January 29, 2009

VIA UPS OVERNIGHT DELIVERY

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United States Environmental Protection Agency - Region 1
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Glenn Haas
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Mirant Canal Station, Sandwich, Massachusetts
Renoticed NPDES Permit No. MA 0004928

Gentlemen:

Mirant Canal, LLC is pleased to provide the enclosed comments on renoticed NPDES permit No. MA0004928. We will also send the comments by e-mail today.

Sincerely,

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Enclosures

Comments of

MIRANT CANAL, LLC

on

Draft National Pollutant Discharge

Elimination System (NPDES) Permit

No. MA0004928

Proposed by EPA New England - Region 1

and

Massachusetts Department of Environmental Protection

Public Notice No. MA-004-09

January 29, 2009

INTRODUCTION

These are comments by the permittee, Mirant Canal, LLC ("Mirant Canal"), on proposed permit conditions for NPDES permit MA0004928 for the Mirant Canal Station in Sandwich, Massachusetts.

EPA Region 1 and the Massachusetts Department of Environmental Protection ("the Agencies") issued a final permit effective August 1, 2008. Parts I.A.13.g and h of the permit required the permittee to reduce current levels of entrainment of marine organisms through the facility's cooling water intake structures to an extent "comparable to what would be achieved by the use of closed-cycle cooling" for all electrical generating units, with the closed-cycle cooling system optimized to maximize cooling water intake flow reductions to the extent practicable in light of site-specific constraints (*e.g.*, restrictions on chloride discharges). Permit No. MA0004928 of August 1, 2008, Part I.A.13.g, p. 16 of 21.

By Joint Public Notice No. MA-004-09 of December 12, 2008, the Agencies withdrew Parts I.A.2.f, I.A.7.f, I.A.8, I.A.13.g, and I.A.13.h of the August 1 permit and reproposed them as draft permit conditions for public comment. The Agencies "recognize[d] the possibility that a commenter might wish to comment on additional permit conditions that the commenter believes are inextricably intertwined with the BTA determination for entrainment." Joint Public Notice No. MA-004-09 at 3 (December 12, 2008).

These comments are in response to that public notice.

BACKGROUND

Mirant Canal, LLC owns and operates the Canal Station ("Canal Station" or "the Station"), a 1,112-megawatt power plant in Sandwich, Massachusetts, on the bank of the Cape Cod Canal. The Canal Station has operated since the 1960s and has had an NPDES Permit since permitting began under the Clean Water Act ("CWA"). The Station has been operating under a permit issued in 1989.

In May 1994 Mirant Canal applied for reissuance of its NPDES permit. Responding to an April 30, 2003, request by Region 1, Mirant Canal supplemented its permit application on October 30, 2003. The supplement included a preliminary evaluation of fish protection alternatives by Alden Research Laboratory, Inc. ("Alden").

In December 2005, Region 1 issued a draft NPDES renewal permit. Proposing cooling water intake structure requirements in the draft permit, Region 1 was guided by EPA's new "Phase II" rule, especially for entrainment, but made the proposal on a "best professional judgment" ("BPJ") basis. See December 2005 Fact Sheet at 26, 45. The 2005 Draft Permit and accompanying Fact Sheet proposed to continue to authorize the discharge of once-through cooling water but to require biological monitoring because "[m]onitoring is needed to better determine the magnitude of environmental impacts associated with the CWIS, the effectiveness of BTA measures, and whether additional changes to the facility's CWA § 316(b)-related permit requirements would be warranted in the future…." December 2005 Fact Sheet at 45.

For entrainment, the Region observed that "further evaluation is needed of [other intake technologies'] entrainment reduction capabilities, any offsetting impingement mortality increases they might cause, their costs, and any problems with engineering/logistical practicability that they might pose…." *Id.* at 46. Accordingly, the Region proposed to require Mirant Canal to follow the procedures required by the then-effective Phase II regulations, 40 C.F.R. §§ 125.90-.99.

Mirant Canal and other interested parties submitted comments on the 2005 Draft Permit by the end of the public comment period, February 4, 2006. After the comment period, there were changes to EPA's regulatory program for cooling water intake structures. The Second Circuit Court of Appeals remanded EPA's Phase II rule for cooling water intake structures at "existing" power plants, which applied to the Canal Station. *Riverkeeper, Inc. v. EPA*, 475 F.3d 83 (2d Cir. 2007), *cert. granted sub nom. Entergy Corp. v. EPA*, 128 S. Ct. 1867, 1868 (2008) (*Riverkeeper II)*. The court found that § 316(b) of the CWA "precludes cost-benefit analysis" (*id.* at 99) but allows EPA to consider what technology can be "reasonably borne" and to engage in "cost-effectiveness" analysis (*id.*).

Following the remand, EPA suspended the Phase II rule and directed permit writers to make intake structure decisions under § 316(b) using "best professional judgment" ("BPJ"). 72 Fed. Reg. 37,107-09 (July 9, 2007). Region 1 has said that suspension of the Phase II rule and the Second Circuit decision are "obviously significant new legal developments." The Region also noted that these new developments "contributed to significant changes" in the permit's intake structure requirements. Response to Comments IX-51.

