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

Dominion

Cooling Water
alternatives

ESSA review
DNC Response
ESSA response
DNC Response

April 30, 2003

D17445

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

Dear Mr. Grier:

The Connecticut Department of Environmental Protection (the "Department"), in a letter dated May 9, 2002, requested that Dominion Nuclear Connecticut, Inc. ("DNC") respond to various issues raised by the Department's independent consultant, ESSA Technologies Ltd. ("ESSA"), as a result of their mutual review of the study entitled "An Evaluation of Cooling Water System Alternatives" (the "2001 Feasibility Study") submitted by DNC on August 31, 2001 for Millstone Power Station ("MPS"). DNC's response was submitted to the Department October 3, 2002. On January 30, 2003, DNC received ESSA's review of the October 3, 2002 DNC response. Subsequently, on February 10, 2003, the Department requested that DNC respond to issues raised by ESSA in its January 30, 2003 review and asked that DNC comment on any other aspect of the review DNC believes warranted. Specifically, the Department requested further information relative to the following areas:

- Groin/jetty Configurations
- Fine-Mesh Screens
- Safety Issues Associated with Cooling-Water Flows

This letter and attached report respond to that request. DNC specifically addresses the various questions and comments identified by the Department and ESSA resulting from their respective reviews of DNC's October 3, 2002 submittal. A detailed chronology of related correspondence is included in the attached report to assist the Department in its review.

Additionally, based on all the analyses performed to date since submittal of the 2001 Feasibility Study, DNC, in the conclusion section of the attached report, outlines an approach which combines various power plant operational changes with planned refueling outages to achieve significant flow reductions, compared to the existing NPDES-permitted baseline flow, during the period when winter flounder larvae are most abundant and vulnerable to entrainment. Changes include operating with various combinations of pumps off and/or throttling, depending on the unit and the timing of the refueling outages when plant condenser cooling water circulating pump flow is otherwise reduced. Corresponding increases in ΔT are also proposed as reduced flow will necessarily increase the temperature differentials across the station.

Coupled with these operational changes is a proposal to examine the potential application of fine-mesh screens at MPS. DNC would undertake laboratory studies of the survival of winter flounder larvae exposed to different fine-mesh screen sizes and intake velocities. DNC believes that preliminary laboratory studies are an appropriate first step as the application of fine-mesh screens in a marine environment such as Niantic Bay is an unproven technology. Existing studies of the survival of winter flounder larvae on fine-mesh screens suggest that mortality of larvae either from passing through the mesh or from impingement on the screens may be sufficiently high to negate any benefits. Furthermore, the extent of mortality resulting from the additional stresses of pumping and sluicing larvae away from the intake is unknown.

In evaluating the various alternatives to the existing once-through cooling water system at MPS to reduce entrainment as part of the NPDES Permit renewal process, DNC believes it has fully supported the Department's efforts to determine Best Technology Available ("BTA") pursuant to the Clean Water Act Section 316(b). Based on this information coupled with more than 27 years of ecological monitoring at MPS, DNC believes that the recommendation outlined above and detailed in the attached report addresses the Department's concerns regarding BTA. DNC continues to maintain that the impact of larval entrainment is but a small fraction of the inherent natural variability observed in the Niantic River winter flounder stock and that MPS is only one of many factors affecting winter flounder abundance.

DNC would be pleased to meet with the Department at a convenient time to discuss matters related to this submission and the ongoing NPDES Permit renewal process. Please contact Mr. Paul Jacobson, Millstone Environmental Services, at (860) 447-1791 ext. 2335 with any questions or to arrange such a meeting.

Very truly yours,

DOMINION NUCLEAR CONNECTICUT, INC.

J. Alan Price - Site Vice President

Enclosure

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

MILLSTONE POWER STATION
COOLING-WATER SYSTEM TECHNOLOGY STUDY
RESPONSE TO ESSA TECHNOLOGIES LTD. REPORT DATED JANUARY 21, 2003 AND CONNECTICUT DEPARTMENT OF ENVIRONMENTAL PROTECTION LETTER OF FEBRUARY 10, 2003

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RESPONSE TO ESSA TECHNOLOGIES LTD. REPORT DATED JANUARY 21, 2003 AND CONNECTICUT DEPARTMENT OF ENVIRONMENTAL PROTECTION LETTER OF FEBRUARY 10, 2003

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

Waterford, Connecticut 06385
April 2003

MILLSTONE POWER STATION COOLING-WATER SYSTEM TECHNOLOGY STUDY RESPONSE TO ESSA TECHNOLOGIES LTD. REPORT DATED JANUARY 21, 2003 AND CONNECTICUT DEPARTMENT OF ENVIRONMENTAL PROTECTION LETTER OF FEBRUARY 10, 2003

I. INTRODUCTION

In a letter dated November 15, 1999 (Reference 1), the Connecticut Department of Environmental Protection (the "Department" or "DEP") requested that Northeast Nuclear Energy Company (NNECO), the former owner of Millstone Power Station ("MPS"), in conjunction with the MPS NPDES permit renewal process, perform a "new evaluation of all measures available to eliminate or minimize the use of once through cooling water." This evaluation was sought to aid in the Department's efforts to determine whether, pursuant to Section 316(b) of the federal Clean Water Act, "the location, design, construction and capacity of the existing once-through cooling water systems at Millstone represent best technology available for minimizing adverse environmental impact."

To undertake this evaluation, the Department requested "a scope of study on those alternatives which can be implemented to minimize entrainment caused by once-through cooling water, and a scope of study on measures which would totally eliminate the use of once-through cooling water" (Reference 1). In response to the Department's request, a Scope of Study (Reference 2) was prepared and submitted and, based on comments received from the Department (References 3 and 4), revised Scopes of Study were submitted (References 5 and 6), which clarified some issues and gave further details of the methods to be used and alternatives to be investigated, and proposed a submission date of August 31, 2001. By way of comments on the draft Scope of Study, the Department also asked to broaden the review to include not only winter flounder, but also other species of fish potentially affected by entrainment of their eggs or larvae.

The Department conditionally approved certain aspects of the Scope of Study on November 14, 2000 (Reference 7). On November 20, 2000, the Department notified NNECO of its intention to contract a third party independent consultant to review the Scope of Study and the Feasibility Study (Reference 8). Subsequently, in August 2001, in accordance with the approved Scope of Study, Dominion Nuclear Connecticut, Inc. ("DNC") submitted a report for MPS entitled "An Evaluation of Cooling Water System Alternatives" ("2001 Feasibility Study"; Reference 9).

By way of background, the request to undertake a new study of alternative cooling water intake systems at MPS follows a determination made in 1992 as part of the NPDES Permit for MPS (Reference 10) that the Station's "intake structure(s) represent(s) the best technology for minimizing adverse environmental impact from impingement and entrainment pursuant to Section 316(b) of the Federal [Clean Water] Act." In that regard, however, the Department, as a condition of the NPDES Permit required a report relative to the feasibility of reducing entrainment of winter flounder larvae. This report, entitled "Feasibility Study of Cooling Water System Alternatives to Reduce Winter Flounder Entrainment at Millstone Units 1, 2, and 3" ("1993 Feasibility Study") was submitted to the Department in January 1993 (Reference 11). The 1993 Feasibility Study concluded that the intake structures and once-through cooling water systems at MPS remained Best Technology Available ("BTA").

In approving the 1993 Feasibility Study (Reference 12), the Commissioner determined that additional studies should be conducted to corroborate this finding. These scientific studies, including comprehensive long-term ecological monitoring of the marine environment surrounding MPS, now span over 27 years. Study results, along with new engineering and economic evaluations of potential technologies and operational changes, provided the basis for the 2001 Feasibility Study (Reference 9). Also assessed were additional considerations, such as avoided air emissions, regional electrical capacity needs, and the overall economic benefit of MPS to the region.

After consideration of the factors discussed in the 2001 Feasibility Study, DNC concluded that the existing intake structures and associated once-through cooling systems at MPS continue to represent BTA. The evaluations performed demonstrated that the technologies and operational changes considered were not prudent and feasible alternatives to the existing intake structures, based on the extensive ecological monitoring performed by MPS, comparable regional trends and declines in the target fish species, and the relative costs of cooling water intake alternatives.

Subsequent to submission of the 2001 Feasibility Study, DNC was notified on December 26, 2001, that the Department had selected ESSA Technologies Ltd. ("ESSA") to perform the third party review (Reference 13). ESSA's review of the Scope of Study was received by DNC on February 6, 2002 (Reference 14) with a request to provide additional information on selected technologies and impingement. This information was provided to the Department on February 26, 2002 (Reference 15). Included was a detailed summary of impingement monitoring performed over a period of 16 years from 1972 through 1987. Successful installation and operation of fish returns at MPS Units 1, 2 and 3 was also discussed. Information on winter flounder larval stock identification using DNA analyses was provided on March 14, 2002 (Reference 16) and details of the larval winter flounder mass-balance model ("MBM") formulation were provided to the Department and ESSA on June 12, 2002 as requested (Reference 17). In addition, DNC responded to numerous requests for additional information and reference material on the MBM, impingement monitoring, fish return survival studies, larval entrainment survival and heat balances.

On May 9, 2002, having received and reviewed ESSA's comments on the 2001 Feasibility Study Report, the Department requested substantial new work and analyses to address ESSA's comments including, as an example, an assessment of the ecological and economic consequences of operating with higher ΔTs as the Department noted "[i]t is possible that seasonally higher discharge temperatures are acceptable to reduce entrainment during the critical winter flounder spawning periods." In addition, the Department requested further evaluation of the use of groins or jetties using near-shore hydrographic modeling; additional information on the potential application of fine-mesh screens; review of "several alternatives by which DNC can reduce intake flows (e.g. variable speed pumps, throttling of existing pumps, by-pass or recirculation concepts, etc) which, especially in combination with a potentially higher ΔT, could result in significant reduced Station inflow and entrainment losses"; and evaluation of various technology combinations (Reference 18).

Accordingly, on October 3, 2002, DNC responded to the Department's May 9, 2002 request for additional information, focusing on those technologies the Department suggested could be used in combination with a higher ΔT and those that the Department believed warranted additional elaboration (Reference 19). The scope of DNC's response also reflected the position taken by the Department in the May 9, 2002 letter that (in responding to ESSA's comments) "[t]he determination that the most effective but far reaching alternatives to reduce cooling water usage at the Station (e.g. natural or mechanical draft cooling towers, off-shore intake, conversion to gas-fired generation etc.) are not practicable to retrofit into an existing facility like Millstone and encumber various adverse impacts in their own right appears to be reasonable and well supported." As a result, no further evaluation of these latter technologies was performed.

On October 29, 2002 (via email from J. Grier to P. Jacobson), DNC received a copy of the ESSA Final Mass Balance Model Review Report. A response to this review was provided by DNC to the Department on February 5, 2003 (Reference 20). In its response, DNC respectfully disagreed with ESSA's overall conclusion: namely, that MPS has had a measurable adverse impact on Niantic River winter flounder. This generalized conclusion is not supported by the weight of evidence collected from MPS ecological monitoring programs over the last 27 years and with numerous special studies including, for example, population dynamics modeling, larval source analyses using DNA, and earlier hydrodynamic modeling supported by dye dispersal studies. It is DNC's conclusion that the MBM, as one of many analytical tools, provides a reasonable approximation of the fraction of winter flounder larvae entrained at MPS that originate from the Niantic River spawning stock.

II. RESPONSE TO THE MOST RECENT DEP REQUEST FOR INFORMATION

On January 30, 2003 (Reference 21), DNC received ESSA's review of its October 3, 2002 response (Reference 19) to the Department's May 9, 2002 request (Reference 18). By way of a letter dated February 10, 2003 (Reference 22) the Department requested that DNC respond to specific issues raised by ESSA and invited DNC to comment on any other aspect of the review DNC believes may be warranted. As a result, DNC herein responds to the Department's request for additional information in Reference 22 and addresses certain issues raised in this latest ESSA review that we believe are germane to the overall 316(b) determination regarding Best [cooling water intake] Technology Available for MPS.

As referred to in Section I, ESSA was asked by DEP to review the adequacy of DNC's evaluation of the feasibility and effectiveness of available technologies to reduce entrainment, DNC's assessment of the economic costs associated with the implementation of various available technologies, and the validity of nuclear safety issues cited as factors in the economic cost analyses of these alternative technologies. In making its determination as to BTA, the Department, as required by Section 316(b) of the Clean Water Act, must consider costs and benefits including a balancing of the ecological information along with the efficacy of the various technologies. As a result, any determination of BTA, as the Department has previously acknowledged, must consider the relative impact of MPS in relation to other perturbations and the relative cost of alternatives. In many respects, DNC's following comments are provided in this context.

Where the Department has already recognized certain technologies as "not practical" at MPS (Reference 18), DNC may suggest that further evaluation of those technologies is therefore not warranted. Where proven, less costly options can achieve the same or better results in reducing entrainment, more costly alternatives are not evaluated further. In several instances, the ESSA comments seek ever-increasing levels of detail and analysis of hypothetical alternatives. In this request, DNC is being asked prematurely to further refine designs and cost estimates to a level typical for a construction phase, irrespective of the technology cost or its effectiveness in comparison to other options. In these cases, DNC may suggest that sufficient analyses have been performed and so notes. DNC believes that with this response, sufficient analyses will have been presented to move beyond information gathering by ESSA to a determination. The comments below reflect this position.

Consistent with past practices and to aid in the Department's review, issues raised by the Department in Reference 22 and by ESSA in its January 21, 2003 report (Reference 21) are first listed and then followed by DNC's response. For the Department's convenience, the response is organized by subject matter and related DEP and ESSA comments are grouped together. DNC's conclusions and recommendations regarding cooling-water technology at MPS are given, followed by a list of references. Finally, a series of appendices completes this report.

A. GROIN/JETTY CONFIGURATIONS

DEP Comment:

1) "ESSA maintains that there may be other, more effective groin/jetty configurations and designs which could circumvent the negative factors cited by DNC for its rejection as a viable alternative to reduce winter flounder entrainment. Please address their questions/comments comprehensively including the suggested model simulation of other designs."

ESSA Comment:

Section 2.1, page 2: [With respect to groins and jetties] "The studies show that these types of shoreline structures do alter nearshore currents and the distribution of entrainable organisms."

DNC Response:

While the hydrographic models show that these types of structures do alter near-shore currents, these same models also show that their benefit in reducing entrainment is negligible.

First, the right-angled jetties evaluated by Alden Research Laboratory, Inc. ("ARL") in DNC's October 3, 2002 letter (Reference 19) provided no reduction of entrained larvae originating from the Niantic River or elsewhere. While the parallel offshore jetty reduced the relative percentage of larvae entrained that originate in the Niantic River by roughly one-half because it was the only design concept that altered the mixture of source waters entering the intake, as ARL points out this option would simply entrain more larvae that originate elsewhere. Given the large annual variability in larval densities, the fact that recruitment of winter flounder in the first year and thereafter is affected by factors other than MPS, and the relatively small percentage of larvae from the river entrained, the benefit of the parallel offshore jetty would likely not be measurable in terms of increases in the Niantic River adult winter flounder spawning population.

In addition, in an extensive review of fish protection at power plants completed by ARL for the Electric Power Research Institute (EPRI 1999; summarized in Taft 2000; see the 2001 Feasibility Study, Reference 9, for full citations) jetties were not listed as a technology applied at any North

American power plant as a protective intake technology. Thus, jetties should be considered as unproven for fish protection and inappropriate for application at MPS as BTA. Furthermore, as noted in Reference 19, impingement would likely increase, as would entrainment of eggs and larvae of organisms resident in and around the relatively massive jetty structure, both of which would contribute to increased impact.

Finally, whether this massive a structure would successfully proceed through the Office of Long Island Sound Programs, U.S. Army Corps of Engineers, and other potential permitting processes is highly questionable.

Objections to jetties as an intake technology were presented in previous submissions by DNC to the Department (Reference 19) and these are amplified in the discussion below, where it is noted that ESSA has presented hypotheses rather than any evidence that jetties have the capability to reduce power plant entrainment at MPS or any other power plant.

ESSA Comment:

Section 2.1, page 2: "To test the potential effectiveness of a groin during an ebb tide, did the model simulations investigate alternative locations further north of the intakes and if so what was the observed effect on concentrations of Niantic River organisms entering the intakes?"

DNC Response:

For elaboration on the comment given above as well as other questions posed by ESSA with respect to jetties, the Department is referred to a document prepared by ARL at DNC's request that is given as Appendix I to this response. As ARL points out in Appendix I, a jetty north of the intakes was not previously evaluated. The net effect of right-angled groins in the simulations is only to delay the arrival of organisms at the intake. There is no net benefit from this type of structure.

Furthermore, any jetty north and west of Bay Point would be situated in a shallow-water habitat containing sandy beaches, rocky areas, and a healthy and widespread eelgrass bed. As a result, DNC does not believe it advisable to locate a jetty or groin in this sensitive area, due to the unintended ecological impacts that would result.

ESSA Comment:

Section 2.1, pages 2-3, Right angled groins, point 2: "...did the simulations consider more than one location for the source of organisms, and if so what was observed?...Organisms originating from shoreline areas immediately north of the intakes (south of Niantic River estuary) could tend to be more concentrated in the shoreline currents. A back eddy induced by a groin at an appropriate location might result in a larger reduction of entrained organisms."

DNC Response:

As DNC previously conveyed to ESSA, more than 27 years of sampling the various life stages of winter flounder has demonstrated that little or no spawning of winter flounder occurs in Niantic Bay. As a result, it is unlikely that the area immediately north of the intakes would produce larvae other than those transported there from the Niantic River or from greater Long Island Sound (LIS). As reported by ARL, right-angled groins did not appear to change the mix of waters entering the intakes. Therefore, locating a groin or jetty north of the intake would not reduce the relative number of entrained larvae originating from the Niantic River.

ESSA Comment:

Section 2.1, page 3, first paragraph: "Would a physical laboratory model provide more confidence in measuring the effectiveness of shoreline structures?"

DNC Response:

The resolution of the hydrodynamic model used by ARL could be increased, but is unlikely to change the overall conclusion that the jetty option, when compared to other less costly alternatives, does not achieve nearly the same relative benefit as flow reduction. Developing a physical model would only be appropriate if jetties were a legitimate cost-effective option. In addition, this investigation would add a significant, unnecessary delay to the permit process. Please see Appendix I for additional information provided by ARL in this regard.

ESSA Comment:

Section 2.1, page 3: ESSA suggests a new groin/jetty option, including gate-equipped openings and the use of either a discharge to the northeast side of the quarry into Jordan Cove or diffuser ports from the quarry to minimize the effect of recirculation of heated water to the intake.

DNC Response:

The analysis provided by ARL in DNC's October 3, 2002 response (Reference 19) was performed to examine the possible use of jetties in relation to their cost, not to take this concept to an actual design and construction stage. This holds true for all of the technology options considered during the Feasibility Study process: that is, conceptual design and construction evaluations were performed to provide a reasonable comparison of construction and operational issues across technologies and their relative costs, recognizing that once a technology or combination of technologies is chosen, in-depth engineering studies and construction phase cost estimates would be developed. Considering that the cost for any of the offshore jetties evaluated by DNC or by ESSA in this latest review would likely be in excess of $20 million, DNC believes that no further evaluations are necessary going forward, because other, more effective options are available.

More importantly, there are fundamental and significant concerns with addressing a thermal recirculation issue created by a jetty with a solution that discharges heated water into Jordan Cove or by adding a diffuser. Putting aside the cost of excavating a new discharge path to the east, the Jordan Cove embayment lacks the volume of flow and dispersal energy afforded by the existing discharge location in Twotree Island Channel. Heated water would pool in Jordan Cove and likely cause dramatic thermal effects, including the loss of important eelgrass beds there and possibly affecting important shellfish resources and finfish habitat. A diffuser into Twotree Island Channel from the quarry would add a significant cost to an already costly option and trigger a Section 316(a) review, including additional in situ thermal plume studies and ecological analyses, further delaying the permit process. Please see Appendix I for ARL's response to ESSA's comment.

In summary, the efficacy and/or feasibility of jetties is a matter of relative cost, construction, permitting, hydrodynamics, and larval deterrence. Jetties remain an unproven intake technology that has not been successfully applied at any power plant to reduce larval entrainment. Since this option does not reduce water inflow, deters only a small fraction of larvae that originate in the Niantic River, and does not diminish overall entrainment, no positive benefit can be attributed to it.

B. FINE-MESH SCREENS

Both the Department and ESSA have provided numerous comments relative to DNC's evaluation of the feasibility of fine-mesh screens at Millstone Station. The Department's comments are as follows:

DEP Comments:

2) "Our consultant is of the opinion that the cost estimates developed for various fine mesh screen scenarios at Millstone are underdeveloped and overstated and do not address the benefits of reduced entrainment. Also, the concern over the absence of any recent entrainment/ impingement monitoring data, the estimates of entrainment, and the very limited studies of

winter flounder entrainment survival at the Station. As stated previously, definitive information on entrainment mortality is crucial to determining the overall benefits of various mitigation alternatives, especially higher condenser cooling water temperatures. Please respond to these observations."

5) "Regarding DNC's evaluation of fine-mesh screen alternatives, it appears that sluicing return systems similar in design concept for the Unit 3 intake were selected. ESSA points out that there are more effective systems available, such as the Fletcher modified screens, which have been shown to reduce impingement mortality. Any failure to optimize fine mesh screen design concepts undercuts DNC's argument that this technology has not been proven to effectively mitigate entrainment impacts and therefore not recommended as BTA at the Station."

6). "Does the cost analysis for the use of various fine mesh traveling screen alternatives discount all applicable O&M and capital (replacement) costs associated with maintaining use of the existing coarse screening systems for Units 2 & 3?"

ESSA's comments are identified in the text of DNC's response where appropriate. Generally, the Department's and ESSA's comments can be grouped into the following categories:

- Application of fine-mesh screens at MPS
- Capital costs
- Operation and maintenance costs.

Each are addressed in turn below:

1. Application of Fine-Mesh Screens at Millstone Power Station

a. Evaluation

Corresponding ESSA Comments:

Section 2.2.1, page 4, third paragraph: "However, we disagree with DNC's assertion that fine mesh when applied to Units 1, 2, and 3 coupled to upgraded fish return systems would not reduce entrainment and impingement mortality at Millstone. It is our opinion that DNC still has not adequately assessed the potential of fine mesh screens for reducing entrainment at Millstone Station."

Section 2.2.1, page 4, fifth paragraph: "The prototype assessment by necessity would include more intensive assessment of entrainment, through-plant entrainment mortality, and impingement mortality. It is our opinion that current understanding of these processes at Millstone is insufficient. ... Entrainment mortality at Millstone is largely unknown, and impingement monitoring has not occurred since 1987."

Section 2.2.2, pages 5-6, all paragraphs: ESSA provides additional comments on fine-mesh screen applications at the Brayton Point (MA), Brunswick (NC), and Salem (NJ) power plants, including survival rates and operational reliability associated with clogging, and further comments with regard to laboratory work investigating larval survival using fine-mesh screens.

DNC Response:

Please see DNC's 2001 Feasibility Study (Reference 9) or the ESSA comments (Reference 21) for all literature references cited in this response.

As ESSA notes on page 4, fourth paragraph: "the effect of fine mesh traveling screens and updated fish return systems ... are site specific", page 4, third paragraph: "[e]ntrainment mitigation with intake screens is inextricably linked to impingement management", and page 5, second paragraph of Section 2.2.2: "[l]arval fish survival on fine-mesh systems tend to be highly species and life-stage specific." These are fundamental issues, as the targeted organisms must have the capacity to survive the process of impingement, removal from the screens, and transport through a contained return system while being returned to the receiving water body at an adequate distance to preclude re-entrainment. Further, fine-mesh screens back-fitted to an existing cooling-water intake structure may impose limitations to survival, as this would be a less than optimal system.

These issues were clearly recognized in the examples of industry experience provided by ESSA. For example, despite improvements to the intake structure, Atlantic menhaden and bay anchovy suffered nearly complete mortality on the fine-mesh traveling screens of the Brunswick Steam Electric Plant in North Carolina (Thompson 2000). These results are similar to the impingement survival experience at MPS, even though the specimens impinged on the 3/8-inch traveling screens at MPS were likely larger than most of those impinged at Brunswick, because larger individuals were excluded at that plant by a barrier screen diversion structure at the head of the intake canal. In general, larger size confers survival advantages to impinged organisms.

Further examining the Brunswick experience, the large reduction in impingement by number and weight noted by ESSA was primarily due to the diversion structure at the head of the intake canal and did not have anything to do with the fine-mesh screen installation. A similar diversion structure cannot be installed at a power plant having a shoreline intake, such as MPS. Barriers such as nets or a Gunderboom were previously deemed unsuitable at MPS in the 2001 Feasibility Study, a conclusion with which the Department concurred (Reference 18). Entrainment at Brunswick was reduced by installation of 1-mm fine-mesh screens, but efficiency (i.e., number impinged rather than entrained) and impingement survival were found to be species-specific. The figure of 80% reduction in entrainment at Brunswick cited by ESSA was a maximum for the figures given in the paper and the proportions varied widely by species and month (see Thompson 2000: Table 3).

