Trawl and impingement catches were also partitioned in various length groupings. However, no satisfactory results were achieved with these regression models, probably because of high sampling variability within seasons and perhaps due to temporal lags between the abundance of winter flounder in Niantic Bay and in their impingement over the course of a year.

TABLE 1. Estimated impingement and impingement mortality of winter flounder at MNPS Unit 2 from 1975 through 1990.

Year	Impingement estimated from actual sampling[a]	Impingement estimated from regression model	Reduction due to Unit 3 operation[b]	Total impingement mortality[c]
1975	357	-	-	357
1976	2692	1987	-	2692
1977	4604	3329	-	4604
1978	3184	4437	-	3184
1979	10076	8428	-	10076
1980	3577	5366	-	3577
1981	6207	6386	-	6207
1982	2733	2348	-	2733
1983	6211	6309	-	6211
1984	2541	3800	-	2541
1985	2770	2304	-	2770
1986	1108	3122	2014	1108
1987	634	1376	742	634
1988	-	1600	800	800
1989	-	1814	907	907
1990	-	1048	524	524

[a] Values for 1976-85 used in the Unit 2 regression model (see text).
[b] For 1988-90, the estimates from the regression model were reduced by 50% (conservatively estimated from reductions noted in 1986-87) to account for Unit 3 operation.
[c] For 1975-87, total impingement mortality is equal to actual sampling estimates and for 1988-90, the regression-predicted values minus the reduction attributed to Unit 3 operation for 1988-90. No fish survive impingement at Unit 2.

The predictive regression model enabled the estimation of impingement at Unit 2 following the end of sampling there by using recent trawl catch data (Table 1). Furthermore, 2 years (1986 and 1987) of data existed for Unit 2 for which the model-predicted estimates could be compared to actual sampling-generated estimates following the start-up of Unit 3. As mentioned previously, a noticeable reduction occurred in winter flounder impingement at Unit 2 once Unit 3 began operating. The sampling-generated estimates for 1986 and 1987 were about 35% and 46%, respectively, of the regression model-predicted estimates. Thus, regression model predictions for Unit 2 for 1988-90 were conservatively reduced by 50% to account for present impingement conditions at MNPS. As no fish return system exists at Unit 2, no impinged fish survive there.

Unit 1

Simple linear regression models of impingement estimates for Unit 1 and trawl catches had poor fits and non-significant regression parameters. This was most likely a result of several years of lengthy shutdowns at Unit 1 during the winter quarter, when most winter flounder were impinged. Consequently, a weighted average annual cooling-water flow term was added to the model to account for the less than expected impingement for those years. Quarterly weight factors were used in calculating mean annual flows to account for the highly seasonal nature of winter flounder impingement. The factors were based on the average quarterly proportions of impinged winter flounder, which were 0.616 for winter, 0.194 for spring, 0.037 for summer, and 0.155 for fall. These weight factors meant that plant operation in winter was much more important in determining annual winter flounder impingement than its operation during summer. The addition of the weighted annual mean flow term greatly improved the predictive regression model for Unit 1 (Fig. 3):

Annual Unit 1 impingement estimate = -11348 + 5.3025(annual NB trawl catch) + 3.9115(weighted annual mean intake cooling-water volume).

Similar to Unit 2 results, no improvement in the Unit 1 multiple regression model resulted from partitioning trawl and impingement catches by quarter or length-frequency groups or by adding data from other trawl stations.

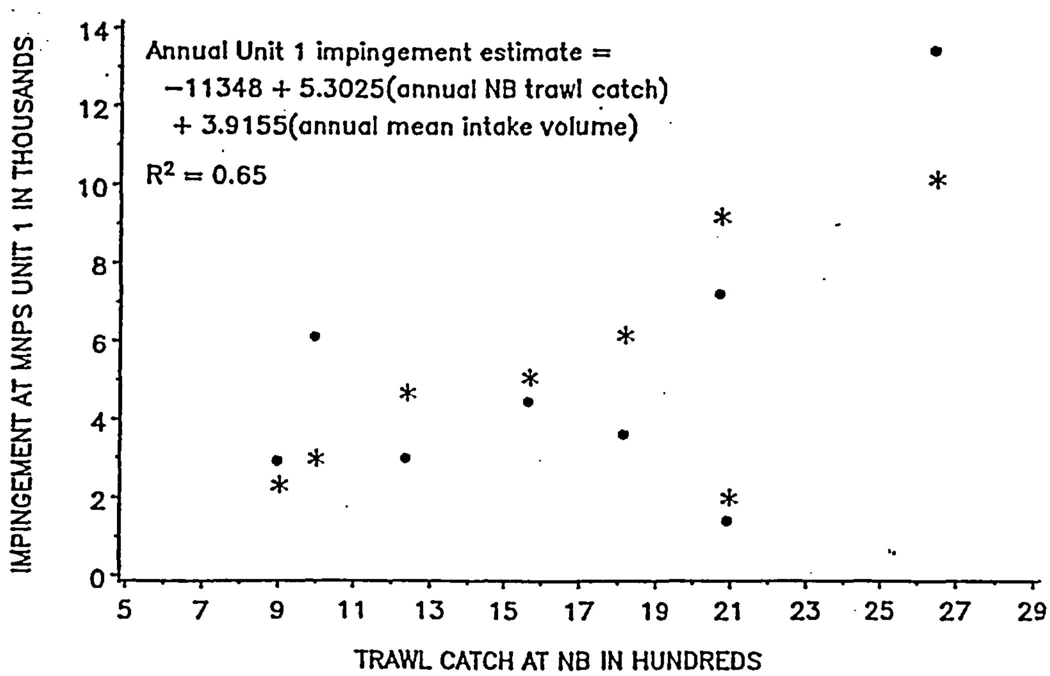

Fig. 3. Regression model illustrating the prediction of impingement at MNPS Unit 1 from the catch of winter flounder at trawl station NB from 1976 through 1983. Actual values are shown by the filled circles and the model predictions by the stars.

Because no comparative impingement data were available after the start-up of Unit 3, no reductions were made to the model-predicted estimates (Table 2). Winter flounder impinged at Unit 1 have been returned to Niantic Bay since 1984 in a fish return sluiceway; estimated mortality due to impingement and sluiceway passage was conservatively estimated as 15% (NUSCO 1981, 1986, 1988b). Additional mortality was also assigned whenever necessary as the sluiceway was periodically taken out of service, mostly because of high seaweed or debris loading that adversely affected plant operation (NUSCO 1990). This mortality was estimated to be 100% mortality of the winter flounder taken during the fraction of each quarter that the sluiceway was not in operation.

TABLE 2. Estimated impingement and impingement mortality of winter flounder at MNPS Unit 1 from 1973 through 1990.

Year	Impingement estimated from actual sampling[a]	Impingement estimated from regression model	Survival due to sluiceway operation[b]	Total impingement mortality[c]
1973	6220	-	0	6220
1974	3735	-	0	3735
1975	2605	-	0	2605
1976	2965	2291	0	2965
1977	3017	4657	0	3017
1978	4491	5061	0	4491
1979	13467	10077	0	13467
1980	3603	6139	0	3603
1981	1432	1971	0	1432
1982	6141	2961	0	6141
1983	7257	9192	0	7257
1984	-	4481	3807	674
1985	-	3060	2465	595
1986	-	5045	4067	978
1987	-	2082	1665	417
1988	-	3080	2465	615
1989	-	2176	1149	1027
1990	-	1752	924	828

[a] Values for 1976-83 used in the Unit 1 regression model (see text).
[b] Accounted for variable operation of fish return system and 85% survival in the fish return sluiceway.
[c] For 1973-83, total impingement mortality is equal to actual sampling estimates and for 1984-90, the regression-predicted values minus the survival due to the fish return sluiceway.

Unit 3

No complete impingement sampling data were available for Unit 3. However, in February-May 1987, 23 comparisons of 24-hour impingement counts were made between Units 2 and 3 (NUSCO 1988a). Comparing the sums of these catches, about 1.74 winter flounder were impinged at Unit 3 for each one at Unit 2. This value was quite similar to the 1.66 to 1 ratio of cooling-water volumes between the two units. Consequently, annual Unit 3 impingement was predicted by multiplying Unit 2 estimates by 1.74 (Table 3). Unit 3 has both a trash trough and a

TABLE 3. Estimated impingement and impingement mortality of winter flounder at MNPS Unit 3 from 1986 through 1990.

Year	Estimated impingement at Unit 2	Estimated impingement at Unit 3[a]	Survival due to sluiceway[b]	Total impingement mortality[c]
1986	1108	1928	590	1338
1987	634	1103	335	768
1988	800	1392	546	846
1989	907	1578	1056	522
1990	524	912	108	804

[a] Unit 3 impingement was estimated as 1.74 times the corresponding annual estimate for Unit 2 (see text).
[b] Accounted for variable fish removal efficiency and 85% survival in the fish return sluiceway.
[c] Total impingement mortality is equal to the estimated impingement minus the survival due to the fish return sluiceway.

fish return sluiceway, but the efficiency of the fish removal system has varied considerably. The removal efficiency (i.e., fraction of fish washed into the fish trough) was less than expected for the first few years of Unit 3 operation: system efficiency was estimated as 36% in 1986-88 (NUSCO 1988c); 79% in 1989 (NUSCO 1989b); zero for the first half of 1990 (fish sprayers out-of-service); and 79% and 74% for the third and fourth quarters of 1990, respectively (NUSCO 1990). Thus, impingement mortality was determined as a function of both system efficiency and the 15% mortality (NUSCO 1981, 1986, 1988b) assigned to fish entering the sluiceway.

Allocation of Impingement Mortality to Gender and Age

The MNPS winter flounder impact assessment models used to date have been age-structured female-only models (NUSCO 1991a). Information on the gender of impinged winter flounder was collected in February-April 1982 and December 1982 through April 1983 (NUSCO 1987a). The sex ratio in first period was 1:1 (number examined=755), but was 1.86:1 (n=1,675) in favor of males in the second time period. For assessment purposes, a conservative 1:1 sex ratio was hypothesized and all impingement estimates were simply divided in half to determine the impact solely to female winter flounder.

As the assessment models are also age-structured, it was desirable to estimate age composition of the impinged fish. Detailed length-frequency information was available for winter flounder impinged at Unit 1 from 1976 through 1983 and for Unit 2 for 1976 through 1987. Generally, length-frequency distributions for the two units were similar, but some differences were found among years. For example, greater numbers of small fish were impinged in the storm-dominated year of 1979 and during the last 2 years of Unit 2 impingement sampling following Unit 3 start-up.

Only small differences in growth occur between males and females during the first 3 years of winter flounder life history (NUSCO 1987a), so an age-length key constructed for Niantic River female winter flounder (NUSCO 1989a) was used to allocate total impingement mortality of females into groups of age-1, age-2, age-3, and age-4+ fish using the length-frequency data. Over all years, average age frequencies were 30% of the fish in age-1, 31% in age-2, 20% in age-3, and 19% in age-4+. These percentages were used for years with no readily available length-frequency data (i.e., prior to 1976 and the years for which impingement was predicted by using the regression models). Final annual estimates of impingement mortality were then allocated to females of ages 1 to 4+ for each unit (Tables 4-6) and all MNPS units combined (Table 7).

The current estimates of impingement mortality may be compared to estimates that were reported previously in NUSCO (1988a). In that report, a final average annual adult-equivalent impingement estimate of 3,323 winter flounder killed by three-unit MNPS operation was given (NUSCO 1988a: Table 2). However, adult-equivalent estimates are inappropriate for use in calculating impingement. Unlike entrainment, which causes mortality only once during the early life history of a fish, impingement occurs year after year, much like fishing. Therefore, adult-equivalent calculations are not meaningful to describe losses due to impingement. However, the mean annual impingement estimates for two-unit operation and total estimated impingement mortalities for three-unit operation presented in NUSCO (1988a) are comparable to values presented in this report.

TABLE 4. Estimated impingement mortality of female winter flounder at MNPS Unit 2 from 1975 through 1990.

Year	Estimated female impingement	Estimated female mortality	Mortality of females for: Age 1	Age 2	Age 3	Age 4+
1975	179	179	54	56	36	34
1976	1346	1346	423	409	253	261
1977	2302	2302	511	765	585	442
1978	1592	1592	343	836	314	99
1979	5038	5038	2589	1403	721	324
1980	1789	1789	386	636	384	383
1981	3104	3104	636	828	831	810
1982	1367	1367	285	514	292	275
1983	3106	3106	1139	730	604	633
1984	1271	1271	172	429	394	276
1985	1385	1385	660	243	239	242
1986	554	554	259	107	75	113
1987	317	317	206	45	33	33
1988	400	400	120	124	80	76
1989	454	454	136	141	91	86
1990	262	262	79	81	52	50

TABLE 5. Estimated impingement mortality of female winter flounder at MNPS Unit 1 from 1973 through 1990.

Year	Estimated female impingement	Estimated female mortality	Total female mortality for: Age 1	Age 2	Age 3	Age 4+
1973	3110	3110	933	964	622	591
1974	1869	1869	561	579	374	355
1975	1303	1303	391	404	261	247
1976	1483	1483	488	320	307	362
1977	1508	1508	438	331	342	398
1978	2246	2246	683	976	383	205
1979	6734	6734	2448	1754	1399	1134
1980	1802	1802	430	471	331	570
1981	717	717	88	410	106	113
1982	3071	3071	568	1204	606	692
1983	3630	3630	1678	886	470	597
1984	2241	337	101	104	67	64
1985	1530	298	89	92	60	57
1986	2523	489	147	152	99	93
1987	1041	209	63	65	42	40
1988	1540	308	92	95	62	59
1989	1088	514	154	159	103	98
1990	876	414	124	128	83	79

TABLE 6. Estimated impingement mortality of female winter flounder at MNPS Unit 3 from 1986 through 1990.

Year	Estimated female impingement	Estimated female mortality	Total female mortality for: Age 1	Age 2	Age 3	Age 4+
1986	964	669	201	207	134	127
1987	552	384	115	119	77	73
1988	696	423	127	131	85	80
1989	789	261	78	81	52	50
1990	450	402	121	125	80	76

The estimates given in NUSCO (1988a) were based on a somewhat different annual time frame (an October-September year rather than January-December), slightly different assumptions on sluiceway efficiencies and survival, and how impingement was extrapolated for Unit 3. Reducing the NUSCO (1988a) two-unit mean impingement estimate of 8,357 by 50% to obtain a female-only impingement estimate for comparison resulted in a total of 4,179. This value was somewhat less than the average of 4,299 determined from the data given in Table 7 for female mortality during the comparable period of 1973-83. The average total mortality for three-unit operation given in NUSCO (1988a) of 3,769 females (50% of the calculated total of 7,538), however, was more than three times as large as the mean of 1,185 female winter flounder estimated to have been killed at MNPS during the 1986-90 three-unit operational period (see Table 7 for data). The estimated mortality given in NUSCO (1988a) was based on an annual mean estimate of impingement determined for a period during which winter flounder were more abundant than at present. Furthermore, although noted in NUSCO (1988a), the effects of Unit 3 start-up in reducing impingement at Unit 2 were not quantified in that report. Therefore, it should be understood that the higher impingement totals given in NUSCO (1988a) for Unit 2 (and, hence, Unit 3) were overestimates.

TABLE 7. Estimated impingement mortality of female winter flounder at MNPS from 1973 through 1990.

Units in operation	Year	Age 1	Age 2	Age 3	Age 4+	Total
Unit 1	1973	933	964	622	591	3110
▽	1974	561	579	374	355	1869
Units 1 & 2	1975	445	460	297	281	1483
	1976	911	729	560	623	2823
	1977	949	1096	927	840	3812
	1978	1026	1812	697	304	3839
	1979	5037	3157	2120	1458	11772
	1980	816	1107	715	953	3591
	1981	724	1238	937	923	3822
	1982	853	1718	898	967	4436
	1983	2817	1616	1074	1230	6737
	1984	273	533	461	340	1607
▽	1985	749	338	299	299	1685
Units 1, 2, 3	1986	607	466	308	333	1714
	1987	384	229	152	146	911
	1988	339	350	227	215	1131
	1989	368	381	246	234	1229
▽	1990	324	334	215	205	1078

Risk of Impingement for Niantic River Winter Flounder

The risk of impingement to individual flounder at least 20 cm in length was evaluated using data from fish tagged with Peterson discs during December 1980 through March 1983 (NUSCO 1987a), summary of which is given in Tables 8 and 9. These data suggested that, except for many of the fish found in Niantic Bay, most fish tagged in other areas near MNPS apparently did not enter the Niantic River, even though some were impinged. This implied that some impinged fish were from other winter flounder stocks or else remained non-spawning fish during the first 2 years following tagging, when most disc-tagging recaptures were made. The fraction of these fish killed by impingement was relatively small in relation to fishing mortality (Table 8). Impingement sampling only took place on 3 of the 7 days of each week during 1980-83, when most tag returns occurred. However, even doubling impingement recaptures to account for the temporally incomplete sampling and ignoring non-compliance in returning tags by fishermen, still resulted in a

TABLE 8. Summary of winter flounder marked[a] with Peterson disc tags at various locations[b] in the vicinity of MNPS from December 1980 through March 1983.

	Date of tagging	Number tagged	Number impinged	Number caught by NUSCO in the Niantic River	Number caught by NUSCO outside the Niantic River	Number caught by sports fishermen	Number caught by commercial fishermen
BR:	12/80	68	0	0	0	1	7
	5/81	4	0	0	0	0	0
	3/82	5	0	0	0	0	0
	5/82	3	0	0	0	0	0
	6/82	131	0	0	0	6	9
	7/82	9	0	0	0	1	0
	10/82	33	0	0	0	2	1
	12/82	25	1	0	0	0	1
	1/83	12	0	0	1	0	1
	Total:	290	1	0	1	10	19
JC:	12/80	10	0	0	0	0	0
	3/82	3	0	0	0	0	0
	5/82	2	0	0	1	0	0
	6/82	9	0	0	0	2	0
	7/82	11	0	0	0	3	0
	9/82	28	0	1	4	7 (1 in NR)	2
	10/82	78	1	0	3	16	7
	1/83	6	0	0	1	0	0
	Total	147	1	1	9	28 (1 in NR)	9
TT:	12/80	47	0	1	0	7 (1 in NR)	7
	5/81	29	0	1	2	0	3
	3/82	2	0	0	0	0	0
	5/82	23	0	0	0	2	3
	6/82	120	0	0	3	5	9
	7/82	16	0	0	1	1	2
	9/82	59	0	0	1	5	6
	10/82	51	0	0	2	3 (1 in NR)	4
	12/82	23	0	0	1	4	0
	Total:	370	0	2	10	27 (2 in NR)	34
NB:	12/80	309	1	7	10	32 (7 in NR)	22
	5/81	965	0	9	12	64 (7 in NR)	92
	10/81	5	0	0	1	2	0
	3/82	5	0	0	0	0	0
	5/82	31	0	1	1	2	3
	6/82	156	0	2	1	12 (2 in NR)	7
	9/82	45	0	0	2	11 (2 in NR)	7
	10/82	43	0	0	5	4	2
	Total:	1559	1	19	32	127 (18 in NR)	128

TABLE 8. (continued).