The U.S. Supreme Court agreed to review the Second Circuit's decision that costs cannot be compared to benefits. *Riverkeeper II, cert. granted sub nom. Entergy Corp. v. EPA*, 128 S. Ct. 1867, 1868 (2008). In July 2008 EPA and the Department of Justice filed a brief with the Supreme Court arguing that the Second Circuit had been wrong about weighing costs and benefits. *See* Brief for the Federal Parties as Respondents Supporting Petitioners, *Entergy Corp. et al. v. EPA et al.,* Nos. 07-588 *et al.* (U.S. July 2008). The Supreme Court heard oral argument December 2, 2008.

On August 1, 2008, the Agencies issued final NPDES Permit No. MA0004928 for the Canal Station, along with a Response to Comments approximately 185 pages long. As noted below, that permit imposes potentially crippling cooling system retrofit requirements on the Canal Station, requiring, in effect, that cooling towers be installed.

Because the Second Circuit decision, the suspension of the Phase II rule, and the Agencies' development of new BPJ cooling water intake structure requirements could not have been addressed during the comment period, Mirant Canal asked the Environmental Appeals Board to review the permit, particularly the requirement of closed-cycle cooling.

See Petition for Review of the Mirant Canal NPDES Permit Issued by EPA Region 1 (September 2, 2008).

Following a status conference before the Appeals Board on November 18, 2008, Region 1 decided to withdraw provisions of the Final Permit that "were based on Region 1's determination that closed-cycle cooling is the best technology available for reducing entrainment by Mirant Canal Station's cooling water intake structures, namely permit conditions I.A.2.f, I.A.7.f, I.A.8, I.A.13.g, and I.A.13.h." Letter, Region 1 Regional Administrator, to Clerk, Environmental Appeals Board, NPDES Appeal No. 08-10, at 2 (December 4, 2008). The Region recognized the possibility that a commenter might wish to comment on additional permit conditions that the commenter believes are "inextricably intertwined" with the BTA determination for entrainment. Therefore the Region "will consider and respond to any significant comments in this regard that it determines to be within the scope of this proposed action." *Id.*; see also Joint Public Notice No. MA-004-09 (December 12, 2008); December 2008 Fact Sheet at 2.

The Region allowed until January 15, 2009, for public comments. Mirant Canal asked that the comment period be extended until February 13. Letter of December 19, 2008, from Mirant Canal counsel to Stephen S. Perkins, EPA Region 1. The Region agreed to a two-week extension until January 29, 2009. Joint Public Notice of an Extension of the Public Comment Period (January 12, 2009).

The Appeals Board dismissed Mirant Canal's petition without prejudice by order of December 11, 2008.

EXECUTIVE SUMMARY

The previous permit for the Mirant Canal Station, issued June 23, 1989, complied with section 316(b) of the Clean Water Act. The 1989 permit reflected Region 1's best professional judgment that the plant in its present configuration, with once-through cooling, satisfied the requirement to "minimize adverse environmental impact" from the cooling water intake.

In its December 2005 Draft Permit Region 1 proposed, based on its best professional judgment, that Mirant Canal should submit a comprehensive demonstration study and other information required by the then-effective Phase II rule. The Region recognized that at least three alternatives (fine-mesh Ristroph screens, wedgewire screens, and closed-cycle cooling) should be studied further (2005 Fact Sheet 41-44). The Region believed that "[s]ome combination of steps will be needed" to satisfy CWA § 316(b) (*id*. at 45) but that "[m]onitoring is needed" to better determine environmental impacts and the effectiveness of BTA measures (*id*.). The Region judged that, both for closed-cycle cooling and other technologies that reduce entrainment, further evaluation was needed (*id*. at 46).

It is still true today that "further evaluation is needed." Accordingly, the final permit should use the same approach as the 2005 Draft Permit and require an assessment of intake technologies. Among its other advantages, this approach would allow the assessment to take into account the Supreme Court's soon-to-be-announced decision on considering costs and benefits under § 316(b), developments in EPA's ongoing rulemaking on the remanded Phase II rule, new studies of intake technologies now underway by the Electric Power Research Institute (EPRI), and current information about the Canal Station's role in the electric power market and in maintaining reliability of electricity supply in southeastern Massachusetts.

Nevertheless, the Region concluded in the 2008 Final Permit that further evaluation was *not* needed, based on two changes since the 2005 proposal: the Second Circuit decision in *Riverkeeper II* and EPA's suspension of the Phase II rule. These events, in the Region's view, cleared up the uncertainties and equitable concerns that had earlier prevented its choosing a best technology (Response to Comments IX-22).

However, other developments have created uncertainties and inequities of their own. In particular, the Supreme Court agreed to review the Second Circuit decision, and EPA argued to the Court that the Second Circuit was incorrect. Some of this uncertainty should be resolved when the Supreme Court reaches its decision, probably within weeks. Some of it may be resolved when EPA revises the Phase II rule on remand.

Apart from the Phase II rule, other significant changes have occurred. Most notably, impingement mortality and entrainment levels at the Canal Station are now even lower, because the Station is operating far less frequently than in 1999-2001, when biological sampling was done, or in 2005, when Region 1 assessed the environmental impact of the Canal Station. Moreover, the estimated costs of cooling towers and intake technologies are greater now than they were in 2003 when the analysis was done on which the Region has relied. Also, market conditions make it economically infeasible for the Station to sustain the multimillion-dollar cost of retrofitting cooling towers. None of these changes argues in favor of cooling towers; they argue instead for an evaluation such as the Draft Permit proposed.

In short, the uncertainties (including uncertainties about reliability requirements in the southeast Massachusetts electric power market) and equitable considerations still favor a study of intake technologies for the Canal Station. The approach proposed in the 2005 Draft Permit was sound and should be adopted in the final permit.