Thompson (2000) also noted that survival was dependent upon size of the organism and traveling screen rotation speed. Invertebrate larvae (shrimp, crab), which have a hard exoskeleton, survived well, although many individuals continued to be entrained through the 1-mm fine-mesh screens during summer. Nearly all the Atlantic menhaden were impinged rather than entrained, but larvae suffered nearly total mortality. Similarly, percent removal and survival of other species varied considerably. The 93% survival for southern and summer flounders noted by ESSA cannot be used as a potential survival rate for winter flounder on fine-mesh screens. These *Paralichthys* spp. flounders do not undergo metamorphosis until about 15 mm in standard length (SL; smaller than total length). The *Paralichthys* specimens observed in the Brunswick studies were larger, late stage, post-larvae ranging in size from 10 to 18 mm (SL); most were from 13 to 15 mm (T. Thompson, Progress Energy, New Hill, NC, pers. comm.). These larger *Paralichthys* specimens appear to be considerably more robust than winter flounder larvae, which metamorphose at about 8-9 mm (total length; TL). Note that about 85% of the winter flounder larvae entrained at MPS are smaller than 7 mm (TL).

ESSA noted that the fine-mesh screens at Brunswick occasionally clogged as a result of detritus and mud, which Thompson (2000) noted could be alleviated by more frequent dredging of this station's intake canal. However, Thompson (2000) also listed hydromedusae, caprellid amphipods, and *Gracilaria* spp. (a red macroalga) as contributing to clogging. All these biota are found near MPS and are present in entrainment samples or observed in impingement debris. The clogging incidents at Brunswick have led to plant shutdowns (Thompson 2000), a highly undesirable outcome. Sediments found in front of the MPS intakes are likely coarser than found in the Cape Fear Estuary, where Brunswick is located, due to the high-energy environment of LIS. Sediment clogging may not be a problem at MPS as larger-grain sands here may be more resistant to suspension. Increased dredging would not be indicated if sediments do not pose a threat to the intake. However, detritus, seaweeds, and other marine biota are another matter. MPS experiences heavy debris loading, particularly during the larval winter flounder season. Much of this material is brought into the intake by strong southwesterly winds common at this time of year. Although the wide-bladed kelps may be removed relatively easily off fine-mesh screens, filamentous algae and fragments of other seaweeds are also common and may cause operational problems by clogging the screens. Further, heavy debris loads may potentially reduce impingement survival by matting on top of any larvae that are impinged on fine-mesh screens.

ESSA commented on several laboratory studies (Taft et al. 1981; ARL and SWEC 1981) related to larval survival that were cited in the 2001 Feasibility Study. ESSA also stated that Stage 3 winter flounder larvae, which make up nearly two-thirds of the larvae entrained at MPS, are 5 to 8 mm in length. However, most Stage 3 larvae collected at MPS range from 5 to 6.5 mm in length (TL), which are similar in size to the "later postlarvae" used by Taft et al. (1981) in their tests. The "early postlarvae" of Taft et al. (1981) correspond to Stage 2 winter flounder larvae. Taft et al. (1981) found that only 63 ± 10% of early postlarvae (4.4 mm) were retained by a 0.5-mm mesh screen, indicating that many smaller larvae would continue to be entrained, even with 0.5-mm fine-mesh screens. As ESSA noted, Taft et al. (1981) reported relatively high (65 ± 28% to 72 ± 24%) impingement mortality for early postlarvae at an approach velocity of 0.5 fps. Mortality at faster approach velocities was very high (>90%) in most tests. However, these larvae also had relatively high (43 ± 34%) control mortality. These same test data were reported in ARL and SWEC (1981). A conclusion of the latter report was that "the high and variable test mortalities for early postlarvae are believed to result primarily from natural causes rather than impingement stress...[T]he added factor of large, naturally-occurring die-offs at this point in their life stage may be indicative of the difficulty in protecting winter flounder during this stage of larval development." MPS studies also indicate a high natural mortality in this life stage, which represents a transition to first feeding. About 19% of winter flounder larvae estimated to be entrained at MPS are in Stage 2 of development. It may be impossible to protect this group of larvae because of relatively low retention, even with 0.5-mm fine-mesh screens, and, in any event, the high natural mortality at this life stage would result in high losses regardless of any intake technology employed.

ESSA's January 21, 2003 report observes that the impingement mortality rates given by Taft et al. (1981) were not corrected for control mortality. However, control mortality for later postlarvae (6.1 mm) was estimated by Taft et al. (1981) to be only 8.3%. Corresponding impingement mortality ranged from 28 ± 34% at an impingement test duration of 16 minutes to 62 ± 31% at 8 minutes (both at an approach velocity of 0.5 fps). Paradoxically, for most test conditions mortality of postlarvae was lower at higher approach velocities, although 95% confidence intervals for survival estimates were relatively broad, indicating that there is some uncertainty associated with all these test results.

Further testing by Taft et al. (1981) showed an inability of the spraywash systems employed to remove impinged winter flounder larvae from the fine-mesh screens, as they tended to adhere to them. Alewife (a representative clupeid species) larvae also adhered to the screens. Taft et al. (1981) also found it difficult to determine what the actual survival of larval winter flounder was when testing jet or Hidrostal pumps, due to the difficulty in collecting small larvae. They concluded that "minor design details in a fine-mesh screen system can greatly affect the capability of this type of collection system for protecting organisms." Thus, with about two-thirds of winter flounder larvae estimated to be entrained at MPS in Stage 3 of development, these laboratory results indicated that mortality of impinged larvae on fine-mesh screens could be relatively high. Additional mortality would be induced by less than efficient removal from the screens, exposure to the air during the screenwash process, and in pumping larvae from the screenhouses back to LIS.

The example ESSA cites of increased survival of weakfish at Salem Nuclear Power Station (NJ) following modifications to the intake screening system of that power plant does not appear to be relevant to the situation at MPS. At Salem, post-larval age-0 weakfish are impinged on 6.3 X 12.7 mm rectangular mesh screens (see Taft 2000). Juvenile weakfish should be considerably more robust than larvae and demonstrate higher impingement survival, as did juvenile fish at the Brunswick Station (Thompson 2000). Many fish larvae are likely still entrained at Salem, given the screen size in use. The intake screen system improvements that have resulted in increased impingement survival at Salem for juvenile and adult fishes and larger invertebrates simply cannot be extrapolated to survival of larvae on fine-mesh screens.

Once again, DNC suggests that the best source of information relevant to potential survival of larval winter flounder (and other larval fishes) on fine-mesh screens is the experience at Brayton Point Station in nearby Massachusetts. Species composition and size ranges of ichthyoplankton found there are very similar to those at MPS. Extensive sampling at Brayton Point Unit 4 showed that the 1-mm fine-mesh screens were unable to reduce mortality of larval fish drawn into the intake of that facility. The design of a system using angled fine-mesh screens rather than a flow-through screening system may not be as relevant for larval fish as it would be for larger motile forms that could take greater advantage of the diversion system. In fact, this was found for fish larvae at both the Brayton Point and Danskammer Point (NY) power plants (LMS 1987), where most fish larvae were not diverted but instead were entrained or impinged.

Details of the larval efficiency and survival studies conducted at Brayton Point Unit 4 are found in LMS (1987). Adjustments to impingement survival estimates for larval winter flounder were made in this study using a collection and handling mortality rate. Note that the sampling nets used at Brayton Point were 0.505-mm mesh, which would tend to under represent smaller winter flounder larvae. Similarly, the 1-mm fine-mesh screens used at Brayton Point would allow more entrainment and less impingement of winter flounder larvae than 0.5-mm fine-mesh screens, a fact also noted in the laboratory work of Taft et al. (1981).

At Brayton Point, 52% of larval winter flounder were entrained, 28% were impinged, and 20% entered the diversion system. At a plant without a diversion system the bypassed specimens would have either been entrained or impinged. As the season progressed, LMS (1987) reported an increase in diversion efficiency with a corresponding decrease in entrainment, so it is likely that over time an increasing proportion of diverted larvae would be impinged rather than entrained at a plant equipped with a through-flow system. Winter flounder larvae impinged on the Brayton Point fine-mesh screens had a significantly lower survival (both initially and after 72 hours) than those diverted or collected at the intake. Only 5.5% of the winter flounder larvae impinged were alive after 72 hours. Given that the 0.5-mm fine-mesh screens examined for use at MPS would likely impinge more smaller winter flounder larvae and that survival is less for smaller and younger larvae, higher mortality would be expected. Thus, the effectiveness of a fine-mesh screen system in reducing power plant mortality of winter flounder larvae is highly questionable. Despite the considerable efforts made at Brayton Point Station under actual operating conditions, the conclusion was that fine-mesh screens were not effective in mitigating larval fish entrainment (LMS 1987). However, despite the findings reported in previous correspondence and herein, given the interest expressed in fine-mesh screens by ESSA and the Department, a proposal for further examination of the efficacy of fine-mesh screens at MPS is given later in this response.

As part of its opinion that the potential for fine-mesh screens at MPS should be further pursued, ESSA has incorrectly stated (Section 2.2.1, page 4, fifth paragraph) that little is known about impingement and entrainment survival at MPS. In Reference 15, DNC provided to the Department (in response to ESSA's review of the cooling water alternatives Scope of Study; Reference 14) a synopsis of impingement studies at MPS. Included as appended material were numerous reports previously submitted to the Department related to fish return sluiceways at each MPS unit and their effectiveness in reducing mortality, assessments of the impingement of winter flounder and other species, and the justification for discontinuing impingement sampling in 1987. Common threads ran among these impingement survival studies: winter flounder, tautog, and other demersal fishes and non-molting crustaceans showed good survival (many species >85%), even when washed off the screens with relatively high spraywash pressures. Conversely, relatively poor survival was found for pelagic fishes (herrings, anchovies, butterfish) and squid, regardless of conditions. The pelagic group also tended to be more commonly impinged during periods of warmer water temperatures in summer along with masses of jellyfish, likely contributing to their mortality.

Regarding the termination of impingement sampling at MPS in 1987, once the Unit 3 intake structure construction cofferdam was removed in September 1983, impingement at Unit 2 dropped off dramatically. Presumably, the rock cofferdam structure attracted organisms and the embayment it created helped funnel them towards the Unit 2 intake. This attraction is one reason why DNC believes a jetty would increase the number of fish and invertebrates impinged. Even if one assumed relatively high impingement survival rates, mortalities would increase proportionately with a higher rate of impingement. Because of the observed decrease in impingement at Unit 2 over several years and with fish return sluiceways in place at Units 1 and 3 at the time, the Department concurred with MPS in eliminating the impingement sampling requirement at Unit 2 as of December 1987 (Reference 23). Once Unit 1 was retired, a fish return sluiceway was installed at Unit 2, which began operation in May 2000 and further decreased the impact of impingement at MPS.

Entrainment survival studies at MPS and relevant information from other power plant or laboratory studies were given for winter flounder, tautog, and other fishes in the 2001 Feasibility Study (Reference 9: Part II, Chapter 3, Sections 3.2.5, 3.3.5, and 3.4.5). MPS entrainment survival studies for winter flounder, including new information from work completed in 2001, were further summarized in the 2001 Annual Report ("Monitoring the Marine Environment of Long Island Sound at Millstone Power Station, Waterford, Connecticut"), submitted to the Department in April 2002. Although the entrainment survival studies for winter flounder larvae at MPS have not been extensive in terms of sampling effort or number of individuals examined, results have been relatively consistent through much of this work: few or no Stage 2 or 3 winter flounder larvae survived through-plant entrainment, whereas 21-79% of Stage 4 larvae and all of the few Stage 5 juveniles collected survived through a 96-hour post-entrainment holding period. However, only about 14% of winter flounder larvae entrained at MPS (estimated over the long-term, varies somewhat annually) are in these two later developmental stages. Thus, only about 3-10% of winter flounder larvae entrained survive the process and the impact assessment modeling conservatively assumes 100% mortality.

Regarding the effect of increased condenser cooling-water temperature that would result from some of the alternatives presently under investigation, it is likely that through-plant entrainment mortality of winter flounder larvae (as well as for many other fish larvae) would increase with increasing ΔT. This was noted in the 2001 Feasibility Study (Part II, Chapter 3, Section 3.2.5), where work at the Oyster Creek Nuclear Generating Station was summarized. The conclusion of this study (EA 1986) was that through-plant entrainment survival was negatively correlated with ΔT. A predictive relationship showed no survival at a ΔT of 21.5°F. Other laboratory studies cited in the 2001 Feasibility Report indicated that winter flounder were relatively resistant to thermal shock, although mortality did increase at higher temperatures and longer exposure times.

However, the laboratory studies did not examine effects due to mechanical damage or the interactions between mechanical and thermal effects.

ESSA Comments:

Section 2.2.3, page 6: "We are of the opinion that testing fine mesh and optimized fish return systems at Units 1 and 2, or at Unit 3 through a prototype design as suggested by DNC is justified given the potential for reducing entrainment and impingement mortality. Given the two scenarios developed by DNC we judge that they should proceed with the retrofit of Unit 1 in conjunction with Unit 2 when considering the reported costs of the two scenarios ($25,100K versus $100,450K)."

"[T]he use of variable speed pumps during the critical spring larval period for winter flounder is very promising and should be pursued. We suggest that other options for reducing cooling water flow such as throttling pumps, putting CWPs on standby, or retrofitting a discharge gate at the quarry not be discarded given that it is our understanding that retrofitting with variable speed pumps is comparatively very expensive."

"It is our opinion that the application of a combination of fine mesh screens, optimized fish return systems and variable speed pumps at Units 1, 2, and 3 as well as a discharge gate at the quarry as described by DNC warrants further assessment. As indicated earlier (ESSA 2002b), we think that these type of mitigation alternatives should be examined completely before other more expensive alternatives, such as cooling towers, are explored."

DNC Response:

The ultimate selection of alternative methods of operation or technology choice hinges on the comparison of larval entrainment before and after any change in technology or operation. Among the above scenarios postulated, the only guaranteed reduction in larval entrainment is through flow reduction. DNC has considered all reasonable alternatives for reducing cooling-water flow, including a reduced number of circulating water pumps ("CWP") in operation and pump throttling. While the efficacy of a fine-mesh screen may be debated, its application at MPS is problematic and at best untested. As noted in the above ESSA comment, the assessments of fine-mesh screens also entail the need for optimized fish return systems. Substantial pumping would be required to transport larvae to some distance from the MPS intake structures to avoid re-entrainment.

DNC believes that given the uncertainty that any flow reduction or alternate technology at MPS will materially benefit the Niantic River winter flounder by way of a measurable increase in the population, the choice of BTA should consider those options that achieve the maximum flow (and entrainment) reductions at the least cost. At the same time that flow reductions are being achieved, experimental evidence can be obtained as to the efficacy of fine-mesh application at MPS through laboratory testing first. This approach is discussed further in the conclusion of this report.

Some of the suggestions noted in the above comments by ESSA were previously evaluated or may be elaborated on here. Refer to Part I, Section 7.2 of the August 2001 Feasibility Study (Reference 9) for a complete discussion of the alternatives for shutting down CWPs and placing the pumps shut down in standby operating mode. A discussion of throttling CWP flow with the condenser discharge valves and estimated costs for replacing the existing condenser discharge valves at Units 2 and 3 with valves designed for throttle service is found in Part I, Section 7.3. The limiting factor to throttling is the minimum allowable pump flow. A review of the Units 2 and 3 manufacturer's pump curves shows that throttling of the CWPs to 75% of design point would be acceptable. This would result in CWP flow rate of approximately 103,000 gpm per pump for Unit 2 and approximately 115,000 gpm for each Unit 3 pump. Throttling pump flow beyond 75% would put the pump operating point close to the unstable region on the pump curve, which could cause the pump to oscillate or vibrate. Operating below the 75% of design point could result in pump damage or even failure. Installation of gate structures at the quarry discharge as a means to reduce station water flow is addressed below in the response to a comment made by ESSA in Section 4 of their report.

b. Alternatives Considered

DEP Comment:

5) "Regarding DNC's evaluation of fine-mesh screen alternatives, it appears that sluicing return systems similar in design concept for the Unit 3 intake were selected. ESSA points out that there are more effective systems available, such as the Fletcher modified screens, which have been shown to reduce impingement mortality. Any failure to optimize fine mesh screen design concepts undercuts DNC's argument that this technology has not been proven to effectively mitigate entrainment impacts and therefore not recommended as BTA at the Station."

DNC Response:

The Fletcher modified screens also require a fish sluicing system of the same design concept as that currently installed at Unit 3 and included with the previously presented fine-mesh screen alternatives for Units 2 and 3. This sluiceway is used to return collected fish removed from the screens and transport them back to LIS. The difference with the Fletcher modified screens is in the screen basket bucket design. The screen basket collects fish impinged on the screen and carries them up with the traveling screen to the low pressure spray, which washes them into the fish sluiceway system. The Fletcher bucket design has been shown to reduce injury to fish while in the buckets and prior to the fish being washed into the fish sluiceway. Features incorporated in the Fletcher bucket design effectively eliminate horizontal swirl in the bucket induced by approach flow to the screen mesh passing over the bucket. This swirl, which occurs in standard bucket designs, has been shown to injure small fish captured in the buckets. The swirling effect causes buffeting of the in the bucket as it rises to and above the water surface.

The Fletcher buckets were already incorporated in the combined Unit 1 and Unit 2 intake fine-mesh screen alternative and for the offshore fine-mesh screen facility developed and presented in the response to the Department in Reference 19. The Fletcher buckets are a detail of the design intended to be included in any of the original fine-mesh screen alternatives for the Units 2 and 3 intakes. This detail adds no significant impact to the estimated costs for these alternatives. Fish return sluicing systems, which are assumed for any of the fine-mesh alternatives, would need to be significantly longer than the existing sluicing systems and the discharge located much further from the intake structure to prevent re-entrainment of planktonic life stages. The design and cost for the sluicing system has not been included in the estimates. The cost for the sluicing system would be approximately the same for each of the fine-mesh screen alternatives presented. Further study would be required to determine the best discharge location for returning marine biota to LIS, other configuration features, and to determine mortality from pumping larval fish greater distances versus the gravity return flow currently installed. The added cost for the sluicing system is small compared to the overall capital cost for implementing any of the fine-mesh screen alternatives, but nevertheless could be substantial. In addition, a security issue may occur as any opening through the security fence must be limited to a specific dimension. This opening restriction would limit the size of any return sluiceway or would necessitate the installation of bars, etc. to meet the regulation, likely to the detriment of returned organisms and also creating a potential clogging point.

ESSA Comment:

Section 2.2.1, page 4, second paragraph: "Both scenarios [i.e., offshore intake screen system for entire MPS; fine-mesh screens at Units 1 and 2 with water at Unit 1 re-directed to Unit 2] also included the use of variable speed cooling water drives (VSD) to reduce cooling water flow during the critical spring larval period for winter flounder. We assume that Unit 3 was not included in the scenario that used Unit 1 CWPs due to cost and insufficient cooling water flow at Unit 1 to effect a significant reduction in intake velocity at Unit 3. That clarification should have been provided."

DNC Response:

Unit 3 is not included in this scenario because of the limited capacity of the Unit 1 intake when retrofitted with fine-mesh screens. Once retrofitted, the Unit 1 intake does not have sufficient flow to supply supplementary flow to both Units 2 and 3. The maximum capacity of the Unit 1 intake with retrofitted fine-mesh traveling screens and an approach velocity of 0.5 feet per second (fps) is 158,000 gallons per minute (gpm) at mean tide level. This is less than one-half of the current Unit 2 circulating water flow of 504,000 gpm. In addition, the through-screen Unit 2 flow must be reduced to 405,200 gpm during winter flounder season in order to meet the 0.5 fps screen approach velocity at both the Unit 1 and Unit 2 intakes. Therefore, there is insufficient capacity at the Unit 1 intake to also provide supplemental flow to Unit 3.

Note that any option incorporating fine-mesh screens remains at the conceptual plan stage. Further detailed engineering design studies would need to be performed to determine if Unit 1 could actually be tied into the Unit 2 condenser cooling water system. Also, no provision or cost estimate has been made for improved fish return systems (e.g., troughs, fish pump, etc.), which would be needed to safely return organisms impinged on the fine-mesh screens of these alternatives to LIS. A return sluiceway would have to be located at some distance from the intake structures to avoid re-circulation and re-impingement of larvae.

2. Capital Costs

ESSA Comments:

Section 3.1, Concern 7, page 9, f. Option 21 Fine Mesh Screens: "Capital costs including taxes (later deducted) are $36 million for Unit 3 and $20 million for Unit 2. These costs are overwhelmed (p 65, line 5) by the estimated lost revenue during installation because complete shutdown of both units is assumed for 6 continuous months and is not scheduled during a refueling outage."

"Considering the large cost of outages, it would be worth the effort to develop a construction plan, perhaps comparable to the $100 million screening facility for the entire facility (Table 12/14-1), that could be used to keep the plants operating during construction. Additionally, part of the construction could be scheduled during a refueling outage."

DNC Response:

The cost concern issue cited above by ESSA is mostly associated with the 6-month construction related outage for each operating unit. The 6-month construction outage estimated for these alternatives is a product of the use of large cofferdams necessary for constructing the fine-mesh screens in close proximity to the face of the existing intakes. The more recently developed fine-mesh screen alternatives, including combining the Unit 1 and 2 intakes to create a fine-mesh screen facility for Unit 2 and the offshore fine-mesh screen facility (the $100 million screening facility) do not require any construction cofferdams and would not entail construction-related unit outages. The cost for this modified option is substantial nevertheless, estimated at over $36 million as shown in Revised Table III-4-1 in Reference 19.

The construction approach assumed for the $100 million offshore fine-mesh screen facility, which consists of pre-casting large sections of the concrete structures at a remote casting facility, floating them to the site by barge, and placing them in the water with a barge crane is probably not feasible for the individual fine-mesh screen system designs for the two units as explained below. However, a different plan using this similar concept may be possible and has the potential to reduce the unit outage costs for implementing the fine screen alternative at Unit 2 and/or Unit 3.

The fine-mesh screen alternative for the Unit 3 intake structure presented in Part I, Section 5.1 of the 2001 Feasibility Study (Reference 9) was originally developed from the 1993 Feasibility Study (Reference 11) as part of an earlier NPDES Permit renewal application. This concept was originally developed prior to the decommissioning of Unit 1 and the design intent was to develop a preliminary design in sufficient detail to determine an order of magnitude cost for conversion of only the Unit 3 intake system to fine-mesh screens. One design objective of that 1993 effort was to minimize the plan area of the screening structure and forebay and place the new screen structure as close as practical to the existing Unit 3 intake while achieving the 0.5 fps approach velocity to the new fine-mesh screens. The purpose of this design objective was to minimize interference to flow patterns to the Units 1 and 2 intakes created by the new Unit 3 fine-mesh screen structure. The approach assumed constructing a single large cofferdam within which the entire screen structure could be constructed in the dry. This large cofferdam would effectively block flow to the existing intake, and therefore it was assumed that Unit 3 would be shut down during construction of the reinforced concrete portions of the structure. This design was included unchanged with updated costs in the 2001 Feasibility Study.

DNC was requested by the Department to include a design and cost estimate for implementing a fine-mesh screen system for Unit 2 in addition to Unit 3 in the 2001 Feasibility Study. A similar design and construction approach to the Unit 3 fine-mesh screen system, scaled down to Unit 2 flow rates, was selected in order to determine consistent costs for Unit 2. Therefore, in order for the effort to be consistent with the method previously proposed in 1993 for backfitting fine-mesh traveling water screens to the Unit 3 intake, the Option 21 fine-mesh screen alternative did not consider different construction methods to reduce the unit outage times.

A second reason that the offshore fine-mesh screen facility construction approach would not easily work for a separate Unit 2 or Unit 3 fine-mesh screening facility has to do with the depth of water at the two intake structures. These structures have deeper inverts (-27.0 feet at Unit 2 and -28.0 feet at Unit 3) than the invert of the offshore screen structure design for the entire station (-18.0 feet) developed in response to comments given by ESSA in May 2002 (Reference 18). The construction approach assumed for this structure is to construct in the water without cofferdams by pre-casting large structural sections at a remote casting facility, bringing the precast sections to the site by barge, and setting them in place on a pre-prepared tremie concrete mat on the sea floor with a large (1,000 ton) crane. This approach allows construction of the screen structure and end structures with no interference with station operations; therefore no construction outages would be required. The estimated weight of these precast sections for the 18-foot deep structure, which would be independently stable when set in place, is 500 tons. Similar sections for the deeper structures (-27 and -28 feet) would have to be significantly heavier. Handling these extremely heavy sections by barge crane may not be feasible. Therefore in the 2001 Feasibility Study, the cofferdam construction approach was considered a valid approach for these deeper-water structures only.