	Date of tagging	Number tagged	Number impinged	Number caught by NUSCO in the Niantic River	Number caught by NUSCO outside the Niantic River	Number caught by sports fishermen	Number caught by commercial fishermen
NR:	12/80	410	2	36	2	28 (16 in NR)	21
	5/81	108	0	5	0	8 (3 in NR)	9
	3/82	557	2	88	0	90 (56 in NR)	22
	4/82	218	1	34	3	29 (18 in NR)	12
	6/82	15	0	0	0	2 (2 in NR)	0
	7/82	93	0	13	0	16 (14 in NR)	1
	9/82	80	0	8	1	7 (6 in NR)	4
	10/82	52	0	6	1	2 (2 in NR)	3
	3/83	770	3	128	2	105 (60 in NR)	27
	Total:	2303	8	318	9	287 (177 in NR)	99

[a] Minimum lengths tagged were 200 mm from December 1980 through May 1981, 230 mm from March through October 1982 and 200 mm in March 1983.

[b] BR is Bartlett Reef, JC is Jordan Cove, TT is Twotree Island Channel, NB is Niantic Bay, and NR is Niantic River.

TABLE 9. Summary of disc-tagged winter flounder recaptured during MNPS impingement sampling.

Station of tagging	Sex	Length at tagging	Date tagged	Date impinged[a]	Days at large
BR	M	245	27 Dec 82	10 Feb 83	45
JC	F	333	19 Oct 82	24 Mar 83	156
NB	M	228	5 Dec 80	10 Apr 81	126
NR	F	219	9 Dec 80	3 Apr 81	115
NR	M	241	9 Dec 80	12 May 81	154
NR	F	275	30 Mar 82	30 Mar 83	365
NR	M	336	30 Mar 82	4 Jun 82	66
NR	M	326	20 Apr 82	4 Apr 83	349
NR	F	421	1 Mar 83	27 Mar 83	26
NR	M	350	2 Mar 83	24 Mar 83	22
NR	M	359	2 Mar 83	22 Apr 83	51

[a] The impingement sampling schedule in 1977-83 was 3 days per week at Units 1 and 2.

small additional risk of mortality from impingement in relation to fishing. Impingement mortality was reduced even further by the installation of the fish return sluiceways at Units 1 and 3, which followed the completion of the disc-tagging work.

Knowledge of the fraction of the Niantic River spawning population affected by impingement is necessary for the simulation models. To determine this, data from fish tagged in the Niantic River from December 1980, March-April 1982, and March 1983 were examined in further detail. Most, if not all, of the fish tagged in the river during these periods were likely from the Niantic River spawning stock. Recaptures of these fish tended to be made in distinct periods following release: four of the fish from these groups were impinged within 1-2 months, two in 4-5 months, and two about 1 year after release. To determine the average fraction of the Niantic River winter flounder population that was impinged, the numbers of tagged fish available for impingement at specific times were determined, as fish were being continually removed from the marked population by fishing and tags were being shed by some of the fish. The decline over time for recaptures received from fishermen and made during NUSCO sampling was examined for fish tagged at all locations during December and during March-April. The slope of the decline in tag returns in the logarithmic scale was considered to be a measure of the apparent mortality rate for the marked population that included tag shedding. An apparent annual mortality rate (Z_a) of 0.9566 (apparent survival S_a of 0.3842) was determined for fish tagged in December and a Z_a of 1.1455 (S_a=0.3181) for March-April fish. These values were used to adjust initial tagged populations to the number of fish at large that were available for impingement during the periods when recaptures were made. The number of tagged winter flounder impinged during a recapture period was doubled to account for incomplete sampling and this adjusted number of impinged tagged fish divided by the calculated tagged population at large was a conservative estimate of the fraction of the Niantic River population killed by impingement. The fractions of adult spawners removed by impingement ranged from 0.43 to 2.90% (Table 10), with a geometric mean of 1.10%. This value was for two-unit operation without any fish return sluiceways in operation.

TABLE 10. Calculation of the proportions of winter flounder disc-tagged in the Niantic River during the spawning season that were impinged at MNPS.

Date of tagging	Number tagged	Date of recapture	Calculated number at large	Calculated number impinged[a]	Proportion of marked population impinged
December 1980	410	March-May 1981	298	4	1.34%
March 1982	557	June 1982	460	2	0.43%
March 1982	557	March 1983	177	2	1.13%
April 1982	218	April 1983	69	2	2.90%
March 1983	770	early April 1983	700	6	0.86%
Geometric mean					1.10%

[a] The actual number impinged was doubled to account for only 3 days of sampling per week at Units 1 and 2 during the recapture period.

Another estimator of the impacted fraction of female winter flounder may be obtained by dividing geometric means of the annual female impingement mortality estimates for each age by the calculated numbers-at-age for the Niantic River female spawning stock during the 1986-90 three-unit operational period. A geometric mean stock size of 26,584 was determined for 1986-90 from NUSCO (1991b: Table 11). Female numbers-at-age were determined using available estimates of Z and scaling the age structure to the average population size given above (Table 11). Using observed maturation rates (NUSCO 1991b), the average number of females and female spawners were determined for each age-class. The average annual female impingement mortality for each age-class during three-unit operation (determined from Table 7) divided by the average female stock size by age (given on Table 11) gave estimates of annual mortality rates that were attributed to impingement (Table 12). These values ranged from 1.00% for age-4+ females to 0.27% for age-0 females. The equivalent instantaneous mortality rates were used in the simulation that follows as the best estimates of MNPS impingement impact. These values were considered to be conservative estimators of impact because they assumed that all impinged winter flounder were from the Niantic River stock. Furthermore, any future improvements in sluiceway efficiency and survival were ignored in the simulation.

TABLE 11. Age composition of the recent (1986-90) average female spawning stock of Niantic River winter flounder.

Age	Assumed total instantaneous mortality rate (Z)[a]	Average number of females[b]	Maturation rates[c]	Average number of female spawners	Average number of fish in the age-groups selected to assess impingement
1	0.50	144,933.45	0.00	0	144,933
2	0.40	87,906.58	0.00	0	87,907
3	0.95	58,925.54	0.08	4,714	58,926[d]
4	0.95	22,789.92	0.36	8,204	
5	0.95	8,813.44	0.92	8,108	
6	0.95	3,408.51	1.00	3,409	
7	0.95	1,318.21	1.00	1,318	
8	0.95	509.81	1.00	510	
9	0.95	197.16	1.00	197	21,870[e]
10	0.95	76.25	1.00	76	
11	0.95	29.49	1.00	30	
12	0.95	11.40	1.00	11	
13	0.95	4.41	1.00	4	
14	0.95	1.71	1.00	2	
15	0.95	0.66	1.00	1	
Total female spawners				26,584	

[a] From Simulation A in NUSCO (1991a).
[b] Scaled to produce an average stock size of 26,584, under the assumption of equilibrium.
[c] From NUSCO (1991b): Table 37.
[d] Number of age-3 females (both mature and immature).
[e] Number of female spawners age-4 and older.

TABLE 12. Estimated annual impingement mortality rates for three-unit MNPS operation.

Age-group	Average number of females in the Niantic River population[a]	Estimated annual impingement mortality for three-unit operation[b]	Annual mortality rate due to impingement	Equivalent instantaneous mortality rate
1	144,933	393	0.27%	0.003
2	87,906	343	0.39%	0.004
3	58,925	224	0.38%	0.004
4+	21,870	219	1.00%	0.010

[a] As determined on Table 11.
[b] Geometric mean of 1986-90 estimates of female three-unit impingement mortality given on Table 7.

Simulation of MNPS Impact of Combined Entrainment and Impingement on the Niantic River Winter Flounder Population

The results of simulating 40 years of continuous three-unit MNPS operation that assumed three different rates of larval entrainment (15, 20 and 25%) were presented in NUSCO (1991a) under the label of "Simulation A". The purpose of that simulation had been to compare current impact predictions to those made 15 years ago for the 316(b) demonstration document (NUSCO 1976). The present simulation is identical to Simulation A in NUSCO (1991a), except that now the effect of winter flounder impingement has been added to the impact of larval entrainment previously given.

The simulation of the combined effect of larval entrainment and fish impingement at MNPS was carried out using the same stochastic population dynamics model (SPDM) as for the above mentioned Simulation A. The input parameters and simulation scenario were also identical except that the age-specific annual mortality rates were incremented by the amounts corresponding to the newly estimated impingement mortality (see last column in Table 12). The complete simulation consisted of four model runs, which provided a set of four time-series of stock size projections under the same scenario but with different plant effects in each run. These plant effects were none in the first run (i.e., the baseline equivalent to conditions that existed prior to MNPS operation) and low, medium, and high entrainment rates with impingement constant mortality in the other three runs. Additionally, a fifth model run in this study was conducted to assess the importance of impingement losses relative to the effect of larval entrainment. This extra run simply duplicated the run with the high entrainment rates, but did not include impingement effects. The three rates of larval entrainment used corresponded to the same three reductions (15, 20 and 25%) of annual larval production hypothesized in NUSCO (1991a). As discussed in the section dealing with "mass-balance" calculations in NUSCO (1991b), the high rate of entrainment (25%) was probably an overestimate of the average entrainment rates for Niantic River larvae under three-unit operating conditions. The simulation describes the dynamics of the unfished (i.e., no fishing mortality simulated) female spawning stock of Niantic River winter flounder during an 80-year period. The results include the projection of the undisturbed stock for a period of 10 years prior to plant operation; a 40-year period of continuous three-unit operation with both entrainment and impingement effects; and a final period of 30 years without any plant effects to simulate the stock recovery.

The simulation results are summarized in Figure 4 and Table 13. The top line (dashed) in Figure 4 is the baseline time-series of projected stock sizes for the undisturbed population which, in the 50th year of the simulation, averaged 75,047 female spawners (Table 13). The fluctuations of this baseline about the mean level of the stock (Fig. 4) are caused by stochastic variability representing natural recruitment variability induced by climatic factors, age-structure effects, and density-dependent mortality during the larval life-stages (NUSCO 1991a). The three solid lines labeled A, B, and D in Figure 4 correspond to the projections of the same stock as in the baseline, but including the effects of constant impingement and three different rates (low, medium, and high) of larval entrainment during a 40-year period. Finally, the dashed line in Figure 4 labeled with a C describes the projected stock with high entrainment rates (as in line D), but with no impingement effects. The difference between the levels of lines C and D in Figure 4 illustrate the further stock reduction caused by the addition of impingement mortality to high larval entrainment rates. This additional loss amounted to a change from a 16.8% stock reduction after 40 years of high entrainment rates alone to a 18.9% reduction when the effect of impingement losses were also simulated (Table 13). Therefore, in the worst possible case under the simulated scenarios, the addition of impingement effects resulted in average stock reductions of 2.1% beyond the reductions already predicted for entrainment effects in NUSCO (1991a).

In comparing the above results to the population reductions predicted in the 316(b) demonstration (Figure 5.4-30 in NUSCO 1976) a number of discrepancies become apparent. First, while the 1976 impact predictions were expressed as changes in the "total winter flounder population", the present simulation predicted changes in the "female spawning stock". This discrepancy does not invalidate direct comparisons between the two studies as long as the comparisons refer to predicted losses as percentages of the corresponding baselines, either total population or spawning stock,

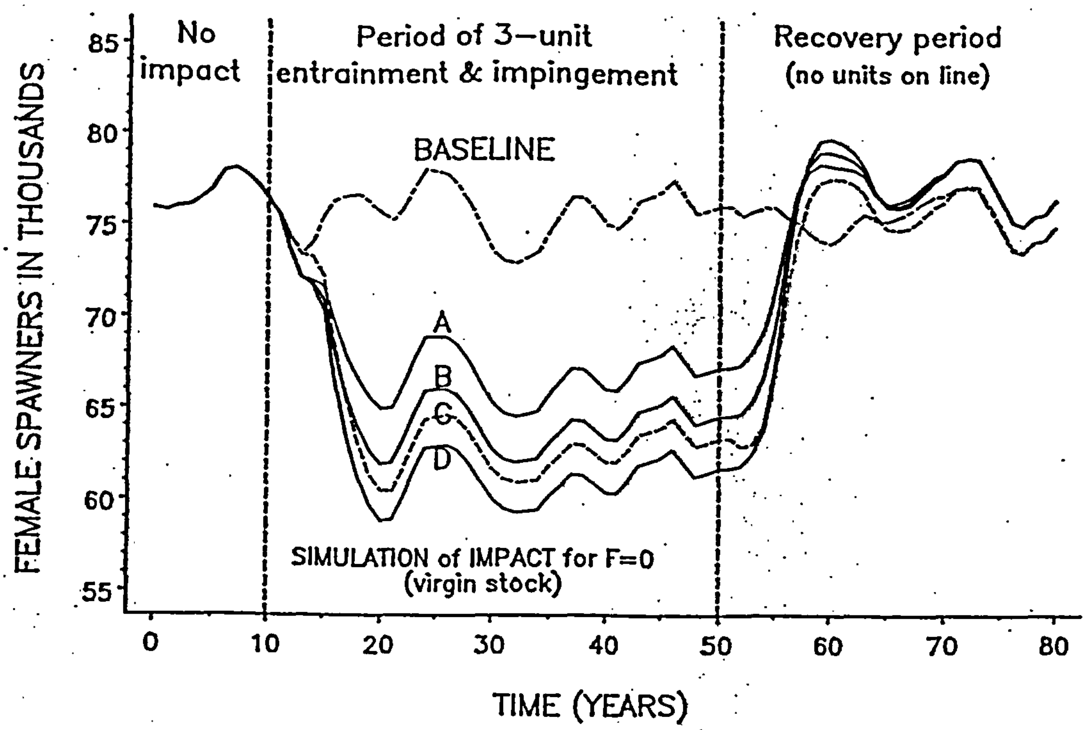

Fig. 4. Results of Simulation A showing the effects of three different larval entrainment rates with annual impingement mortality rates (see Table 12) on the unfished Niantic River winter flounder stock. The rates of entrainment and impingement mortality were held constant for the 40-year impact period. Spawning stock sizes are averages of 50 Monte Carlo replicates. The lines shown are the baseline (no MNPS impact), A (15% entrainment mortality plus impingement), B (20% entrainment mortality plus impingement), C (25% entrainment mortality only), and D (25% entrainment mortality plus impingement).

TABLE 13. Expected number of female winter flounder spawners in the unfished stock (Simulation A in NUSCO 1991a) after 40 years of continuous three-unit operation with low, medium, and high impact corresponding to three rates of larval entrainment and a constant rate of impingement. The projected percentages of stock reductions after 40 years are relative to the corresponding baseline stock size. Stock sizes are averages of 50 Monte Carlo replicates.

	Projection after 40 years of three-unit operation		
Plant effects	Stock size	Reduction	Line labels in Figure 4
Baseline (no plant effects)	75,047	-	Baseline
Low impact ([ENT = 15%] + IMP)[a]	67,190	11.6%	A
Medium impact ([ENT = 20%] + IMP)	64,502	15.2%	B
High impact ([ENT = 25%] + IMP)	61,638	18.9%	D
High entrainment (25%) and no impingement	63,276	16.8%	C

[a] IMP refers to simulated impingement effects according to the constant mortality rates shown in the last column of Table 12. ENT refers to the percentage of larval winter flounder lost each year as a result of entrainment.

instead of as absolute numbers of fish. Reductions in the total population and in the spawning stock are proportional in the context of these two simulation studies because sex ratios, maturation rates, and age-specific mortality rates (including plant induced mortality) were all assumed constant throughout the impact periods in both studies. A second discrepancy is that the impact period of 35 years in the 1976 study was increased by 5 years to agree with the operational life of the plant, which is now expected to be 40 years. This change simply makes the present assessment more conservative because the simulated impact period was longer. Finally, although the overall plant impacts predicted in the two studies were similar, an 18% population reduction in 1976 versus an 18.9% stock reduction at present, the makeup of the impacts was quite different. The present results (Table 13) show larval entrainment as the main source of fish losses (16.8% of the total 18.9% reduction was attributed to entrainment), which contrasts with the 1976 results where impingement losses were responsible for about 16% of the total 18% population reduction predicted. This shift in the main source of plant operation impacts from impingement of fish to entrainment of larvae is supported by the 15 additional years of monitoring data now available.

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NORTHEAST UTILITIES

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WESTERN MASSACHUSETTS ELECTRIC COMPANY
HOLYOKE WATER POWER COMPANY
NORTHEAST UTILITIES SERVICE COMPANY
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June 20, 1991

D04716

Mr. Timothy Keeney, Commissioner
Department of Environmental Protection
State Office Building
165 Capitol Avenue
Hartford, CT 06106

References: 1. Letter (D04339), E. J. Mroczka to L. Carothers, dated January 23, 1991.

2. Northeast Utilities Service Company. 1976. Environmental Assessment of the Condenser Cooling Water Intake Structures (316b demonstration), Volumes 1 and 2.

Dear Commissioner Keeney:

Millstone Nuclear Power Station
Ecological Monitoring Program

Output from several stochastic simulation models on the effects of the three-unit Millstone Nuclear Power Station (MNPS) on the Niantic River population of winter flounder were provided in Reference 1 by Northeast Utilities Service Company (NUSCO), on behalf of Northeast Nuclear Energy Company (NNECO), to the Connecticut Department of Environmental Protection (DEP). One model, termed "Simulation A," was specifically included at the request of the DEP because it was similar to the deterministic impact assessment model used in the MNPS 316(b) demonstration (Reference 2). The assessment model in the 316(b) demonstration included the impact of impingement of winter flounder on the traveling screens at MNPS, whereas the more recent modeling efforts included only the impact of larvae entrained through the cooling water system. As a result, representatives of the DEP have expressed concern that the effects of impingement on winter flounder should also be evaluated.

Accordingly, NUSCO, as agent for NNECO, hereby submits in Enclosure 1 a reassessment of winter flounder impingement at MNPS. Furthermore, results from Simulation A that incorporate the effects of both impingement and entrainment are provided for comparison with the MNPS 316(b) demonstration.

Mr. Timothy Keeney
D04716/Page 2
June 20, 1991

If you have any questions after reviewing this material, please call Mr. Donald Danila, NUSCO Environmental Programs Department, at (203) 444-1791, Extension 4538.

Very truly yours,

NORTHEAST UTILITIES SERVICE COMPANY
As Agent for Northeast Nuclear
Energy Company

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Enclosure 1 to Letter No. D08071

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PROGRESS REPORT ON THE MNPS FISH RETURN SYSTEMS

MILLSTONE NUCLEAR POWER STATION
NORTHEAST NUCLEAR ENERGY COMPANY
NPDES PERMIT No. CT0003263

Northeast Utilities Service Company
PO Box 270
Hartford, Connecticut 06141-0270
October 1994

PROGRESS REPORT ON THE MNPS FISH RETURN SYSTEMS

MILLSTONE NUCLEAR POWER STATION
NORTHEAST NUCLEAR ENERGY COMPANY
NPDES PERMIT No. CT0003263

Prepared by: Christine A. Gauthier

Approved by: Milan Keser
Milan Keser

MNPS UNIT 1 FISH RETURN SLUICEWAY

Under NPDES Permit No. CT0003263, the Connecticut Department of Environmental Protection (DEP) issued DEP Order No. 2859 on July 2, 1980, to the Northeast Nuclear Energy Company (NNECO) to investigate the feasibility of modifying the cooling-water intake systems of Millstone Nuclear Power Station (MNPS) Units 1 and 2 to improve the return of fish and shellfish back to Long Island Sound (LIS). A report (NUSCO 1981) was submitted to the DEP on July 31, 1981, which demonstrated that backfitting a fish return sluiceway at MNPS Unit 1 was a prudent alternative. With the concurrence of the DEP, the Unit 1 sluiceway was put into operation in mid-December 1983.