Even without a study, though, retrofitting closed-cycle cooling at the Canal Station cannot be justified. By any standard the cost of cooling towers would be excessive, certainly in terms of dollars and more so in light of adverse environmental impacts (like air pollution and noise) that cooling towers would create. The costs of cooling towers are "wholly disproportionate" to their benefits, closed-cycle cooling would not be "cost-effective," and the costs could not be "reasonably borne" by the Canal Station. For these reasons, closed-cycle cooling is not "best technology available" for this particular power plant, and it should not be required by the NPDES permit.

The provisions in the Final Permit for reducing impingement mortality should also not be required until Mirant Canal completes an assessment of technologies for reducing entrainment. Entrainment and impingement are so closely related that creating permit requirements for each of them separately would be wasteful and unwise. In particular, a new fish return system should not be required because the record does not show a need for it. It is being required to address harms that are only theoretical or speculative.

Likewise, the biological monitoring and reporting requirements in the Final Permit should not be in the permit because such requirements depend on what technology is used to reduce entrainment. Even if closed-cycle cooling were the appropriate technology, the monitoring requirements would be inappropriate. Some monitoring may be needed to assess environmental impact and inform the selection of best technology available, but this should not be required for the life of the plant. And monitoring to verify the performance of an installed intake technology should likewise be of limited duration; the Phase II rule, for example, prescribed two years of verification monitoring. See 40 C.F.R. § 125.95(b)(7) (suspended), 69 Fed. Reg. 41,690 col. 3 (July 9, 2004).

Finally, these comments assert that the final permit should contain a reasonable compliance period for several of the permit requirements. The comments also object to limits on cooling tower blowdown, requirements for segregating metal cleaning wastes, annual heat load reports, and providing source water physical data and cooling water intake structure data.

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1. Comments on Process

1.1 Agencies' Response to Comments

Mirant Canal's comments on reopened NPDES Permit No. MA0004928 are based on our review of the 438 documents in the Administrative Record, including Nos. 408-38 that were added when the permit was reopened for comment, as well as the Agencies' permitting documents, which include the following:

Draft NPDES Permit MA0004928 (December 19, 2005)

Joint Public Notice (December 22, 2005)

2005 Fact Sheet (December 2005)

Final NPDES Permit MA0004928 (July 31, 2008)

2008 Response to Public Comments for Mirant Canal Station

Draft NPDES Permit MA0004928 (December 2008)

Joint Public Notice No. MA-004-09 (December 12, 2008)

December 2008 Fact Sheet

Mirant Canal has assigned, below, a numerical identifier for each comment to which Mirant Canal believes Region 1 should respond pursuant to 40 C.F.R. § 124.17 and 314 C.M.R. § 2.09. Each of the enumerated comments is significant for purposes of the cited regulations. Some of the enumerated comments present more than one issue that should be addressed by the Agencies' response. *See Puerto Rico Sun Oil Co.* v. *U.S. EPA*, 8 F.3d 73, 79 (1st Cir. 1993).

Recently Region 1 published a response to comments on the Mirant Kendall Station in Cambridge, Massachusetts. Response to Comments, Mirant Kendall Station (NPDES Permit No. MA0004898, http://www.epa.gov/region1/npdes/mirantkendall/). Because the EPA Response to Kendall Comments explains Region 1's position on certain legal and policy issues that affect the Canal Station as well, we will refer to the Kendall document through these Canal Station comments.

We understand the Region's position, as stated in the EPA Response to Kendall Comments, to be that it must respond to all significant comments:

> EPA is obligated to "[b]riefly describe and respond to all significant comments on the draft permit [modification] . . . raised during the public comment period, or during any hearing." 40 C.F.R. § 124.17(a)(2). "The regulation does not require the Region 'to respond to each comment in an individualized manner,' nor does it require that 'the Region's response be of the same length or level of detail as the comment.'"

EPA Response to Kendall Comments at 1-2.

1.2 Terminology in These Comments

Specialized terms and citations used in these comments are listed in this glossary:

Term	Definition
Administrative Record or A.R.	The administrative record compiled by EPA Region 1 regarding NPDES Permit No. MA0004928, consisting of 438 documents
AEI	"Adverse environmental impact" as used in CWA § 316(b), 33 U.S.C. § 1326(b)
Agencies	EPA Region 1 – New England and the Massachusetts Department of Environmental Protection (DEP)
BAT	"Best available technology" as used in CWA § 301(b)(2)(A) and § 304(b)(2)(A)
BPJ	Best professional judgment
BTA	"Best technology available" for cooling water intake structures as used in CWA § 316(b)
Canal Station or the Station	Mirant Canal's station in Sandwich, Massachusetts
CWA	The federal Clean Water Act, 33 U.S.C. §§ 1251 - 1387
CWIS	Cooling water intake structure
December 2008 Fact Sheet	Fact Sheet issued by EPA Region 1 along with the Renoticed Permit
De minimis environmental impact	Some level of impingement mortality and entrainment that § 316(b) of the Clean Water Act does not require to be reduced, either because it is not "adverse" or simply because § 316(b) does not require it to be "minimized" further
EAB	EPA Environmental Appeals Board
EPA	U.S. Environmental Protection Agency
EPA Response to Kendall Comments	EPA Region 1 Response to Comments for the Mirant Kendall Station (NPDES Permit No. MA0004989, http://www.epa.gov/region1/npdes/mirantkendall/)
Equivalent Adults or EA	The quantity of adult fish expected to result from a number of fish eggs or larvae
Final Permit or the 2008 Final Permit	The final NPDES Permit No. MA0004928 as signed July 31, 2008, and issued by the Agencies August 1, 2008
IM/E	Impingement mortality and entrainment.
MassDEP	Massachusetts Department of Environmental Protection