It may still be feasible that the deeper-water screen structures for the individual fine-mesh screen designs for Units 2 and 3 could be constructed using a series of smaller cofferdams, which would not block flow to the existing intakes. This construction approach, if done in concert with scheduled refueling outages, could potentially reduce unit outage associated with construction from 6 months per unit to as little as 1 to 2 months per unit. The resulting costs of the Option 21 fine-mesh screens for Unit 2 are in excess of $28 million if the outage is limited to 1 month and $46 million for a 2-month outage. For Unit 3, the corresponding costs are $46 million and $69 million, if the construction outage is reduced to 1 or 2 months, respectively.

This approach would also increase construction costs and probably require that the screen structures be placed further out in Niantic Bay than the locations shown for the Option 21 fine-mesh alternative. This extension would result in a larger forebay for each unit, increase the overall structure capital costs, and usurp a larger part of Niantic Bay for use by the station. DNC has not done a detailed cost and construction study for this alternative cofferdam construction method. Based on a review of the current capital cost estimates for these alternatives, the overall capital cost increases in order to reduce the unit outage from 6 months per unit to 1 month are estimated to be in the range of $3 to $6 million for Unit 2 and $5 to $10 million for Unit 3. As a result, even if construction allowed for a shorter outage, the costs of the fine-mesh screen option overwhelm the costs of the options based on operational changes as proposed later in this letter.

3. Operation and Maintenance Costs

DEP Question 6:

6). "Does the cost analysis for the use of various fine mesh traveling screen alternatives discount all applicable O&M and capital (replacement) costs associated with maintaining use of the existing coarse screening systems for Units 2 & 3?"

DNC Response:

The estimated O&M and capital costs presented for the four fine-mesh screen alternatives include only estimated costs for additional equipment and structures as detailed below. Capital and O&M costs estimated for the individual fine-mesh screening facilities for Units 2 and 3 include only costs for new structures and equipment. No O&M costs for the existing traveling screens are included. The original traveling screens would remain in place and in service to provide back-up screening capability in the even that flows to the new fine-mesh screens are bypassed due to clogging with debris or to other failure of the fine-mesh screens. It is assumed that these existing screens would require the same maintenance as they currently require and these ongoing O&M costs are not included in the total O&M costs for the fine-mesh screen alternatives.

The alternative that combines the decommissioned Unit 1 intake with the existing Unit 2 intake to form a fine-mesh screening system includes capital costs for eight new fine-mesh traveling screens. O&M costs for this alternative only includes O&M costs for the four additional traveling screens in the Unit 1 intake. The assumption is made that the costs required to maintain the four new fine-mesh screens in the Unit 2 intake would be the same as that for the existing screens. Therefore, there would be no O&M cost additions for these existing screens. Estimated capital and O&M costs for the offshore fine-mesh screen facility include costs only for the new structure and associated new equipment.

C. SAFETY ISSUES ASSOCIATED WITH REDUCED COOLING-WATER FLOWS

DEP Comment:

3) "ESSA has taken issue with the completeness of the Probabilistic Risk Assessment, as stated in Section 4.0 of their report, and recommends DNC provide a comparison of acceptable risk level of

the overall plant operation to the increased risks caused by the reduced cooling water flows analyzed in the PRA. Also, they have pointed out an inconsistency with respect to the Unit 2 heat balance (figure 7.2-1) in DNC's October response which has not been sufficiently addressed and that this be clarified or corrected as appropriate."

ESSA Comments:

Section 4.0, page 12, first paragraph: "DNC has confirmed that increased risk of plant trips from operation at reduced cooling flows can be eliminated by modified operation."

Section 4.0, page 12, last paragraph: "On page 72 of Enclosure 1, DNC has agreed with ESSA's contention that 'the Unit(s) could be operated with reduced number of CWPs operating with no additional risk of tripping...' ...From these comments, it appears DNC agrees that any degradation in safety margins with reduced cooling flow could be restored, but at an economic cost, as suggested in ESSA's report (ESSA 2002b)."

DNC Response:

As an initial matter, in no case did DNC conclude that risk of plant trip due to operation at reduced flow could be eliminated. In contrast, DNC concluded that "[a]ny new design and method of operation must undergo a rigorous review of risk of reactor trip and incorporate measures to limit that risk compared to the original design bases" (page 71, third paragraph, Reference 19). Furthermore, DNC stated that "[t]his design evaluation [of alternatives] must include the ability of plant operators to diagnose and respond to the new operating scenarios likely to result in a reactor trip" (page 72, first paragraph, Reference 19). In this regard, DNC has incorporated the risk of a reactor trip in its more detailed engineering studies that have been underway since October 3, 2002. As shown in the conclusion of this letter, the Net Present Value ("NPV") estimates for several alternatives, including operating with pumps off, includes the potential added cost attributed to incremental risk of reactor trip and subsequent shutdown. In addition, operational measures to anticipate conditions that may result in reactor trip during reduced-flow conditions have been considered and incorporated into the assessment of flow reduction options.

For purposes of background, the following explains why there is incremental risk of a reactor trip due to operating with reduced number of pumps, and the actions that can be taken to minimize those risks. Both Units 2 and 3 are designed such that two CWPs operate in tandem to cool each condenser section. Unit 3 has three condenser sections or shells, further divided into six water-boxes. Unit 2 has two condenser sections and four water-boxes. A CWP cools each water-box. As a result, each pump cools one-half of its condenser section. If a CWP trips while its corresponding partner is out of service, the plant will trip off-line, because the pressure in the condensers will exceed the steam turbine generator design limits. Flow rate through the condensers determines the backpressure. The units are designed to operate with up to 5 inches-mercury (in-Hg) backpressure in a condenser, and no more than 2 in-Hg differential pressure between the three condensers. Operating procedures require manual trips if pressures continue above these limits, and automatic trips occur at slightly higher levels, e.g., at 7 in-Hg backpressure. These trips prevent catastrophic failure of the main turbine generator.

The pumps cannot be cross-connected when they are already in service because a pump trip would immediately cause reverse flow to the tripped pump and no flow would go through the condenser. This would cause an immediate plant trip and likely damage to pumps and valves. Under carefully controlled procedures, one pump can be shut off during normal operation by slowly throttling valves and realigning flow paths. However, when one pump is off, if its partner pump trips, the main turbine and reactor must be tripped, because one of the condensers and its main turbine would have no load, while the remaining condensers and turbine would be at full load. This would exceed the condenser pressure limits in a matter of seconds. Similarly, assuming full-power operation, if one CWP supplying one condenser is off, and a separate pump trips that supplies a different condenser, it is not possible to keep the plant on line. The plant would trip regardless of whether the inlet water boxes are cross-tied. The resulting pressure differential between the condensers would require a plant trip to prevent a main turbine catastrophic failure. The plant is designed to safely trip because there is no instrumentation or standby operation that can handle the very large energy forces that would need to be controlled in a matter of seconds to keep the plant on line. Even if instantly diagnosed, the idle circulating pumps and valve positions cannot respond fast enough to reduce condenser pressures. These trips are not theoretical – they are serious events because they challenge the major high-energy systems throughout the plant and are to be avoided whenever possible. Further, any unnecessary plant trips create unnecessary challenges to safety-related safe shutdown systems.

Due to the importance of circulating water flow to the integrity and operation of the plants, measures have been put in place and are continually being improved to minimize pump failure or respond to conditions that may lead to pump trip, such as debris loading on the intake screens and the corresponding pressure drop across the screens. Each MPS unit has procedures that provide instructions to determine the challenge to the plant due to degrading environmental conditions or intake structure equipment problems. These procedures prescribe actions, guidance, and supporting information to respond to predicted or actual degraded intake equipment status or weather conditions. The conditions that are monitored at least every 12 hours and more frequently when challenged include the following: circulating pump operation; traveling screen integrity; screenwash pump operability; screenwash strainer operation; screen spray systems; trash racks; trash rakes; and current/predicted environmental factors, such as tidal amplitude, wind speed and direction, wave height, barometric pressure, and season. When these factors approach various thresholds, successive actions are taken. One of the instructions, for example, requires restoration of equipment that is not operating.

Beyond these precautions, MPS has developed maintenance plans ensuring the long-term operability of key systems, including the intake structures. Circulating water pump overhaul and intake bay cleaning are included. The requests for Temporary Authorizations to perform intake de-mucking and pump maintenance are tied to these activities.

ESSA Comments:

Section 4.0, page 12, second paragraph: "The actual increased risk calculated does not take into account any of the mitigating approaches presented by ESSA or DNC, and yet the calculated risk still seems quite low."

Section 4.0, page 15, Missing Information, third bullet: "Third, DNC should have stated what is considered an acceptable level of risk for reactor core damage over the licensed life of the facility."

DNC Response:

Perspective relative to the increased risk of reactor trip and plant shutdown from operations with reduced number of operating pumps is shown in a probabilistic risk assessment (Appendix II to this response). This assessment revises and updates the technical evaluation provided as an attachment to DNC's October 3, 2003 letter (Reference 19). As suggested by ESSA, the conditional core damage probability associated with increased reactor trips is presented in Appendix II. These estimates can be compared to the core damage probabilities that are of concern to the United States Nuclear Regulatory Commission ("NRC"). In general, while operation with reduced number of pumps increases risk of reactor trip, the overall risk does not meet the definition of a significant event per NRC criteria. This analysis assumed of course that the plant does not undertake maintenance activities during pump outages that will simultaneously impact plant nuclear safety systems and that the event is classified as an uncomplicated reactor trip (no loss of primary or secondary integrity or failure of a critical support system). In addition, the analysis was based on operating experience with one pump out of service. Extended operation with only half the CWPs operating will likely increase the risk of reactor trip but is difficult to estimate without actual operating experience.

The relative qualitative risk among different operational and/or technology changes is also given in Appendix II. These estimates have been revised to reflect the assumption that most reactor trips attributed to operation with reduced number of pumps occur as a result of debris loading and that operators can anticipate such events and restart idle pumps. Such actions serve to reduce the risk of reactor trip.

The Department will note, therefore, that the operational changes suggested in the conclusion of this report consider the relative vulnerability of the units to debris loading and the corresponding relative economic and public risk consequences due to the increased likelihood of reactor trip between the units. Unit 2 for example, has historically been less challenged by debris loading and so operating with reduced number of pumps is somewhat less problematic than at Unit 3, assuming such operation is limited in duration. By contrast, condenser valve throttling is the preferred method of operation to reduce flow at Unit 3, where debris loading has been an historical problem. To the extent that operation with reduced number of pumps is undertaken at Unit 3, operating history suggests that idle pumps will need to be restarted frequently to avoid reactor trips attributable to heavy intake debris loading. This reduces the net flow reduction achievable. Finally, the economic analyses of options given in the conclusion of this report also account for the relative probability of mechanical pump failure. Lost revenues due to an outage from pump failure are incorporated into the NPV calculations.

D. REQUEST FOR INCREASED COOLING-WATER FLOW ALLOWANCE

DEP Comment:

4) "One of the alternatives evaluated for higher ΔT /lower flow alternatives was an allowance for an approximate 10% increase in cooling water flow during summer and early fall (mid-June through mid-October) to partially recover electrical power generation lost during the larval winter flounder season. While this may be desirable for the Station from an economic operating standpoint, it would be fundamentally contrary to the intent of EPA's proposed 316(b) rulemaking in progress, and extremely difficult for this Department to endorse."

DNC Response:

As the Department suggests, the purpose of this analysis was to determine if the investment in variable speed pumps could be recovered by operating at higher flows when summer temperatures result in reduced electrical output from the station merely due to decreased heat transfer efficiencies at warm summer water temperatures. The analyses show that the electrical output gained does not result in a payback of the investment in new pumps and therefore will not be considered at this time. However, as previously discussed with the Department, MPS is actively pursuing options that will increase electrical output. Options include: replacing the Unit 2 and 3 turbines with more efficient rotors; improved reactor feedwater flow measurement, which further reduces uncertainties in calculation of reactor power level and allows for higher output on the order of 1.5%; and, finally, a stretch power up-rate at Unit 3 up to 10% through increases in fuel energy. Engineering evaluations are underway to determine the design considerations associated with each of these options. The Unit 3 stretch power up-rate will increase ΔT by as much as 3.5°F and, as a result, must be considered as part of the ongoing permit renewal process. The impact on ΔT is discussed later in the conclusion of this report.

E. VARIABLE SPEED DRIVES (VSD)

DEP Comment:

7) "Why are annual O&M costs for VSDs (i.e. $20k for Unit 2: $30k for Unit 3, page 38 of the DNC response) any higher than pump and motor maintenance costs for the existing fixed speed CWPs?"

DNC Comment:

Estimated annual maintenance costs for variable speed drives for CWP motors are based on actual maintenance experience with variable speed drives for CWPs installed at a large fossil-fueled generating station in New England. These estimated O&M costs are for the variable speed drive units, which have additional maintenance costs above and beyond normal maintenance for the pumps and conventional single speed motors.

III. RESPONSE TO ADDITIONAL ESSA COMMENTS

A. CONTRIBUTION OF MPS TO REGIONAL ELECTRICAL CAPACITY

ESSA Comment:

Section 3.1, Concern 14c, page 11, three paragraphs excerpted: "...Millstone is only one of many possible suppliers of electricity. Reductions of Millstone's generating capability could have profound impact on the utility's management and shareholders, but less impact on the ratepayers. ...the costs of lost generation would be the marginal increment they would pay for electricity from an alternative source within or without the region. This could be an order of magnitude less than the cost to the utility...DNC has not provided support for their contention that reductions in Millstone output will cause regional electricity prices to rise."

DNC Response:

With respect to the first matter, that MPS is only one of many possible suppliers of electricity, the Department is referred to the Connecticut Siting Council Review of the Connecticut Electric Utilities' Ten-Year Forecasts of Loads and Resources, 2002 (accessed at www.ct.gov/csc/lib/csc/16225_resource_book.pdf) and to information from ISO New England (www.iso-ne.com). MPS now represents about 28% of Connecticut's capacity and in 2001 represented over 45% of the state's production. This relatively large contribution can be attributed to a reduction in baseload nuclear-powered electric generation now available to the Connecticut and New England electric grid due to the retirements of Connecticut Yankee, Millstone 1, Maine Yankee, and Yankee Rowe.

The Connecticut Siting Council points out the future of the oil-fired electric plants in Connecticut is in serious question given the age of these plants and the recent state legislation instituting further sulfur dioxide emission limits that "may reduce or eliminate the potential of over 2,700 MW of generation" (Connecticut Siting Council). In the event the MPS units or other large baseload units are not available, the Siting Council suggests the emergency measures would be needed to avoid capacity deficiencies. A complicating factor is the limited transmission capabilities in certain load pockets, most notably in southwestern Connecticut. ISO New England predicts that the loss of aging oil-fired plants in this portion of the state could overload grid connections between New York and New England with a corresponding loss of reliability. Furthermore, ISO New England has identified significant transmission constraints in Connecticut, which are as of yet unresolved. ESSA's statement that MPS is one of many possible suppliers of electricity, as though its replacement were a trivial matter, is an understatement of the current condition and ignores the reality of the electricity generation and transmission challenges facing Connecticut.

As to the second matter, that "from the perspective of ratepayers, the costs of lost generation would be the marginal increment they would pay for electricity from an alternate power source within or without the region," the Department is referred to production cost data from the Nuclear Energy Institute ("NEI"; www.nei.org). The data show that the average year 2000 U.S. production cost of electricity with nuclear power was 1.76 cents per kilowatt-hour (cents/kWh). Comparative levels within the New England Power Pool ("NEPOOL") were 4.11 cents/kWh for gas, 4.76 cents/kWh for oil, and 1.65 cents/kWh for coal. Average production cost at MPS in 2000 was 1.92 cents/kWh, making it extremely cost competitive compared to the NEPOOL average price of 2.89 cents/kWh. Assuming that combined cycle natural gas plants replaced MPS's capacity, NEI estimates that average generation costs for the entire NEPOOL region would increase from 2.89 cents/kWh to

3.21 cents/kWh, an 11% increase. Furthermore, that MPS operations constrain regional electrical costs is a benefit above and beyond the substantial economic base MPS provides to the southeastern region of Connecticut as discussed in the 2001 Feasibility Study Report (Appendix A to Part III).

B. COOLING TOWERS

ESSA Comment:

Section 3.2, page 11, Question B1. Cooling Tower Design Criteria: "DNC has not responded to questions about the objective and design criteria for cooling tower operation only during the environmentally sensitive times of year. (ESSA 2002b, p. 14, Section 3.3)."

DNC Response:

As noted above, the Department in its letter of May 9, 2002 (Reference 18) indicated that "the most effective but far reaching alternatives to reduce cooling water usage at the Station (e.g. natural or mechanical draft cooling towers, off-shore intake, conversion to gas-fired generation etc.) are not practicable to retrofit into an existing facility like Millstone and encumber various adverse impacts in their own right appears to be reasonable and well supported." For this reason and since their cost is clearly disproportionate to any benefit, DNC did not perform any additional analyses on tower design criteria or seasonal operation. While there are efficiency losses and corresponding economic penalties from operating a tower, the high cost of towers is attributed largely to capital and construction costs. Once incurred, these costs are not recoverable, whether a tower is operated seasonally or year-round. DNC focused instead on those options suggested by the Department, such as variable speed pumps, throttling of existing pumps, etc., which in combination with a higher ΔT could result in reduced flow. As a result, no additional evaluation of towers is warranted.

C. RE-PRIMING AND RE-STARTING CIRCULATING WATER PUMPS (CWP)

ESSA Comment:

Section 3.2, page 11, Question B2. Refueling Outages to Reduce Entrainment: "DNC has not provided estimates for enhanced capability for re-priming and restarting CWPs so that potential disadvantages to considering environmental requirements when scheduling refueling could be overcome (ESSA 2002b, p. 15, Section 3.6)."

DNC Response:

DNC is unaware of any measures that would allow restart of a CWP during a trip condition and prevent a reactor trip. Once automatically initiated, the reactor trip will proceed with its safety function. When operating at either two of four CWPs at Unit 2 or three of six CWPs at Unit 3, the loss of another pump would automatically result in a reactor trip without sufficient time for operator action. However, this is not to say that in certain conditions such as storm events or high debris seasons, operators cannot take actions to minimize a reactor trip by tracking condenser backpressure. As backpressure increases, CWPs can be returned to service in appropriate intake bays to ensure action levels triggering a plant trip are not exceeded. The efficacy, including ΔT and economic consequences of operating with reduced number of CWPs, is discussed in the conclusion of this report.

D. GAS-FUELED POWER PLANTS

ESSA Comment:

Section 3.2, page 11, Question B3. Conversion to Natural Gas: "DNC has not commented on environmental and cost comparisons for locating gas-fired plants that would provide equivalent energy at other sites (ESSA 2002b, p. 15, Section 3.6)."

DNC Response:

DNC's 2001 Feasibility Study did consider the environmental and cost implications of locating gas-fired plants that would provide equivalent energy (see Part I, pages I-109 through I-115 and Part II, page II-2-27). More specifically to the point, there are two important matters here that relate to the consideration of either converting MPS to gas or developing alternative sites elsewhere using natural gas in lieu of MPS operations. The first relates to the issue at hand, specifically whether the location, design, construction and capacity of the MPS cooling water intakes represent BTA. The statutory language does not afford a construct such that shutting down a facility and developing an alternative power plant elsewhere is appropriate pursuant to Section 316(b). Secondly, the practical implication of ESSA's suggestion is that having recently purchased MPS for $1.3 billion, DNC spend upwards of another $1.0 billion (2001 Feasibility Study, Reference 9) to locate, permit, construct, and operate a new facility. Expenditures of this magnitude cannot be reconciled in the context of a Section 316(b) determination, particularly in this case, given the questionable ecological benefit of any change to MPS operations. As a result, DNC believes that no further evaluation of this option is warranted. The Department appears to have concurred with this conclusion in noting that a conversion of MPS to a gas-fueled facility is not practical (Ref. 18).

E. COST ESTIMATES

ESSA Comment:

Section 3.2, page 11, Question B4. Relative Uncertainties in Cost: "DNC has commented that costs could be higher than indicated in the tables, but has not placed this comment in the context of relative uncertainties associated with the various alternatives."

DNC Response:

Given that the cost estimates provided to date are based on conceptual designs and used for relative comparison among technologies, further refinement of cost probabilities is premature. Costs developed to date show the disproportionately large cost of certain alternatives such as cooling towers and are sufficiently robust for that purpose. Selection of certain alternatives such as operating with pumps off, throttling, and variable speed pumps have been refined and are discussed later in this letter.

F. CIRCULATING-WATER FLOW RATES

ESSA Comment:

Section 3.2, page 11, Question B5. Flow rates and Screen Velocities: "DNC has not commented on ESSA's contentions that design flow rates are higher than the flow rates that now prevail. Calculated areas and costs for screens therefore are higher than actually needed (ESSA 2002b, p. 16, Section 3.7)." The latter citation is from Reference 18 and reads as follows: "The flow rates used to calculate the required screen areas were based on the flow rates used in the original design of the plant. These design flow rates are higher than the actual flow rates that now prevail. Thus, the calculated required area of the intake screens and the corresponding costs need to be re-visited because they are probably higher than actually needed. The construction cost could be 15 to 30 percent less than the reported estimate."

DNC Response:

The actual calculated flows with all CWPs in the Units 2 and 3 intakes under current system conditions and including service water flows are actually higher than the design flows used to size fine-mesh screen systems for Units 2 and 3. Fine-mesh screen design flow rates as well as the calculated total flow rates for each unit at mean sea level are shown in Table 1.

The fine-mesh screen systems could also be operated in conjunction with a flow reduction scheme. However, the intent of any of the alternative flow reduction schemes is to reduce flows (and thus entrainment) during fish larval seasons and resume full normal flows at other times. Any screen systems designed for MPS would be expected to handle the highest normal system flows.

TABLE 1. Design and calculated flow rates for fine-mesh screen alternative.

Unit	Design flow rate for fine-mesh screen intake structure (gpm)	Calculated total intake flow rate (including service water) at MSL (gpm)
2	500,000[1]	509,000
3	918,000[1]	931,000

Note: The design flow rates for the Units 2 and 3 fine-mesh screens are from Section 5 of Part I of the 2001 Feasibility Study (Reference 9).

G. DISCHARGE GATES

ESSA Comments:

Section 4.0, page 13, Alternative Flow Reduction Method: "The modifications to accommodate a partial discharge gate, which DNC discussed at length, would undoubtedly be necessary, but not as difficult as portrayed by DNC. As mentioned in ESSA's prior comments a differential head of approximately 5 ft. would be sufficient to accomplish the flow reductions described. Flow control gate systems at hydroelectric plants commonly operate at heads of 30 to 50 feet. Designing a partial gate for a 5 foot differential is not difficult from an engineering perspective. For additional comments on this option see the comments on Risk Assessment, Section II, below."

Section 4.0, page 15, Section II: Qualitative Risk Insights, second bullet: "This adjustment of the throttling valves would not be required of the partial discharge gate option. This option would not require any adjustment and would not block more flow than was intended through any water box. However, DNC states on page 74 of Enclosure 1 that 'new gates with controls and like the unit discharge stop log option above offer no advantage over the throttling valve alternative...' Apparently, there is a safety advantage to the partial discharge gate, yet in an apparent conflict of logic DNC provides no more consideration of this option and did not include it in the Risk Assessment."

DNC Response:

The assumption that a 5-foot increase in system resistance is all that is needed to achieve the desired flow reduction does not consider the effects of reduced flow on the system resistance. For example, results from hydraulic modeling for the Unit 3 circulating water system shows that in order to reduce the circulating water flow rate to 690,000 gpm, the system would require approximately 17 feet of added resistance. Most of flow resistance in the circulating water system is due to dynamic flow resistance, which varies with the square of the flow rate. Static lift is a small component (3.5 feet at mean tide level) of the total flow resistance at the design flow rate. As the flow rate is reduced, the system dynamic head losses drop off rapidly such that the majority of the pump head has to be dissipated either through the throttle valves or by throttle gates at the quarry. The Unit 2 circulating water system is similar. A throttling discharge gate system into the quarry would have to be capable of controlling water pressures in the discharge tunnels to the quarry to as much as 20 feet above the current operating pressures.

This throttling device would require the existing open discharge structures to be effectively sealed so that the throttle gates can build up pressure in the discharge tunnel. As a minimum this would require structural modifications to the existing Units 2 and 3 discharge structures to seal the structures and resist the large forces that would be generated by the gates in the throttle position. This would also raise the following major design issues:

- The nuclear safety-related service water systems of both units discharge into their respective discharge tunnels at the upstream ends. These throttle gates would have the potential, if inadvertently fully closed, to block service water discharge to the ultimate heat sink. This would require the design of the throttle gate to allow passage of the service water flow regardless of the gate position. Also, in the throttle mode, the service water pumps would have to pump against this additional head, which was not a part of their original design basis.

- The design of the discharge tunnels is based on open-ended discharges. The throttle gates would subject the entire discharge tunnel systems to pressures they were not designed for. These discharge tunnels operate entirely full during all operating modes. They are currently open-ended conduits. Installing throttle gates at the downstream ends would provide the potential to stop the flow from the CWPs. Standard design practice for a pipe/conduit with a gate or valve at the downstream end is to design for the shutoff head of the pumps supplying the pipe or the maximum transient pressure, which could occur in the pipe, whichever is larger.