A study to examine the mortality of fishes and invertebrates impinged at Unit 1 and returned to LIS via the sluiceway began in January 1984 and continued through July 1985 (NUSCO 1986). Survival of most demersal fish and non-molting crustaceans exceeded 70%. These groups included both winter flounder and American lobster. However, pelagic fishes, including herring, small forage fishes and squids suffered almost complete mortality. The process of impingement alone probably caused most mortalities and the addition of the sluiceway did not increase survival.

NUSCO and DEP agreed (NUSCO 1986) that the Unit 1 sluiceway could be taken out of service during periods of high debris loading that would adversely affect plant operations. The DEP requested accounting of the number of days the sluiceway was out of service.

The number of days that the Unit 1 sluiceway was out of service each month from 1986 through 1993 is included in Table 1. Typically, the sluiceway was taken out of service when mussel removal resulted in high debris loading. As indicated on Table 1, the sluiceway was out of service for 33 days during 1993. This was the smallest number of days the sluiceway has been removed in a 1-year period since 1985.

Table 1. Total number of days when the MNPS Unit 1 sluiceway was not in service.

Month	1985	1986	1987	1988	1989	1990	1991	1992	1993
January	0	0	0	0	2	0	b	0a	4
February	0	0	0	0	6	0	b	0a	2
March	0	0	1	0	31	2	b	10	7
April	0	0	21	0	15a	3a	ba	0	0
May	3	8	2	0	31a	18	ba	0	0
June	4	1	6a	8	6a	1a	ca	0	0
July	2	6	31a	10	3	0	0a	0a	2
August	8	21	10a	3	6	4	15a	6a	4
September	28	3	4	18	11	3a	22	9	5
October	7	5	0	15	0	18a	4a	4	2
November	30a	0	3	3	2	6	4a	6	4
December	21a	0	0	0	0	8	0a	7	3

a Unit 1 shutdown.
b No information available (NUSCO 1992).
c No information June 1-15, 1991, sluiceway in service from June 16-30, 1991.

MNPS UNIT 3 FISH RETURN SLUICEWAY

Introduction

The design of the Millstone Nuclear Power Station (MNPS) Unit 3 intake structure incorporated a system to return fish and invertebrates impinged on the traveling screens back to Long Island Sound. The fish return system consists of fine mesh (0.375-in) screens, fish trays on each screen panel; and low and high pressure nozzles that direct material accumulated on the screens into a sluiceway and a debris trough, respectively. Fish and invertebrates are removed by a low pressure wash and returned to Long Island Sound through the fish sluiceway. To prevent debris recirculation, the material washed into the debris trough is accumulated in a trash hopper and removed. The system was operational when MNPS Unit 3 began commercial generation in April 1986. A 1-yr study of the system in 1986 demonstrated that only 41% of the organisms impinged on the traveling screens were washed into the sluiceway (NUSCO 1988). In response to the study results Connecticut Department of Environmental Protection (DEP) issued and enforcement letter dated February 17, 1988 requiring at least a 70% rate of return sluiceway efficiency and an assessment of improvements.

Over the next year, the fish sprayers were re-angled a number of times in attempts to increase sluiceway efficiency. Return rates ranging from 75-87% were achieved. But along with the increase of fish, the amount of seaweed that exited the sluiceway also increased. Seaweed fouling at Unit 3 caused seven unplanned outages. As a result, from January 1990 through July 1992, six new traveling screens were installed at the intake. Improvements to the traveling screens, fish spray wash system, and debris removal system were completed by the end of 1992. A 1-yr study to determine sluiceway survival and efficiency began in January 1993.

In December 1993, in accordance with Paragraph 5 of NPDES Permit No. CT003263, Northeast Utilities Service company (NUSCO) completed a 1-yr evaluation of the efficiency of the system in separating fish from debris and a study to examine the mortality of returned fishes and invertebrates. This report presents the results of that study.

The Intake Structure and Fish Return System

The Unit 3 intake structure is divided into six bays and contains six circulating, four service water and two screenwash pumps. At full capacity, about 56.6 m^3/sec of water is pumped through the entire structure. Water within each bay passes through a trash rack and a traveling screen. During normal operations, the average water velocity through each bay is 0.24 m/sec. The trash racks in each bay are 4.9-m wide and consist of 1.3-cm thick by 8.9-cm deep vertical steel bars installed 6.4 cm apart at a slope of 5 to 1. The traveling screens, located upstream of the circulating water pumps, consist of an endless band of screening panels 4.3-m wide by 0.61-m high constructed of 9.5-mm mesh copper cloth. The screens automatically rotate when the difference in the water elevation upstream and downstream of any screen reaches 100 mm; rotation can be initiated manually.

After screen rotation begins, screenwash water is directed through the low pressure (10 psi) spray header to flush aquatic organisms out of the fish baskets on the screen panels into the lower fish sluiceway trough, and also through a high pressure (85 psi) spray to clean debris off the screens into an upper trash trough. The 70-cm diameter lower trough exits the west wall of the intake structure and connects to a 30-cm diameter pipe, which runs down along a seawall about 22 m to the north. A 76-cm section of the sluiceway pipe about 30 cm to the west of the intake structure is open to allow for sampling. The sluiceway ends about 10 m from rock rip-rap along the shore. The debris trough exits the intake structure through the east wall and material is removed from the trough by a motorized conveyor system and deposited in a trash hopper for removal offsite.

Materials and Methods

Samples were taken biweekly from January through December 1993, except during the week of September 9, 1993 when no fish were impinged because all six circulating water pumps were inoperatable. Most impingement occurs between dusk and dawn, thus most sampling was done in early morning shortly before or after dawn. Before a sample was collected, the traveling screens were washed to clean them of previously accumulated debris and organisms and then the screens were not allowed to rotate or wash for about 2-3 h. On three occasions, high differential water level due to debris loading caused the screens to run continuously and samples were taken during a 40-min period.

Organisms were simultaneously collected from both the sluiceway and debris troughs. To collect organisms from the sluiceway, a 57-cm long, 6-mm mesh net was attached to a 26-cm diameter metal ring and placed over the end of the sluiceway pipe. Sampling at the end of the sluiceway pipe allowed for a measure of mortality that included impingement, screenwash, and passage through the fish return pipe. The screens were rotated and cleaned and as material accumulated in the sampler during the approximate 40-min wash cycle, the net was emptied about every 5 min. Sampling was continuous during the entire wash cycle as the net was designed to be emptied at the codend while the mouth of the net remained attached to the end of the sluiceway pipe. All organisms were separated from algae and jellyfish by hand and placed into an insulated cooler or bucket containing seawater. During the same time, organisms were counted at the discharge of the debris conveyor system. Live organisms collected from the sluiceway were returned to the laboratory and held in tanks with running seawater for up to 72 hrs. Observations were made at 6 and 24 h following collection and dead organisms were removed. Any specimen with obvious injuries or exhibiting aberrent behavior at the final 72-h observation was classified as dead. Total length of fish, carapace width of crabs, carapace length of lobsters, and mantle length of squid were recorded to the nearest mm. Water temperature at the intake and the laboratory holding tanks were recorded.

Efficiency of the sluiceway system was calculated as a percentage by dividing the number of organisms collected in the sluiceway by the total number of organisms collected in both troughs and multiplying this number by 100. Percent efficiency was calculated by both sampling date and for each species.

Survival estimates were calculated for individual species as well as for groups of organisms classified by body type and season of occurrence based on water temperature. Survival was calculated from the proportion of total numbers of specimens alive at the initial, 6-, 24-, and 72-h observations. Organisms were classified into four body-type groups, which included "pelagic", "demersal", "crustacean" and "squid". Free-swimming fishes (e.g., herrings, silversides, butterfish) were considered pelagic, whereas bottom dwellers (e.g. sculpins, flounders) as well as those with hard integuments (e.g., sticklebacks, pipefish) were classified as demersal. The crustacean group was comprised of crabs and American lobster. The Atlantic long-finned squid was considered as a separate group. For some survival calculations, samples were assigned to three temperature groups: "cold", "cool" and "warm" based on water temperatures at the time of the collection. The water temperatures ranged from 3.5 to 7.0°C (cold), 8.0 to 15.0°C (cool), and 16.0 to 22.0°C (warm).

Results

A total of 24 samples were taken during the study period and 32 species of fish and 11 macroinvertebrates were taken in sluiceway and debris trough collections (Tables 2 and 3). The 952 specimens collected during the study were dominated by 12 species and these comprised 81% of the total: Atlantic long-finned squid (222), Atlantic silverside (160), rock crab (72), Atlantic herring (49), winter flounder (43), spider crab (43), grubby (42), threespine stickleback (41), lady crab (31), butterfish (26), American lobster (26), and mud crab (21).

Table 2. Number of organisms sampled, water temperature and percent efficiency by sample date.

Date	Number Sampled Sluiceway	Number Sampled Debris	Water Temperature (°C)	Efficiency (%)
January 19	115	0	4.5	100
February 2	47	0	1.3	100
February 16	40	0	3.3	100
March 2	15	0	1.6	100
March 16	102	1	1.3	99
March 30	21	0	4.5	100
April 13	28	1	4.9	96
April 27	11	0	6.2	100
May 11	5	0	10.4	100
May 25	32	1	12.5	97
June 7	11	0	13.0	100
June 22	41	2	16.7	96
July 6	52	0	16.9	100
July 20	85	6	18.1	93
August 3	29	1	21.7	97
August 17	62	1	20.5	98
August 31	56	1	21.5	98
September 29	20	3	17.5	87
October 14	24	0	15.1	100
October 26	20	1	14.0	95
November 9	21	1	12.3	95
November 23	51	2	11.0	96
December 7	27	1	10.1	96
December 20	15	1	7.9	94

The numbers of fish and macroinvertebrates collected from the sluiceway trough were compared to the numbers collected from the debris trough to determine the efficiency of the sluiceway. The percent efficiency was calculated for each date (Table 2) for each species (Table 3) and averaged 96% for all specimens collected. Of the 43 species were collected only one, the harvestfish (1 collected in debris trough), had an efficiency of less than 85%. The percent efficiency averaged 96% for fishes and 86% for macroinvertebrates.

Organisms collected from the sluiceway were held in the laboratory for 72 h to determine their survival. In general, demersal fish and crustacean groups had the greatest survival (Table 4). Survival of crustaceans was best in cool water (93%) and lowest in warm water (84%) (Table 5).

Table 3. Species specific efficiency of the Unit 3 Fish Return System in separating fish and invertebrates from debris.

Species	Common Name	Numbers Collected Sluiceway Trough	Numbers Collected Debris Trough	Percent Efficiency
Alosa aestivalis	blueback herring	2	0	100
Alosa pseudoharengus	alewife	19	0	100
Anchoa mitchilli	bay anchovy	15	0	100
Brevoortia tyrannus	Atlantic menhaden	16	0	100
Callinectes sapidus	blue crab	4	0	100
Cancer irroratus	rock crab	72	2	97
Carcinus maenus	green crab	12	2	85
Clupea harengus	Atlantic herring	49	0	100
Cyclopterus lumpus	lumpfish	5	0	100
Etropus microstomus	smallmouth flounder	2	0	100
Gasterosteus aculeatus	threespine stickleback	41	6	85
Gasterosteus wheatlandi	blackspotted stickleback	10	0	100
Homarus americanus	American lobster	26	6	80
Libinia spp.	spider crab	43	1	98
Loligo pealei	Atlantic long-finned squid	222	6	97
Lophius americanus	goosefish	3	0	100
Menidia menidia	Atlantic silverside	160	2	99
Merluccius bilinearis	silver hake	3	0	100
Monacanthus hispidus	planehead filefish	1	0	100
Morone americana	white perch	1	0	100
Myoxocephalus aenaeus	grubby	42	0	100
Neopanope texana	mud crab	21	0	100
Ophidion marginatum	striped cusk-eel	4	0	100
Opsanus tau	oyster toadfish	1	0	100
Osmerus mordax	rainbow smelt	1	0	100
Ovalipes ocellatus	lady crab	31	4	89
Pagurus longicarpus	hermit crab	5	0	100
Penaeus aztecus	brown shrimp	5	0	100
Peprilus alepidotus	harvestfish	0	1	0
Peprilus triacanthus	butterfish	26	1	96
Pholis gunnellus	rock gunnel	2	0	100
Pleuronectes americanus	winter flounder	43	1	98
Pomatomus saltatrix	bluefish	1	0	100
Prionotus evolans	striped searobin	4	0	100
Scophthalmus aquosus	windowpane	7	1	86
Selene vomer	lookdown	2	0	100
Sphoeroides maculatus	northern puffer	1	0	100
Syngnathus fuscus	northern pipefish	12	0	100
Tautogolabrus adspersus	cunner	3	0	100
Tautoga onitis	tautog	8	0	100
Urophycis chuss	red hake	2	0	100
Urophycis regia	spotted hake	4	0	100
Total:		919	33	Average % Efficiency: 96%

Table 4. Millstone Unit 3 sluiceway survival by species following various holding periods.

Species	Common Name	Body Type Group[a]	Number Examined	(%) Initial Survival	(%) Survival at 6h	(%) Survival at 24h	(%) Survival at 72h
Alosa aestivalis	blueback herring	P	2	100	0	0	0
Alosa pseudoharengus	alewife	P	19	47	21	0	0
Anchoa mitchilli	bay anchovy	P	15	0	0	0	0
Brevoortia tyrannus	Atlantic menhaden	P	16	50	31	6	0
Callinectes sapidus	blue crab	C	4	100	100	75	75
Cancer irroratus	rock crab	C	72	100	100	98	91
Carcinus maenus	green crab	C	12	82	82	82	82
Clupea harengus	Atlantic herring	P	49	0	0	0	0
Cyclopterus lumpus	lumpfish	D	5	100	100	100	100
Etr opus microstomus	smallmouth flounder	D	2	100	100	100	50
Gasterosteus aculeatus	threespine stickleback	D	41	86	86	86	86
Gasterosteus wheatlandi	blackspotted stickleback	D	10	90	90	90	90
Homarus americanus	American lobster	C	26	100	100	100	100
Libinia spp.	spider crab	C	43	100	100	100	89
Loligo pealei	Atlantic long-finned squid	S	222	41	60	20	6
Lophius americanus	goosefish	D	3	33	0	0	0
Menidia menidia	Atlantic silverside	P	160	63	53	30	0
Merluccius bilinearis	silver hake	P	3	33	0	0	0
Monacanthus hispidus	planehead filefish	P	1	100	100	100	100
Morone americana	white perch	P	1	100	100	100	100
Myoxocephalus aenaeus	grubby	D	42	100	100	100	866
Neopanope texana	mud crab	C	21	100	95	95	95
Ophidion marginatum	striped cusk-eel	D	4	75	75	75	50
Opsanus tau	oyster toadfish	D	1	100	100	100	100
Osmerus mordox	rainbow smelt	P	1	0	0	0	0
Ovalipes ocellatus	lady crab	C	31	100	100	87	71
Pagurus longicarpus	hermit crab	C	5	100	100	100	100
Penaeus aztecus	brown shrimp	C	5	80	80	80	80
Peprilus triacanthus	butterfish	P	26	15	8	4	0
Pholis gunnellus	rock gunnel	D	2	100	100	100	100
Pleuronectes americanus	winter flounder	D	43	97	97	94	94
Pomatomus saltatrix	bluefish	P	1	0	0	0	0
Prionotus evolans	striped searobin	D	4	75	75	75	75
Scophthalmus aquosus	windowpane	D	7	100	100	100	83
Selene vomer	lookdown	P	2	0	0	0	0
Sphoeroides maculatus	northern puffer	D	1	100	100	100	100
Syngnathus fuscus	northern pipefish	D	12	92	92	92	92
Tautogolabrus adspersus	cunner	D	3	67	67	67	67
Tautoga onitis	tautog	D	8	100	100	100	87
Urophycis chuss	red hake	P	2	100	100	100	100
Urophycis regia	spotted hake	P	4	50	50	50	50

[a] P=pelagic
D=demersal
C=crustacean
S=squid

Table 5. Percent initial and extended survival for groups (body type and water temperature) of organisms taken in the Millstone Unit 3 sluiceway from January through December 1993.

Body type group	Temperature group	Number examined	Initial survival (%)	Survival at 6 h (%)	Survival at 24 h (%)	Survival at 72 h (%)
crustacean	cold	29	96	93	93	90
	cool	74	97	97	96	93
	warm	102	100	100	95	84
demersal	cold	127	94	94	93	88
	cool	33	94	94	94	88
	warm	9	78	78	78	67
pelagic	cold	140	61	46	23	0
	cool	23	13	9	4	0
	warm	45	4	0	0	0
squid	cool	82	56	41	28	7
	warm	60	22	15	10	5

Survival of crustaceans was similar to the survival of demersal fishes which was highest in cold and cool water (88%) and lowest in warm water (67%) (Table 5). Although more tha half of the pelagic fish and squid survived impingement and sluiceway passage, most died within the 72-h holding period (Table 5).

The eleven most abundant species collected in the study had varying rates of survival, depending on their body type. Over 40% of the Atlantic long-finned squid initially survived impingement , but only 6% survived the 3-d holding period. This species is fragile and in previous studies most did not survive initial impingement and none survived a 72-h holding period. Atlantic silverside, Atlantic herring, and butterfish are all pelagic species and none survived the holding period. However, most of the three abundant demersal fish species survived impingement and had high 3-d survival rates: winter flounder (94%), grubby (86%), and threespine stickleback (86%). All of the five dominant crustaceans had high survival rates, which ranged from 71% for the lady crab to 100% for the American lobster. In general, only crustaceans that were molting when impinged suffered high mortality.

Discussion

The Unit 3 fish return system is a two-trough system. Sluiceway studies conducted in 1986 resulted in poor (41%) return rates and improvements were undertaken to produce at least a 70% rate of return. Intake modifications that took place from 1988 through 1992 improved fish return rates. The new traveling screens increased debris removal capacity three-fold. This improved fish returns because previously fish sprayers were shut-off during periods of heavy loading to prevent recirculation; thus, fish were not washed into the fish return during these periods. New fish spray piping was redesigned to position the fish spray wash directly into the path of the fish buckets. This provided longer spray time and nearly continuous bucket flushing. Plastic fish spray deflectors were replaced with steel and relocated so they were out of the path of damaged fish buckets. Prior to the redesign, some traveling screen panels had buckled and sheered off fish sprayers. Also, some of the older metallic fish buckets corroded and fell off the traveling screens. This problem was resolved by the use of non-metallic attachments to the fish buckets. Following these improvements to the intake the rate of returned of impinged organisms increased from 41% to 96%.

Results of the sluiceway survival study also demonstrated an improvement in the survival of impinged organisms. These finding were conservative in that no control specimens were used to ascertain mortality due to handling and holding in the laboratory. In addition, all injured specimens were considered dead, although some may have recovered if released immediately. Thus, actual survival for most species was probably greater than reported. Survival of most organisms classified as demersal and crustaceans exceeded 80%. These groups include the commercially and recreational important winter flounder and American lobster.