Term	Definition
MCZM	Massachusetts Office of Coastal Zone Management
Mirant Canal	Mirant Canal, LLC, owner and operator of the Canal Station
Mirant Corporation	A public company of which Mirant Canal, LLC, is a wholly owned subsidiary
Petition for Review	Mirant Canal's Petition for Review to the Environmental Appeals Board, dated September 2, 2008
Phase I and Phase II Rules	66 Fed. Reg. 65,255 (December 18, 2001), 69 Fed. Reg. 41,576 (July 9, 2004)
Region 1 or the Region	EPA New England - Region 1
Renoticed Permit	Draft NPDES Permit No. MA0004928 with Parts I.A.2.f, I.A.7.f, I.A.8, I.A.13.g, and I.A.13.h withdrawn and renoticed December 2008
Response to Comments	Mirant Canal Station NPDES Permit MA0004928 2008 Response to Public Comments dated August 1, 2008
WQS or Mass. WQS	Massachusetts Water Quality Standards, 314 C.M.R.§ 4

1.3 EPA and MassDEP as Intended Recipients of These Comments

The final permit will be issued jointly by EPA Region 1 under the federal Clean Water Act and by MassDEP under the Massachusetts Clean Waters Act, each pursuant to its respective permitting authorities. Under the Commonwealth's permitting procedures, 314 C.M.R. § 2.09, MassDEP is required to respond to comments on the Renoticed Permit. Accordingly, Mirant Canal directs these comments to both EPA Region 1 and MassDEP.

1.4 MassDEP Fact Sheet or Statement of Basis

Under the Commonwealth's permitting procedures, 314 C.M.R. § 2.05, MassDEP is required to prepare and issue a fact sheet or statement of basis for every draft surface water discharge permit. Because the December 2008 Fact Sheet says that both EPA Region 1 and MassDEP are withdrawing and reproposing parts of the Final Permit, Mirant Canal understands that the Fact Sheet is on behalf of MassDEP.

1.5 Comments to MCZM

The Massachusetts Office of Coastal Zone Management must certify that the final Permit Modification is consistent with MCZM's enforceable policies under the Coastal Zone Management Act. Although MCZM has not requested comments on whether the Renoticed Permit is consistent with MCZM's enforceable policies, these comments also are directed to MCZM for consideration in making its determination.

MCZM's enforceable policies at 301 C.M.R. § 21 include Water Quality Policy #1, which includes ensuring "that point-source discharges in or affecting the coastal zone are consistent with federally-approved state effluent limitations and water quality standards." 301 C.M.R. § 21.98(3). For the reasons stated in Mirant Canal's earlier submissions for the Administrative Record and in these comments, renewing the Canal Station's NPDES permit as requested by Mirant Canal will be consistent with state effluent limitations and water quality standards.

1.6 Mirant Canal's Earlier Comments Should Be Taken into Account

Mirant Canal reserves its right to rely on its prior communications and data submissions to EPA Region 1 or MassDEP concerning the renewal of Permit No. MA0004928. In particular, Mirant Canal's comments of February 3, 2006 (A.R. 190) are still relevant to some issues raised by the Renoticed Permit. The earlier comments should be considered preserved for the purposes of 40 C.F.R. § 124.13.

1.7 Costs of CWIS Modifications

Preliminary cost analyses submitted by Mirant Canal in previous years should not be used as cost estimates for intake technologies or closed-cycle cooling. In particular, the cost estimates in the 2003 Alden Report, which the Region used in its Response to Comments, are out of date.

In addition, the 2003 Alden Report was explicitly preliminary and incomplete. See Exhibit 13. Also, the Alden Report was not focused on a requirement for closed-cycle cooling because no such requirement had been proposed in 2003.

Updated cost estimates, recently done by Shaw Stone & Webster ("Shaw") and Alden, are included in these comments. Although still not the detailed analyses that would have to be done before actually designing and installing cooling towers or intake technologies, these 2009 estimates are more up-to-date, focus more specifically on the characteristics of the Canal Station, and reflect experience gained with the technologies over the last several years. These 2009 estimates are therefore significantly better than earlier ones.

1.8 Scope of the Renoticed Issues

The Agencies intend that the Renoticed Permit and comments on it concern only the parts of the August 2008 Final Permit that were withdrawn pursuant to 40 C.F.R. § 124.19(b) by EPA New England's letter of December 4, 2008 (A.R. 437), namely permit conditions I.A.2.f, I.A.7.f, I.A.8, I.A.13.g, and I.A.13.h.

These comments by Mirant Canal do focus on the parts of the August 2008 Final Permit withdrawn by EPA New England and now renoticed. To support these comments, however, Mirant Canal is providing updated data that are pertinent to other portions of the 2008 Final Permit as well.

Also, these comments address issues that are either (1) intertwined with the issue of best technology available for the intake structures or (2) raised by permit requirements that in our view were not a "logical outgrowth" of the 2005 Draft Permit.