The throttle gates offer no technical advantage over throttle valves at the condenser discharge. The throttle valves, located at the condenser outlet water box discharge pipes, are upstream of the service water discharges and would have no effect on service water system operation. Also, the throttle valves would not subject any part of the discharge tunnel systems to overpressures during throttling or if inadvertently completely closed. The circulating water pipe and condenser water passages upstream of the throttle valves are designed to withstand the full shutoff head of the CWPs and any transient pressures, which might be generated in the system with valve closure. Throttling valves can be installed in place of the existing condenser discharge valves with no effect on the discharge structures. Retrofit of throttle valves at the condenser discharges would be significantly less costly than retrofit of throttle gates at the discharge structures to the quarry. Any retrofit of throttling gates at the quarry discharge would require major modifications or reinforcement of the discharge tunnel and redesign of the service water system. For these reasons, a detailed engineering and cost evaluation of throttle gates at the quarry discharge structures was not considered reasonable.

ESSA states (p. 15) "[t]his adjustment of the throttling valves would not be required of the partial discharge gate option. This option would not require any adjustment and would not block more flow than was intended through any water box." This is incorrect, as the discharge gates would need to be adjusted at the beginning and end of the larval abundance season as necessary with throttle valves at the condenser discharges. At the beginning of the larval winter flounder season, when reduced flows are required, the gates would be closed to their throttle positions. At the end of the larval abundance season these gates would have to be fully opened to allow normal circulating water flow rates to resume. As noted in Sections 7.2 and 7.3 of the 2001 Feasibility Study, these design flows are required to maintain adequate condenser cooling when the inlet circulating water temperatures are higher during the summer.

H. FLOW RATES AND HEAT BALANCES

ESSA Comment:

Section 4.0, page 13, last section, Heat balance and Figure 7.2-1: ESSA raises additional issues associated with the Unit 2 heat balances used to calculate relative megawatts lost. Paragraph 1, p. 13: "There are still remaining questions about the heat balance issue. The main concern is discrepancies between the new heat balance and the DNC Evaluation of Cooling Water Alternatives study. The original Unit 2 heat balance dated 4/3/00 showed a total cooling flow for 3 pump operation of 403,200 GPM with a CW ΔT of 30.5°F at a 65°F inlet temperature. This original heat balance shows a minor loss of output: however, DNC is stating this heat balance is incorrect. The new heat balance they provided, dated 2/19/02, shows a total CW flow of 362,560

GPM and shows the 104 MW loss of output. Therefore, if the new heat balance is correct, the cooling water flow rate in the original heat balance must have been too high by 10%. However, the DNC Evaluation of Cooling Water Alternatives report, in table 7.11-1 (including the revised Table 7.11-1 in Enclosure 1), lists the total unit flow for Unit 2 with 3 pump operation as 403,200 GPM, consistent with the <u>original</u> heat balance, not the new one."

DNC Response:

The differences in the flow rate in the 4/3/00 and 2/19/02 heat balances can be attributed to a refinement intended to more accurately reflect the seasonal flow and conservatively estimate the lost generation. As stated in DNC's October 3, 2002 letter (Reference 19), the flow rate for the Unit 2 CWPs was reduced during the summer months in order to match the unit's condenser ΔT of 27°F that is observed during this season. This results in a reduction of the CWP flow rate from 126,000 gpm/pump to approximately 113,300 gpm/pump. This reduced flow rate and consequent higher condenser ΔT is due to increased tube fouling/blockage, which typically occurs during summer. The Unit 2 heat balance was run with this reduced flow rate for the base case when the circulating water inlet temperature (CWIT) was greater than 55°F. The total CWP flow rate (at a 65°F CWIT) for four-pump operation and a condenser ΔT of 27°F is 453,200 gpm. This flow rate and condenser ΔT matches the heat balance dated 2/19/02.

When one of the CWPs is secured, the corresponding condenser cross connect valve is opened to allow flow to be maintained through all four of the condenser water boxes (i.e., one CWP supplying two condenser water boxes). This arrangement results in a reduction in the system flow resistance for the operating pump supplying two condenser water boxes (i.e., parallel flow through two condenser water boxes). This results in that CWP operating further out (at a higher flow rate) on its pump curve. The flow rate for the CWP supplying two condenser water boxes will increase by approximately 20% (i.e., 1.2 x 113,300 = 135,960 gpm) due to the reduced flow resistance. The total CWP flow rate (at a 65°F CWIT) for three pumps operating is 362,560 gpm. This flow rate matches the heat balance dated 2/19/02.

Since the CWP flow rate varies with tide level and condenser fouling/blockage, the CWP flow rate of 126,000 gpm/pump with 4 pumps operating was used as the basis for determining the percent flow reduction. With 3 CWPs operating, a total flow rate of 403,200 gpm was used (i.e., Pumps 1 and 2 = 126,000 gpm each, Pump 3 = 0 gpm, Pump 4 = 151,200 gpm [+ 20%]) as the base flow condition for comparison of percent flow reduction. This flow rate matches the value in Table 7.11-1. Note that the percent flow reduction calculation did not consider the reduced CWS flow rate since this only occurs at the end of the winter flounder season. This results in a conservative percent flow reduction calculation.

ESSA Comment:

Section 4.0, second and third paragraphs of Heat Balances and Figure 7.2-1, p. 13: "The DNC Alternatives Report, section 7.1.2 lists the pump current design flow rates for Unit 2 as 130,625 gpm per pump for 391,875 gpm for 3 pumps. It also states the current flow based on calculation to be 126,000 gpm per pump or 378,000 gpm for 3 pumps.

The DNC report goes on to state in the same section "The design flow rates will be used to evaluate the effects of the flow reduction alternatives. This is conservative for evaluating the effects of flow reduction on both the electrical generation rate and entrainment." However, they have not used the design flow rate for either the flow reduction calculations or the heat balance calculations."

DNC Response:

As stated in the 2001 Feasibility Study (Part I, Section 7.1.2), the original Unit 2 CWS flow rate was reduced from 137,000 gpm per pump to be approximately 130,625 gpm per pump with the installation of a new condenser with smaller-diameter titanium tubes. This flow rate was further reduced to 126,000 gpm, based on the results of calculations. Therefore, the use of a flow rate greater than 126,000 gpm per pump (based on four pumps operating) is not appropriate. As discussed in DNC's response to the comments in the first paragraph of Section 4.0 of ESSA's review, the system flow resistance is reduced when one CWP is secured due to parallel flow paths and the total CWS flow rate can not be determined by multiplying the flow per pump by three. The flow rate for the CWP supplying two condenser water boxes will increase since the pump will be operating further out on its pump curve. Operating with three CWPs results in a total Unit 2 flow rate of approximately 403,200 gpm.

The current flow rate (126,000 gpm), modified to reflect reduced pump operation, was used to determine the percent flow reduction. However, as explained in the responses to the comments in the first paragraph of Section 4.0 of ESSA's review, the CWP flow rate used in the heat balance at higher CWITs was reduced to match the actual seasonal condenser ΔT. In addition, depending on the system operating conditions (e.g., number of operating CWPs), the CWP flow rate will change. The flow rate used in the heat balances was appropriately modified to account for this effect and produce conservative estimates of the flow reduction.

ESSA Comment:

Section 4.0, fourth paragraph of Heat Balances and Figure 7.2-1, p. 13: "The CW system flow rate is a function of the pump and cooling system characteristic and is not affected by cooling water temperature or the time of year. It is affected by tide and other conditions such as screen and condenser tubesheet fouling. It has a significant effect on the CW system ΔT and, therefore, the output of the unit under the NPDES permit during the summer. Therefore, ESSA believes that DNC should have clarified what it believes are the correct flow rates for the Unit 2 pumps under conservative conditions and used those flow rates for <u>all</u> analyses, including the energy loss calculations."

DNC Response:

ESSA is correct that the CW system flow rate is a function of the pump and cooling system characteristic. As stated in the DNC responses above for paragraphs one through three, plant operating data show that condenser ΔT increases and flow decreases during the summer months. This is the result of increased tube fouling/blockage. In addition, the flow rate is a function of the CW system operating condition (e.g., three CWPs operating with condenser cross-connect valves open). DNC used CW system flow rates based on the seasonally appropriate CW system alignment and operating conditions in the heat balances.

In order to determine the MWe loss, a comparison was made between the unit's output for two scenarios at varying CWIT: 1) a baseline heat balance with all pumps operating, and 2) the particular scenario that is being analyzed (e.g., pumps off, throttling, variable speed drives, etc.). Since the original submittal of the 2001 Feasibility Study (Reference 9), a reduced CWP flow rate of approximately 113,300 gpm/pump has been used for the baseline heat balance case in order to maintain a condenser ΔT of 27°F. This is conservative since it results in a lower unit electrical output (i.e., base case) compared with the analyzed scenario and will result in a smaller MWe loss for input into the financial model.

The actual CWP flow rate varies based on tide levels, condenser conditions, and system operating conditions. To conduct the evaluation of alternatives, a constant CWP flow rate was approximated based on the system operating conditions to determine the percent flow reduction. This CWP flow rate was compared against the value of 126,000 gpm/pump. This results in a consistent basis for determining the percent flow reduction for the various alternatives that are analyzed.

ESSA Comment:

Section 4.0, fifth and sixth paragraphs of Heat Balances and Figure 7.2-1, p. 14: "The revised heat balance provided does show a 104 MW loss in output, but it is calculated at a 65°F cooling water inlet temperature, which does not occur until July 14. Additionally, the total temperature rise is 30.8°F, not 32°F as allowed by the NPDES permit. Figure 7.2-1 shows the July 14 MW loss at approximately 110 and not the 104 MW loss shown in the heat balances. These are not significant differences and although there is no apparent reason for the discrepancies they are not the main concern.

If the restriction on Unit 2 operation was based solely on the ΔT, the loss should have a smooth curve without the two lower discontinuities in slope that occur in Figure 7.2-1. Perhaps there are more issues in the NPDES Permit than stated in Enclosure 1. Heat balances run at 55°F and 60°F inlet temperature would have been helpful in understanding this figure. These runs must have been performed in developing the figure."

DNC Response:

Figure 7.2-1 was developed to show the change in the Unit's generation rate as a function of the inlet water temperature and NPDES Permit limitations. The curves for operation of both four and three CWPs were developed by subtracting the heat balance results at a cooling-water intake temperature ("CWIT") from a constant unit's generation rate. However, to determine the MWe loss, which is used in the financial model, the differences between the two heat balances at the same CWIT were used and corrected for pump power.

As stated in the response to the first paragraph of Section 4.0 of ESSA's review, the CWP flow rate was reduced whenever the CWIT was greater than 55°F in order to be consistent with actual plant operating condition. This change in flow rate resulted in a step change in the MW loss, as shown in Figure 7.2-1, for 3 CWP operating condition. In addition, for three CWP operation, the reactor power also had to be reduced to approximately 2,450 MWt in order to avoid exceeding the NPDES permit ΔT limit of 32°F. This resulted in a major step increase in the MW loss.

As ESSA correctly pointed out, the condenser ΔT at a CWIT of 65°F was approximately 31°F, rather than the allowed 32°F in the NPDES permit. Raising the condenser ΔT to 32°F would have resulted in a smaller MW loss. Additional heat balances performed for the other alternatives matched the NPDES or proposed condenser ΔT limits. Since this specific alternative is not being considered, the analysis was not rerun in order to match the 32°F condenser ΔT limit.

IV. CONCLUSIONS AND RECOMMENDATIONS

Throughout the process of evaluating technology and/or operational alternatives to the existing once-through cooling-water system at MPS for reducing entrainment of fish eggs and larvae, DNC has been fully responsive to the requests made by the Department. DNC has provided a substantial amount of engineering, economic, and ecological information encompassing the full range of possible options. In addition, the Department, with the support of ESSA, its third party independent consultant, has thoroughly examined information provided and requested elaborations or clarifications as necessary. As a result of this process, DNC has concluded that, at this time, there remains considerable uncertainty that any measurable benefit will accrue to the recreationally and commercially important fisheries resources of LIS from an alternative cooling-water intake technology at MPS. In this regard, without changing the current cooling-water intake technology, DNC is proposing a suite of operational measures focused specifically on reducing the entrainment of larval winter flounder. DNC continues to maintain that the impact of MPS is only one of many factors affecting the regional decline of this species, and that until these factors are fully understood and resolved, actions taken at MPS should be commensurate with the estimated level of impact from the station. DNC has reviewed five options in further detail, each of which includes a combination or suite of operational measures or technologies intended to reduce larval winter flounder entrainment (Attachment III). The option suggested by DNC for implementation is discussed below with respect to the potential magnitude of flow reduction, the seasonality of winter flounder abundance, the scheduling of planned refueling outages, economic consequences, and changes to station ΔT and corresponding changes to the thermal plume.

DNC is also proposing additional research on larval winter flounder survival on fine-mesh screens. The intent of this research is to clarify the uncertainty associated with this technology and further evaluate its application at MPS.

A. Proposed Flow Reduction

This DNC proposal is based on the guidance provided by the Department in Reference 18, specifically that there are "several alternatives by which DNC can reduce intake flows...which, especially in combination with a potentially higher ΔT, could result in significant reduced Station inflow and entrainment losses". Further, DNC's suggested approach allows for operational flexibility to achieve flow reduction commensurate with that which could be achieved through the use of variable speed pumps. DNC estimates that peak entrainment season average annual flow reductions on the order of 35% can be achieved when compared to the existing cooling water flow at Units 2 and 3. When compared to the existing NPDES-permitted flow at MPS (including Unit

1), this achieves on the order of 50% flow reduction during the peak larval winter flounder entrainment season.

DNC's proposal is tied to an increase in ΔT during the winter flounder season and smaller ΔT increases during the remainder of the year to accommodate pump maintenance and planned power up-rates. The operational measures suggested include the use of pumps off, throttling, and refueling outages to achieve an average station flow reduction of up to 35% during the peak larval winter flounder entrainment season averaged over a 3-year period, the rationale for which is given below. Actual entrainment reduction expressed as a percentage of larvae that would have been entrained compared with full station flow (current NPDES-permitted flow) will vary from year to year in relation to the actual timing of spawning and larval development, which occurs independently of the flow reduction schedule.

B. Winter Flounder Season of Peak Abundance

As indicated in the 2001 Feasibility Study (Section II, page II-3-8), winter flounder larvae are mostly entrained from March through early June. An analysis of entrainment data collected from 1976 through 1999 indicated that, on average, over 95% of the larvae were collected between the dates of March 22 through June 5. The peak larval entrainment season for purposes of planning intake cooling-water flow reductions was estimated to occur from April 4 to May 14, when a long-term average of 76% of winter flounder larvae are entrained. The DNC-recommended option is based on flow reductions for the April 4 to May 14 period.

C. Cooling-Water Flow Reduction Protocol

As previously indicated in the 2001 Feasibility Study (Reference 9), MPS Units 2 and 3 now operate on 18-month cycles with alternating Fall-Spring refueling outages. The next Spring refueling outage at Unit 3 occurs in 2004. Unit 2 follows in Spring 2005. No Spring refueling outage occurs in 2006. Thus, in 2 of every 3 years, at least one refueling outage will occur during the larval winter flounder season. To the extent that the refueling outage does not encompass the entire larval winter flounder season, MPS will reduce flow with a combination of pumps off and throttling. In those years when a refueling outage occurs, it may be possible to achieve more than the desired 35% flow reduction, but it would be less in those years when no Spring refueling outage occurs. Nevertheless, the goal will be to achieve an average 35% flow reduction over the 3 years. Examples of the timing and combinations of flow reduction options are shown in Appendix III. Note that additional operational measures can be taken either before or after the refueling outage to achieve the desired flow reduction. As is currently the practice, DNC will report to the Department annually its success in meeting this objective, including an estimate of flow reduction and in the number of winter flounder larvae entrained.

D. Economic Evaluation of Recommendation

The additional reduction in operational flow, other than that taken during the refueling outage, will require a corresponding reduction in MPS power level and total megawatts produced. The economic consequences of this expressed in terms of NPV are also shown in Appendix III. This appendix also summarizes the suite of operational measures used for each option to achieve flow reductions. As indicated above, the economic analyses are based on fewer than the full complement of pumps in operation and/or throttling and consider the added risk of reactor trip while operating in those conditions. However, as discussed elsewhere in this report, actions to minimize those risks would be put in place. Further, operating with reduced number of pumps is restricted in this proposal to relatively short time periods encompassing the larval winter flounder season of abundance. While it remains an option and may be utilized to some extent, extended operation of Unit 3 with less than six CWPs is not recommended as a routine matter due to the higher incidence of intake debris loading experienced historically at that unit and the corresponding increased risk of plant trip.

DNC believes that implementing Option 2 as shown in Appendix III (i.e., securing two Unit 2 CWPs and throttling all the Unit 3 CWPs) during the peak season of winter flounder larval occurrence (April 4-May 14) provides the best overall balance between flow reduction and cost, given the uncertainty that an alternative technology will measurably benefit the Niantic River winter flounder population. Option 2 includes condenser cooling-water flow reductions during refueling outages that coincide with the larval winter flounder season, and, within that portion of the larval season that falls outside of the refueling outage period, operation of Unit 2 with two of four CWPs off and operation of Unit 3 with throttled condenser outlet valves. To supplement flow reductions during a year when Unit 2 undergoes a refueling outage, Unit 3 will employ condenser outlet valve throttling during the Unit 2 outage period as well.

Variables affecting reductions in percent flow and larval entrainment achieved in any given year, as also discussed in the 2001 Feasibility Study, include the exact timing of the refueling outage and its duration, the occurrence of peak larval occurrence and operational events such as storm related debris loading, which may require restart of pumps on the operating unit to prevent a reactor trip. During refueling outage periods, the cooling-water flow reductions shown in Attachment III for Units 2 and 3 are substantial and these charts do not reflect the benefit of the additional condenser cooling-water flow reductions from the Unit 1 shutdown. Accounting for the shutdown of Unit 1 yields flow reductions, when compared to the existing NPDES-permitted flow, well in excess of

60% during a Unit 3 refueling outage and over 50% during a Unit 2 refueling outage. Averaged over the entire larval winter flounder season, the annual flow reductions for Option 2 range from approximately 42% in 2004 to 28% in 2006, not including the benefit of the Unit 1 shutdown. A 20-day outage, during which maximum flow reductions are achieved, was assumed for purposes of the scenarios shown in Attachment III. During the initial phases of a shutdown, pumps operate for a period to remove decay heat and are restarted prior to the end of an outage to support reactor and steam generator reheat.

Options 3 and 5, based on operation with variable speed pumps during non-outage periods, are included by way of comparison. These options provide modest reductions in flow compared with the Option 2 operational changes alone (refueling outages, pumps off and/or throttling), however, the capital cost is substantially higher for these options, due to the costs of variable frequency drives (pump motor controllers) and associated building and electrical connections. Costs for each of the options encompassing both the winter flounder larval season and tautog spawning periods (March 22-August 22) are much higher due to the additional MWe lost when intake water temperatures increase during summer and additional power reductions are necessary to meet even the higher proposed ΔT limits.

E. Increased ΔT

An allowance for higher ΔT is requested as part of this proposal to implement Option 2 since, as suggested by ESSA and the Department, the MWe lost due to flow reduction can be partly ameliorated, if not constrained by the difference in temperature across the unit. Accordingly, DNC is proposing higher ΔTs as discussed below. The water quality implications of these higher discharge limits are discussed in a following section. During the larval winter flounder season, when flow reductions are achieved, the ΔT at Unit 2 would be limited to 46° F with an allowance up to 48°F for 24 hours due to tidal changes or operational conditions such as condenser fouling or a pump trip. The corresponding ΔT limits at Unit 3 would be 38°F and 40°F. The effective operational ΔTs may be less than indicated in these limits as they allow for some operating margin, but experience is needed to determine the actual operating range. The derivation of these limits (across the condenser) is shown in Tables 2 and 3. Note that due to normal tidal and diurnal variation, these temperatures may vary as much as ±2°F.

The total temperature rise reflects: 1) an accounting for discharge temperatures actually observed (experienced), which are typically higher than design due to condenser fouling; 2) expected temperature rise from planned power up-rates: 1°F for Unit 2; and up to 3.3°F for Unit 3; and 3) an allowance for operator margin.

TABLE 2. Summary of MPS Unit 3 condenser outlet discharge temperature (°F) under various operating conditions.

Description	Design temperature rise (°F)	Modified for experience (°F)	Including power uprate (°F)	With operating margin (°F)
3 of 6 pumps secured	28	32	35.3	37
VFD Drives 27° F Rise or 3" Vacuum-limited	27	31	34.3	36
VFD Drives 32° F Rise or 4" Vacuum-limited	32	36	39.3	41
VFD Drives 4" Vacuum-limited	36	40	43.3	45
Throttle Condenser discharge valves	22	26	29.3	31
Normal Operation	17	21	23	25
Normal Operation w/maintenance, pump off		24	26.4	28

Normal tidal variations are +/- 2° F from these values.

TABLE 3. Summary of MPS Unit 2 condenser outlet discharge temperature (°F) under various operating conditions.

Description	Design temperature rise (°F)	Modified for experience (°F)	Including power uprate (°F)	With operating margin (°F)
2 of 4 pumps secured	40	44	45	47
VFD Drives 36° F Rise or 3" Vacuum-limited	36	40	41	43
VFD Drives 44° F Rise or 4" Vacuum-limited	44	48	49	52
Normal Operation	24	28	29	31
Normal Operation w/maintenance, pump off		36	37	38

Normal tidal variations are +/- 2° F from these values.

As shown in the above tables, an additional thermal allowance is requested for Unit 2 operation with one or more pumps shut down during times of the year other than the larval winter flounder season when pump maintenance or intake cleaning are necessary. The existing permitted ΔT limit for normal operation of up to 32°F would be retained for four-pump operation with a provision for extended operation up to 38°F with one or more pumps out of service, and an upper limit of 44°F for no more that 24 hours to account for pump trips or other emergency conditions.

For Unit 3, DNC requests a ΔT limit of 28°F for normal operation. This will accommodate the planned power up-rate of about 10% and the corresponding 3.3°F temperature rise. A 30°F ΔT with a 24-hour upper limit of 36°F is proposed, should a planned or unplanned pump outage occur requiring extended maintenance. Since intake maintenance activities generally occur during the colder months of the year, any impact of the higher ΔT would be lessened. It would not be the intention to routinely operate with one or more pumps shut down outside of the larval winter flounder season, except for intake maintenance, pump repairs, or other necessary circulating-water system maintenance.

In summary, proposed changes to NPDES Permit ΔT limits at each MPS unit and at the Quarry Cut into LIS are given in Table 4. No specific ΔT limits are proposed for the Quarry Cut. However, a maximum discharge temperature of 105°F is proposed for routine operation and during pump maintenance activities. A Quarry Cut maximum temperature limit of 108°F is requested for operation during the larval winter flounder season. It is expected that Quarry discharge temperatures would not routinely approach the 108°F limit except near the end of the larval winter flounder season, should ambient water temperature reach 60°F.

TABLE 4. Existing and proposed ΔT limits (°F) at MPS Units 2 and 3 discharges into the MPS Quarry and at the Quarry Cut into LIS.

ΔT limit	Unit 2	Unit 3	Quarry Cut
Existing	32 (44)[a]	24 (30)	32 (105 maximum temp.)
Proposed routine operation	32 (44)	28 (30)	none (105 maximum temp.)
Proposed larval winter flounder season	46 (48)	38 (40)	none (108 maximum temp.)
Proposed for pump maintenance	38 (44)	30 (36)	none (105 maximum temp.)

[a] Numbers in parentheses are a 24-hour maximum limit.

These proposed ΔT limits will provide allowances for start-up and shutdown evolutions, operation during storms or other periods of high debris loading potentially affecting pumps online, and provides for routine backwash maintenance activities. Flexibility will enable reduced flow operation during the larval winter flounder season with reduced number of pumps or by throttling.

F. Water Quality Criteria Evaluation of Increased ΔT

Dr. Eric Adams of The Massachusetts Institute of Technology completed an analysis of thermal plume size and behavior for DNC (see Appendix IV). For his modeling, flow conditions at MPS included a CW flow of 281,00 gpm with a ΔT of 48°F at Unit 2 and 461,000 gpm with a ΔT of 40°F at Unit 3. As noted in the previous section, these ΔTs represent the higher allowances for Units 2 and 3 and, therefore, are a worst-case condition for modeling. After averaging in service water flow, the MPS combined discharge at the Millstone quarry cuts under this scenario was 796,000 gpm having a ΔT of 41.3°F. Although this operating condition would likely only occur during the larval winter flounder season, Dr. Adams determined some effects under both winter and summer ambient temperature conditions. Note that the worst-case scenario (i.e., Unit 3 in shutdown with only Unit 2 operating at lower flow and higher ΔT than normal) was not completed in this analysis. If Unit 3 were to unexpectedly shutdown during the period of reduced flow, Unit 2 was expected to resume operation with its normal complement of CWPs once Unit 3 has completed its shutdown.