Pelagic fishes, which included mostly herrings and small forage fishes, and squid suffered almost complete mortality. Most of these species were impinged during the summer, when warm water temperatures and concurrent impingement of large masses of jellyfish tend to reduce survival. Many years of impingement data collected at MNPS Unit 1 and 2 indicated that these species rarely survive the impingement process.

The rates of survival found for most species and groups during this study were similar or greater than those reported for the MNPS Unit 1 sluiceway (NUSCO 1986; Table 6). The survival of American lobster, northern pipefish, and cunner was higher at Unit 3 than Unit 1. A high proportion of molting lobsters was collected during the Unit 1 sluiceway study, however, which could have accounted for the difference in the survival rates for that species. At Unit 1, impinged organisms are washed from the screens using a high pressure spray (80 psi), while those at Unit 3 are washed with a low pressure spray (10 psi). As many survival rates were similar, regardless of spray wash pressure, this indicated that the process of impingement on the traveling screens alone may cause much of the mortality.

Results of impingement survival studies at other northeastern Atlantic coastal and estuarine power stations were summarized on Table 7 and compared to the results of this study. Findings were similar, even though sampling methods and plant operations differed among the studies. Survival of fish from MNPS Unit 3 appears to be similar to that found at Brayton Point, Mass. and greater than at Pilgram, Mass. for similar wash cycles. Initial survival for demersal species was similar to that at Oyster Creek, N.J. even though less time elapsed between screen washes there.

Table 6. Comparison of extended percent survival of aquatic organisms returned at Millstone Unit 3 and Unit 1.

Species	Common Name	Percent Extended Survival Unit 3 (1993)	Unit 3 (1986)	Unit 1
Anchoa mitchilli	bay anchovy	0	0	0
Brevoortia tyrannus	Atlantic menhaden	0	0	0
Callinectes sapidus	blue crab	75	100	86
Cancer irroratus	rock crab	91	83	92
Carcinus maenus	green crab	82	77	62
Gasterosteus aculeatus	threespine stickleback	86	72	91
Homarus americanus	American lobster	100	86	38
Libinia spp.	spider crab	89	94	71
Loligo pealei	Atlantic long-finned squid	6	0	0
Menidia menidia	Atlantic silverside	0	0	0
Myoxocephalus aenaeus	grubby	86	97	74
Neopanope texana	mud crab	95	86	100
Ovalipes ocellatus	lady crab	71	90	81
Peprilus triacanthus	butterfish	0	2	0
Pomatomus saltatrix	bluefish	0	0	0
Pseudopleuronectes americanus	winter flounder	94	100	86
Syngnathus fuscus	northern pipefish	92	91	16
Tautogolabrus adspersus	cunner	67	86	20

Conclusion

Improvements to the Unit 3 fish return system more than doubled the percentage of fish returning the Long Island Sound. Removal efficiency exceeded the targeted rate of 70%. Survival of most organisms returned was high, especially for demersal fish and crustaceans. The commercially and recreationally important winter flounder and American lobster both had rates of return greater than 80% and 72-h survival of more than 90%. The improved efficiency of the Unit 3 fish return sluiceway has lessened the impact of impingement on the local aquatic community.

Table 7. Comparison of data from impingement survival studies at other northeastern power stations.

Power Station	Species	Species group[a]	Wash cycle (h)	Holding period (h)	% Survival	Remarks	Reference
Bowline, NY	white perch	P	0[b]	96	56	Not adjusted for	King et al.
	white perch	P	4	96	19	control mortality.	1977
Brayton Point,	Atlantic silverside	P	0-8	48	43		LMS 1985
MA	bay anchovy	P	0-8	48	0		
	northern pipefish	D	0-8	48	94		
	tautog	D	0-8	48	95		
	winter flounder	D	0-8	48	75		
Brayton Point,	Atlantic silverside	P	0-8	48	18		LMS 1986
MA	bay anchovy	P	0-8	48	2		
	cunner	D	0-8	48	75		
	grubby	D	0-8	48	100		
	tautog	D	0-8	48	98		
	winter flounder	D	0-8	48	94		
Danskammer Pt,	white perch	P	0	84	40-61	Adjusted for	King et al.
NY	white perch	P	4	84	9	control mortality	1977
	Atlantic tomcod	D	0	84	83		
	Atlantic tomcod	D	2	84	87		
Oyster Creek,	blueback herring	P	2	none[c]	17		Tatham et al.
NJ	Atlantic herring	P	2	none[c]	8		1977
	bay anchovy	P	2	none[c]	7		
	Atlantic silverside	P	2	none[c]	34		
	northern pipefish	D	2	none[c]	90		
	striped searobin	D	2	none[c]	82		
	smallmouth flounder	D	2	none[c]	74		
	winter flounder	D	2	none[c]	85		
	blue crab	C	2	none[c]	93		
Pilgrim, MA	Atlantic silverside	P	8	56	3	Data combined for	Anderson
	grubby	D	8	56	30	1984-85 studies.	1985a,b
	winter flounder	D	8	56	33		
Pilgrim, MA	Atlantic silverside	P	8	none[c]	77		Anderson 1993
	tautog	D	8	none[c]	87		
	grubby	D	8	none[c]	95		
	winter flounder	D	8	none[c]	88		
Roseton, NY	white perch	P	0	84	29-60	Adjusted for	King et al.
	white perch	P	4	84	23-36	control mortality	1977
	Atlantic tomcod	D	0	84	81		
	Atlantic tomcod	D	2	84	72		

[a] P indicates pelagic, D demersal, and C crustacean.
[b] 0 indicates continuous wash
[c] Immediate survival estimates given as relatively few specimens held for delayed mortality.

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The Northeast Utilities System

October 20, 1994
D08071

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References:
1. Letter (D02278), E.J. Mroczka to L. Carothers, dated October 28, 1988
2. Letter (D03141), E.J. Mroczka to L. Carothers, dated October 31, 1989
3. Letter (D04143), E.J. Mroczka to L. Carothers, dated October 30, 1990
4. Letter (D05008), J.F. Opeka to T. Keeney, dated October 29, 1991
5. Letter (D05905), J.F. Opeka to T. Keeney, dated October 29, 1992
6. Letter (D06995), C.F. Sears to T. Keeney, dated October 21, 1993

Dear Commissioner Keeney:

Millstone Nuclear Power Station
Ecological Monitoring Program

Northeast Utilities Service Company (NUSCO), as agent for Northeast Nuclear Energy Company (NNECO), during October of the previous six years has presented to the Connecticut Department of Environmental Protection (DEP) an update on the status of the Millstone Nuclear Power Station (MNPS) fish return sluiceways (References 1 through 6). Attached is the Progress Report on the MNPS Fish Return System (Enclosure 1). It includes the results of a one-year study to determine the effectiveness of the MNPS Unit 3 Fish Return System as well as a summary of the number of days the MNPS Unit 1 Fish Return System has been out of service.

Over 90% of the organisms impinged at Unit 3 were returned to Long Island Sound via the fish return sluiceway and survival of most organisms returned was high, especially for demersal fish and crustaceans. No further studies of impingement at MNPS are presently planned. The MNPS Unit 1 fish return sluiceway may be taken out of service for relatively short periods due to high debris loads and subsequent re-impingement of returned material. The number of days the Unit 1 fish return was taken out of service in 1993 was 33; future summaries will be reported in forthcoming Annual Reports of Ecological Studies for MNPS. Any unusual impingement events at Unit 2 (more than 300 organisms in a 24-hr period) that occur will be reported to the DEP as per the annual study plan.

If you have any questions after reviewing this submission, please call Milan Keser, NUSCO Environmental Services Division, at (203) 444-4238.

Very truly yours,

Northeast Nuclear Energy Company

D. Miller
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Enclosure

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Aquatic Organism Return Feasibility Study

Millstone Unit 2

September 1999

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Executive Summary

This report presents the results of a feasibility study of design alternatives for returning aquatic organisms impinged at Millstone Unit 2 to Long Island Sound. The report consists of a review of historic impingement, a review of current technologies available to protect aquatic organisms at water intakes, a comprehensive review of selected alternatives, including an engineering evaluation, a biological evaluation, order of magnitude cost estimates, and a review of permits needed for construction of each alternative.

Available technologies include fish diversion systems, physical barriers, behavioral barriers and fish collection systems. Fish diversion systems include angled screens, modular incline screens, and angled bar racks. Physical barriers include dual-flow screens, wedge-wire screens, and submerged diversion sills. Various behavioral barriers, including strobe lights, air bubble curtains, sound, mercury light, electric screens, jet curtain and hanging chains, have been tested at cooling water intakes to divert fish. Fish collection systems including sluiceways and modified traveling screens have been used at a number of power plants. A review of available technologies revealed that fish collection systems have been most effective in improving survival of impinged aquatic organisms.

The four alternatives chosen for further investigation were all fish collection systems and include:

1. A sluice pipe that terminates on the rock outcrop between Units 1 and 2.
2. A sluice pipe that extends to the existing Unit 1 sluiceway.
3. Install Ristroph screens - as found at Millstone Unit 3 with sluice pipe.
4. Install Ristroph screens - as found at Salem Nuclear Power Station with sluice pipe.

After completing engineering and biological evaluations, a sluiceway that terminates on the rock outcrop between the Units 1 and 2 intake structures, as described in Alternative 1, is proposed. The proposed sluiceway is much shorter in length than Alternative 2; thus it is less likely to clog with debris and will return the organisms to the water more rapidly. Studies conducted near the Millstone Unit 2 intake revealed that after release only 5% of the winter flounder were reimpinged. The terminus of the sluiceway is proposed to be placed on the south side of the rock outcrop closer to the Unit 1 intake, which should further reduce reimpingement.

A comparison of results between two survival studies showed little difference in the survival of aquatic organisms impinged and returned at Unit 1 (85 psi sprayers) to Unit 3 (10 psi sprayers). These results has been observed at other power plants where hardy demersal fish, crabs and lobsters exhibit good survival. Based on these results, the existing spray wash system is proposed to be used to return organisms to the sluiceway. Along with the organisms, the debris will also be returned down the sluiceway, which will result in 100% return of all aquatic organisms to LIS.

After installation, a study of the survival of organisms returned via the Unit 2 sluiceway is proposed. The study is planned to be similar to those conducted at Millstone Units 1 and 3. Samples will be collected every other week for a one-year period. Aquatic organisms collected at the terminus of the sluiceway will be brought back to the NU Environmental Lab and held for a period of 72-h. Both initial and delayed mortality will be determined.

Section I. Introduction

This report presents the results of a comprehensive feasibility study of aquatic return design alternatives for the Millstone Unit 2 cooling water intake to reduce the effects of impingement of juvenile and adult aquatic organisms.

MNPS is situated on Millstone Point, about 8 km west-southwest of New London on the Connecticut shore of Long Island Sound (LIS). The property, covering an area of about 200 ha, is bounded to the west by Niantic Bay, to the east by Jordan Cove, and to the south by Twotree Island Channel. Strong tidal currents predominate in the vicinity of Millstone Point and influence the physical characteristics of the area. Average tidal flow through Twotree Island Channel is approximately 3,400 $m^3 \times sec^{-1}$ and at maximum is about 8,500 $m^3 \times sec^{-1}$. Current velocities are about 1 to 1.8 knots in the channel, slightly less (1 to 1.5 knots) near the plant and in Niantic Bay. The currents are driven by semi-diurnal tides that have a mean and maximum range of 0.8 and 1.0 m, respectively. The greatest temperature variation has been observed in nearshore areas where water temperature can vary from -3 to 25°C; salinity varies much less and ranges from 26 to 30‰. The bottom is generally composed of fine to medium sand throughout the area, but also includes some rock outcrops and muddy sand, especially near shore. Strong winds, particularly from the southwest, can at times result in locally heavy seas (to 1.5 m or greater) near Millstone Point.

Millstone Unit 2

Millstone Unit 2 is an 870-MWe pressurized water reactor that began commercial operation in December 1975. Cooling water is drawn from depths below about 1 m mean sea level by a shoreline intake located on Niantic Bay (Fig. 1). The intake structure, typical of many coastal power plants, has a curtain wall which extends below lowest mean water level, coarse bar racks that exclude debris and fish larger than 2-inches in size, and 3/8-inch mesh vertical traveling screens to prevent smaller fish and debris from entering the pump forebay. The curtain wall prevents warm surface water, ice and surface marine organisms from entering the intake. The intake has lateral fish passageways installed in the bay walls upstream of the traveling screens to allow fish to escape the screen faces. A typical intake section is shown in Figure 2. The intake structure contains four separate bays, designated from north to south as 'A', 'B', 'C' and 'D' Bays. The 'A' Bay contains the 'A' Traveling Screen, the 'A' Service Water Pump, and the 'A' Circulating Water Pump; the 'B' Bay contains the 'B' Traveling Screen, the 'B' Service Water Pump, and the 'B' Circulating Water Pump; the 'C' Bay contains the 'C' Traveling Screen, the 'C' Service Water Pump, the 'A' Screenwash Pump, and the 'C' Circulating Water Pump; the 'D' Bay contains the 'D' Traveling Screen, the 'B' Screenwash Pump, and the 'D' Circulating Water Pump.

The four circulating water pumps in the intake structure are rated at 137,200 gpm each, delivering a total maximum flow of 548,800 gpm (~1,220 cfs) cooling water to the condensers. The intake also contains three service water pumps, each rated at 12,000 gpm (~27 cfs) each. The water velocity approaching the traveling screen is about 0.8 fps (NNECO 1976).

The Unit 2 screenwash system operates automatically in accordance with the differential pressure (dp) across the traveling water screen. Instrumentation on each screen measures differential pressure between the upstream and downstream sides of the traveling screen and inputs to level switches that control the screenwash pumps. At 6 in. water dp, the selected screenwash pump motor autostarts and runs about 8 minutes while the traveling screen drive motors run in slow (5 fpm) speed (if screenwash water pressure is >50 psi); at 9 in. water dp, the traveling screen motors go into fast (20 fpm) speed; at 12" water dp, a high level alarm annunciates, and at 30" water dp the associated Circulating Water Pump trips. The traveling screens are vertical through-flow type manufactured by Stephens-Adamson (Fig. 3). The traveling screen drive motor is an Allis-Chalmers dual-speed unit, operating at either a rated load of 7.5 HP (during fast speed operation) or 1.875 hp (during slow speed operation). The screenwash pumps provide a rated flow of 1760 gpm each at 210 ft. head (approx. 93 psi) with a motor rated load of 125 HP, through a 10 in OD lined carbon steel header with five 6 in. take-offs, one for each of the traveling screens, and one for spraying down the trash trough to provide motive flow for sweeping the debris down the pitched trough to the trash basket pit outside the south side of the intake structure (NNECO 1976).

Impingement of Aquatic Organisms at Millstone Unit 2

Impingement at Millstone Unit 2 was intensively monitored to quantify losses and determine local species impacted beginning in September 1975, just prior to full-power operation (NUSCO 1987a). Monitoring at Unit 2 was discontinued in December 1987, when the CT DEP agreed that after 11 years of sampling, impingement losses had been well-documented and that further quantification was unnecessary.

Beginning in 1976, all impinged organisms were collected, identified, and counted daily over a 24-h period (Jacobson et al. 1999). In 1977, collection frequency was reduced to three 24-h samples per week and monthly impingement rates were estimated from the count data and actual water volumes. Within each month, an estimate for each day not sampled was calculated by multiplying the average impingement density (number·m^{-3} of cooling water used on days sampled) by the volume of cooling water on days not sampled. Monthly and annual impingement estimates were sums of daily impingement, either actual counts or estimated. A simulation data analysis showed that at this reduced level of effort, more than 85% of all impinged organisms were represented. Beginning in 1984, sampling effort was further stratified to increase the precision of impingement estimates for winter flounder and other fishes that were primarily taken during late winter, a period of high impingement. Sampling effort ranged from once weekly (April-November) to three (March) or four times per week (February).

Impingement rates at Unit 2 decreased following the removal of a coffer dam in 1983 that was in place during the construction of the Unit 3 intake structure. This coffer dam existed when Unit 2 began operating and it provided a reef-like habitat in the vicinity of the Unit 2 intake. Analysis of daily monitoring data revealed a significant ($p<0.01$) reduction in the average number of organisms impinged at Unit 2 after the coffer dam removal (NUSCO 1987a). A further decline in Unit 2 impingement was evident when Unit 3 began operating. Changes in water circulation patterns caused by the start-up of Unit 3 probably contributed to this decrease in impingement at Unit 2.

During the years that impingement sampling was conducted at Millstone Unit 2, over 100 taxa of marine organisms were collected. At Unit 2, an estimated 390,000 American sand lance were impinged during one 24-h sampling period in July 1984; this single event of sand lance impingement during 1984 accounted for nearly half of the total impingement from 1976 through 1987. Excluding the single sand lance impingement event, five fish taxa dominated impingement. These were the winter flounder, anchovies, grubby, silversides and Atlantic tomcod (Table 1).

In 1981, a study was conducted to determine the feasibility of backfitting the Unit 1 and Unit 2 intakes with fish return sluiceways (NUSCO 1981). As a result of this study, a sluiceway was constructed at Unit 1. A sluiceway at Unit 2 was deemed not prudent at the time because of recirculation concerns caused by its location between Units 1 and 3.

Available Alternatives

Biologists and engineers have conducted extensive research to develop methods to protect fish at water intakes. Throughout the design, construction and operation of MNPS, consideration was given to ways of reducing impingement. In earlier years of MNPS operation (early 1970's), devices tested to divert fish from the intakes included electric fish screens, fish barrier nets, acoustic devices, underwater lights, and surface and bottom booms. None of these devices was found to reduce impingement in any measurable and consistent manner. Research has been conducted since the early 1970's to develop technologies to lessen impingement effects. Available technologies include fish diversion systems, physical barriers, behavioral barriers and fish collection systems (Taft 1999).

Fish diversion systems include angled screens, modular incline screens, and angled bar racks. Angled screens are essentially modified traveling screens with a flush surface to guide fish to a bypass. These screens are not effective for fragile species and hardier species exhibit survival rates ranging from 50 to 100%. To employ angled screens, specific hydraulic conditions need to exist and high debris loading can cause problems. Modular incline screens consist of an entrance with trash racks, dewatering stop logs in slots, inclined screen set at a shallow angle, and a bypass. Studies to date have only evaluated applications at hydroelectric facilities. No full-scale facility has been constructed and operated at a steam electric plant. Angled bar racks have only been tested for migratory fish in rivers. No studies have been conducted to determine the potential use at cooling-water intake structures.

Physical barriers include dual-flow screens, wedge-wire screens, and submerged diversion sills. Dual flow traveling screens (single entry/double exit or double entry/single exit) have increased surface area for water filtration. The greater screen filtration area allows for lower through-screen velocities. Two dual flow traveling screens were installed at Calvert Cliffs Nuclear Power Plant. There was no difference in the survival rates of impinged fish between dual-flow and conventional traveling screens (LMS Engineers 1989). Wedge-wire screens are passive and use "V" or wedge-shaped cross section wire welded to a framing system to form a slotted screen. Ambient currents with high velocity cross-flow are needed to carry organisms away from screens. Wedge-wire screens have been successfully employed at two power plants: J.H. Campbell Plant Unit 3 on Lake Michigan and Eddystone Station Unit 1 on the Delaware River (NUSCO 1993). The flow rate, biofouling, detritus, and sand loads at MNPS are much higher than at either Campbell or Eddystone. The ambient flow velocities approach zero at slack tides and currents are variable with tide at MNPS, so that high velocity cross-flows necessary for screen flushing are not available. A submerged diversion sill is a V-shaped barrier on the bay floor that is constructed of Jersey-barrier concrete units about 6 feet high. This would have some potential of diverting some benthic organisms away from the plant. However, silt build up is a potential problem. Unless periodically dredged, the build-up of silt would render the sill ineffective as a diversion barrier. The effectiveness of the sill could only be determined by testing. The sill could disrupt existing water flows and possibly increase debris load and impingement and entrainment of organisms by attracting reef fish such as tautog and cunner.