1.9 Inadequate Time to Prepare Comments

Region 1 has not provided enough time for Mirant Canal or the public to comment adequately on the Renoticed Permit. The notice of reopening was December 10, 2008, allowing until January 15, 2009, for comments. As discussed in Exhibit 8, retrofitting closed-cycle cooling to an already-built power station raises complex issues about the balance-of-plant, feasibility, and cost. Region 1 allowed only the standard 30 days for comment.

Mirant Canal requested four additional weeks, until February 13, 2009. The Town of Sandwich, by letter of December 31, 2008, asked that the four-week extension be granted. An industry group, the Utility Water Act Group (UWAG), likewise supported the extension. As the Town said in its letter "the extension of the comment period is in the public interest as it allows all stakeholders and interested parties adequate time to review the Draft Permit, to prepare for and participate in the public hearing [on January 14] and to draft and file public comments."

Because the engineering, biological, and cost issues are complex and require extensive technical analysis, because the comment period coincided with the year-end holidays, and because preparation for the public hearing on January 14 had to be done at the same time, the time allowed for comment was too brief.

Mirant Canal accordingly reserves the right to supplement these comments with additional information that it has not had adequate opportunity to develop during the comment period and with any new information or data that arise concerning alternate intake technologies or the Cape Cod Canal. The Agencies should give full attention to such later comments and information as if they had been submitted along with these comments.

We understand Region 1's position to be that it is obligated to provide only a 30-day comment period, any more time being purely a matter of agency discretion. See EPA Response to Kendall Comments at 1-1. There may be cases, however, when the time allowed is inadequate to deal with the complexity of the issues, so that failing to allow enough time is an abuse of discretion.

In this case the Region did grant an additional two weeks for comments, until January 29, 2009, half the time requested by Mirant Canal, the Town of Sandwich, and UWAG. This is still not enough. This is a case in which the Region changed from requiring Mirant Canal to gather data and select an intake technology to a requirement that, in effect, Mirant redesign and reconstruct the power station. Although Mirant Canal is grateful for the two additional weeks, we still believe the time for comment was too brief.

1.10 A Reasonable Compliance Schedule Is Needed If Modifications to the Intake Are Required

Everyone agrees, we believe, that closed-cycle cooling (even if feasible) cannot be designed and installed in time to comply with the permit. Response to Comments IX-8. Region 1 expects to issue an Administrative Compliance Order Under CWA § 309(a) that will specify a schedule for coming into compliance with the new permit requirements. *Id.*

A reasonable compliance period should be written into the permit so that the permittee can rely on it, not merely offered in response to comments. The Region should not issue a permit that it knows Mirant Canal cannot comply with for years, leaving Mirant Canal vulnerable to citizen suits even if the Region does eventually issue an Administrative Compliance Order. *United States. v. Smithfield Foods,* 965 F. Supp. 769 (E.D. Va. 1997), shows that a permit issuer cannot change permit requirements by special orders, nor is such an order binding on people who were not parties to it. *Id.* at 788, 790.

Also, at least before mounting an enforcement proceeding, an agency must give "fair warning" of a new interpretation of its regulations. *See Gen. Elec. Co. v. U.S. EPA,* 53 F.3d 1324, 1333 (D.C. Cir. 1995). This requirement is not met by new permit provisions, effective in 60 days, that will take years to implement.

According to 40 C.F.R. § 122.47(a), a permit may specify a schedule of compliance "when appropriate." Surely a compliance period is appropriate for intake requirements under § 316(b) of the CWA, where new requirements (in the Phase II rule) became effective September 7, 2004, but were then suspended July 9, 2007, and where the Region itself imposed a new interpretation of "best technology available" in July 2008. (This argument also applies to the limits for metal cleaning wastes at Outfall 011, where the Region departed from longstanding EPA guidance (the "Jordan Memorandum") and imposed new limits on non-chemical metal cleaning wastes.)

It is true that CWA § 301(b) sets a "timetable" for meeting effluent limitations and that the dates in it have long passed: 1977 for BPT and water quality standards-based limits, 1989 for BAT (best available technology) for toxics and BCT (best conventional pollutant control technology) for conventional pollutants. See Response to Comments X-3. But these dates are expressly for "effluent limitations," and § 316(b) requirements are not effluent limitations.

Moreover, the timetable does not apply to requirements set after the dates in the statute. In the present case, the Canal Station has been in compliance all along with the § 316(b) determination embodied in the 1989 permit. Region 1 used "BPJ" to set *new* BTA requirements (and new BAT requirements for metal cleaning wastes) with a mere 60 days' notice before the permit's original compliance date. Congress never intended *new* technology-based requirements, set *after* statutory deadlines, to be instantly effective, and making them so in a permit would be arbitrary and capricious.

With respect to intake requirements under § 316(b), the statute sets no deadline. Decision of General Counsel 41, cited by Region 1, says that § 316(b) determinations are bound by § 301(b)(2)(A), which requires compliance with BAT limits by the statutory deadline (then 1983). *In re Brunswick Steam Elec. Plant*, No. 41, 1976 WL 25235 (EPA G.C. June 1, 1976) (hereinafter "GCO 41"), cited at Response to Comments X-3 n. 2. But this decision looked at whether § 316(b) requirements would be imposed earlier, not later, than the § 301(b) deadline. Moreover, the decision assumed a link between § 316(b) and the dates in § 301(b) but did not provide a legal analysis for that link.