The thermal plume under the proposed higher delta T operating condition during the winter flounder larval season would be smaller and shallower in extent than under present two-unit operation or former three-unit plant operation. The plume size dimensions determined in the present analysis were about 8% larger than those given in the Units 2 and 3 reduced flow model analyzed in Reference 19 (p. 7). Similar conclusions reached in Reference 19 with regard to environmental effects associated with the thermal plume are applicable to the present operating scenario. There would be a potential change to the nearby rocky shore community located to the northeast of the quarry cut openings, including a replacement of natural flora by more opportunistic and warm water-tolerant seaweeds, and a reduction or loss of both sessile invertebrates (barnacles, blue mussels) and animals having limited mobility (e.g., predatory and grazing snails). This would occur despite the limited period of reduced flow/higher ΔT operation because it would take place during the spring period of settlement for many of these forms. Nevertheless, any changes would be limited to a small, near-field area of the shoreline close to the MPS quarry cut discharges. Far-field effects would likely be less than had occurred under former three-unit operation. For example, all the isotherms for the present scenario are smaller in aerial extent and the 1.5, 4, and 6°F isotherms are about one-half to two-thirds the calculated depth of the thermal plume determined at low slack under former three-unit operation. It is during this tidal condition that the MPS thermal plume has its maximum extent within Jordan Cove. Extensive ecological studies have shown no evidence of thermal effects to resident flora and fauna within Jordan Cove, including eelgrass, benthic infauna, shore-zone fishes, and the rocky shore community.

One potential environmental effect noted by Dr. Adams in his report for reduced flow/higher ΔT operation is the possibility of ambient bay water entering the MPS quarry underneath the outgoing thermal plume. This could result in the entrainment of plankton, including the eggs and larvae of fish, into the quarry. However, this potential effect was limited to summer and there is little probability of occurrence during the spring larval winter flounder season.

The postulated thermal plume for reduced flow/higher ΔT operation is consistent with Connecticut Water Quality Standards and present NPDES-permitted thermal allowances for MPS. By operating routinely this way only during the larval winter flounder season the maximum permitted discharge temperature of 105°F would probably not be exceeded except near the end of the larval winter flounder season as ambient water temperature approaches 60°F. As noted above, a maximum quarry cut temperature limit of 108°F was requested to allow for this condition. The thermal plume would not affect other water quality parameters given by the Department for coastal and marine surface waters. NPDES Permit conditions for parameters such as pH and chemical constituents would remain in place and would be monitored in accordance with the permit. Allowing for a mixing zone of 8,000 feet (as in the present NPDES Permit), the average temperature of the receiving waters would not be warmed by more than 4°F nor would the maximum increase in temperature exceed 83°F. Finally, the zone of passage for aquatic organisms would not be impeded by this mode of operation.

As with previous examinations of the MPS thermal plume (e.g., Reference 19), the dynamic nature of the plume is a result of rapid mixing and dilution, facilitated by considerable tidal movements. Many years of ecological studies have shown that the MPS thermal plume has resulted in little or no impact to aquatic biota beyond the immediate vicinity of the quarry cuts.

G. Fine-Mesh Screen Research

As indicated above in the DNC response to ESSA's comments on the efficacy of fine-mesh screens, this technology has not been proven successful in reducing mortality of winter flounder larvae at cooling-water intakes located in high energy, high debris marine environments. The uncertainty associated with its application at MPS and considering the high cost of retrofit or prototype testing at the station, argues for an experimental and incremental approach. DNC proposes, therefore, to undertake laboratory experimentation to determine the survival of winter flounder larvae exposed to fine-mesh screens at different simulated intake velocities and levels of debris. This work would be performed by ARL at their facility in Holden, Massachusetts. ARL's proposal, including a summary of their experience, is attached as Appendix V to this response.

V. REFERENCES

1. Letter C09668, M.J. Harder to F.C. Rothen, dated November 15, 1999.
2. Letter D15309, F.C. Rothen to M.J. Harder, dated December 30, 1999.
3. Letter C09872, M.J. Harder to F.C. Rothen, dated February 16, 2000.
4. Letter C10302, M.J. Harder to F.C. Rothen, dated July 13, 2000.
5. Letter D15614, F.C. Rothen to M.J. Harder, dated March 13, 2000.
6. Letter D16199, F.C. Rothen to M.J. Harder, dated August 30, 2000.
7. Letter C10566, M.J. Harder to F.C. Rothen, dated November 14, 2000.
8. Letter from M. J. Harder to F.C. Rothen, dated November 20, 2000.
9. Letter D17249, W. Matthews to M. J. Harder, dated August 31, 2001.
10. NPDES Permit No. CT0003263, Millstone Nuclear Power Station, Units 1, 2 and 3, Northeast Nuclear Energy Company, issued December 14, 1992.
11. Letter D06112, C.F. Sears to T. Keeney, dated January 27, 1993.
12. Letter C05513, E.C. Parker to D. Miller, dated January 14, 1994.
13. Letter, M. J. Harder to DNC, dated December 26, 2001.
14. Letter C10827 from J.F. Grier to M. Keser, dated February 6, 2002.
15. Letter D17305, G. W. Johnson to J. F. Grier, dated February 26, 2002.
16. Letter D17306, G. W. Johnson to J. F. Grier, dated March 14, 2002.
17. Letter D17333, G. D. Hicks to J. F. Grier, dated June 12, 2002.
18. Letter C10845, J. F. Grier to P. Jacobson, dated May 9, 2002.
19. Letter D17347, G. D. Hicks to J. Grier, dated October 3, 2002.
20. Letter D17404, G. D. Hicks to J. Grier, dated February 5, 2003.
21. C10885, ESSA Report dated January 21, 2003, submitted to CT DEP.
22. Letter C10880, J. F. Grier to P. Jacobson, dated February 10, 2003.
23. Letter C01591, R. Barlow to J.F. Opeka, dated November 23, 1987.

APPENDIX I OF ENCLOSURE TO DNC LETTER D17445

ALDEN RESEARCH LABORATORY, INC. JETTY STUDY

Information provided to Dominion Nuclear Connecticut, Inc. by:

**Alden Research Laboratory, Inc.
30 Shrewsbury Street
Holden, MA**

ALDEN Solving Flow Problems Since 1894

April 9, 2003

Mr. Paul Jacobson
Manager - Environmental Services
Dominion Nuclear Connecticut, Inc. (DNC)
Rope Ferry Road
Waterford, CT 06385-0128

Dear Mr. Jacobson:

Thank you for providing Alden Research Laboratory, Inc. (Alden) a copy of a report submitted to the Bureau of Water Management (CTDEP) by ESSA Technologies Ltd. (Toronto, ON and Vancouver, BC). The report contains comments on DNC's response to NPDES review.[1]

In support of DNC's response, Alden performed several computer analyses designed to assess the ability of shoreline structures to reduce the entrainment of organisms from Niantic River.[2] The results of these analyses are discussed in Section 2.1 of the ESSA report.

Model Summary

In their report, the ESSA reviewers acknowledge the ability of Alden's computer model to show the effects of shoreline structures intended to reduce the concentration of organisms entering the plant intakes from Niantic River. The depth-averaged flow model extends from a Western limit at Black Point to an Eastern limit at Goshen Point. The Northern limit of the model is located in Niantic River and the Southern limit of the model is located in Long Island Sound. Tidal boundary conditions were specified in Long Island Sound and "source" and "sink" elements were defined at the locations of intake numbers 2 and 3 and at the location of the heated water discharge at the end of Millstone Point. Together, these elements account for the (volumetric) loss of cooling water drawn into the intakes and the (volumetric) gain of heated water released by the plant.

To determine the ability of shoreline structures to reduce the entrainment of organisms from Niantic River a continuous scalar source was located in the mouth of the river. The movement of this scalar quantity was computed in tandem with the calculation of tidally driven flows in Niantic Bay and the results were used to estimate concentrations of organisms entering the intakes under different conditions (*i.e.*, for situations where different shoreline structures were

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[1] Reference Document: "Comments on Dominion Nuclear Connecticut's Response to ESSA Review of the Evaluation of Cooling Water System Alternatives to Reduce Entrainment at Millstone Nuclear Power Station," submitted to Bureau of Water Management (Connecticut DEP), by ESSA Technologies Ltd. (Toronto, ON and Vancouver, BC), January 2003.

[2] Reference Document: "Evaluation of Shoreline Structures Designed to Minimize the Entrainment of Organisms into the Cooling Water Intakes at the Millstone Power Station," submitted to Dominion Nuclear Connecticut, by Alden Research Laboratory, Inc., August 2002.

placed in the vicinity of the intakes). The shoreline structure that minimized the concentration of organisms entering the intakes was said to be the "best."

In response to their review, ESSA requested clarification and comment on a number of points regarding Alden's assessment of shoreline structures used to reduce the entrainment of organisms from Niantic River. Each of ESSA's comments is provided in the section that follows as well as Alden's response. Similar to the ESSA report, the comments for "right angled groins" and "parallel offshore barrier" are provided separately.

Right Angled Groins

ESSA Comment: "In the model simulations the groins appear to have been situated such that the intakes themselves were located within the back eddy induced on an ebb tide. To test the potential effectiveness of a groin during an ebb tide, did the model simulations investigate alternative locations further north of the intakes, and if so what was the observed effect on concentrations of Niantic River organisms entering the intakes?"

Response: No, other model simulations with groins located further north of the intakes were not performed. The groin designs considered in Scenarios 1 and 3 were intended to represent reasonable alternatives. In Scenario 1, the ability of two large shoreline perpendicular structures was analyzed (the nominal length of these structures was 700 feet); and in Scenario 3, the ability of two smaller shoreline perpendicular structures was analyzed (the nominal length of these structures was 400 feet).

The results of Scenarios 1 and 3 indicate that right angled groins, of the size modeled, tend to delay the arrival of larvae at the Millstone intakes. However, the right angled groins do not significantly change the circulation patterns in Niantic Bay. Therefore, essentially the same "mix" of water arrives at the intakes with or without the groins in place and the concentration of organisms entering the intakes is about the same.

The animated results show that organisms from the river enter Niantic Bay during an ebb tide. As time progresses, the concentration of organisms in the head of the bay increases and gradually the organisms progress towards Millstone Point on successive ebb tides. Organisms that encounter groins located along the Eastern shore of Niantic Bay (*i.e.*, between the mouth of Niantic River and the Millstone intakes) are prevented from moving directly towards the intakes. However, the concentration of organisms on the riverside (*i.e.*, upstream side) of the groins increases with time and eventually the organisms pass around the groins (similar to the way sand bypasses a groin at the conclusion of a beach nourishment project). The net effect of the groins, in this case, is to delay the arrival of organisms only. Based on these observations, we conjecture that moving a groin further north of the intakes will not appreciably change the amount of Niantic River water entrained by the Millstone intakes.

In contrast to this, building very long groins (*e.g.*, groins greater than 700 feet in length) could change the concentration of organisms from Niantic River that is entrained into the Millstone intakes. In this case, the placement of very long groins would effectively cause the intakes to draw water from a great distance offshore (where concentrations of Winter flounder larvae may be different - although data suggests that concentrations of larvae would be similar). However, the placement of extremely long groins could affect the circulation of water through Niantic Bay and have unforeseen consequences (*e.g.*, sedimentation/erosion patterns in the bay could change and a significant navigation hazard would be created).

To summarize: additional analysis related to the design of right angled groins was not performed since the use of right angled groins (of reasonable length) did not appear to offer significant benefit. Furthermore, Alden could not identify a project where right angled groins were used, successfully, to minimize the entrainment of organisms at a power plant intake (if ESSA or the CTDEP could provide an example, then Alden would be pleased to assess the performance of a similar design installed at this location).

<u>ESSA Comment</u>: "In concert with the investigation of groins, did the simulations consider more than one location for the source of organisms, and if so, what was observed? Organisms originating from Niantic River probably tend to be dispersed in the ebbing tidal flow - the estuary discharges a large volume of stored tidal water into the Bay. Organisms originating from the shoreline areas immediately north of the intakes (South of the Niantic River Estuary) could tend to be more concentrated in the shoreline currents. A back eddy induced by a groin at an appropriate location might results in a larger reduction of entrained organisms."

<u>Response</u>: No, studies addressing the entrainment of organisms originating at "other" locations were not performed together with the investigation of groins since the addition of the right angled groins did not appear to change the "mix" of waters entering the intakes.[3]

Note: Since the original report was drafted by Alden (2002), additional studies addressing the fate of organisms originating at other locations in Niantic Bay without the groins have been completed as part of an Electric Power Research Institute (EPRI) sponsored research project. Figure 1 shows the percentage of organisms entrained from twenty-six starting locations positioned in Niantic River, Niantic Bay, and Long Island Sound (*i.e.*, Figure 1 shows the Hydraulic Zone of Influence (HZI) of the Millstone plant as it exists today).

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[3] As the comment suggests, organisms originating from the shoreline areas immediately north of the intakes would tend to be more concentrated in the shoreline currents than organisms originating in the Niantic River. Hence, the right angled groins could work more effectively to reduce the entrainment of organisms originating along the shoreline immediately to the north of the intakes. However, this study concentrated on the movement of organisms originating in Niantic River since the fate of these organisms was of particular concern. Also, field data suggests that the concentration of Winter flounder larvae is fairly uniform measured from the shoreline to locations well offshore into Niantic Bay and for a uniform distribution of organisms groins of any length will not reduce entrainment.

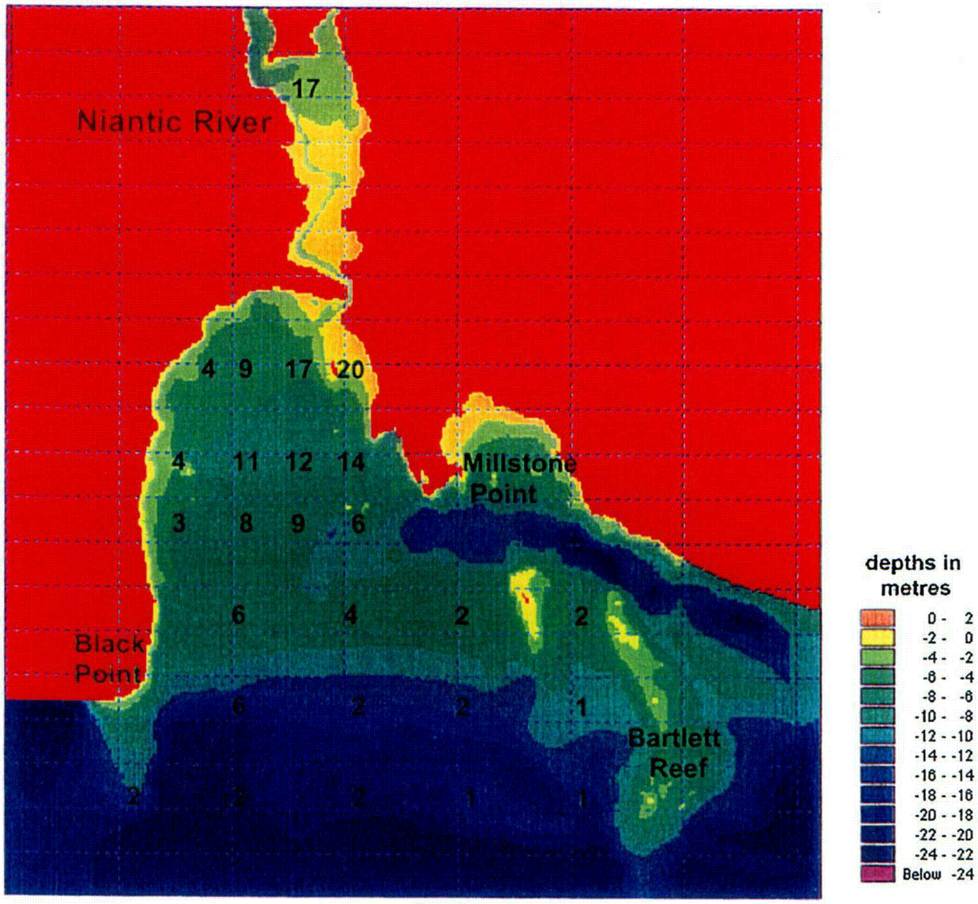


Figure 1: Probability of Entrainment, Percentage
(preliminary results, colored by water depth)

The depth-averaged flow model used for the jetty study was constructed as part of EPRI's Hydraulic Zone of Influence research project. As part of this study, "passive organisms" (*i.e.,* conservative scalar quantities) were released into the coastal waters surrounding Millstone Point at twenty-six different locations. The percentage of organisms entrained by Millstone from each of the twenty-six locations was calculated. Figure 1 shows the probability of entrainment for organisms released at each of the twenty-six test locations for existing conditions (note: probabilities are overlain on a map colored by water depths). It is plainly seen, in Figure 1, that it is more likely for an organism to be entrained from a starting location in Niantic Bay than from a starting location in Long Island Sound.

ESSA Comment: "It is not clear that the computer model can account quantitatively for the boundary layer separation and resulting effects of such a groin. Would a physical laboratory model provide more confidence in measuring the effectiveness of shoreline structures?"

C01

Response: Numerical models such as this can account for flow separations around structures such as the right angled groin. The resolution of flow separations depends mostly on the grid spacing used for the computations, as well as the approach used for turbulence closure. In Alden's study, the numerical model was constructed on a twenty-five meter uniform grid. This provided adequate resolution for the definition of the shoreline structures and produced an overall model consisting of 75,000 active control volumes. Seven day simulations (*i.e.*, 14 tidal cycles) required about 24 hours of computer time. Long term, 50-day, simulations required about one week of computer time. If the grid size was reduced by half, then the overall model would have consisted of four times as many control volumes (300,000 active control volumes) and the time required to complete the simulations would have increased by at least a factor of four as well (seven-day simulations would have required four days of computation and 50-day simulations would have required four weeks of computation). Since the 75,000 control volume model produced reasonable results - we chose to use it for the EPRI and Millstone studies.

As an alternative to the numerical model, a physical laboratory model could also have been used for this study. However, the cost of such a project would be consider higher than the cost associated with this study and the results would not necessarily be more reliable (*e.g.*, scale effects might be difficult to overcome depending on the chosen size of the physical model).

Parallel Offshore Barrier

ESSA Comment: "A potential solution to recirculation that could be easily investigated with the computer model is the effectiveness of gate-equipped opens located at both ends of the parallel barrier. The following two modes of operation could be assessed:

1. During the flood tide only the gates nearest to the intakes would be open - the model studies show that this will provide a source of water relatively free from passive organisms originating from Niantic River. At this time the gates nearest to the heated water from the quarry would be closed - this would eliminate concern for heated water recirculation."
2. During the ebb tide the gates nearest to the intakes would be closed - the model studies show that this will provide a source of water relatively free from passive organisms originating from Niantic River. At this time the gates nearest to the heated water from the quarry would be open - the model studies show that this would eliminate concerns for heated water recirculation."

Response: The parallel offshore barrier, proposed by DNC, successfully reduces the entrainment of winter flounder larvae at the Millstone intakes because the approach "essentially" moves the entrance of the intakes into the Long Island Sound. The multi-gate solution, proposed by ESSA, would work during the ebb-tide but not during the flood tide since water containing organisms from Niantic River would have been transported to the vicinity of the "northern" gate by the previous ebb-tide. The entrainment of Niantic River larvae would be reduced by about 25% compared to a 50% reduction associated with the DNC design (see Figure 2). The cost of the

ESSA alternative would also be quite high and the finished product would still suffer from the same limitations as the DNC design (*e.g.*, safety would be a concern).

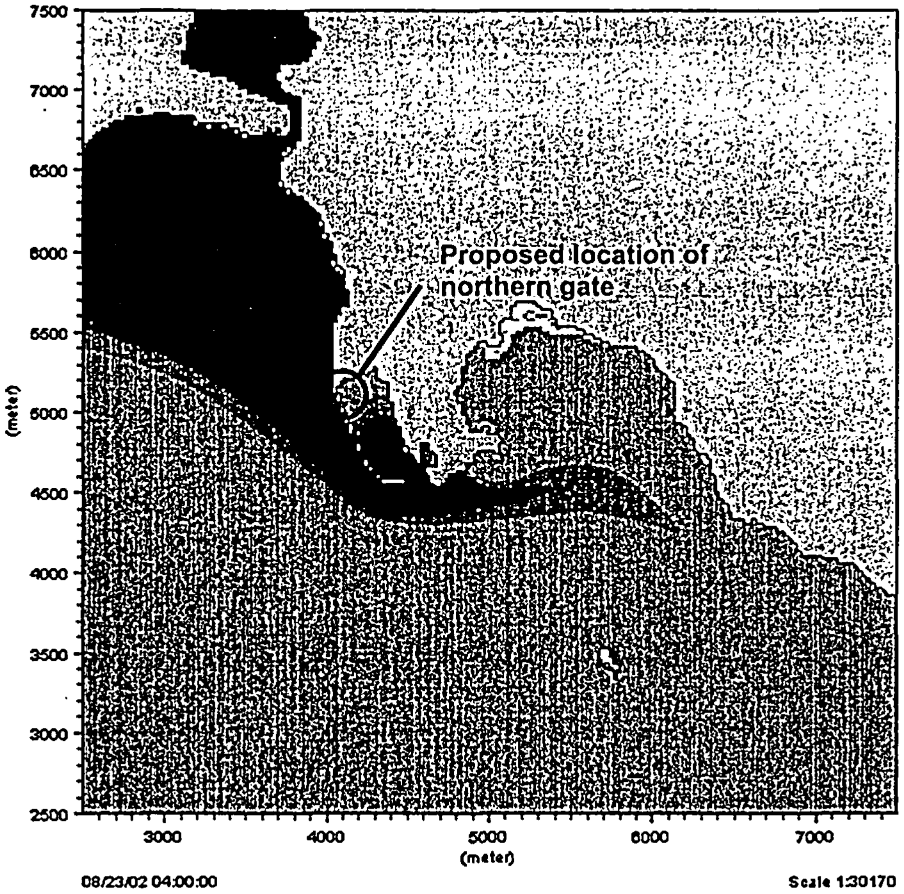


Figure 2: Parallel Offshore Barrier, Proposed DNC design
(colored by larvae concentration)

ESSA Comment: "A third possible strategy to mitigate recirculation of heated discharge with the shoreline barrier that could be simulated with the model is the effect of the discharge from the quarry being relocated to the Northeast side of the quarry into the bay that is opposite to the intakes. Discharging the heated effluent to the Northeast side of the quarry headland may be sufficiently far from the intakes to prevent recirculation of the discharge during a flood tide."

Response: This modification could be studied with the numerical model (at least in a rudimentary way). However, discharging water into the bay that is opposite the intakes would heat the water of the embayment substantially. With the current design, the discharge at the end of Millstone Point releases heated water into a relatively deep area in Niantic Bay where tidal flows are vigorous (Figure 1 – deep water areas at the end of Millstone Point) this helps to disperse the heated plume. The heated plume would not be as easy to disperse if the discharge location was moved into the adjacent embayment.

Summary

The results of Alden's study suggest that reasonably sized right angled groins cannot be used to reduce the entrainment of organisms at the Millstone Plant. A parallel offshore barrier could be used to reduce the concentration of organisms originating in Niantic River that enter the Millstone intakes; however, a great number of drawbacks affect this design concept.

Do not hesitate to contact me if you have any additional questions regarding Alden's study.

Sincerely,

John E. Richardson, Ph.D., P.E.
Senior Fluids Engineer

JER/sjb

APPENDIX II OF ENCLOSURE TO DNC LETTER D17445

RISK ASSESSMENT OF PROPOSED COOLING WATER SYSTEM (CWS) ALTERNATIVES TO MITIGATE IMPACT ON MARINE LIFE IN THE LONG ISLAND SOUND MILLSTONE UNIT 2 AND 3

Prepared by Dominion Nuclear Connecticut, Inc.

1.0 Purpose

This technical evaluation assesses the public risk of proposed cooling water system operation alternatives designed to mitigate the impact on marine life in the Long Island Sound. The original risk assessment was modified to address comments provided in the ESSA report dated January 21, 2003 (Ref. 5.8). The previous assessment was appended to DNC's October 3, 2003 letter (Ref. 5.7).

Note that change bars were not used due to the extensive number of revisions made.

2.0 Discussion

To lessen the potential environmental impact of Millstone Station on the Niantic River population of winter flounder, one option is to operate the units with at least one circulating water pump secured at either Unit 2 or 3 during spawning season. This will reduce the total flow extracted from the Long Island Sound which is postulated to decrease the entrainment of winter flounder larvae. The winter flounder larval spawning season is between 3/22 and 6/5 (Ref. 5.3). DNC has suggested a reduction in flow during the period of peak concentration of winter flounder larvae which is between 4/4 and 5/15. Therefore, the proposed timeframe of operation with at least one circulating water pump secured at each plant is between 4/4 and 5/15.