Various behavioral barriers including strobe lights, air bubble curtains, sound, mercury light, electric screens, jet curtain and hanging chains have been tested at cooling water intakes to divert fish (Stone and Webster 1994). Air bubble curtains, water jet curtains, and hanging chains have all been found to be ineffective as fish protection measures (Micheletti 1988). Strobe lights, mercury lights and sound have worked to repel selected single species. High-frequency (120 Hz) sound had shown to effectively repel herrings (American shad, alewife, and blueback herring). However, other studies have shown that sound has failed in repelling largemouth and smallmouth bass, yellow perch, walleye, rainbow trout, gizzard shad, and bay anchovies. Mercury lights have been shown to be species specific with some fish being repelled and others being attracted. Behavioral barriers have shown some limited success for specifically targeted species. However, considering that over 100 different species have been recorded at the MNPS intakes, they would most likely be of little value here.

Fish collection systems have been shown to improve fish survival. Modified traveling screens or "Ristroph screens" have been successfully used at a number of power plants, including Salem Station, Delaware River, N.J.; Indian Point, Hudson River, N.Y.; Surry Station, James River; Oyster Creek, Barnegat Bay, N.J.; Brayton Point, Mt. Hope Bay, MA.; and Millstone Unit 3. Each screen basket is equipped with a water-filled lifting bucket which safely contains collected fish as they are carried upward with the rotation of the screen. Fish are then washed from the buckets into a collection trough and are transported to a safe release location.

A review of available technologies (Taft 1999) revealed that collection systems have been most effective in improving survival of aquatic organisms. As such, the four alternatives selected for further investigation were all fish collection systems and include:

1. A sluice pipe that terminates on the rock outcrop between Units 1 and 2.
2. A sluice pipe that extends to the existing Unit 1 sluiceway.
3. Install Ristroph screens - as found at Millstone Unit 3 with sluice pipe.
4. Install Ristroph screens - as found at Salem Nuclear Power Station with sluice pipe.

Permitting

The following discusses potential environmental permits and approvals required for proposed Unit 2 aquatic organism return design alternatives:

State of Connecticut Permits and Approvals

Written CT DEP Bureau of Water Management approval/concurrence with the selected design alternative is required in accordance with terms and conditions of Millstone Station's NPDES Permit. Permit determinations may be required under various Connecticut General Statutes (CGS) and regulations. Discussions will be held with the department to determine the applicability of such statutes and regulations.

For example, all alternative designs may require NNECO to submit a Permit Application for Structures, Dredging and Fill under Connecticut General Statutes (CGS) 22a-361 to the CT DEP Office of Long Island Sound. CT DEP authorizations for activities in the states coastal area include an evaluation by the Office of Long Island Sound Program regarding consistency and concurrence with the coastal zone management program. However, while a structures, dredging and fill permit may be required prior to conducting work waterward of the high tide line in tidal, coastal, or navigable waters of the State, none of the alternatives propose work waterward of the high tide line.

Alternative #2 proposes to build a Unit 2 fish return which ties into the Unit 1 sluiceway. Unit 1 has a Section 22a-361 Certificate of Permission (No. 199802106-KZ) which was issued on October 4, 1998 authorizing the installation of the Unit 1 metal sluice pipe and support saddle. Work conducted on the Unit 1 sluiceway, other than routine maintenance (as defined in the Permit and CGS 22a-363(a)) may require an amendment to the COP.

Department of the Army

This project may be eligible for General Permits as authorized by the New England District of the U.S. Army Corps of Engineers. The Army Corps of Engineers issues a Programmatic General Permit (PGP) which expedites the review of minimal impact work in coastal and inland waters within the State of Connecticut. Category I projects are eligible without screening, and non-reporting. Category II requires a determination of eligibility made during a review /screening meeting by the Corps, Federal Resource Agencies, and the CT DEP. Discussions will be held with the Department relative to 401 Certification and the Army Corp. regarding PGP eligibility.

Local Government Permits

NNECO will forward copies of any Permit Application submitted to the Town of Waterford Planning and Zoning Office, Conservation Commission, Harbor Management Commission, and Shell Fish Commission to request that each office or commission review the project to determine whether the work is regulated by the Town of Waterford.

Costs
A cost of about $1,400,000 is estimated for either Alternative 1 or Alternative 2.

Alternatives 3 and 4 are somewhat similar in nature. Piping costs would be the same as Alternatives 1 and 2 ($1,400,000). An additional cost for screen modifications of $3,500,000 is estimated for either Alternatives 3 or 4.

	Sluiceway Pipe	Screen Modifications	Total Cost
Alternatives 1	$1,400,000	N/A	$1,400,000
Alternatives 1	$1,400,000	N/A	$1,400,000
Alternatives 3	$1,400,000	$3,500,000	$4,900,000
Alternatives 4	$1,400,000	$3,500,000	$4,900,000

Section II. Aquatic Return - Conceptual Review of Selected Alternatives

Alternative 1

Engineering Evaluation

Brief Description of Option:

Construct a trough or pipe from the existing Unit 2 trash basket trough through the security fence terminating in a sluiceway that runs along the western seawall and discharges from the rock outcrop between Units 1 and 2 (Fig. 4).

Technical Feasibility of Option:

There were two design considerations evaluated for this alternative. The adaptability of the existing screenwash system to support flow rates required to provide the motive force necessary to wash both the aquatic organisms and any other debris back out to the Niantic Bay was the primary consideration. A second consideration was that of preventing reimpingement of aquatic organisms and recirculation of detritus. Based on the screenwash system design flows, an estimated sluiceway flow rate of 1320 gpm would be expected, since approximately 25% of the screenwash spray is lost back into the intake bays. This flow is more than sufficient for moving debris and aquatic organisms down the additional 150 ft. length of sluiceway piping. The sluiceway is proposed to be added adjacent to the trash pit at the exit of the trash trough and will consist of 15 in. OD smooth-walled lined steel or fiberglass piping with large radius elbows and a slope of approximately 0.01 ft/ft along the flattest run, and then a slope of approximately 0.40 ft/ft at the chute end. A diverter plate will also be installed between the sluiceway and the trash pit and positioned to place the new sluiceway or the trash pit in service.

Heavy debris loading may result in operational difficulties if recirculation becomes a large problem. This is an important consideration from the standpoint of having increased debris loading on the screens in the bays that provide water to the safety-related service water pumps, which would increase the probability of a loss of service water. However, the greatest risk of fouling due to recirculation would be at the 'D' intake bay, which contains the 'B' Screenwash Pump, but no safety-related service water pump. The Salem Station solved its recirculation problem by having two sluiceway discharges, one on each side of the intake structure, with a manual diversion valve to direct the sluiceway discharge in accordance with tidal conditions; i.e., discharge to the south side of the plant when the tide is going out, and to the north side of the plant when the tide is coming in. With Unit 1 no longer operating, this would be acceptable when the tide is going out, but not when the tide is coming in due to Unit 3's intake being to the north and west of the Unit 2 intake. Thus the Unit 2 sluiceway discharge to the north would have to be extended just beyond the northwest side of Unit 3's intake. Clearly the extent of excavation makes this dual-discharge sluiceway design impractical for application at Unit 2.

A diversion plate design is proposed for any sluiceway at Millstone Unit 2 to allow operational flexibility. This diverter plate could be used during heavy debris loading conditions and would be designed to transfer debris into trash baskets instead of the sluiceway, if conditions threaten the safe operation of the plant.

Scope of Modifications:

The scope of the modifications would be performed under the oversight of security, as the protected area barrier will be breached during the proposed construction process, and compensatory actions will be required. A new screenwash trench/sluiceway would be cut into the existing intake structure exterior concrete slab and covered with checkered plate properly secured to meet security requirements. In addition, the intake structure exterior concrete slab would be cut to accommodate the new sluiceway diverter and cover plates. A transition piping section will be utilized to connect the rectangular cross section at the exit of the screenwash trough with the sluiceway piping. This enables the sluiceway to be unbolted from its pipe hangers and removed in the future, if necessary, to unclog or perform other maintenance of the sluiceway piping. The sluiceway would also be connected together as three flanged piping sections to enable any of the sections to be removed for maintenance. The sluiceway piping will be attached to the seawall and then elbow out at a 45° angle to the end of the outcropping of rock between Units 1 and 2.

Biological evaluation

The proposed aquatic organism return is similar to the sluiceway employed at Unit 1 since December 17, 1983. After the installation of the Unit 1 aquatic organism return, a study to examine the survival of fish and invertebrates using the sluiceway was conducted from January 1984 through July 1985 (NUSCO 1986). Twenty-three samples were taken in the sluiceway pipe in the early morning. To collect organisms, a net was placed in the sluiceway pipe and all organisms and material entering the sluiceway were collected during a 20-min wash cycle. The net was emptied periodically. Specimens were returned to the laboratory and held in tanks with running seawater for up to 72 hours. Dead organisms were removed and measured, following the initial collection period, and after 6 and 24 h. After 72 h all organisms were removed, measured and live organisms were released. Any individual that looked stressed was recorded as dead.

Forty-five species of fish and nine macroinvertebrates were collected in sluiceway samples. Numerically, 1,356 specimens were collected during the study. Survival of each species was calculated based on the proportion of specimens alive at 6-, 24- and 72-h observations (Table 2). For some survival estimates species were assigned to three groups, pelagic (18 fish species), demersal (27 fish species), and crustaceans (8 crabs and lobsters). The Atlantic long-finned squid was placed in its own group because it is fragile and difficult to keep alive following collection. These groupings were based on habitat and body types. Free-swimming fish such as herring, Atlantic silversides and butterfish were considered pelagic, bottom fish such as sculpins and flounders as well as those with armored or hard integument such as sticklebacks and northern pipefish were classified as demersal.

The demersal and crustacean groups had the greatest survival with overall survival rates of 77 and 71%, respectively. Few pelagic fish survived impingement and sluiceway passage. No Atlantic long-finned squid survived impingement. These results were compared to other northeastern Atlantic coastal or estuarine power plants in Bowline, NY, Brayton Point, MA, Danskammer Point, NY, Oyster Creek, NJ, Pilgrim, MA, and Roseton, NY (NUSCO 1986). Although sampling methods and plant operational characteristics differed among the plants, the overall findings were similar. Generally, pelagic fishes had relatively high mortality whereas demersal fishes and crustaceans had good survival.

From 1981 to 1983, 299 tagged winter flounder were released near the proposed terminus of Alternative 1 (NUSCO 1986). Of these, 198 were fish that had been captured by trawl and 101 were fish that had been collected alive in impingement samples. Fifteen of these fish (5%) were subsequently re-impinged and 17 were recaptured by sport and commercial fisheries. On only one occasion were more than two tagged fish impinged. This occurred after the June 3, 1981 release, when nine fish out of 89 released were recaptured. These were the only fish that had been released at night.

No seaweed recirculation study has been conducted at Unit 2. However a study done at Unit 3 where the sluiceway terminus is located against the wall of the intake structure revealed out of 440 pieces of seaweed marked with a biodegradable material, 10 pieces (2%) were recirculated back to the Unit 3 intake.

Alternative 2

Engineering Evaluation

Brief Description of Option:
Extend a pipe from the intake trash basket pit, running along the western seawall between the Units 1 and 2 Intake structures, around the Unit 1 Intake structure, then tap into the existing Unit 1 sluice pipe with a wye connection, subsequently emptying back into Niantic Bay (Fig. 4).

Technical Feasibility of Option:

The same two design considerations as those for Alternative 1 were evaluated. The adaptability of the existing screenwash system to support flow rates required to provide the motive force necessary to wash both the aquatic organisms and any other debris back out to the Niantic Bay was one consideration. The second consideration was that of preventing reimpingement of aquatic organisms and seagrass back onto the screens after having returned them once back to the bay.

The screenwash flow of approximately 1320 gpm is sufficient for moving debris and aquatic organisms down the additional 375 ft. length of sluiceway piping at a slope of approximately 0.004 ft/ft. After joining the Unit 1 sluiceway header, the combined sluiceway will run at about a 0.008 ft/ft slope and empty into the existing Unit 1 sluice pipe. However, the additional elbows, the additional length and the reduced pitch of the piping run increases the likelihood of the sluiceway becoming more frequently clogged, possibly requiring frequent maintenance.

Scope of Modifications:

The modifications would be performed under the oversight of security, as the protected area barrier would be breached during the proposed construction process, and compensatory actions would be required. A new screenwash trench/sluiceway would be cut into the existing intake structure exterior concrete slab and covered with checkered plate properly secured to meet security requirements. In addition, the intake structure exterior concrete slab would be cut to accommodate the new sluiceway diverter and cover plates. A transition piping section would be utilized to connect the rectangular cross section at the exit of the screenwash trough with the sluiceway piping. This would enable the sluiceway to be unbolted from its pipe hangers and removed in the future if necessary to unclog or perform other maintenance of the sluiceway piping. The sluiceway piping would be run along the west face of the Unit 1 intake structure, and then tied into the Unit 1 sluiceway at a wye connection at the proper elevation to enable adequate flow by gravity. This point may be either inside or outside the protected area fence, and would require additional excavation and the temporary removal of the Unit 1 sluiceway from service during installation of the wye connection as well as the final tie-in. The newly installed Unit 1 sluice pipe would be common to both Units 1 and 2.

Biological evaluation

Alternative 2 is similar to Alternative 1 except the sluiceway terminus would be further away from the Unit 2 intake. Locating the sluiceway terminus away from the Unit 2 intake would prevent potential recirculation of fish and seaweed which is described in Alternative 1.

Alternative 3

Engineering Evaluation

Brief Description of Option:
Retrofit Ristroph-type fish baskets at the base of each traveling screen panel, similar to that of the Unit 3 traveling screens, add a low pressure (10 psi) fish spray header below the existing (85 psi) high pressure screenwash spray header, and convert the existing fish/debris wash trough to a "fish only" wash trough, emptying into a new sluiceway designed per Alternative 1 or 2 (Fig. 5). Add a "debris only" wash trough above the fish wash trough that either empties into the new sluiceway or can be diverted to the existing trash basket pit, depending on debris loading.

Technical Feasibility of Option:

Although Unit 3 was designed and built with Ristroph-type fish baskets noted above, the initial rate of return of organisms was less than 50%. Additionally, debris loading caused numerous forced outages. The Unit undertook a complete redesign and retrofit of the traveling screen/screenwash system. While the best available technology at the time was utilized, there were also lessons learned from that experience that enable better assessment of which design attributes provided the greatest benefit. The design attributes specifically evaluated to be of greatest benefit were the addition of non-metallic fish buckets, and the screen material change from coated carbon steel to uncoated stainless steel.

The Unit 3 Traveling Screen/Screenwash design separates aquatic organisms from other debris and discharges them to the northwest of Unit 3 intake structure. Debris is discharged to the southeast of the intake into a trash hopper. During normal operations, the average water velocity through each intake bay is approximately 0.79 ft/sec, slightly less than the average water velocity through each Unit 2 intake bay, which is approximately 0.81 ft/sec. As the traveling screen rotates, a low pressure (10 psig) spray header moves fish and other aquatic organisms into the lower fish trough. As the traveling screen rotates upward, the high pressure (85 psig) spray header washes seaweed, kelp and other debris into the upper debris trough, discharging it to the trash basket pit/conveyor debris removal system. The traveling screens consist of screening panels about 14 ft wide by 2 ft high with 3/8 in. mesh stainless steel cloth.

Discussions were held with a project engineer at Envirex, the manufacturer of the traveling screens, who has been involved in many retrofit/upgrade projects (including Salem Station and to a lesser extent, Unit 3). These discussions have enabled the scope of modifications to be more clearly identified to incorporate the beneficial design attributes of the Unit 3 design into the existing Unit 2 traveling screen/screenwash system design.

To make more space available for the addition of an upper debris trough, the traveling screen head sprocket assembly would have to be raised an additional 2 feet. This would require 4 additional links of chain, and two additional screen panels. The upper trough would have to be positioned such that the high pressure screenwash spray would clean off any debris, such as eelgrass and kelp, from the screen, washing it off into the upper trough, and sending it to the sluiceway or trash basket. The existing high pressure screenwash spray header may require repositioning at a higher elevation to ensure the proper spray angle is maintained to minimize carryover of debris. The existing lower debris trough would be utilized to transport the aquatic organisms removed with a newly installed low pressure spray header to the sluiceway. This low pressure header would be added to the existing high pressure screenwash system but would be reduced in pressure through the use of pressure reducing valves or a series of orifices (similar to the Unit 3 design). It is anticipated that sufficient flow capacity margin exists in the screenwash system to accommodate this additional flow requirement; however, additional analysis will be required to verify this. As with the Unit 3 design, non-metallic screen panels would be utilized and will be an integral part of the screen panel assembly (Fig. 6). In addition, the coated carbon steel mesh cloth would be replaced with 304 or 316 SS mesh, with a 3/8 in. square pitch. The material change would enable the screens to remain uncoated, thus reducing the maintenance costs associated with coating and re-coating them.

Scope of Modifications:

The scope of modifications would consist of removing and replacing the existing screen wash spray hoods; removing and replacing the screen panels outfitted with SS mesh and new fish buckets, reworking the screen panel mounting configuration; remove and replace the chain drive, adding two additional links; and raising the head sprocket assembly by approximately 2 feet.

Biological evaluation

In December 1993, NUSCO completed a 1-yr evaluation of the efficiency of the Unit 3 system in separating aquatic organisms from debris and a study to examine the mortality of returned fishes and invertebrates. Samples were taken biweekly from January 1993 through December 1993. Sampling was conducted in early morning shortly before dawn, as most impingement occurs at night. Before a sample was collected, the traveling screens were washed to clean them of previously accumulated debris and organisms and then were not allowed to rotate or wash for about 2-3 h. On three occasions, high differential water level due to debris loading caused the screens to run continuously and samples were taken during a 40-min period.

Organisms were simultaneously collected from both the sluiceway and debris troughs. To collect organisms from the sluiceway, a net was attached at the end of the sluiceway pipe. The screens were rotated and cleaned and as material accumulated in the sampler during the approximate 40-min wash cycle, the net was emptied about every 5 min. During the same time, organisms were counted at the discharge of the debris conveyor system. Live organisms collected from the sluiceway were returned to the laboratory and held in tanks with running seawater for up to 72 hrs. Observations were made at 6 and 24 h following collection and dead organisms were removed. Any specimen with obvious injuries or exhibiting aberrant behavior at the final 72-h observation was classified as dead.

A total of 24 samples were taken during the study period and 32 species of fish and 11 macroinvertebrates were taken in sluiceway and debris trough collections. The numbers of fish and macroinvertebrates collected from the sluiceway trough were compared to the numbers collected from the debris trough to determine the efficiency of the sluiceway. The percent efficiency averaged 93% for all specimens collected. The percent efficiency averaged 96% for fishes and 86% for macroinvertebrates.