Even if GCO 41 were correct (which we believe it is not) it is not reasonable for the Region to conclude from GCO 41 that newly conceived § 316(b) requirements are immediately effective. GCO 41 also says that a technology is not "available" until it can be implemented:

> Under §316(b) the best technology available must, of course, be available. In other words, a compliance schedule under the §316(b) regulations must take into consideration the time necessary to implement the appropriate technology at a given intake structure.

GCO 41 at 199 (footnote omitted). Particularly for closed-cycle cooling, footnote 5 to GCO 41 assumes a compliance schedule and discusses how to establish it:

> The capacity of a cooling water intake could be restricted under 316(b) so as to necessitate the construction of a closed cycle cooling system. If so, a compliance schedule for such a restriction should be co-ordinated with any independent requirement for the installation of a closed-cycle cooling system under the Steam Electric guidelines.

GCO 41 at 199 n. 5. In some cases, best technology available under § 316(b) might entail substantial changes, and it might not be feasible to make the changes by the then-statutory-deadline of 1981. GCO 41. Thus, EPA's General Counsel concluded that while in some cases compliance might be called for *before* the deadline (where only modest alterations in design are needed, for example) in others it might not be feasible to meet the deadline. Thus "the benefits of a flexible case-by-case § 316(b) implementation schedule cut both ways." *Id.*

EPA Region 1 concludes from GCO 41 that there can be no compliance schedule for new § 316(b) requirements. See Response to Comments X-3. In light of the passages quoted above, that conclusion is not a reasonable interpretation of the opinion.

Moreover, how EPA Headquarters handled compliance schedules in the PhaseII rule shows that new § 316(b) intake requirements were never intended to be immediately effective. The Phase II rule was published July 9, 2004, and effective September 7, 2004. 69 Fed. Reg. 41,576 col. 2 (July 9, 2004). It required permit renewal applicants to submit information "as expeditiously as practicable" but no later than January 7, 2008. *Id.* at 41,687 col. 2, 41,691 col. 2.

Even after the best technology available was selected, the Phase II rule provided for a Technology Installation and Operation Plan that would include a schedule for installing and maintaining any new design and construction technologies, and downtime for installation or maintenance was to be scheduled to coincide with otherwise necessary downtime for repairs or maintenance as practicable and to minimize impacts to electric supply. *Id.* at 41,689 col. 1. Thus EPA headquarters signaled unmistakably that even § 316(b) requirements short of retrofitting closed-cycle cooling would require time to accomplish; up to 3½ years was allowed for submitting the necessary information.

In this respect EPA has been consistent for over 30 years. In the preamble to the original § 316(b) rules, EPA said that compliance dates should be determined on a case-by-case basis taking into consideration compliance dates for limits on the discharge of heated effluent and other pertinent factors. 41 Fed. Reg. 17,389 col. 1 (April 26, 1976).

The Administrative Procedure Act ("APA") provides that (with certain exceptions) the withdrawal, suspension, revocation, or annulment of a license is lawful only if the licensee has been given --

> (1) notice by the agency in writing of the facts or conduct which may warrant the action; and
>
> (2) opportunity to demonstrate or achieve compliance with all lawful requirements.

5 U.S.C. § 558(c). Although a new permit requirement requiring a power plant to be redesigned and rebuilt is not "revocation" of a license, the APA does demonstrate that Congress, as a general matter, intended licensees to have an opportunity to "achieve compliance."

When EPA creates new BAT requirements for effluent limitations post-1987, it allows permittees time to comply. EPA's practice when publishing new BAT requirements after the 1987 BAT deadline has passed is to make the new requirements effective "immediately upon issuance or reissuance of the National Pollutant Discharge Elimination System (NPDES) permit." See 65 Fed. Reg. 3008 col. 2 (Jan. 19, 2000) (landfills); 65 Fed. Reg. 4360 col. 2 (Jan. 27, 2000) (existing direct waste combustors must comply with BAT limitations "as soon as their [NPDES] permit includes such limitations; existing indirect dischargers have three years to comply with pretreatment standards); 65 Fed. Reg. 49,667 col. 1 (Aug. 14, 2000) (deadlines for BAT for transportation equipment cleaning are established in the NPDES permits); 69 Fed. Reg. 51,893 col. 1-2 (Aug. 23, 2004) (as soon as the NPDES permits for concentrated aquatic animal production include such limitations).

Thus, the permittee may have almost five years to install control technology (if the BAT requirement comes out soon after the NPDES permit has been issued or reissued). Moreover, in most cases the permittee will have had several *more* years' warning about the BAT requirement that was likely to come because EPA would have published a development document and a proposed rule.

Monitoring requirements, like the biomonitoring requirements in the Canal Station permit, are a special case. They are not subject to the deadlines of § 301(b) because they are not "effluent limitations." An "effluent limitation" is a "restriction . . . on quantities, rates, and concentrations" of pollutants, including schedules of compliance. 33 U.S.C. § 1362(11). So judges distinguish between "effluent limitations" and "monitoring requirements." *Northwest Bypass Group v. U.S. Army Corps of Eng'rs*, 552 F. Supp. 2d 97, 123 (D. N.H. 2008) (§ 401 certification must set forth "effluent limitations and other limitations, and monitoring requirements"). Similarly, *Envtl. Prot. Info. Ctr. v. Pac. Lumber Co.*, 266 F. Supp. 2d 1101, 1118 (N.D. Cal. 2003), found that a nonpoint source requirement for silviculture was not an "effluent limitation or other limitation" and distinguished limitations "under section 301" from other requirements. Monitoring requirements are not "under section 301" either. EPA's authority to prescribe monitoring requirements is § 304(i)(A), and its authority to prescribe conditions on data and information collection and reporting for NPDES permits is § 402(a)(2). Thus monitoring requirements in particular are not subject to ironclad deadlines.