However, the practice of operating with one circulating water pump secured makes the affected unit more susceptible to a plant trip. The circulating water pumps provide cooling water from the Long Island Sound to the main condenser that ultimately removes heat generated by the reactor coolant system. The main condenser is subdivided into bays with 2 circulating water pumps supplying cooling to each bay. Millstone Unit 2 has 2 condenser bays served by 4 circulating water pumps; Millstone Unit 3 has 3 condenser bays and 6 circulating pumps. Failure to supply cooling to one condenser bay results in an automatic plant trip. Therefore, operating with one circulating water pump secured makes each unit vulnerable to a plant trip due to failure of the remaining circulating water pump in the affected condenser bay.

Although the nominal reactor trip event is not considered an accident within the plants' Final Safety Analysis Report (FSAR), it is modeled within the Probabilistic Risk Assessment (PRA) since it presents a challenge to the plants' ability to achieve a safe shutdown. The reactivity control, Reactor Coolant System (RCS) integrity, and RCS decay heat removal safety functions are required to operate following a reactor trip to ensure safe shutdown and thus, prevent core damage.

3.0 Safety Significance

This evaluation consists of the following 3 sections:

- Section I provides a qualitative risk assessment of the proposed option of operating with one circulating water pump secured. This option is one of the four qualitatively evaluated in Section II.

- Section II provides a risk assessment of the four proposed options designed to reduce the adverse impact of Millstone Station operation on marine life.
- Section III discusses the regulatory concerns associated with unplanned reactor trips.

Section I: Qualitative Risk Assessment of Operating with one Circulating Water Pump Secured

Plant Operating History

A review of plant operating history was performed to determine if there had been any instances of either unit incurring an automatic plant trip due to loss of circulating water flow to one condenser bay given one pump is not operating. The search yielded the following:

Unit 2

On 4/29/01, a unit trip occurred due to a loss of a second circulating water pump, which caused a degraded condenser vacuum and turbine trip (Ref.: Root Cause Investigation of CR-01-04614).

On 5/7/01, the unit was manually tripped due to the loss of two circulating water pumps supplying cooling to one condenser. The A circulating pump and its traveling screen were tagged out for work in the bay; the traveling screen in the adjacent B bay was also tagged out for diver protection. This was a normal plant configuration for this work evolution at the unit since there had been no history of rapid intake structure fouling. Accumulating seaweed and eelgrass on the B screen eventually caused the screen high differential pressure, which tripped the B pump. (Ref.: Root Cause Investigation of CR-01-04910) The root cause investigation concluded that the probable reason Unit 2 had not experienced an intake structure fouling event prior to 5/7/01 was the additional debris removal capability provided by operation of the Unit 1 screen wash system (which was recently disabled as part of that Unit's decommissioning process). The Unit 1 and Unit 2 intake structures are located directly adjacent to each other and it is postulated that Unit 1 screen wash system operation assisted the Unit 2 screen wash system with removing debris from the Unit 2 intake structure.

Given that the Unit 1 screen wash system is no longer in operation coupled with the history of trips that have occurred at Unit 3 due to excessive debris build-up, operating with one circulating water pump secured increases the potential for a reactor trip.

Unit 3

On 5/10/90, a manual reactor trip occurred due to rapid buildup of seaweed on the B traveling screen resulting in trip of the B circulating water pump which was supplying both waterboxes in the condenser bay. (Ref. 5.4)

On 4/5/92, after performing thermal backwash of the E circulating water pump bay and while preparing to perform thermal backwash of the F bay, the E circulating water pump tripped resulting in loss of circulating water to one condenser bay causing a reactor trip. (Ref. 5.4)

On 11/11/98, with the A circulating water pump removed from service to facilitate back-flushing the A waterbox, high delta P across the B traveling screen caused the B circulating water pump to trip resulting in a reactor trip. (Ref. 5.4)

There have been three instances where Unit 3 experienced a reactor trip when operating with one circulating water pump out of service. Furthermore, each event occurred either directly due to rapid debris buildup or during attempts to prevent excessive debris buildup from occurring (i.e., when back-flushing). Therefore, the conclusion is that Unit 3 is highly susceptible to incurring a reactor trip when operating with one circulating water pump secured during periods of excessive debris buildup.

Public Risk Impact

The proposed timeframe of operation with at least one circulating water pump secured is between 4/4 and 5/15 or 40 days. With one pump secured, failure of the adjacent pump within the condenser bay would result in a plant trip. There are 2 possible failure mechanisms for an operating pump; 1) equipment failure or, 2) loss of pump suction due to excessive debris buildup. Both possibilities were evaluated probabilistically and it was concluded that the loss of pump suction scenario is much more likely to occur and therefore, the equipment failure scenario is not discussed further.

The proposed 40-day timeframe is considered a high debris activity period at the intake structures in which several of the reactor trip events discussed above, have occurred. Each occurrence of a reactor trip event is reported to the NRC in a Licensee Event Report and, per Ref. 5.6, is subject to additional NRC investigation based on the conditional core damage probability. A conditional core damage probability between 1E-06 and 1E-05 would be subject to additional investigation at the discretion of the NRC.

Unit 2

Assuming that Unit 2 will be operating for the next 30 years with license extension granted, the plant is postulated to be operating with at least one circulating water pump secured for an equivalent of 3.3 of those years. Assuming that the 5/7/01 event is an indication that Unit 2 will have future excess debris build-up issues, it is anticipated that at least one event will occur which challenges the operators to start a secured circulating water pump to prevent a reactor trip event.

According to the most recent PRA model update (Ref. 5.1), the average reactor trip event frequency is 2.43/year and the associated core damage frequency is 1.09E-06/year. The conditional core damage probability for reactor trip events is 4.49E-07. The reactor trip event is defined as an uncomplicated plant transient (i.e., neither loss of primary/secondary system integrity nor failure of a critical support system). The reactor trip event contributes 2% to the overall Unit 2 core damage frequency of 5.31E-05/yr.

Unit 3

If Unit 3 is assumed to be in operation for the next 40 years with license extension granted, the plant is postulated to be operating with one circulating water pump secured for an equivalent of 4.4 of those years.

Based on the large exposure time of 4.4 years and plant operating experience indicating that three trips have occurred when operating with one circulating water pump out of service, it is anticipated that at least one event will occur which challenges the operators to start a secured circulating water pump to prevent a reactor trip event.

According to the most recent PRA model (Ref. 5.2), the reactor trip event frequency is 1.24/year and the associated core damage frequency is 3.68E-06/year. The conditional core damage probability for reactor trip events is 2.97E-06. The reactor trip event is defined as an uncomplicated plant transient involving no loss of primary/secondary system integrity or total failure of a critical support system. The reactor trip event contributes 18% to the overall Unit 3 core damage frequency of 2.04E-05/yr.

The Effect of Reduced Power on Offsite Grid Stability

Running the plants at reduced power would not have much impact on the stability of the grid voltage; there are sufficient reserves to meet the demand. In the summer months however, when the power demand is at its peak, the margin will decrease. This may impact the grid stability. However, the proposed forty day window for operation with one pump shutdown is over before the peak summer load typically occurs.

A plant trip at Millstone will cause a small, momentary voltage instability on the grid. The voltage dip will be short-lived however, until the standby units start and synchronize to the grid.

Section II: Risk Insights Associated with Proposed Cooling Water System Alternatives

Several options have been proposed to reduce the impact of Millstone Station on marine life in the Long Island Sound. The main objective of these alternatives is to reduce the circulating water flow at the Unit 2 and 3 Intake Structures, respectively, and hence reduce entrainment of fish larvae during specific months of the year. These options were evaluated, independently of the risk assessment, against several criteria including: technological feasibility, implementation costs, required plant modifications, and operational constraints.

As discussed in Ref. 5.7, page 74 in response to DEP comments, the partial discharge gate option requires that the plant be shut down to install the stop logs. It will also need to be shut down again in order to remove them at the end of the spawning season. In addition, the cost to design and install even such a rudimentary design change is significantly more than the option of throttling the condenser discharge valves. Therefore, the partial discharge gate option was screened from further consideration.

Subsequently, several other options were screened out based on cost or judged not feasible alternatives; thus, the remaining four options were analyzed:

1. reduce the number of operating circulating water pumps
2. reduce the number of operating circulating water pumps with new cross-connects installed between condenser bays
3. throttle the condenser discharge valves
4. provide variable speed motors for the circulating water pumps.

The subsequent qualitative risk assessment ranks the four proposed alternatives according to the potential risk of incurring a reactor trip which challenges the plant's engineered safety features and, as calculated in Section I, can lead to core damage.

Option	Potential Reactor Trip Risk
Reduce the number of operating circulating water pumps.	Millstone 3 operational experience indicates that this plant configuration has led to 3 reactor trips. Millstone 2 operational experience indicates that this plant configuration has led to 1 reactor trip. The root cause of 3 of the 4 trips was excessive debris build-up resulting in total loss of flow to one condenser bay. In this proposed option, the secured circulating water would be considered standby equipment able to be placed in service if intake conditions become degraded. Operator action would be necessary to identify the degrading conditions and then to start the pump. Since the winter flounder larval season coincides with the high debris activity period, the likelihood of operator action being necessary to avoid a reactor trip is high. However, given that sufficient indication is available to detect degraded intake conditions, and operator action is considered uncomplicated, the operator failure probability is determined to be low. Therefore, the overall risk of this option is considered MEDIUM. This conclusion differs from the original analysis because this evaluation determined that the most likely scenario for losing an operating circulating water pump is loss of suction due to debris buildup and not random failure.
Reduce the number of operating circulating water pumps with new cross-connects installed between condenser bays.	The benefit of this option is that flow would still be provided to a condenser bay that had lost both circulating water pumps. The cross-connect valves would be opened prior to removing one circulating water pump from service and thus, would not challenge the operators' ability to cope with a plant transient caused by loss of 2 adjacent circulating water pumps. The risk of this option is considered LOW.
Throttle the condenser discharge valves, or Provide variable speed motors for the circulating water pumps.	The benefit of these options is that no circulating water pumps would need to be secured. At the beginning of the larval season, operators would place the plant equipment in a pre-determined position until the spawning season ended. Therefore, this would not significantly challenge the operators' ability to control condenser vacuum. The risk of these options is considered LOW. The conclusion for the discharge valve option differs from the original analysis because this evaluation determined that the operator failure probability is low since the action is not continuous (i.e., valve position adjusted per procedure and further monitoring not required).

Section III: Regulatory Concerns of Unplanned Nuclear Reactor Trips

Unplanned reactor trips/scrams (both automatic and manual) pose safety concerns to the nuclear licensees as well as the Nuclear Regulatory Commission (NRC). Each reactor trip event would be subject to an NRC inspection per the Incident Investigation Program (Ref. 5.7) and tracked as a measure of performance by the NRC Reactor Oversight Program. The complete NRC reactor oversight process is provided in NUREG-1649, "New NRC Reactor Inspection and Oversight Program," and SECY 99-007, "Recommendations for Reactor Oversight Process Improvement," as amended in SECY 99-007A.

Under the NRC reactor oversight process, nuclear licensees are required to submit quarterly performance indicator (PI) reports within seven key areas referred to as cornerstones. One of the seven cornerstones monitored by the NRC oversight process is "Initiating Events" which has the following three performance indicators:

- Unplanned (automatic and manual) trips per 7,000 critical hours.
- Reactor trips with loss of normal heat removal per 12 quarters.
- Unplanned power changes per 7,000 critical hours.

Therefore, since each reactor trip event occurring at Millstone leads to an increase in regulatory scrutiny, minimizing the trip frequency is highly desirable.

4.0 Conclusion

Of the four feasible options, operating with at least one circulating water pump in standby is judged to result in a higher risk than the other options due to an increased potential of incurring a reactor trip. However, the overall public risk impact of an uncomplicated reactor trip does not meet the definition of a significant operational event per Ref. 5.6.

5.0 References

5.1 PRA99YQA-02863S2 "MP2 Final Quantification" Rev. 3 CCN-1.

5.2 PRA00YQA-01822S3 "Millstone 3 PRA Model" Rev. 0 CCN-1.

5.3 Millstone Power Station, "An Evaluation of Cooling Water System Alternatives," August 31, 2001.

5.4 Calculation No. PRA94YQA-01051-S3, Rev. 2, "MP3 Data Update."

5.5 Memo NE-02-F-168 "Risk Assessment of Proposed Cooling Water System (CWS) Alternatives to Mitigate Impact on Marine Life in the Long Island Sound," July 29, 2002

5.6 NRC Incident Investigation Program Directive 8.3, March 27, 2001.

5.7 Millstone Power Station Cooling Water System Technology Study Response to DEP Comments, October 3, 2002.

5.8 ESSA Technologies Ltd. Report, "Comments on Dominion Nuclear Connecticut's Response to ESSA Review of the Evaluation of Cooling Water System Alternatives to Reduce Entrainment at Millstone Nuclear Power Station, " January 21, 2003

APPENDIX III OF ENCLOSURE TO DNC LETTER D17445

SUMMARY OF OPERATIONAL AND ECONOMIC EVALUATION FOR PROPOSED COOLING WATER SYSTEM (CWS) ALTERNATIVES AT MPS UNITS 2 AND 3

Prepared by Dominion Nuclear Connecticut, Inc.

Circulating Water Flow Reduction Option Summary

Flow Reduction Net Present Cost ($000s)

Season	Option 1	Option 2	Option 3	Option 4	Option 5
Peak Winter Flounder Season April 4 - May 14	$1,736	$4,053	$11,572	$2,323	$9,403
Full Winter Flounder Season March 22 - June 5	$2,671	$6,930	$14,188	$4,239	$13,141
Full Winter Flounder + Tautog Season March 22 - August 22	$11,561	$34,815	$20,497	$26,282	$37,754

Option 1

Credit for MP2 / MP3 Outages.
Secure 1/2 MP2 Pumps only during non outage years.
Throttle MP3 Pumps only during non outage years.

Option 2

Credit for MP2 / MP3 Outages.
Secure 1/2 MP2 Pumps during all MP2 and MP3 non outage periods.
Throttle MP3 Pumps during all MP3 non outage periods.

Option 3

Credit for MP2 / MP3 Outages.
Use MP2 VFD's during all MP2 non outage periods.
Use MP3 VFD's during all MP3 non outage periods.

Option 4

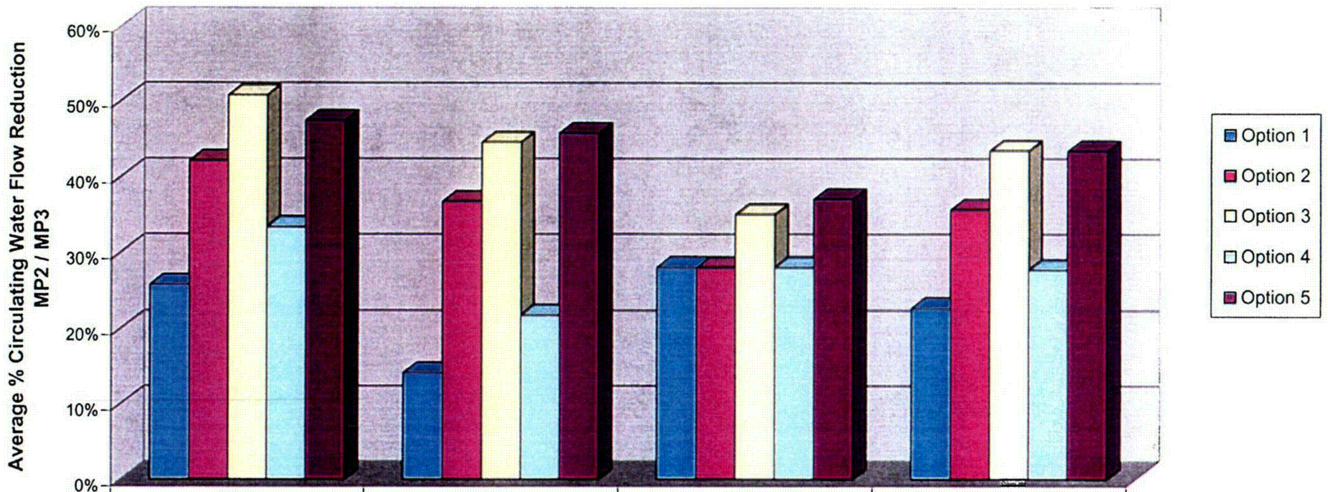
Credit for MP2 / MP3 Outages.
Secure 1/2 MP2 Pumps before / after MP2 and MP3 outage periods.
Throttle MP3 Pumps and secure 1/2 MP2 Pumps during MP2 / MP3 non outage years beginning in 2006.

Option 5

Take Credit for MP2 / MP3 Outages.
Secure 1/2 MP2 Pumps during all MP2 and MP3 non outage periods.
Use MP3 VFD's during all MP3 non outage periods.

04/29/2003

Circulating Water Flow Reduction Option Summary
Peak Flounder Season April 4 - May 14


1 / 3 Year Average Flow Reduction MP2 / MP3

	2004	2005	2006	3 Year Running Average
Option 1	26%	14%	28%	23%
Option 2	42%	37%	28%	36%
Option 3	51%	45%	35%	43%
Option 4	33%	22%	28%	28%
Option 5	47%	46%	37%	43%

The same three year pattern repeats through plant life

➡ **Option 1**
Credit for MP2 / MP3 Outages.
Secure 1/2 MP2 Pumps only during non outage years.
Throttle MP3 Pumps only during non outage years.

➡ **Option 2**
Credit for MP2 / MP3 Outages.
Secure 1/2 MP2 Pumps during all MP2 and MP3 non outage periods.
Throttle MP3 Pumps during all MP3 non outage periods.

➡ **Option 3**
Credit for MP2 / MP3 Outages.
Use MP2 VFD's during all MP2 non outage periods.
Use MP3 VFD's during all MP3 non outage periods.

➡ **Option 4**
Credit for MP2 / MP3 Outages.
Secure 1/2 MP2 Pumps before / after MP2 and MP3 outage periods.
Throttle MP3 Pumps and secure 1/2 MP2 Pumps during MP2 / MP3 non outage years beginning in 2006.

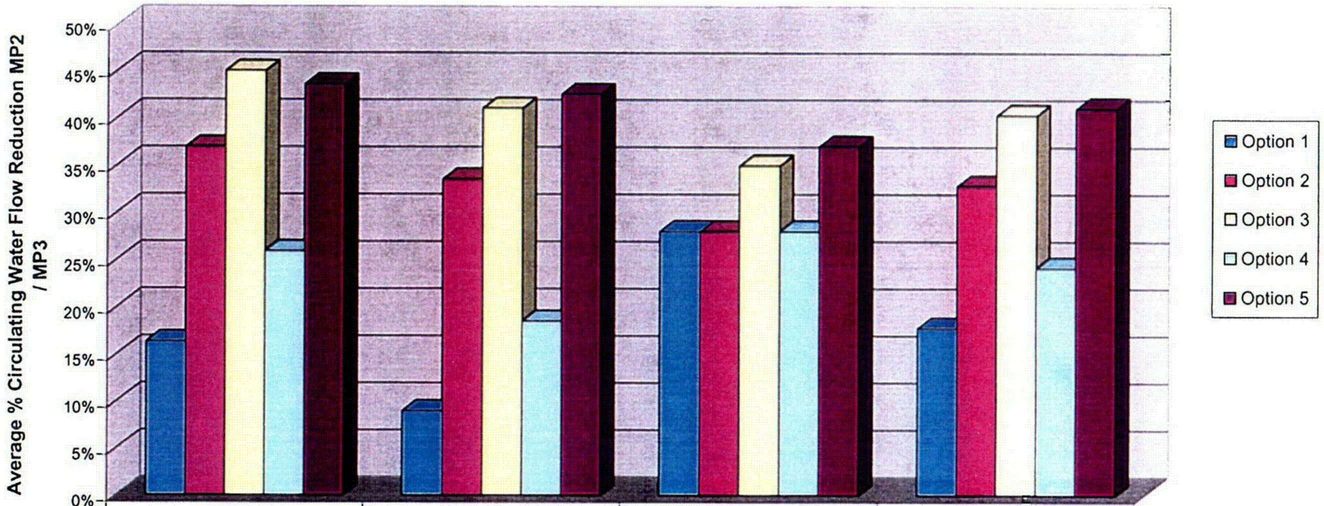
➡ **Option 5**
Take Credit for MP2 / MP3 Outages.
Secure 1/2 MP2 Pumps during all MP2 and MP3 non outage periods.
Use MP3 VFD's during all MP3 non outage periods.

04/29/2003

C02

Circulating Water Flow Reduction Option Summary
Full Flounder Season March 22 - June 5

1 / 3 Year Average Flow Reduction MP2 / MP3



	2004	2005	2006	3 Year Running Average
🟦 Option 1	16%	9%	28%	18%
🟥 Option 2	37%	34%	28%	33%
☐ Option 3	45%	41%	35%	40%
☐ Option 4	26%	19%	28%	24%
🟪 Option 5	44%	43%	37%	41%

The same three year pattern repeats through plant life

➡ **Option 1**
Credit for MP2 / MP3 Outages.
Secure 1/2 MP2 Pumps only during non outage years.
Throttle MP3 Pumps only during non outage years.

➡ **Option 2**
Credit for MP2 / MP3 Outages.
Secure 1/2 MP2 Pumps during all MP2 andMP3 non outage periods.
Throttle MP3 Pumps during all non outage periods.

➡ **Option 3**
Credit for MP2 / MP3 Outages.
Use MP2 VFD's during all non outage periods.
Use MP3 VFD's during all non outage periods.

➡ **Option 4**
Credit for MP2 / MP3 Outages.
Secure 1/2 MP2 Pumps after outage periods.
Throttle MP3 Pumps and secure 1/2 MP2 Pumps during non outage years beginning in 2006.

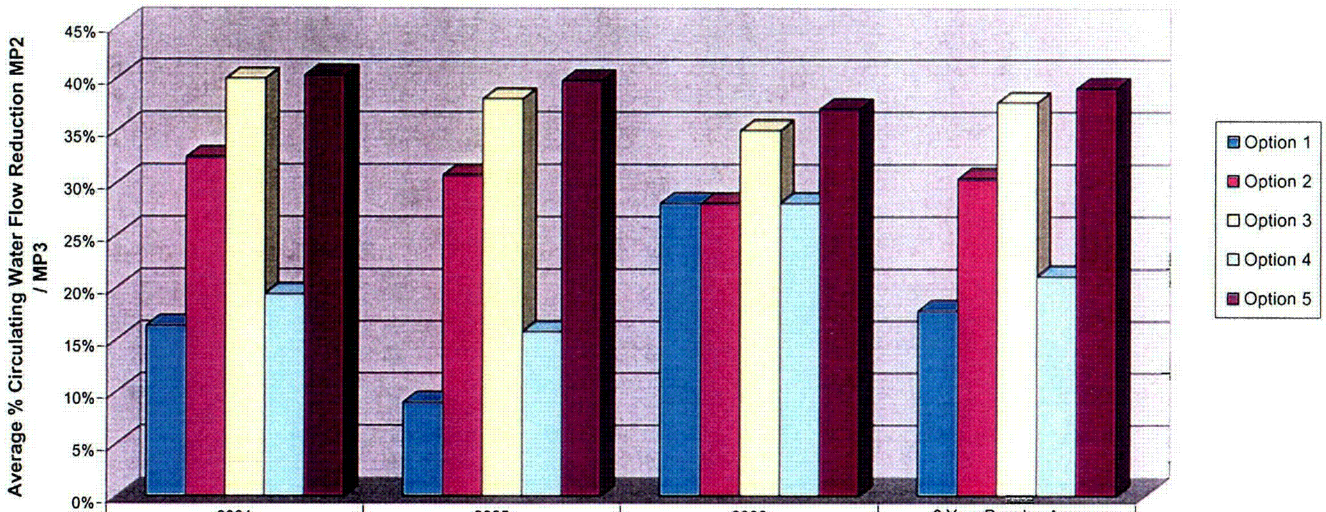
➡ **Option 5**
Take Credit for MP2 / MP3 Outages.
Secure 1/2 MP2 Pumps during all MP2 and MP3 non outage periods.
Use MP3 VFD's during all MP3 non outage periods.

04/29/2003

C03

Circulating Water Flow Reduction Option Summary
Full Flounder + Tautog Season March 22 - August 22

1 / 3 Year Average Flow Reduction MP2 / MP3



	2004	2005	2006	3 Year Running Average
■ Option 1	16%	9%	28%	18%
■ Option 2	32%	31%	28%	30%
□ Option 3	40%	38%	35%	38%
□ Option 4	19%	16%	28%	21%
■ Option 5	40%	40%	37%	39%

The same three year pattern repeats through plant life

Option 1
Credit for MP2 / MP3 Outages.
Secure 1/2 MP2 Pumps only during non outage years.
Throttle MP3 Pumps only during non outage years.

Option 2
Credit for MP2 / MP3 Outages.
Secure 1/2 MP2 Pumps during all MP2 and MP3 non outage periods.
Throttle MP3 Pumps during all non outage periods.