Organisms collected from the sluiceway were held in the laboratory for 72 h to determine their survival. In general, demersal fish and crustacean groups had the greatest survival. Although more than half of the pelagic fish and squid survived impingement and sluiceway passage, most died within the 72-h holding period (Table 3).

The eleven most abundant species collected in the study had varying rates of survival, depending on their body type. Over 40% of the Atlantic long-finned squid initially survived impingement, but only 6% survived the 3-d holding period. This species is fragile and in previous studies most did not survive initial impingement and none survived a 72-h holding period (NUSCO 1982, 1987). Atlantic silverside, Atlantic herring, and butterfish are all pelagic species and none survived the holding period. However, most of the three abundant demersal fish species survived impingement and had high 3-d survival rates: winter flounder (94%), grubby (86%), and threespine stickleback (86%). All of the five dominant crustaceans had high survival rates, which ranged from 71% for the lady crab to 100% for the American lobster. In general, only crustaceans that were molting when impinged suffered high mortality. Survival of most organisms classified as demersal and crustaceans exceeded 80%. These groups include the commercially and recreational important winter flounder and American lobster.

The survival of impinged organisms at Unit 3 where 10 psi is used to wash organisms from the screens were similar to the survival at Unit 1 where 85 psi was used (Table 4). Only three species: American lobster, northern pipefish, and cunner had higher survival at Unit 3 than Unit 1. A high proportion of molting lobsters was collected during the Unit 1 sluiceway study, which could have accounted for the difference in the survival rates for that species. Many survival rates were similar, regardless of spray wash pressure, indicating that the process of impingement on the traveling screens alone may be the cause of much of the mortality.

Alternative 4

Engineering Evaluation

Brief Description of Option:

Retrofit new traveling screen assemblies and upgrade the screenwash spray system to incorporate the specific design features. This new design would replace the existing screen panels with hydraulically improved fish buckets integral to the bottom support member; change the basket frame material to a lighter non-metallic composite material; change the existing 3/8" square basket mesh size to a smooth woven mesh screen with a ¼" x ½" rectangular mesh size; upgrade screen drive motor and gearbox to enable increased screen rotational speed; add low pressure screenwash spray headers and fish trough to the east side of the screens to facilitate the "over-the top" Ristroph basket fish removal concept; reposition the high pressure screenwash header so as to spray off the debris from the back side of the screen, directing the debris to the existing trash basket pit (Fig. 7). The fish trough will be designed to empty into a new sluiceway designed per Alternative 1 or 2.

Technical Feasibility of Option:

The design objective of the most recent upgrade of the screenwash/traveling screen systems at the Salem Station was to improve the survivability of fragile aquatic organisms. Reducing turbulent flow in the fish buckets, transferring the fish gently from the fish buckets to the fish trough, and reducing fish descaling during the impingement and removal process were concepts incorporated into the design. Additional operational considerations included improving the debris handling capability during peak debris loading conditions.

The general conceptual design of the Ristroph traveling screen panels incorporates a fish bucket that is integral to the bottom flange of each individual screen frame. The lip of this bucket curves inward, forming a fish "sluice" on each screen panel (Figs. 8 and 9). As the screen rotates upward out of the water, any otherwise impinged fish or aquatic organisms are retained in this bucket until the individual basket panel rounds the top sprocket of the traveling screen assembly. At that time, the bucket empties its contents across the basket screen face, with the assistance of two inside low pressure spray headers and one outside low pressure spray header. The fish and other aquatic organisms are washed into a fish trough which in turn empties into a fish sluiceway and returned to the original body of water. The fish sluice trough would be made of smooth fiberglass, is rectangular in shape with 6 in. radius rounded corners at the bottom, and its dimensions are 30 inches wide and 18 inches deep, and provides at least 3 in. of water depth while the fish are being transferred. This is an optimum fish sluice trough design as recommended by Fletcher 1990. As the screen panel continues further down the back side of the traveling screen, two inside high pressure spray headers clean seaweed and other remaining debris from the screen and wash it into the trash trough which at Salem Station is then diverted back to the Delaware River in the direction of the tide to prevent reimpingement.

The non-metallic panels are made of a strong composite material in place of the existing steel in the construction of the panels. This allows the use of smaller sized stainless steel wire for the screen mesh and a smoother screen weave pattern. These changes increase the open area by 20-25% and, as a result, reduce the velocity of water flowing through a unit area of screen mesh. This reduction in velocity decreases the force an aquatic organism experiences while impinged onto the screen and opens up more flow area for screening debris. Mounting and structural hardware for the fish basket have been relocated from the front of the screen to behind the new screen mesh weave. This, in conjunction with the smooth weave pattern, has resulted in a smooth, contiguous screen surface that eliminates obstacles that not only cause biological damage to fish, but also inhibits the efficiency of debris removal. These new screen assemblies could increase the ease of debris removal from the screen basket panels, while also reducing debris carryover to the circulating and service water system. In addition, the use of lighter composite materials would enabled the screen rotational speed to be increased from a maximum of 17.5 fpm to 35 fpm, which greatly enhances debris removal capability. Unit 3 had also increased their traveling screen carriage speed to resolve seasonal debris loading problems, and currently have 4 speed screens based on increasing screen dP (5 fpm for a 6 in. dP, 10 fpm for a 7"dP, 16 fpm for a 9"dP, 32 fpm for a 10"dP). For comparison, Unit 2 has only two speeds, 5 fpm for a 6"dP, and 20 fpm for a 9"dP. By doubling the maximum speed during high debris load periods, the traveling screen unit has less debris on each screen, permitting the spray wash system to be more effective in assisting fish removal to the fish sluice trough and debris removal to the debris sluice trough. This minimizes fish and debris bypassing the troughs and the carry-over of debris to the condenser. In addition, the debris filtration capability was increased, which resulted in maintaining lower dP across the basket screen surfaces during periods of high debris loading. (Ronafalvy et al. 1999)

Several design considerations were evaluated. The two-trough system, i.e. one fish trough and one debris trough located on the back side of the traveling screen, requires additional height of the screen assembly, as in Alternative 3. In conjunction with this, two additional screen panels and two additional chain drive links would be required. With much less physical room on the back side of the screen assembly, extensive modifications to the rear splash housing are required. The screenwash system capacity would have to be increased. With the Unit 3 screens the same physical size as Unit 2's, the screenwash flow capacity would be approximately 2/3, since Unit 3 has six bays whereas Unit 2 has only four bays. Thus, two-thirds of the 4000 gpm required for Unit 3 for slow speed screen operation and 8000 gpm for fast speed operation would equate to approximately 2666 gpm for Unit 2 at slow speed screen operation and approximately 5333 gpm for fast speed screen operation. Clearly, 1760 gpm flow from each existing Unit 2 screenwash pump would be insufficient. In addition, the screen drive motors would more than likely have to upsized to a larger horsepower motor if increased rotational speed was desired for heavy debris loading conditions.

Scope of Modifications:
The scope of modifications would consist of removing and replacing the existing screen wash spray hoods with prefabricated ones that could accommodate the two-trough system on the back side of the traveling screens; removing and replacing the screen panels outfitted with smooth SS mesh and new Ristroph style fish baskets, reworking the screen panel mounting configuration; removing and replacing the chain drive, adding two additional links; raise the head sprocket assembly by approximately 2 feet. The screenwash pumps would also need to be upgraded.

Biological evaluation

Salem Nuclear Power Station is located on the shores of the Delaware River and fish assemblages there differ from those found at Millstone. Unlike Millstone, where the dominant species are hardy, demersal fish or crustaceans, the most abundant fishes at Salem are more delicate pelagic species that do not survive impingement as well. To enhance survival of these fragile fish, a number of improvements were made to their Ristroph traveling screens, including using hydraulically improved the fish baskets (Fletcher 1990), placing the fish trough on the back of the screen, and using smooth stainless steel mesh screen panels (Rovafalvy et al. 1999). These improvements enhanced survival of the dominant fish species at Salem. Initial and delayed (48

h) survival studies were conducted for the six most abundant species at Salem (Table 5). Survival ranged from 18% to 98% for the dominant species (Salem 1999).

As noted above, a comparison of survival of organisms impinged at MNPS showed little difference in the survival of fish wash off the traveling screens at 10 psi (Unit 3) compared to 85 psi (Unit 1).

Section III. Selection of Final Option

A number of considerations were included in the selection of a preferred alternative. The survival rate and return rate of the aquatic organisms, reimpingement and recirculation of debris, the potential of the pipe to clog with debris, as well as the time frame to complete the project were considered during the final selection process. After considering these factors, Alternative 1 (a sluiceway that terminates on the rock outcrop between the Units 1 and 2 intake structures) was selected.

A comparison of results between two previously described survival studies showed little difference in the survival of aquatic organisms impinged and returned at Unit 1 (85 psi sprayers) as compared to Unit 3 (10 psi sprayers). This is important as the Unit 1 sluiceway is comparable to Alternative 1 and the Unit 3 fish return was the basis for Alternative 3 (also similar to Alternative 4). Corresponding results have been observed at other power plants where hardy demersal fish, crabs and lobsters exhibit good survival. Based on these results, the existing spray wash system is proposed to be used to return organisms to the sluiceway. Returning both the aquatic organisms and the debris down the sluiceway, as is done at Unit 1 (Alternatives 1 and 2), will result in 100% return of all aquatic organisms to LIS. Separating the organisms from the debris, as is done at Unit 3 (Alternative 3 and 4), would result in return rates less the 100%.

Previous studies have also revealed that only 5% of the winter flounder were reimpinged when released in front of the rock outcropping between Units 1 and 2. The terminus of the Alternative 1 sluiceway is located even farther away from the Unit 2 intake, on the south side of the rock closer to the Unit 1 intake (see Fig. 4), which substantially reduces the likelihood of reimpingement. The proposed sluiceway is shorter than Alternative 2; thus, it is less likely to clog with debris.

Consideration has also been given to the fact that Alternatives 1 and 2 can be constructed and became operational in a matter of months, permitting notwithstanding, while it would take several years to complete the screen modifications associated with Alternatives 3 and 4. Any screen modifications would result in the total rebuild of each traveling screen unit. To accommodate new fish buckets and additional troughs, each traveling screen would need to be elevated at least 2 feet. New motors, chains and associated hardware would also be needed. A traveling screen rebuild was undertaken at Unit 3; this project was completed over several years. Installation of Alternative 1 would not preclude more extensive screen modifications in the future, if necessary.

A detailed construction schedule is outlined in Table 6. Currently, final design work and material procurement is planned for October 1999. Pending DEP approval, construction is proposed to occur in early to mid-November 1999, weather permitting. A survival study is proposed to begin upon installation of the sluiceway. The study is proposed to be similar to those conducted at Units 1 and 3 (NUSCO 1986, 1987b, 1994). Samples will be collected every other week for a one-year period. Aquatic organisms collected in the sluiceway will be brought back to the NU Environmental Lab and held for a period of 72-h. Both initial and delayed mortality will be determined.

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Table 1. Annual impingement estimates for fish taxa impinged at MNPS Unit 2 from January 1, 1976 through December 11, 1987.

Fish

Taxon	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Total
Sand lance	46	20	239	59	168	223	81	161	5E+05	73	42	8	486531
Winter Flounder	2783	4604	3184	10077	3576	6207	2735	6213	2542	2769	1049	624	46363
Grubby	1027	1299	3980	1721	9167	3262	2671	7023	2359	4621	1427	647	39204
Anchovy	848	177	774	2508	4073	3722	4085	12726	4200	342	38	12	33505
Silversides	853	503	2292	3319	8676	2769	800	3759	1042	1484	511	136	26144
Atlantic tomcod	45	86	1956	768	1213	2809	10302	2264	4938	1130	8	206	25725
sticklebacks	1533	3609	3480	2241	6710	5883	1188	4638	1055	859	921	572	15116
Northern pipefish	559	260	875	425	766	1417	557	3503	1467	460	858	748	11895
butterfish	114	122	233	1091	781	1416	2414	465	1455	1337	1406	946	11780
cunner	357	598	1399	1656	751	883	1787	694	1188	466	57	642	10478
Total (top ten)	8156	11278	18412	23865	35881	28591	26620	41446	5E+05	13541	6317	4541	706741
Total (others)	3921	3399	3569	3403	4941	6045	6125	18964	5730	2819	3882	4019	84381
Total (all)	12077	14677	21981	27268	40822	34636	32745	60410	5E+05	16360	10199	8560	7911222

Invertebrate

Taxon	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Total
Lady crab	1402	2289	1831	4708	14224	13054	23194	4876	4118	2838	1552	1343	75429
Atlantic squid	5095	1257	2430	10763	11083	7895	6846	2779	14748	3298	1912	1491	69597
rock crab	457	389	442	438	560	3919	5179	4036	6680	4456	6264	2365	35185
green crab	425	408	368	408	670	2339	1532	4311	5647	2727	2960	1571	23366
blue crab	564	193	499	945	927	964	1120	468	1020	733	621	988	9042
lobster	663	308	261	402	392	1043	1032	458	1167	505	549	825	7605
spider crab	1244	205	93	91	124	516	475	887	1484	407	689	283	6498
mud crab	0	13	16	13	18	104	362	288	1496	244	373	186	3113
horseshoe crab	281	11	17	54	46	152	86	10	164	0	41	275	1137
hermit crab	227	37	8	4	88	38	14	11	12	7	83	54	583
Total (top ten)	10358	5110	5965	17826	28132	30024	39840	18124	36536	15215	15044	9381	231555
Total (others)	65	47	15	79	46	46	108	115	49	10	7	65	814
Total (all)	10423	5157	5980	17905	28340	30070	39948	18239	36585	15225	15051	9446	232369

Table 2. Percent initial and extended survival and species groups of fishes and macroinvertebrates taken in the MNPS Unit 1 Sluiceway from January 1984 through July 1985.

Species	Common Name[a]	Species Group[b]	Number Examined	Initial Survival	Survival at 6h	Survival at 24h	Survival at 72h
Alosa aestivalis	blueback herring	P	6	0	0	0	0
Alosa pseudoharengus	alewife	P	8	0	0	0	0
Ammodytes sp.	sand lance	P	2	0	0	0	0
Anchoa mitchilli	bay anchovy	P	28	0	0	0	0
Anguilla rostrata	American eel	D	1	100	100	100	100
Astroscopus guttatus	northern stargazer	D	1	100	100	100	100
Brevoortia tyrannus	Atlantic menhaden	P	4	100	75	25	0
Callinectes sapidus	blue crab	C	7	86	86	86	86
Cancer irroratus	rock crab	C	12	92	92	92	92
Caranx hippos	crevalle jack	P	1	0	0	0	0
Carcinus maenus	green crab	C	39	82	77	67	62
Centropristis striata	black sea bass	D	1	100	0	0	0
Clupea harengus	Atlantic herring	P	1	0	0	0	0
Cyclopterus lumpus	lumpfish	D	9	89	67	56	56
Dorosoma cepedianum	gizzard shad	P	1	0	0	0	0
Enchelopus cimbrius	fourbeard rockling	D	1	0	0	0	0
Etropus microstomus	smallmouth flounder	D	2	50	50	50	50
Fundulus heteroclitus	mummichog	D	3	100	100	67	67
Gasterosteus aculeatus	threespine stickleback	D	217	95	93	92	91
Gasterosteus wheatlandi	blackspotted stickleback	D	184	91	90	89	86
Homarus americanus	Northern lobster	C	8	38	38	38	38
Lactophrys spp.	trunkfish	D	1	100	100	100	100
Libinia spp.	spider crab	C	7	71	71	71	71
Liparis spp.	snailfish	D	1	100	100	100	100
Loligo pealei	Atlantic long-finned squid	—[c]	416	0	0	0	0
Lophius americanus	goosefish	P[d]	9	0	0	0	0
Menidia menidia	Atlantic silverside	P	13	54	15	8	0
Merluccius bilinearis	silver hake	P	6	0	0	0	0
Microgadus tomcod	Atlantic tomcod	D	26	35	35	27	27
Morone americana	white perch	P	1	0	0	0	0
Mugil cephalus	striped mullet	P	1	0	0	0	0
Myoxocephalus aenaeus	grubby	D	74	87	78	76	74
Neopanope texana	mud crab	C	3	100	100	100	100
Ophidion marginatum	striped cusk-eel	D	2	100	50	50	50
Opsanus tau	oyster toadfish	D	2	100	100	100	100
Osmerus mordax	rainbow smelt	P	3	33	0	0	0
Ovalipes ocellatus	lady crab	C	21	95	91	86	81
Pagurus pollicaris	hermit crab	C	1	100	100	100	100
Peprillus triacanthus	butterfish	P	104	1	0	0	0
Pholis gunnellus	rock gunnel	D	1	100	100	100	100
Pollachius virens	pollock	D	1	0	0	0	0
Pomatomus saltatrix	bluefish	P	3	33	33	0	0
Prionotus carolinus	northern searobin	D	1	0	0	0	0
Prionotus evolans	striped searobin	D	1	100	100	100	100
Pseudopleurenectes americanus	winter flounder	D	44	93	91	89	86
Pungitius pungitius	ninespine stickleback	D	1	100	100	100	100
Raja spp.	skate	D	11	100	100	100	82
Scophthalmus aquosus	windowpane	D	3	100	100	100	100
Selene vomer	lookdown	P	4	0	0	0	0
Sphyraena borealis	northern sennet	P	1	0	0	0	0
Sphoeroides maculatus	northern puffer	D	3	100	100	100	67
Syngnathus fuscus	northern pipefish	D	49	55	45	33	16
Tautogolabrus adspersus	cunner	D	5	20	20	20	20
Urophycis tenuis	white hake	D	1	0	0	0	0

[a] Fishes from Robins et al. (1980) and invertebrates from Gosner (1971)
[b] 'C' Indicates crustaceans, 'D' demersal fishes, and 'P' pelagic fishes
[c] Treated separately during analyses
[d] Pelagic prejuvenile stage of development

Table 3. Millstone Unit 3 Sluiceway survival by species following various holding periods.