In the EPA Response to Kendall Comments, Region 1 repeats its position that NPDES permits "may not require compliance schedules for CWA § 316(b) requirements." EPA Response to Kendall Comments at 2-69. In light of what we have said above, Mirant Canal asks the Region to reconsider that position for Canal Station.

1.11 Mirant Canal Will Provide Additional Financial Information If Region 1 Needs It for its Review

The analysis in Exhibit 12 of whether Mirant Canal can afford cooling towers relies to some extent on financial information that is confidential business information with commercial value to Mirant Canal. In particular, Exhibit 12 includes an attachment from which certain confidential business information has been redacted. We believe we have provided enough information in these comments and exhibits to allow Region 1 to review the analysis.

However, if Region 1 decides after reviewing these comments that it needs additional financial information, Mirant Canal will be happy to provide it, though we will want to apply for protection from public disclosure for confidential business information under 40 C.F.R. § 2.203(b). Region 1 need only request what additional information it needs, and we will attempt to supply it promptly.

1.12 Region 1 Should Ask for Any Additional Technical Information It Needs

If Region 1, upon reviewing these comments, finds that it needs more detailed information to complete its review, Mirant Canal will supply it promptly if it can reasonably do so. In particular, we present in these comments analyses by five consultants (Veritas, Normandeau Associates, Shaw, Alden Laboratory, and PwrSolutions). In some cases raw data, spreadsheets, or other information may form the basis for the reports included here as exhibits. The permit process will work best if the

Region tells us what information it needs to perform a thorough review. We ask, therefore, that the Region request any information it needs to understand and evaluate these submissions, and we will do our best to provide what is needed.

2. Comments on Law

2.1 Determining BTA on a Site-Specific, BPJ Basis

Mirant Canal agrees with Region 1 that the § 316(b) requirements for an existing power generating station should be established on a BPJ, site-specific basis. Response to Comments IX-23; 40 C.F.R. §§ 125.3(c)(2) & (c)(3), 125.90(b). That requires a careful look at the facts of the power plant and site. It is not compatible with a rule-of-thumb approach such as "closed-cycle cooling is presumed best" or "whatever will most reduce impingement and entrainment is best."

It would be inconsistent with BPJ decision making, for example, to decide that closed-cycle cooling is the Regional "standard" for intakes and require it as a sort of default for all plants where closed-cycle cooling is physically possible. It would also be unfortunate, because such a standard would most likely force more than one non-baseload generating plant to close.

2.2 Site-Specific BAT Factors

Mirant Canal agrees with Region 1 that the BAT factors set out under CWA § 304 are relevant to a BPJ determination of BTA limits. Region 1's position, however, is that it is not *required* to consider the CWA § 304 factors. EPA Response to Kendall Comments at 2-2.

Nevertheless, no one denies that EPA is authorized to consider factors like adverse environmental impacts, cost, and energy impacts, and in fact routinely does so. Hence these comments address the adverse environmental impacts of cooling towers like air pollution and noise, as well as impacts on energy supply.

The Canal Station Response to Comments acknowledges the relevance of the BAT factors and purports to consider them in determining BTA for the Station. Response to Comments IX-23 to -53. But it does not adequately consider three of the BAT factors in particular: site-specific costs, engineering constraints, and nonaquatic environmental impacts of technologies for reducing impingement mortality and entrainment ("IM/E").

2.3 Region 1 Should Follow First Circuit Precedent Rather than a Second Circuit Decision that EPA Headquarters Believes Is Wrong

Region 1's Response to Comments relies on the decision of the U.S. Court of Appeals for the Second Circuit on setting BTA requirements in a nationwide rule, specifically the Phase II rule for existing facilities that the court remanded for further consideration. See *Riverkeeper II*. According to Region 1, "EPA is presently abiding by the Second Circuit's decision." Responses to Comments at IX-20.

Riverkeeper II, however, should not apply to the Renoticed Permit. To be sure, the Second Circuit decision led EPA to suspend the Phase II rule and to return to determining BTA on a site-specific BPJ basis. But *Riverkeeper II* addressed only the industry-wide rule and said nothing about how to conduct site-specific BPJ determinations.

Moreover, Region 1 has disregarded binding precedent from the U.S. Court of Appeals for the First Circuit, the circuit with jurisdiction over Massachusetts. The Response to Comments does not even cite, let alone discuss, *Seacoast Anti-Pollution League v. Costle*, 597 F.2d 306 (1st Cir. 1979) (*Seacoast*), which specifically reviewed a permit issued on a BPJ basis. *Seacoast* should guide EPA's decision making here.

When they issue the final permit for the Canal Station, the Agencies should apply the standard for CWA § 316(b) that was endorsed in *Seacoast*, not *Riverkeeper II*. In particular, *Seacoast* requires the Agencies to determine whether the costs of proposed BTA requirements at the Canal Station would be "wholly disproportionate" to the benefits.