Option 3
Credit for MP2 / MP3 Outages.
Use MP2 VFD's during all non outage periods.
Use MP3 VFD's during all non outage periods.

Option 4
Credit for MP2 / MP3 Outages.
Secure 1/2 MP2 Pumps after outage periods.
Throttle MP3 Pumps and secure 1/2 MP2 Pumps during non outage years beginning in 2006.

Option 5
Take Credit for MP2 / MP3 Outages.
Secure 1/2 MP2 Pumps during all MP2 and MP3 non outage periods.
Use MP3 VFD's during all MP3 non outage periods.

04/29/2003

C04

APPENDIX IV OF ENCLOSURE TO DNC LETTER D17445

ADDITIONAL THERMAL PLUME ANALYSIS FOR MILLSTONE POWER STATION, UNITS 2-3

Information provided to Dominion Nuclear Connecticut, Inc. by:

E. Eric Adams, Ph.D., PE
The Massachusetts Institute of Technology
Cambridge, MA

ADDITIONAL THERMAL PLUME ANALYSIS FOR MILLSTONE POWER STATION, UNITS 2-3

By

E. Eric Adams, Ph.D., PE

Prepared for

Millstone Environmental Laboratory
Millstone Power Station
Rope Ferry Rd.
Waterford, CT 06385-0285

Attn: Mr. Donald Danila

March 2003

Introduction

The purpose of this report is to report results from additional thermal plume analysis for the Millstone Power Station using the approach of Adams (2001, 2002). The analysis involves scaling the results of earlier mathematical model studies (Stolzenbach and Adams, 1979) that have been calibrated against field observations.

The present analysis considers a worst-case scenario from the standpoint of plume temperatures involving reduced flow from Units 2 and 3:

Flows and Temperature Rises

Flows and temperatures were provided by Donald Danila in a 2/24/03 email to me, and include:

Unit 2: condenser cooling water flow of 281,000 gpm at a delta-T of 48°F coupled with a service water flow of 24,000 gpm at a delta-T of 29°F. The total flow for Unit 2 would be 305,000 gpm and the temperature would be the weighted average temperature or 46.5°F.

Unit 3: condenser cooling water flow of 461,000 gpm at a delta-T of 40°F coupled with a service water flow of 30,000 gpm at a delta-T of 8°F. The total flow and temperature for Unit 3 would thus be 491,000 gpm at 38°F.

The total flow and temperature for Units 2 plus 3 would be 796,000 and 41.3°F.

Results and Discussion

Methodology described in Adams (2001) was used to compute the plume dimensions (isotherm lengths, widths and depths) under four tidal conditions. Results are displayed in Table 1 for the above scenario as well as for historical operation of Units 1-3 with no reduction in flow.

We can draw the following conclusions from these results:

- Compared with historical operation with Units 1-3, operation with Units 2-3 under this scenario will generate slightly smaller isotherms. This is primarily because of the lower rate of heat addition (two units rather than three). Additionally, as the flow rate decreases, the temperature rise increases. Since the discharge cross-sectional area (through two quarry cuts) remains the same, the discharge velocities are reduced. The combination of reduced discharge velocity and increased discharge temperature produces lower values of the modified densimetric Froude number F_o' (Eq. 1 of Adams, 2001), implying less mixing and shorter, shallower plumes.

Table 1a Isotherm lengths (L), widths (W) and depths (H) in feet-- maximum flood

	Units 1-3 with normal flow			Units 2-3 with reduced flow		
Isotherm	L	W	H	L	W	H
12	460-720			420-660		
10	540-960			460-890		
8	700-1300			650-1200		
6	1020-1820	1250	18	940-1680	1150	11
4	1620-2500	2050	19	1490-2150	1890	11
1.5	11000*	6800	21	10149	6270	11

Table 1b Isotherm lengths (L), widths (W) and depths (H) in feet of--slack after flood

	Units 1-3 with normal flow			Units 2-3 with reduced flow		
Isotherm	L	W	H	L	W	H
12	400-480			370-440		
10	560-640			520-590		
8	780-1000			720-920		
6	1360-2400	1360-2400	18	1250-2040	1250-2040	12
4	2100-3000	1480-3000	19	1940-2770	1360-2770	12
1.5	4000	7400	21	3690	6830	12

Table 1c Isotherm lengths (L), widths (W) and depths (H) in feet--maximum ebb

	Units 1-3 with normal flow			Units 2-3 with reduced flow		
Isotherm	L	W	H	L	W	H
12	720-920			660-850		
10	920-1320			850-1220		
8	1320-2120			1220-1950		
6	2080-4230	960-1940	17-19	1920-3900	790-1790	11
4	4200-7200	1830-3400	20-22	3870-6640	1690-3130	11
1.5	14000*	5700	22-24	12900	5260	11

Table 1d Isotherm lengths (L), widths (W) and depths (H) in feet--slack after ebb

	Units 1-3 with normal flow			Units 2-3 with reduced flow		
Isotherm	L	W	H	L	W	H
12	480-560			440-520		
10	720-1000			660-920		
8	1260-2000			1160-1840		
6	2500-4700	1420-4050	19-22	2300-4330	1310-3730	10
4	4800-5470	4000-5130	21-24	4430-5040	3690-4730	10
1.5	10830	6270	23-26	9960	5330	10

- Because of the reduced mixing, near field analysis suggests that the plume will not penetrate deeply into the ambient water. Hence the predicted maximum depths of the 6, 4 and 1.5°F isotherms are all actually equal to the initial discharge depths of 10-12 feet, depending on tidal stage.
- Although the size of given isotherms is smaller, this scenario experiences higher peak temperatures. For example, the maximum plume temperature rise would be the discharge temperature rise of 41.3°F, which is significantly higher than the corresponding temperature rise of approximately 20°F characterizing the historical Units 1-3 operation.

As the densimetric Froude number decreases, there is a greater tendency for the ambient bay water to intrude *into* the quarry, beneath the overlying *outgoing* heated discharge. As discussed in Adams (2002), a slightly different definition of densimetric Froude number is used to evaluate this condition:

$$F_o = \frac{u_o}{\sqrt{g\beta\Delta T_o h_o}} \qquad (1)$$

F_o defined above differs from F_o' defined in Adams (2001) in the use of the discharge opening depth h_o rather than the square root of half the discharge area ℓ_o as the governing length scale. As before, u_o, g, β *and* ΔT_o are the discharge exit velocity, acceleration of gravity, coefficient of thermal expansion and discharge temperature rise. The critical value of F_o below which intrusion takes place is one (Stolzenbach et al., 1973). Indeed, when F_o falls below one, the depth of the outgoing flow h_o^*, adjusts itself so that the value of F_o, based on h_o^* becomes one (Ryan, et al., 1974).

The values of F_o for the analyzed scenario are shown in Table 2 as a function of season and tidal stage. In general, the lowest values of F_o occur during the summer, when the value of β is greatest (meaning the density difference corresponding to a given temperature difference is greatest), and at high tide, when the velocity u_o is lowest and the depth h_o is greatest.

For the reduced flow scenario addressed by this report, the value of F_o drops below 1 during the summer throughout most tidal stages. Thus I would expect to see ambient seawater intruding into the quarry for this scenario.

Table 2 Values of densimetric Froude number for different conditions

Scenario	Summer			Winter		
	MHW	MSL	MLW	MHW	MSL	MLW
Units 1-3 Normal Flow	2.8	3.2	3.7	4.0	4.6	5.3
Units 2-3 Reduced Flow	0.7	0.9	1.0	1.0	1.1	1.3

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APPENDIX V OF ENCLOSURE TO DNC LETTER D17445

IMPINGEMENT SURVIVAL OF WINTER FLOUNDER ON FINE-MESH-SCREENS. PROPOSAL PREPARED FOR DOMINION NUCLEAR CONNECTICUT, INC.

Information provided to Dominion Nuclear Connecticut, Inc. by:

Alden Research Laboratory, Inc.
30 Shrewsbury Street
Holden, MA

Millstone Power Station

NPDES Permit No. CT0003263

Impingement Survival of Winter Flounder on Fine-mesh Screens

Proposal

Prepared for:

Dominion Nuclear Connecticut, Inc.

Prepared by:

ALDEN Research Laboratory, Inc.
Environmental Services
30 Shrewsbury Street
Holden, MA 01520

April 2003

Impingement Survival of Winter Flounder on Fine-mesh Screens

INTRODUCTION

In 1992, the Connecticut Department of Environmental Protection (DEP) issued a five-year National Pollutant Discharge Elimination System (NPDES) Permit to Dominion Nuclear Connecticut, Inc. (DNC) for the Millstone Nuclear Power Station (MPS or Millstone). Millstone, located in Waterford, Connecticut, consists of three generating units. Unit 1 was shut down in November, 1995. Units 2 and 3 (both pressurized water reactors) are 870- and 1,150 megawatts (respectively). Both units are equipped with a conventional once-through cooling water system. Water is drawn from the Niantic Bay and released into a quarry before passing into Twotree Island Channel (Figure 1). The NPDES Permit (Permit number CT0003263) includes conditions that require DNC to continue monitoring winter flounder population characteristics in the Niantic River. The evaluation of this species (and 6 others including Atlantic menhaden, anchovies, grubby, tautog, cunner, and American sand lance) was specifically requested by DEP in 2000. The species evaluated were chosen because of their numerical dominance in entrainment samples at Millstone (Table 1). A description of each winter flounder larval stage is presented in Table 2.

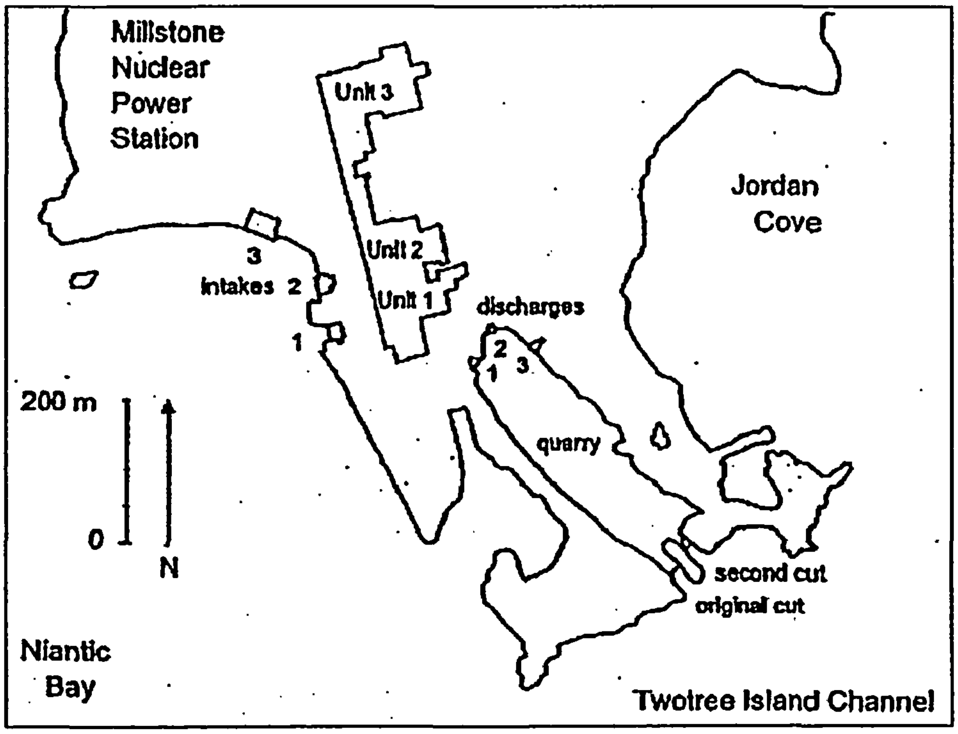

Figure 1. Location map and water bodies surrounding the Millstone Power Station.

Table 1. Taxonomic composition of fish larvae and eggs collected at the MPS discharge (percent of total) from June 1976 through May 2000 (larvae) and May 1979 through September 1999 (eggs) (Source: DNC 2001).

Taxon	*Larvae*	*Eggs*
Anchovy	47.2	5.3
Winter Flounder	14.4	-*
American sand lance	7.5	-
Atlantic menhaden	7.4	-
Grubby	5.4	-
Rock gunnel	2.8	-
Cunner	2.2	54.0
Tautog	2.0	27.6
Fourbeard rockling	1.5	-
Radiated shanny	1.2	-
Snailfishes	1.1	-
Atlantic herring	1.0	-
Northern pipefish	0.7	-
Windowpane	0.7	-
Butterfish	0.7	-
Others	4.2	13.1

*** Little or no entrainment of eggs**

Table 2. The five larval stages of winter flounder and the relative proportion in which they occur in entrainment samples at MPS (Source: DNC 2001).

Stage	**Brief description**	**Approximate duration of stage in days***	**Approximate size (mm) of stage****	**Percent of total larvae collected during entrainment sampling**
Egg	Demersal and adhesive	15	0.70-0.85	N/A
1	Yolk-sac present or eyes not pigmented	10	2.5-3.5	3.7
2	Eyes pigmented, but no yolk-sac present, no fin flexion of notochord	20	3.0-4.0	19.0
3	Fin rays present and flexion of notochord started, but left eye not yet migrated to the midline	10	4.5-7.5	63.7
4	Left eye migrated to midline, but typical juvenile characteristics not present	10	7.0-9.0	13.2
5	Transformation to juvenile complete with intense Pigmentation present near the caudal fin base	-	>9.0	N/A

* Developmental rates dependent upon water temperature.
**To nearest 0.05 mm for larvae. Includes most individuals in life stage, although some may be smaller or larger than the ranges given.

DNC has evaluated various alternative cooling water intake structure (CWIS) technologies to determine their potential use at MPS (DNC 2001). Criteria used to determine which technologies would be practicable were that they 1) had the potential to reduce entrainment mortality; 2) would be viable for a facility the size of MPS; 3) would not be overly susceptible to biofouling and debris loading; 4) would not occupy or exclude large areas of habitat; and 5) would not represent an unacceptable navigational hazard. Of the technologies assessed, fine-mesh screens were among those considered for more detailed assessment as a potentially practicable method of reducing entrainment. The final assessment provided to the DEP by DNC rated as low the potential for fine-mesh screens to reduce entrainment mortality (DNC 2001). DNC also cited cost and the potential for excessive debris loading as factors affecting the overall practicability of fine-mesh screens at MPS. The intake structure for Millstone Unit 1 could potentially be used to conduct fine-mesh screen tests in the field. However, a field study of larval winter flounder impingement would be costly even though a structure for mounting the screens is already in place. Laboratory testing could provide additional data on winter flounder survival under best case (laboratory) conditions, and enable DNC to determine whether more extensive or field trials are warranted to determine the practicability of fine-mesh screens at MPS.

Alden Research Laboratory, Inc. (Alden) proposes to evaluate larval winter flounder survival in the laboratory to determine if further prototype testing is warranted. Larval winter flounder would be exposed to fine-mesh screen material similar to the type that could be backfitted into the existing (or installed in new) screens at MPS. The goal of the project would be to determine the size-specific mortality rate for winter flounder when exposed to screen material in a laboratory size test flume. In addition to mortality data, larval retention (*i.e.*, the ratio of impingement vs. entrainment) will also be investigated.

SCOPE OF WORK

Alden proposes to meet the objectives of this project by completing the following tasks:

Task 1 – Examining the size-specific latent impingement mortality and retention of larval fish when exposed to a fine-mesh screen.

Task 2 – Preparing and submitting a detailed report on the investigation, including the development of mortality curves, graphs and functions that can be used to estimate the retention and survival probability of specific size classes exposed to fine-mesh screen material.

Information gathered will be used to better understand the mortality rates that could be experienced by fish encountering a fine-mesh screen system at MPS. To effectively relate the results of this study to the conditions that would exist at MPS after installation of fine-mesh screens, we propose to use a small test facility and incorporate four variables into the test design – larval length, mesh size, approach velocity, and the presence or absence of debris.

Test Species and Holding Facility

Alden proposes to use winter flounder (*Pseudopleuronectes americanus*) provided by DNC as the test species for all screen evaluations. Winter flounder is considered appropriate for the following reasons:

- It has been identified by DEP as being an important species for both commercial and recreational fisherman;
- It comprises approximately 14 percent of the larval fish entrained at MPS;
- Test specimens are available from the same wild genetic stock that occur at MPS;
- Winter flounder have been successfully held and tested at Alden in past studies.

DNC will provide fertilized flounder eggs via truck or federal express delivery. Alden will raise these fish in its Fish Testing Facility until they reach the appropriate stage for testing. For the purposes of this proposal, it is assumed that Stage 1 through 4 larvae will raised and tested. Alternatively, Alden could procure larval flounder from a rearing facility (*e.g.*, Llennoco) at an additional cost. Fish raised at another facility would not be from the same genetic stock as those provided by DNC.

At Alden, fish will be held in a recirculating larval fish holding facility. Fish will be held in four tanks that each drain into a shared reservoir. Water will be pumped through water treatment filters before flowing back to the fish holding tanks. Bag filters and an activated charcoal filter will be used to remove solid waste materials and other impurities. An ultraviolet light sterilizer and a fluidized bed (sand) bio-filter will be used to control bacteria and soluble waste products. Water quality (dissolved oxygen, temperature, hardness, alkalinity, ammonia and salinity) will be monitored daily and salinity levels will be maintained at appropriate levels (depending on larval stage) to match optimal survival conditions. Appropriate water temperatures will be maintained through the use of chillers or heaters to ensure larval survival and desired growth rate. Fish will be fed rotifers, *Artemia*, and other food as they grow and their dietary needs change. Fish in the holding facility will be monitored for disease, fungus, or infection by parasites.

Test Parameters

To effectively simulate the conditions as they would exist at MPS, we propose to examine the following test variables:

- Approach velocity: Screen tests will be conducted using two approach velocities - a velocity that matches the estimated average approach velocity at MPS and 0.5 ft/sec to reflect a reduced approach velocity that may be required to maximize survival.

- Screen type: Two mesh sizes will be tested – 0.5 mm and 1.0 mm (sizes that could be considered for use at MPS). Mesh size may have an effect on survival and larval retention rates.

- Impingement Duration: One impingement duration will be tested. The duration will equal the maximum exposure that an organism would experience if it impinged near the bottom of a fine-mesh screen at Millstone with the screen rotating at slow speed (e.g., 3 ft/min). It is expected that the duration will be on the order of eight to ten minutes.

- Debris: Tests will be run with and without debris. Debris will be either natural debris found at MPS (provided by DNC) or a Mylar debris surrogate. The final decision on the type of debris and method of debris introduction will be made after consultation between Alden and DNC.

- Size Class (Larval Stage): Tests will be conducted three days a week over 8 weeks to determine impingement mortalities of Stage 1 – Stage 4 fish (based on growth data presented in Table 2).

Temperature, salinity, and dissolved oxygen levels during testing will approximate those of the larval holding facility. Exposure time (the test duration) will be kept constant between trials and will represent the longest period of time a larva would be expected to spend on the traveling screen (i.e., if the fish was to encounter the screen at the deepest point in the water column and then be washed off after passing over the head sprocket).

Testing in the laboratory will not replicate conditions that would exist at a full-scale installation (i.e., screen movement, tidal effects, water clarity, exposure to spraywash system, or gaps, joints or other structural components associated with the screen). Potential injury to fish in a gravity-flow fish return system also will not be tested. However, experience at the Big Bend Station in Florida indicates that even the long fish return and pumping system at that plant does not contribute to overall mortality in the fine mesh screen system (Bruggemeyer et al. 1988). In any case, laboratory studies will examine the survival of fish exposed to the mesh and give valuable insight into the potential application of fine-mesh screening at MPS. Laboratory testing will also provide valuable data on size-specific retention rates for the four larval stages when exposed to two mesh sizes. Poor survival of retained larvae after adjustment for control mortality would indicate that a second phase consisting of field trials may not be warranted. High survival could indicate that valuable information could be gained from conducting a field study.

Task 1 – Testing

The test facility will be based on one previously tested at Alden during a study examining impingement survival of larvae (Alden and SWEC1981). A description of the test facility is given below.

Tests will be conducted in two small flumes that have fine-mesh screens mounted perpendicular to the flow in a 12-inch wide test channel, as shown in Figure 2. Two channels will be built into each of two flumes, for a total of four test channels. Each flume will be supplied with water by a single pump, but individual valves will regulate flow to each channel. A clear acrylic frame will hold the screen in each channel and incorporate a collection bucket at its base. The screen frame will be placed so that its sides are flush with the side walls, and the collection bucket will be recessed into the floor to avoid obstructing flow to the screen. Acrylic sections in the sides of the flume will allow observation and video taping of the larvae during testing. At the upstream end of the test channel, a fine-mesh containment screen will be used to obtain a uniform flow distribution and to prevent fish from exiting the test enclosure by moving upstream. The downstream end of the test channel will also have a containment screen to prevent entrained fish from being re-circulated and to allow entrained fish to be collected. A depth control gate will be used to adjust the initial water depth. Once the test is complete, the screen can be raised out of the water and impinged fish will be washed off the screen into the bucket at the base of the screen frame. Fish passing the fine-mesh screen panel will be enumerated.

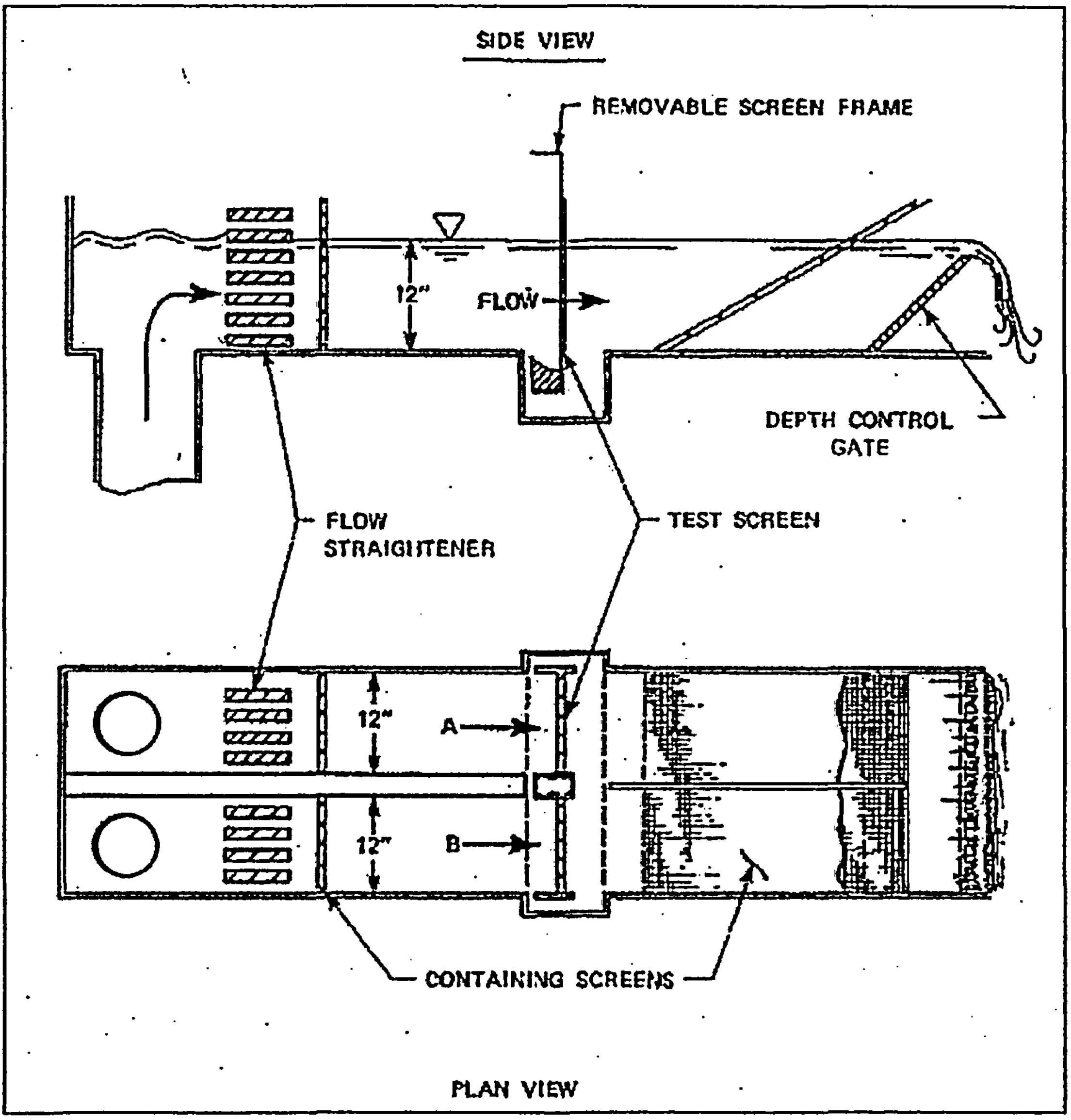

Figure 2. Test flume, as modified from Alden and SWEC 1981.

Experimental Design

The experiment is designed to determine a length vs. survival curve for each possible combination of debris, velocity and mesh.