Species	Common Name	Body Type Group[a]	Number Examined	(%) Initial Survival	(%) Survival at 6h	(%) Survival at 24h	(%) Survival at 72h
Alosa aestivalis	blueback herring	P	2	100	0	0	0
Alosa pseudoharengus	alewife	P	19	47	21	0	0
Anchoa mitchilli	bay anchovy	P	15	0	0	0	0
Brevoortia tyrannus	Atlantic menhaden	P	16	50	31	6	0
Callenectes sapidus	blue crab	C	4	100	100	75	75
Cancer irroratus	rock crab	C	72	100	100	98	91
Carcinus maenus	green crab	C	12	82	82	82	82
Clupea harengus	Atlantic herring	P	49	0	0	0	0
Cyclopterus lumpus	lumpfish	D	5	100	100	100	100
Etropus microstomus	smallmouth flounder	D	2	100	100	100	50
Gasterosteus aculeatus	threespine stickleback	D	41	86	86	86	86
Gasterosteus wheatlandi	blackspotted stickleback	D	10	90	90	90	90
Homarus americanus	American lobster	C	26	100	100	100	100
Libinia spp.	spider crab	C	43	100	100	100	89
Loligo pealei	Atlantic squid	S	222	41	60	20	6
Lophius americanus	goosefish	D	3	33	0	0	0
Menidia menidia	Atlantic silverside	P	160	63	53	30	0
Merluccius bilinearis	silver hake	P	3	33	0	0	0
Monacanthus hispidus	planehead filefish	P	1	100	100	100	100
Morone americana	white perch	P	1	100	100	100	100
Myoxocephalus aenaeus	grubby	D	42	100	100	100	86
Neopanope texana	mud crab	C	21	100	95	95	95
Ophidion marginatum	striped cusk-eel	D	4	75	75	75	50
Opsanus tau	oyster toadfish	D	1	100	100	100	100
Osmerus mordax	rainbow smelt	P	1	0	0	0	0
Ovalipes ocellatus	lady crab	C	31	100	100	87	71
Pagurus longicarpus	hermit crab	C	5	100	100	100	100
Penaeus aztecus	brown shrimp	C	5	80	80	80	80
Peprillus triacanthus	butterfish	P	26	15	8	4	0
Pholis gunnellus	rock gunnel	D	2	100	100	100	100
Pseudopleuronectes americanus	winter flounder	D	43	97	97	94	94
Pomatomus saltatrix	bluefish	P	1	0	0	0	0
Prionotus evolans	striped searobin	D	4	75	75	75	75
Scophthalmus aquosus	windowpane	D	7	100	100	100	83
Selene vomer	lookdown	P	2	0	0	0	0
Sphoeroides maculatus	northern puffer	D	1	100	100	100	100
Syngnathus fuscus	northern pipefish	D	12	92	92	92	92
Tautogolabrus adspersus	cunner	D	3	67	67	67	67
Tautoga onitis	tautog	D	8	100	100	100	87
Urophycis chuss	red hake	P	2	100	100	100	100
Urophycis regia	spotted hake	P	4	50	50	50	50

[a] P = Pelagic
D = demersal
C = crustacean
S = squid

Table 4. Comparison of extended percent survival (72-h) of aquatic organisms at Millstone Units 1 & 3.

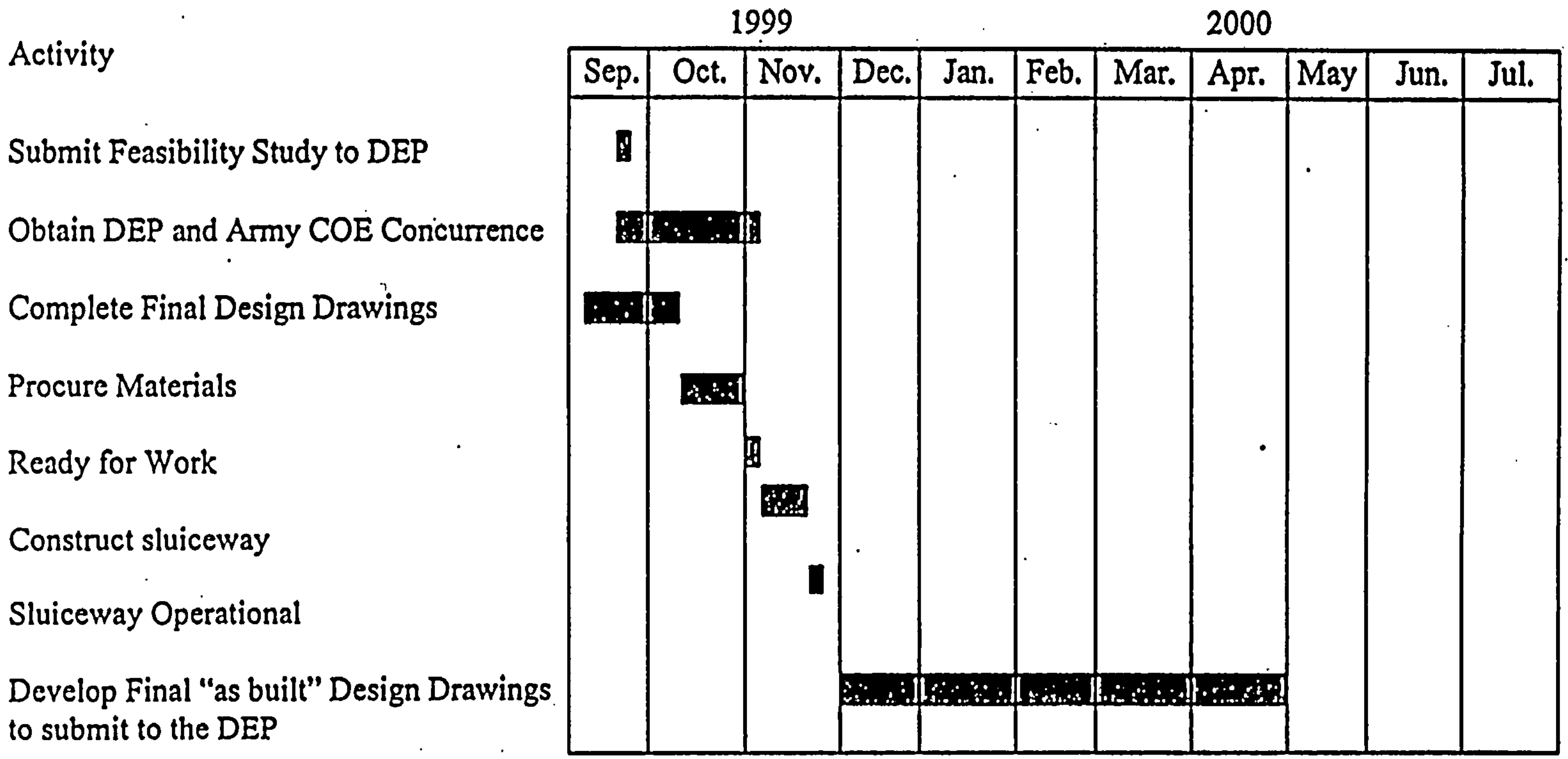
Species	Common Name	Percent Survival Unit 3 (1993)	Unit 3 (1986)	Unit 1 (1981)
Anchoa mitichilli	bay anchovy	0	0	0
Brevoortia tyrannus	Atlantic menhaden	0	0	0
Callinectes sapidus	blue crab	75	100	86
Cancer irroratus	rock crab	91	83	92
Carcinus maenus	green crab	82	77	62
Gasterosteus aculeatus	threespine stickleback	86	72	91
Homarus americanus	American lobster	100	86	38*
Libinia spp.	Spider crab	89	94	71
Loligo pealei	Atlantic long-finned squid	6	0	0
Menidia menidia	Atlantic silverside	0	0	0
Myoxoephalus aenaeus	grubby	86	97	74
Nepanope texana	mud crab	95	86	100
Ovalipes ocellatus	lady crab	71	90	81
Peprilus triacanthus	butterfish	0	2	0
Pomotomus saltatrix	bluefish	0	0	0
Pseudopleuronectes americanus	winter flounder	94	100	86
Syngnathus fucus	northern pipefish	92	91	16
Tautogolabrus adspersus	cunner	67	86	20

* based on 8 lobsters of these 4 were molting , impingement survival over 70%

Table 5. Impingement survival rates at Salem Nuclear Power Station ristroph traveling screens.

Species	Scientific Name	Month	Survival Rate
Weakfish	*Cynoscion regalis*	June	21%
		July	18%
		August	62%
		September	88%
White Perch	*Morone americana*	April	93%
		November	93%
		December	98%
Bay Anchovy	*Anchoa mitchilli*	April	46%
		May	45%
		June	22%
		July	20%
		October	65%
		November	72%
Atlantic Croaker	*Micropogon undulatus*	April	46%
		May	66%
		June	72%
		July	65%
		October	95%
		November	98%
		Dec-Jan	85%
Spot	*Leiostomus xanthurus*	November	93%
Alosa sp.		Mar-Apr	82%
		Oct-Dec	78%

Table 6. Detailed Design/Cons[illegible]tion Schedule for the Millstone 2 Sluiceway.



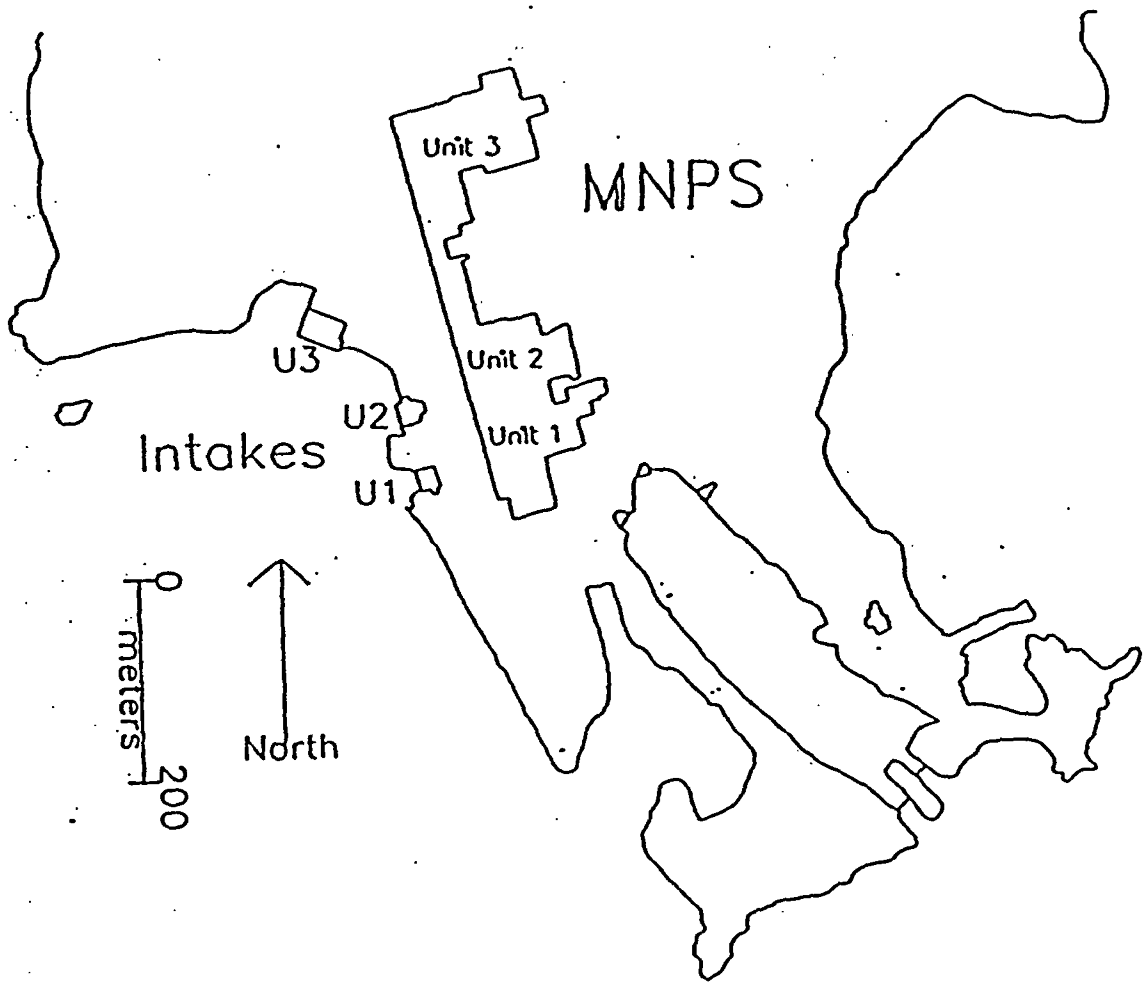


Figure 1. Location of Millstone Unit 2 intake at the Millstone Nuclear Power Station (MNPS) in Waterford, CT.

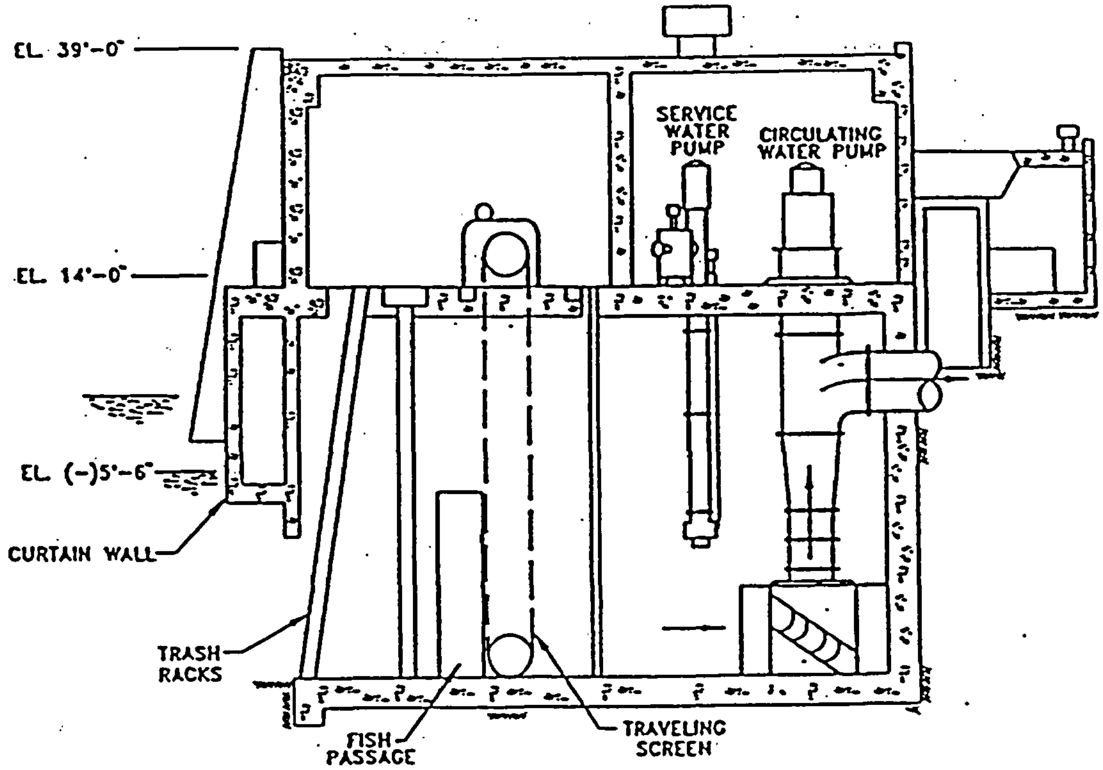


Figure 2. Typical section of the Millstone Unit 2 Circulating Water Intake Structure.

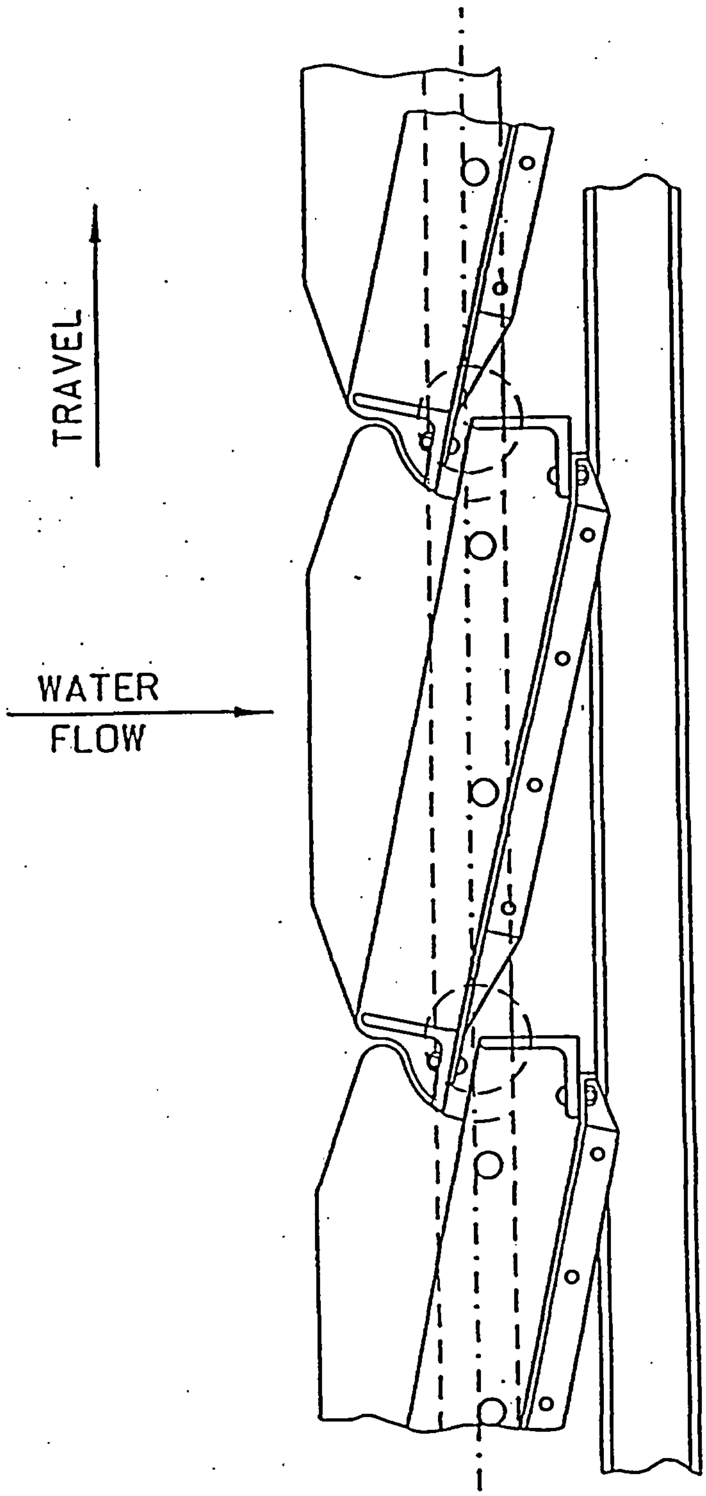


Figure 3. Existing Millstone Unit 2 traveling screen panel profile.