(2 debris conditions) X (2 velocities) X (2 mesh sizes) X (6 replicates per condition) = 48 treatment replicates per week

In addition, 12 controls per week will be used to determine the losses associated with handling.

Testing will be conducted for 8 weeks to test each of the four larval stages entrained at MPS, for a total of 480 replicates. The test configuration is presented in Table 3.

Table 3. Proposed impingement survival testing - winter flounder.

Conditions			**Replicates per week for 8 weeks**	**Analysis Conducted**
Debris	**Velocity**	**Mesh Size**		
Debris	Velocity 1	Mesh 1	6	Percent Survival: Immediately after Test 24-Hours after Test 48-Hours after Test
		Mesh 2		
	Velocity 2	Mesh 1		
		Mesh 2		
	Control (no flow, no mesh)			
No Debris	Velocity 1	Mesh 1		
		Mesh 2		
	Velocity 2	Mesh 1		
		Mesh 2		
	Control (no flow, no mesh)			
			Total number of replicates:	480
			Number of fish needed for testing (@50 fish/replicate) (not compensating for mortality)	24,000
			Total number of fish needed from DNC (including X2 mortality cushion)	48,000

Test Procedures

Preliminary tests will be run to determine the best standardized method for fish introduction, use of debris, and collection procedures. If these tests indicate that the procedures outlined below are not workable, modifications will be made to the protocols after consultation with DNC.

The following procedures are proposed for use when testing treatment fish:

1. Prior to testing, 25 fish will be selected at random from the chosen source tank and measured. The mean fork length (FL) will be used to determine mean size class.
2. Four groups of 50 fish will be placed into beakers for introduction into the test channels. Any dead larvae will be discarded and replaced. Beakers will be kept in a shared water bath to maintain the same water temperature that exists in the test flumes.
3. Using pre-generated daily test sheets, personnel will set conditions for each test channel (mesh size and flow velocity). The velocity will be set in each test channel using a pump equipped with a flow meter. The velocity will either match existing conditions at Millstone or be set at 0.5 ft/s to represent an expanded intake with more screens. The flow rate will be set prior to introducing fish.
4. As the test begins, fish will be placed into the upstream-most portion of each test channel just downstream of the containing screen.
5. For replicates using debris, the chosen material will be placed in beakers next to the appropriate test channel(s) prior to testing and debris will be added just after the test fish have been introduced. The actual method of debris introduction will be determined through further discussions between Alden and DNC.
6. During testing, observations of fish behavior will be recorded to determine if a pattern exists in the way that fish interact with the screen under the various test conditions. Representative digital video recordings will be made each week.
7. Immediately after the test period, the test screen will be drawn out of the flow slowly (with the flow still moving at the test velocity) to avoid dislodging any impinged fish. A low flow rinsing hose will be used to gently wash fish (and debris) into the screen bucket.
8. Any entrained fish will be collected from the downstream portion of the test channel and enumerated but not kept for estimating latent mortality.

9. Collected (impinged) fish and debris will then be transferred into shallow dishes where any debris will be separated out and dead fish will be enumerated and removed from the sample.

10. Live fish will be placed into individually coded beakers. Fish that do not exhibit any movement after gentle prodding will be considered dead and will be removed and enumerated.

11. Once in the collection beaker, the larvae will be placed in a water bath and held for subsequent mortality assessments. Fish in each beaker will be assessed immediately after testing, at 24-hours, and at 48-hours after testing to determine the rate of latent impingement mortality.

The following procedures are proposed for testing control fish:

1. Control replicates will be counted and placed in beakers in the same way as treatment fish.

2. Control fish will then be poured into the bucket section of a test screen and allowed to sit for approximately one minute.

3. For control trials with debris, the same amount of debris introduced into treatment tests will be placed in the beaker just prior to pouring the larvae into the test screen bucket.

4. Once the contents of the bucket have been transferred to a glass dish, debris will be removed and any dead larvae will be enumerated and removed from the sample. The best method of effectively separating debris from the test fish will be determined through consultation between Alden and DNC, and also during the preliminary test period.

5. Control fish will then be transferred into coded glass beakers and immersed in the same water bath that holds the treatment fish.

6. Control fish mortality evaluations will be conducted in the same way as those for treatment replicates.

Data Input and Analysis

All data collected will be entered into an Excel spreadsheet for analysis, including the test code, water quality data, date and time of test, number of mortalities for each of the three checks conducted, the number of fish entrained per replicate, and any comments.

A statistical analysis will be conducted to determine if there are significant differences between survival rates for each combination of test conditions and larval stages. A retention curve will be developed using larval stage, and mesh size as variables. The final statistical design and analysis will be conducted by DNC.

Task II – Reporting

Following completion of the impingement study, a comprehensive report documenting the findings will be prepared. The report will include the following sections:

1. introduction and objectives;
2. methods and procedures; and
3. data analyses, results and discussion, including the development of a mortality relationship curve for the test conditions and comparisons to existing mortality data gleaned from ongoing discharge sampling.

The summary report will include all tables, figures, photographs and engineering drawings as necessary to fully document the evaluations conducted. The report will be organized with supporting information and detail in attached appendices.

SCHEDULE

Timing of the study will need to coincide with the availability of spawning adult flounder (spring). Sufficient lead time will be necessary in order to make arrangements for larval holding, acquiring larvae from DNC, and test facility design and construction. Construction of the each facility is projected to take two weeks per flume (each flume will have two channels) once the design is finalized. Alden expects to conduct 60 tests per week for a period of 8 weeks, along with 2 weeks for preliminary testing and engineering shakedown. A draft report will be submitted to DNC for review approximately eight weeks after testing has been completed. The final report will be submitted about three weeks after final comments are received from DNC.

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ENVIRONMENTAL SERVICES

QUALIFICATIONS

Alden Research Laboratory, Inc. (Alden) has a team of engineers and scientists that is widely recognized for developing fish protection systems and upstream and downstream fish passage facilities, as well as the resolution of environmental issues associated with project licensing. The team provides extensive experience and capabilities in the development, design, evaluation and construction of fish protection and passage facilities at a variety of water intakes. Team members are recognized in the industry and within regulatory agencies as leaders in the development of innovative technologies and have been instrumental in resolving difficult issues related to the hydroelectric licensing process and 316(b) requirements under the Clean Water Act. This team has authored several authoritative documents on the subjects of fish entrainment/impingement, turbine passage survival, and protective measures.

The need for fish protection or passage facilities is often one of the most contentious issues associated with water resource projects. Alden's expertise allows our team to use the best available data to assess the magnitude of entrainment impacts and to evaluate the cost and potential effectiveness of alternative fish passage measures. Several members of our team are applying this expertise in the analysis of aquatic issues in various NEPA documents (Environmental Impact Statements and Environmental Assessments) being prepared under contract to the Federal Energy Regulatory Commission. Our staff prepares EISs and EAs for hydroelectric projects including facilities located in Oregon, California, Idaho, Wisconsin, Connecticut and Vermont. Our staff has experience in addressing the full range of aquatic resource issues associated with water developments including minimum flow and base flow requirements, ramping rates, water temperature, dissolved oxygen, gas supersaturation, sediment transport, and protection of ESA-listed species.

Alden's experience in fish passage and protection is extensive. Biological and engineering evaluations of alternative technologies have been performed for application at many cooling water intakes, conventional hydro sites, pumped storage projects, and irrigation diversions situated in river, lake and marine environments. Through both hydraulic model studies and laboratory and field biological evaluations, Alden has participated in the development of state-of-the-art fish protection facilities that are in use throughout the United States. Various types of fish screens have been developed, including coarse- and fine-mesh modified traveling screens (Ristroph-type collection screens with fish lifting buckets), fixed and traveling fish diversion screens, and rotary drum screens. In addition, Alden staff has conducted extensive research on the effectiveness of behavioral barriers for preventing fish entrainment and/or impingement, including strobe lights, sound deterrent systems, air bubble curtains, hanging chains, and water jet barriers. Alden is also active in program to develop and evaluate a fish tolerant turbine runner for the U.S. Department of Energy.

Alden is dedicated to maintaining a leadership role in further developments in fish protection and passage and to keeping abreast of all ongoing research efforts. The fisheries team has compiled four comprehensive reviews on fish passage and protection technologies for the Electric Power

Research Institute (EPRI). The first report, published in 1986, has become a standard reference which describes the advantages and limitations of all applicable technologies, with an emphasis on hydroelectric applications. The next two reviews, published in 1994 and 1998, are updates of the 1986 report and summarize recent developments in the use of technologies such as strobe lights, sound projectors and high velocity fish screens. In 1999, Alden prepare a comprehensive review of state-of-the-art fish protection technologies for use at cooling water intakes to satisfy requirements of Section 316(b) of the Clean Water Act.

Our team has compiled several reviews pertaining to fish entrainment and turbine passage survival. Documents prepared for EPRI include a review of entrainment and turbine passage survival studies published in 1992, a guideline on methodologies used in entrainment and passage survival studies published in 1997, and a database of entrainment and survival studies published in 1997. Alden staff also co-authored a review of entrainment studies and protective measures that was published by FERC in 1995. As a result of these efforts, the Alden staff has compiled entrainment and passage survival data from hundreds of recent studies. Our staff is well positioned to select the most appropriate data sets for estimating entrainment rates and turbine passage survival without conducting costly, site-specific studies.

Recent upstream fish passage experience includes design development for 17 facilities including five fish elevators and twelve ladders. A number of these facilities were also hydraulically modeled at Alden prior to construction. In addition, staff authored a comprehensive review on the design and effectiveness of tailrace barriers for protecting upstream migrating fish that was published by FERC in 1995.

Alden's staff understand the importance of involving the resource agencies in the process of designing fish passage structures, and are able to obtain rapid and meaningful agency interaction and response to permitting issues. A long-standing working relationship has been established with the Environmental Protection Agency, the Federal Energy Regulatory Commission, the U.S. Fish & Wildlife Service, the National Marine Fisheries Service, and many regional, state and local agencies that is based on a history of successful interaction and mutual respect.

Recognizing that the cost of conventional fish protection systems is often prohibitive, Alden personnel are at the forefront in developing more affordable fish protection technologies. Our work with EPRI has demonstrated that high velocity screening systems can provide effective protection at about half the cost of the low velocity systems commonly prescribed by fisheries agencies. We have also designed, installed and demonstrated the effectiveness of a barrier net system that can eliminate entrainment at very low cost if site conditions are appropriate.

Alden staff has made significant improvements in the design of underwater strobe light systems, and we have demonstrated a strong avoidance response by several species of fish in laboratory and field evaluations. Alden staff has designed and installed several full-scale strobe light diversion systems, including one system which has proven to be very effective in guiding juvenile American shad towards a bypass.

Our staff has evaluated several sonic fish deterrent systems, including one recent study which found that high frequency sound and strobe lights were effective, especially when used in combination, in repelling juvenile American shad. Alden has now configured a sound deterrent system and a portable test facility so that we can offer full services in the design, installation and evaluation of this promising technology in the most scientific manner possible.

Encouraging results have been obtained in a large-scale program conducted by Alden to develop acoustic signals for repelling nine estuarine species of fish from the cooling water intake structure Public Service Electric & Gas Company's Salem Generating Station. This test program examined the response of all nine species to signals from 100 Hz to 150 kHz, and succeeded in producing avoidance responses for most species.

FISH SCREENING – COOLING WATER INTAKE STRUCTURES

Alden staff has extensive experience in the research and development, evaluation and design of fish protection technologies. Through both hydraulic model studies and laboratory and field biological evaluations, Alden has participated in the development of state-of-the-art fish protection facilities that are in use throughout the United States. Various types of fish screens have been developed, including coarse- and fine-mesh modified traveling screens (Ristroph-type collection screens with fish lifting buckets), fixed and traveling fish diversion screens, and rotary drum screens. These screening systems have been installed in fresh and brackish water, as well as marine environments and have performed to specification. In addition, Alden staff have conducted extensive research on the effectiveness of behavioral barriers for preventing fish impingement, including strobe lights, sound deterrent systems, infrasound, air bubble curtains, hanging chains, and water jet barriers.

Alden's team members are dedicated to maintaining a leadership role in further developments in the state-of-the art in fish protection and keep abreast of all ongoing research efforts. The team has compiled four comprehensive reviews on fish passage and protection technologies for the Electric Power Research Institute. The first report, published in 1986, has become a standard reference text which describes the advantages and limitations of all applicable technologies. The second review, published in 1994, summarizes recent research including significant developments in the use of strobe lights, sound projectors and high velocity fish screens. The third report, published in 1998, is an update of the 1994 report. The fourth report, published in 1999, reviews the state-of-the-art in protecting fish at cooling water intake structures (References: Electric Power Research Institute. 1986. *Assessment of Downstream Migrant Fish Protection Technologies for Hydroelectric Application.* EPRI AP-4711; Electric Power Research Institute. 1994. *Research Update on Fish Protection Technologies for Water Intakes.* EPRI TR-104122; Electric Power Research Institute. 1994. *Review of Downstream Fish Passage and Protection Technology Evaluations and Effectiveness.* EPRI TR-111517. Electric Power Research Institute. 1999. *Fish Protection at Cooling Water Intake Structures: Status Report.* EPRI TR-114013.

Alden's uses an integrated approach in developing designs for fish protection at steam electric facility intakes. This approach involves close cooperation between engineers and scientists to ensure that a design will be biologically effective, practicable to construct, operate and maintain, and cost-effective while meeting regulatory requirements. Alden staff have been involved in all aspects of design development, evaluation and installation, including (1) conceptual engineering design development, (2) laboratory studies, and (3) field studies.

<u>Conceptual Engineering Design.</u> During the conceptual design phase, Alden reviews all potentially effective fish protection alternative designs that might meet Best Technology Available (BTA) requirements of Section 316(b) of the Federal Water Pollution Control Act Amendments of 1972. Alden staff has conducted numerous alternative technology evaluations for steam stations throughout the U. S. During such studies, available fish protection technologies are subjected to a multiphase screening process which leads to the identification of

several systems or devices that can be considered BTA at a given site. The resulting study reports have permitted utilities to negotiate appropriate cost-effective measures to be taken, often as part of the NPDES Permitting process. Selected projects follow: Public Service Electric and Gas Company (Salem, Hudson and Mercer Generating Stations); San Diego Gas & Electric Station (Station B, Silver Gate, Encina, and South Bay Power Plants); Detroit Edison Company (Monroe, Delray, Conners Creek and St. Clair Power Plants; Toledo Edison Company (Bayshore Generating Station); Wisconsin Electric Power Company (Haven Power Plant); Wisconsin Public Service Company (Pulliam Power Plant); Northern States Power Company (Prairie Island Nuclear Station); Consolidated Edison Company of New York, Inc. (Indian Point Nuclear Generating Station); Orange and Rockland Utilities, Inc. (Bowline Point Generating Station).

Laboratory Studies. New fish protection concepts often require some degree of laboratory development prior to field evaluation. Alden has a long history of performing studies to optimize design and operational features of new designs and to evaluate their biological potential with live fish. Many studies have been conducted with fish diversion screens, louvers, bypasses, and pumps to identify operational characteristics and select optimum conditions for fish testing. These conditions are then incorporated into large-scale laboratory facilities for fish testing. At the completion of the laboratory efforts, new facilities can be designed for field application with a high potential for successful operation. Selected projects follow: Electric Power Research Institute (Aquatic Filter Barrier; wedge wire screens; angled bar racks; louvers; behavioral barriers; hydraulic and biological testing of the patented Modular Inclined Screen); Consolidated Edison Company (Indian Point angled diversion screens and louvers); Niagara Mohawk Power Corporation (Oswego and Nine Mile Point angled screen and pump return system; velocity cap intake); Empire State Electric Energy Research Corporation (Generic studies of angled coarse and fine-mesh diversion screens with larval and juvenile fish, jet pump and screw pumps evaluation, fine-mesh fish collection screens, and behavioral barriers); Northern States Power Company (Prairie Island fine-mesh screening study); New England Power Company (Brayton Point coarse/fine mesh fish diversion and pump return system; porous dike fish barrier; Vernon louver diversion system); Northeast Utilities (development of the NU-Alden Weir for improving fish passage through bypasses; improvements to Hadley Falls flow regime to increase fish bypass to an existing weir).

Field Studies. Alden staff is highly experienced in conducting prototype field studies that are sometimes needed to finalize design and operational parameters under the conditions existing at the site of intended use. In addition to the field work described previously for hydroelectric applications, Alden staff has conducted several large-scale evaluations of fish screens that, in some cases, have led to full-scale application. Selected projects follow: Electric Power Research Institute (strobe lights, incandescent lights, sound; Modular Inclined Screen; Eicher screen); Tampa Electric Company (Big Bend Station fine-mesh screening system; operational since 1986); Empire State Electric Energy Research Corporation Danskammer Point Station coarse/fine mesh fish diversion/collection system demonstration project); Boston Edison Company (Mystic Station modified fish screen evaluation); WE-Energies (behavioral barriers); Alaska Power Authority (Bristol Bay Hydroelectric Development fish diversion and collection screen studies).

Once all fish protection system design and operational parameters have been developed for a given site, Alden assists its clients in developing detailed designs for installation and operation and maintenance plans.

FISH SCREENING - HYDRO AND IRRIGATION

Review of Fish Protection Technologies, Electric Power Research Institute. Team members compiled three comprehensive reviews on fish passage and protection technologies. The first report, published in 1986, has become a standard reference text that describes the advantages and limitations of all applicable technologies. The second and third reviews, published in 1994 and 1998, summarize recent research including significant developments in the use of strobe lights, sound projectors and high velocity fish screens. References: Electric Power Research Institute. 1986. *Assessment of Downstream Migrant Fish Protection Technologies for Hydroelectric Application.* EPRI AP-4711. Electric Power Research Institute. 1994. *Research Update on Fish Protection Technologies for Water Intakes.* EPRI TR-104122. Electric Power Research Institute. 1998. *Review of Downstream Fish Passage and Protection Technology Evaluations and Effectiveness.* EPRI TR-111517.

Black River Fish Screen, Nova Scotia Power Company. Developed a design of a state-of-the-art fish diversion screen system for use in diverting juvenile alewives from the Black River to the Gaspereau River, thereby bypassing three hydroelectric projects. Used three-dimensional mathematical analysis (CFD) to develop geometries that would cost-effectively create optimal conditions for fish guidance.

Laboratory Evaluation of Novel Angled Screen Design, Alberta Public Works, Supply and Services. Performed hydraulic and biological evaluations of a unique fish diversion design developed by APWS&S. The hydraulic model study was conducted to optimize conditions for fish guidance along the screen, which has gradually decreasing slot sizes to create uniform flow distributions. The biological tests were conducted in Alden's fish testing facility using 2 to 4 inch juvenile rainbow trout. The screen has since been installed at the Pine Coulee Project in Alberta.

Glenn-Colusa Irrigation Diversion, California Dept. of Water Resources. As the project's fish screening specialists, contractor to HDR Engineering to develop six conceptual designs for fish screening facilities (3,000 cfs capacity). Designs include angled fixed and rotary drum screens and a high velocity screening system.

Prairie Du Sac Hydroelectric Project, Wisconsin Power & Light Company. Developed conceptual designs, cost estimates, and preferred design for seven alternative downstream passage or protection facilities.

Multiple Hydro Sites (Brule, Pine, Weyauwega, Sturgeon, Chalk Hill, White Rapids, Oconto Falls and Big Quinnesec), Wisconsin Electric Power Company. Developed conceptual designs, cost estimates, and preferred design for fish protection and downstream passage facilities at eight hydro sites. The barrier net recommended for the Pine site was successfully installed and evaluated (see below). The barrier net recommended for the Brule site is scheduled to be installed and tested in the near future.

Pine Hydro Barrier Net, Wisconsin Electric Power Company. Installed and evaluated a barrier net over two years to reduce entrainment into the 625 cfs capacity intake of the Pine Hydroelectric Project. Mark-recapture studies indicated that the net was effective in reducing entrainment by 92% over the test period, and a 100% reduction was observed after adjustments were made to pull the net fully to the water surface. This net has been proposed to the FERC as a permanent installation to satisfy relicensing requirements.

Wapatox Canal, Washington, Pacific Power & Light Company. Developed three alternative conceptual designs for screening facilities to divert salmon smolts from a 565 cfs capacity irrigation canal. Designs included fixed barrier screens, angled fish screens, and angled rotary drum screens.

Yakima Angled Drum Screening Facilities, Washington, U.S. Bureau of Reclamation. Responsible for biological evaluation of four state-of-the-art angled drum screening facilities (up to 2,200 cfs capacity) constructed at irrigation diversions on the Yakima River.

Pumped Storage Projects, multiple sites and clients. The team has conducted many alternative fish protection studies for pumped storage projects including the 1872 MW Ludington Project, the 160 MW Harry S. Truman Dam and Reservoir and the 600 MW Richard B. Russell Dam.

ALDEN

LABORATORY FACILITIES FOR FISHERIES RESEARCH

Alden has a long history of conducting fisheries related studies. Beginning in the early 1970's, Alden began research with live fish that has led to the development of various fish protection and passage systems that are in common use. Systems, devices and system components that have been evaluated at Alden are listed below by category:

FISH DIVERSION DEVICES	BEHAVIORAL BARRIERS
• Aquatic Filter Barrier (AFB) • Modular Inclined Screen • Eicher screen • Angled fixed screen • Angled traveling screen • Louvers • Fine-mesh larval diversion screens	• Sonic fish deterrent systems • Strobe lights • Mercury lights • Air bubble curtains • Water jet curtains • Hanging chain barriers • Visual keys • Velocity barriers
FISH COLLECTION AND TRANSPORT	**SPECIAL STUDIES**
• Fine-mesh traveling screens • Hidrostal fish pump (larval and juvenile fishes) • Jet pumps (peripheral and core types) • NU-Alden weir (new design to improve acceptance of bypasses by fish)	• Pressure (studies of stress resulting from increases and decreases in pressure) • Shear (studies of injury and stress resulting from exposure to shear forces) • Pipes (studies of stress resulting from transport through long pipes) • Fish-friendly turbine (development of new runner design to reduce injury)

In the process of conducting these biological studies, Alden's fisheries biologists, engineers and support staff have developed unique capabilities in the holding and rearing of larval and juvenile fishes for testing purposes. The laboratory has a variety of water supplies available that have proven adequate for holding large numbers of freshwater, brackish water and marine species for long periods in both closed and open circulating water systems. Environmental controls are supplied to ensure that fish are not stressed by typical factors that cause problems in experimental facilities (temperature, dissolved oxygen, ammonia). Alden collects or arranges for the delivery of fish from across the U.S. All collection, importation and state holding permits are obtained by Alden; holding facilities are constructed by Alden and have been certified by the Division of Fisheries and Wildlife.

Alden has full capabilities to design, fabricate and test any aspect of fish protection and passage technologies and to conduct special studies related to fish behavior. Full-time staff are available to provide carpentry, plastic and metal working, electrical and computer skills to assist in the fabrication of specialty products. Alden's engineers routinely design and install monitoring equipment (developed mostly in-house) for determining the performance of equipment and models being tested.

Alden has numerous large buildings housing a wide array of hydraulic and fisheries test facilities. While many models and other test equipment currently occupy portions of these buildings, sufficient area is always available for new experiments. Further, many of the buildings contain flumes and sumps which are available for use at any time. With 25 years of experience in testing live fish at Alden, a large variety of fish holding and rearing facilities has been developed which have proven highly effective in many past studies.

LIST OF FISH SPECIES REARED AND TESTED AT ALDEN

Diadromous Species

Atlantic salmon	*Salmo salar*
chinook salmon	*Oncorhynchus tshawytscha*
coho salmon	*Oncorhynchus kisutch*
American shad	*Alosa sapidissima*
blueback herring	*Alosa aestivalis*
alewife	*Alosa pseudoharengus*
American eel	*Anguilla rostrata*

Freshwater Species

walleye	*Stizostedion vitreum*
rainbow trout	*Oncorhynchus mykiss*
brown trout	*Salmo trutta*
smallmouth bass	*Micropterus dolomieui*
largemouth bass	*Micropterus salmoides*
yellow perch	*Perca flavescens*
bluegill	*Lepomis macrochirus*
channel catfish	*Ictalurus punctatus*
rainbow smelt	*Osmerus mordax*
golden shiner	*Notemigonus crysoleucas*
white sucker	*Catostomus commersoni*
common carp	*Cyprinus carpio*
landlocked alewife	*Alosa pseudoharengus*
lake sturgeon	*Acipenser fulvescens*
white sturgeon	*Acipenser transmontanus*
shortnose sturgeon	*Acipenser brevirostrum*

Brackish Water/Marine Species

striped bass	*Morone saxatilis*
white perch	*Morone americana*
Atlantic menhaden	*Brevoortia tyrannus*
winter flounder	*Pseudopleuronectes americanus*
Atlantic tomcod	*Microgadus tomcod*
weakfish	*Cynoscion regalis*
spot	*Leiostomus xanthurus*
Atlantic croaker	*Micropogonias undulatus*
bay anchovy	*Anchoa mitchilli*

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