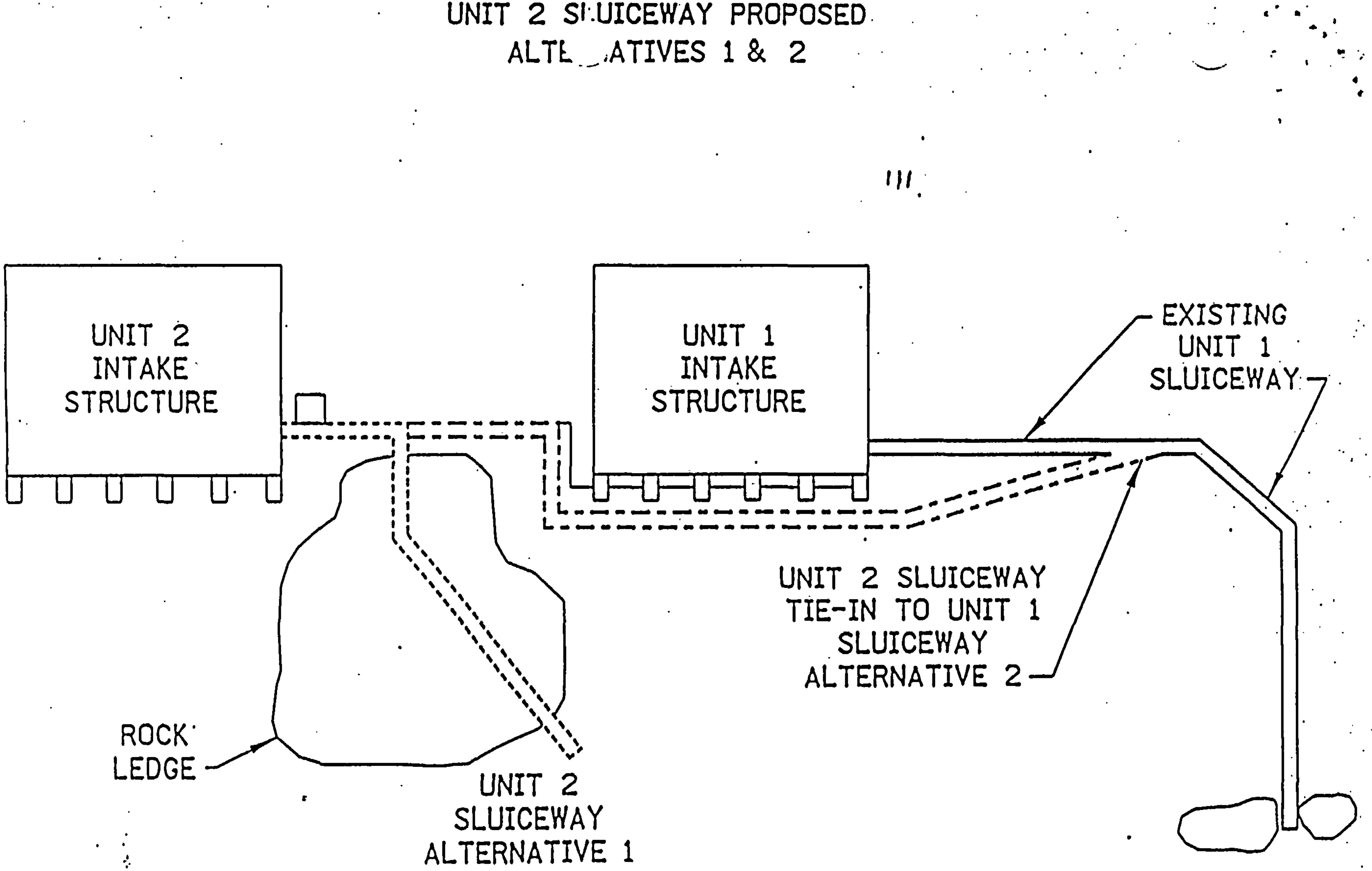


Figure 4. Conceptual drawing of the proposed Millstone Unit 2 sluiceway, Alternatives 1 and 2.

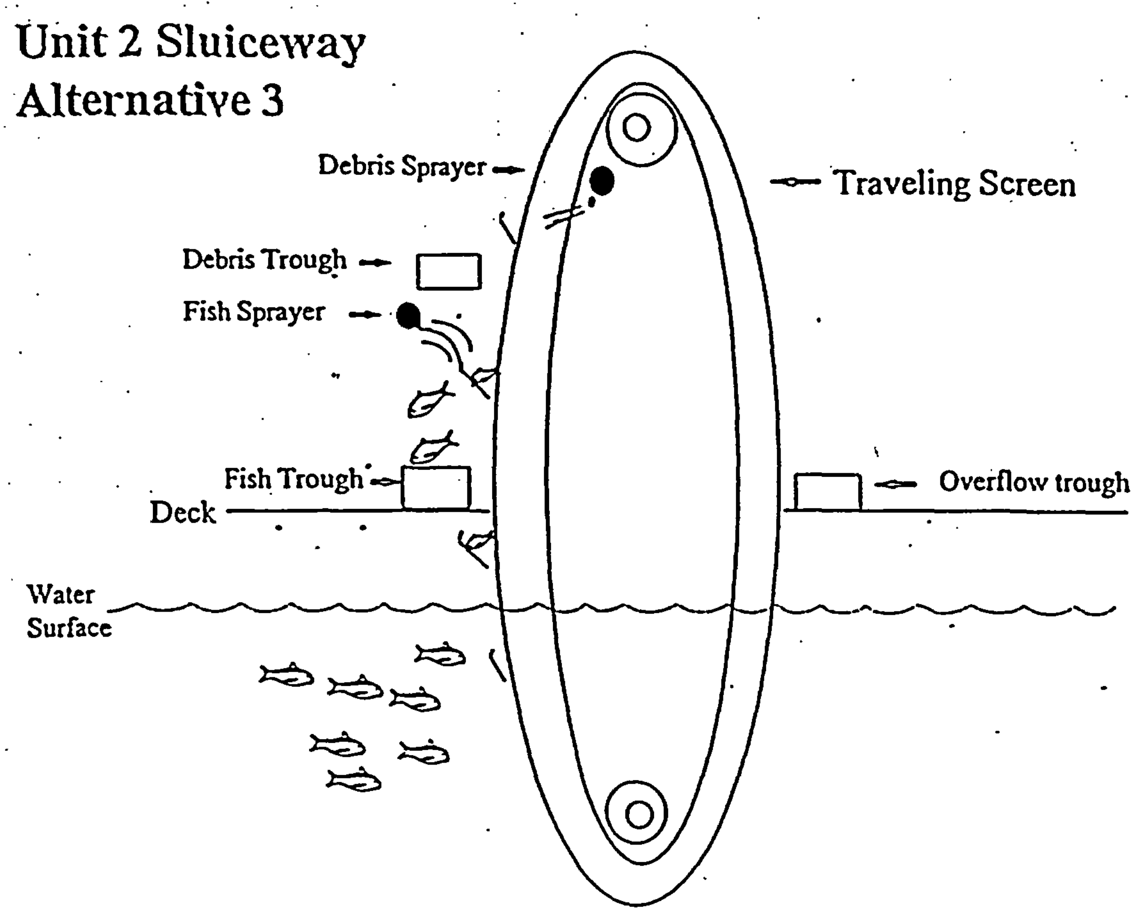


Figure 5. Schematic of Millstone Unit 2 Aquatic Return System Alternative 3.

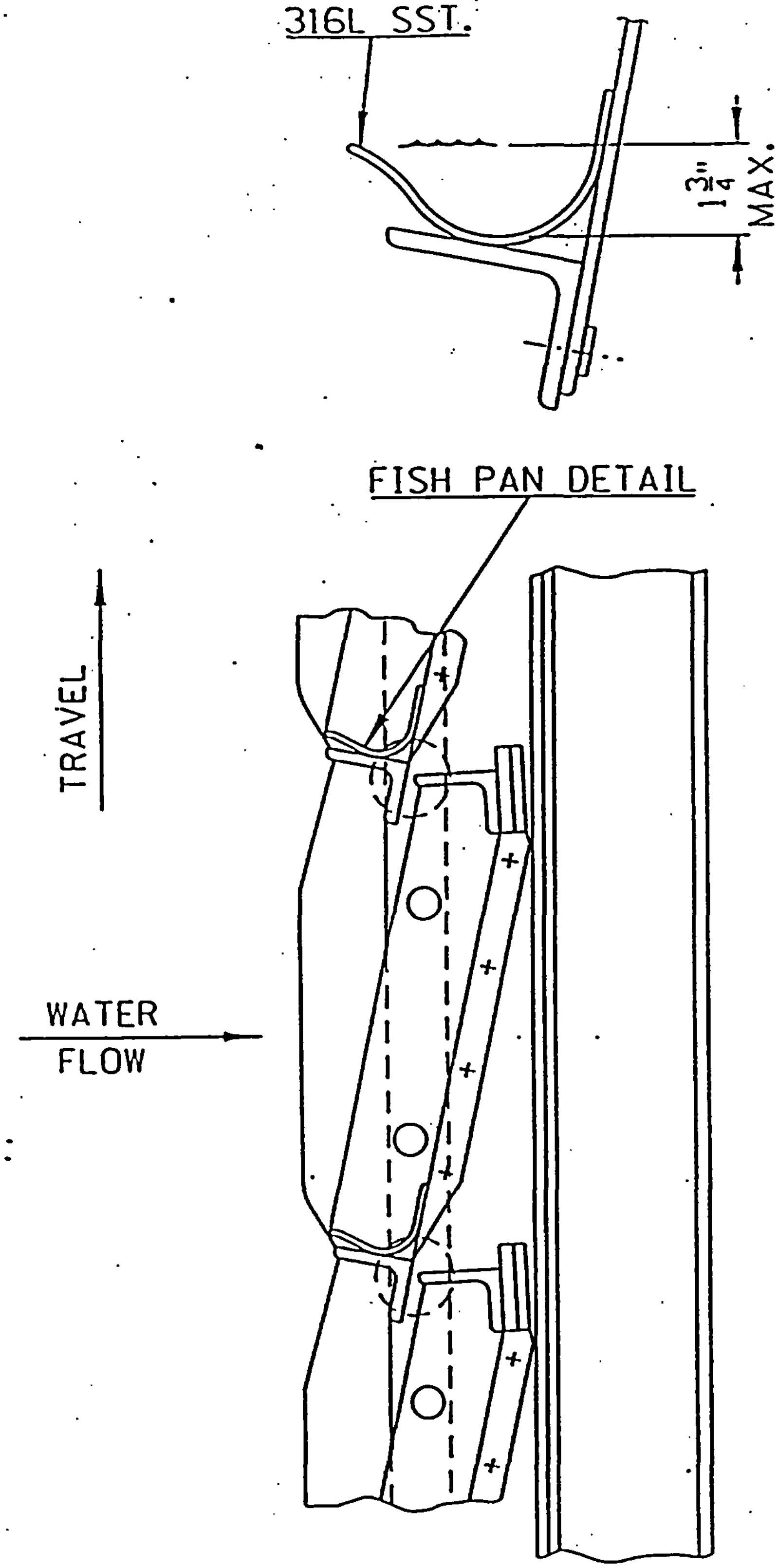


Figure 6. Existing Millstone Unit 3 traveling screen panel profile.

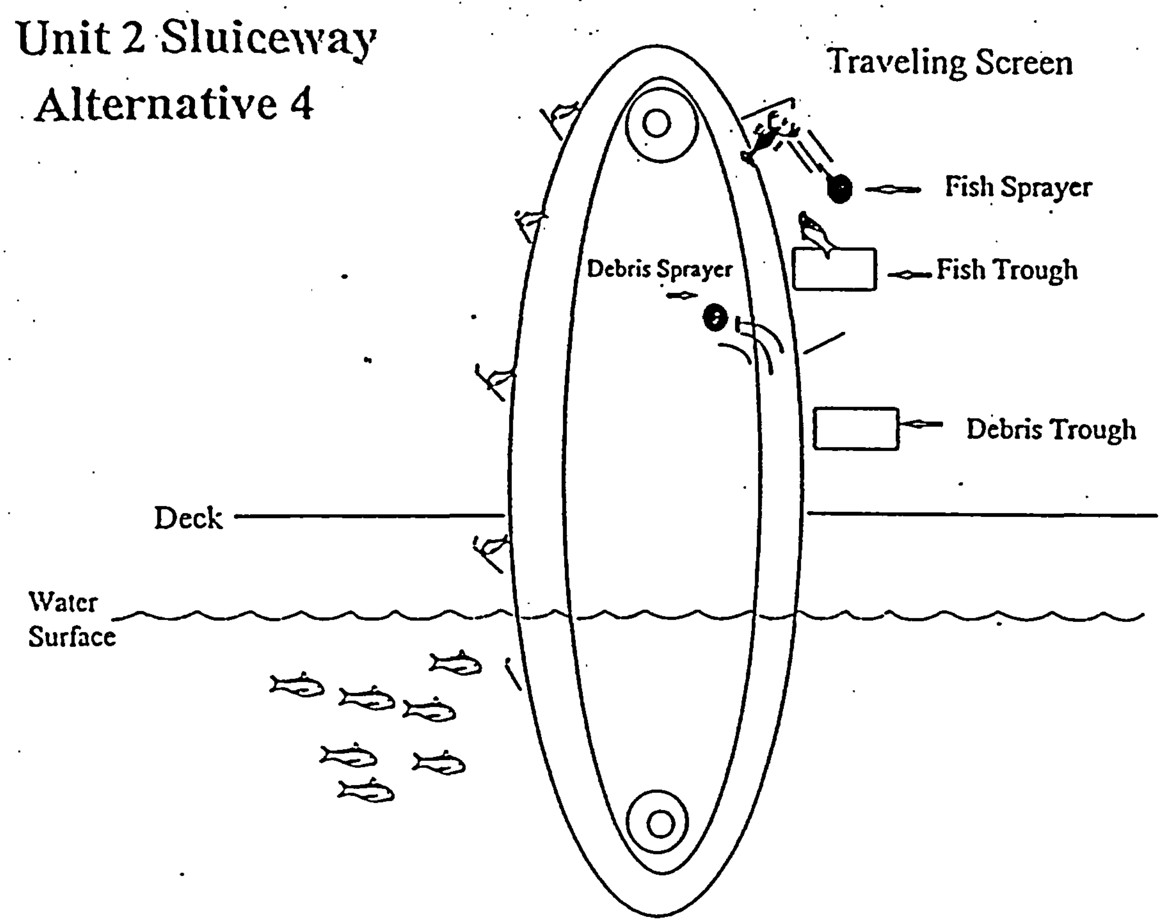


Figure 7. Schematic of Millstone Unit 2 Aquatic Return System Alternative 4.

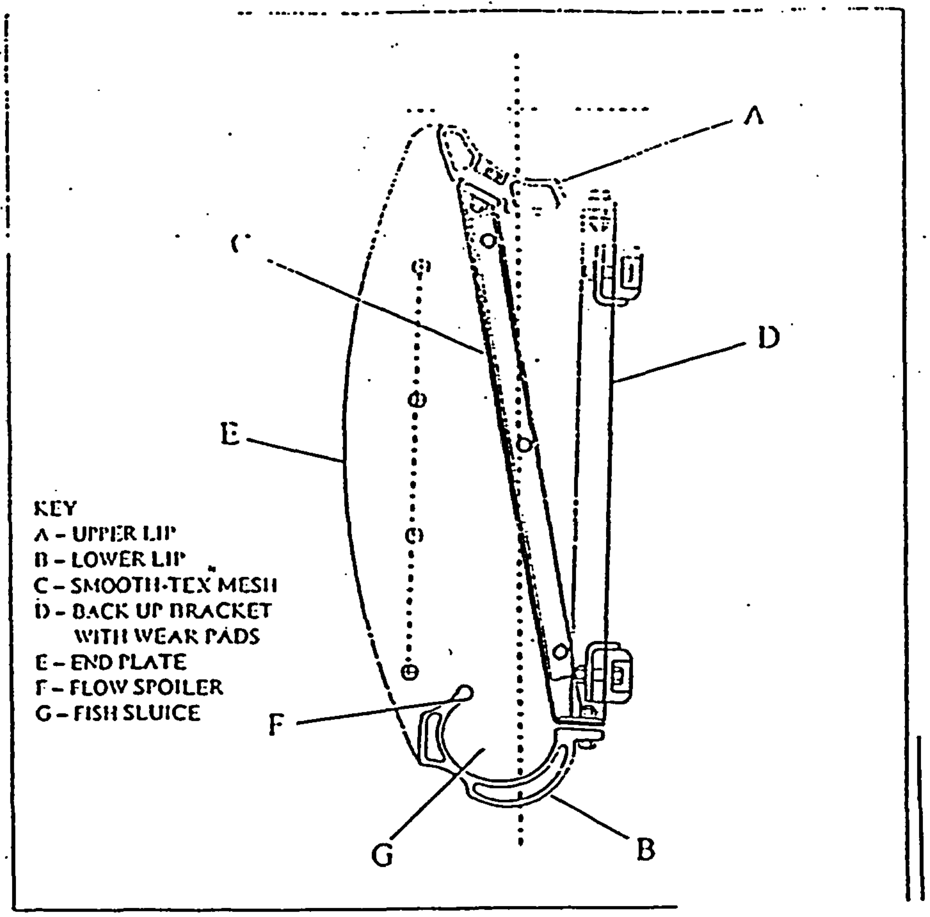


Figure 8. Profile of the Salem Units 1 and 2 screen panels.

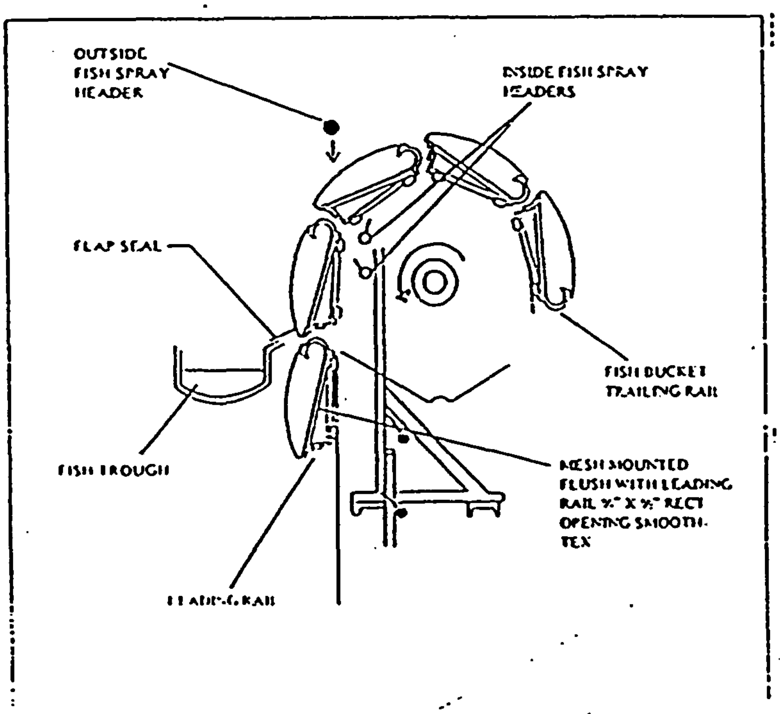


Figure 9. Profile of the Salem Units 1 and 2 fish spray header.

Northeast
Utilities System

Northeast Nuclear Energy Company

Millstone Nuclear Power Station
Rope Ferry Road
PO Box 128
Waterford, CT 06385-0128
(860) 447-1791 ext 2335

September 22, 1999

FCR-99-ENV-186
D14958

Mr. Michael Harder
Bureau of Water Management, PERD
Connecticut Department of Environmental Protection
79 Elm Street
Hartford, CT 06106-5127

Millstone Nuclear Power Station
Unit 2 Aquatic Organism Sluiceway Feasibility Study

Dear Mr. Harder:

Northeast Nuclear Energy Company (NNECo) has recently completed a study to determine the feasibility of building a sluiceway for returning aquatic organisms at Millstone Unit 2. The study is enclosed for your comments and review. The study concluded that an aquatic organism return should mitigate impingement impacts at Millstone Unit 2. Out of the four options examined in detail in the report, a sluiceway that returns all aquatic organisms and seaweed (Alternative 1) was selected as the preferred alternative.

Should the Connecticut Department of Environmental Protection (the Department) concur with the selection of Alternative 1, construction could be completed by year-end. In this regard, NNECo would request the Department's assistance in coordinating the Departments' permit review process. Specifically, a permit review meeting is requested at the Department's earliest convenience.

Should you have any questions concerning this application, please call me, at 447-1791 x2335.

Very truly yours,

NORTHEAST NUCLEAR ENERGY COMPANY

Paul M. Jacobson

Paul M. Jacobson
Manager-Environmental Services, Nuclear

cc: Mr. D. Cherico (CT DEP)
Mr. J. Grier (CT DEP)
Mr. E. Beckwith (CT DEP)
Mr. E. Smith (CT DEP)
NRC Resident Inspectors