In filings made with the Supreme Court as part of the Court's review of *Riverkeeper II*, EPA itself has indicated both that it need not follow *Riverkeeper II* when issuing NPDES permits outside the Second Circuit and that it continues to support the holdings in *Seacoast*. See Brief for the Federal Respondents in Opposition, filed March 3, 2008 in *Entergy Corporation v. EPA*, Nos. 07-588, 07-589 and 07-587 (U.S. Supreme Court), at pp. 13, 15, which is the Solicitor General's response to the petitions for certiorari in *Riverkeeper II*. Although EPA thinks *Seacoast* does not present a "square conflict" with *Riverkeeper II*, it is "in tension with it," and EPA's brief adds that, unless the Supreme Court acts, permitting authorities will no longer be able to consider the relationship between costs and benefits "[a]t least in the Second Circuit."

2.4 *Riverkeeper II* Does Not Prescribe How to Weigh Factors when Making Site-Specific BTA Decisions

Although it is relevant to the factors that may be considered in choosing BTA (at least in the Second Circuit), *Riverkeeper II* is silent on most of the factors that the Agencies consider in issuing a BPJ determination under CWA § 316(b). Specifically, the Second Circuit did not define how permit writers may evaluate whether IM/E is causing AEI or the point at which costs become unreasonably burdensome. Nor did the Court define how permit writers should balance IM/E reductions against other factors associated with a technology, including its adverse environmental impact, energy impacts, non-environmental impacts like recreational impacts, non-water related environmental impacts like air emissions and noise, site-specific availability of technologies, and other factors that necessarily must be considered in issuing BPJ-based permitting requirements. Nothing in *Riverkeeper II* or indeed in CWA § 316(b) dictates how the Agencies must balance these factors against marginal AEI from existing IM/E and against marginal reductions in AEI from different intake technologies.

Accordingly, in finalizing the Mirant Canal permit, the Agencies are not bound by *Riverkeeper II* or otherwise to elevate IM/E reductions above other factors the Agencies must consider. They are not bound, in other words, to select only technologies that maximally reduce IM/E no matter the effects on other values affecting the location and the facility. Rather, the Agencies should address all the pertinent factors and are free to develop a reasonable approach that establishes BTA in light of site-specific considerations.

In the EPA Response to Kendall Comments, Region 1 recognizes that EPA disagrees with the Second Circuit's decision. EPA Response to Kendall Comments at 2-1. The Region also notes the "tension" between the First Circuit *Seacoast* decision and *Riverkeeper II*. *Id*. at 2-2. It also says that EPA is not currently authorized to make its BTA determinations under § 316(b) on the basis of a cost/benefit comparison due to the decision in *Riverkeeper II*. *Id*. The Region says it "disagrees with Mirant's interpretation of *Seacoast*." *Id*. at 2-15. But it does not explain why it follows the Second Circuit precedent rather than the First Circuit decision, which is more closely on point (because it addresses a specific BPJ permit decision instead of a nationwide rule) and from the circuit that includes Massachusetts. Nor does the Region explain the basis on which it disagrees with Mirant Kendall about the meaning of *Seacoast*. See *id.* at 2-2, 2-15.

Also in the EPA Response to Kendall Comments, Region 1 says that if the Supreme Court decides that § 316(b) authorizes EPA to compare costs and benefits in determining BTA-based limits, it will review the permit in light of the decision and consider any further steps that may be suggested. EPA Response to Kendall Comments at 2-2. The same reconsideration would be needed for the Canal Station. Indeed, if the permit were issued before the Supreme Court decision was released, it should contain a reopener provision allowing the permit to be reopened to consider the Court's future decision.

In particular, Region 1 should follow the First Circuit *Seacoast* decision and reject a technology if its costs would be "wholly disproportionate" to its benefits. It should not limit itself to the discussion of costs in *Riverkeeper II* (which in any event does not address site-specific BPJ decisions).

It is important that Region 1 compare the benefits of a technology to the social, economic, and environmental costs so that stakeholders, who will have to bear the costs, can see the tradeoffs that the Region is requiring. A narrow focus on just the numbers of fish lost defeats the purpose of revealing these tradeoffs to the public.

2.5 EPA's Draft 1977 Guidance Is Still Operative

With the suspension of the Phase II rule, the draft 1977 guidance is the most pertinent and most authoritative guidance available for making § 316(b) intake technology decisions. See section 2.8 below. Region 1 should use it.

2.6 The Permit Should Provide for a New or Revised Phase II Rule

As noted above, the U.S. Supreme Court has granted *certiorari* in *Riverkeeper II* and will review the central issue of EPA's authority to conduct cost-benefit analyses when it makes BTA determinations under CWA § 316(b). After the Court makes its decision, EPA will promulgate a new or revised rule for existing power plants like the Canal Station, based on the Supreme Court's reasoning and the parts of the Second Circuit decision that the Supreme Court did not review.

If the revised Phase II rule includes provisions that, as applied to Canal Station, would change the Agencies' determination of BTA from the provisions in the August 2008 Final Permit or the Renoticed Permit, the permit should authorize Mirant Canal to comply with the final rule rather than the Agencies' pre-rule BPJ decision.

In particular, the suspended Phase II rule included a well-considered set of schedules for complying with the rule, including a schedule for submitting Comprehensive Demonstration Studies. 40 C.F.R. § 125.95(b) (suspended). The revised Phase II rule may also contain a compliance schedule. The final permit for the Canal Station should provide that, when EPA promulgates a new or revised Phase II rule, the Canal Station may comply with the requirements of the rule rather than any inconsistent provisions in the permit.

2.7 Region 1 Should Evaluate the Size and Nature of Biological Impacts of IM/E

Region 1's Response to Comments provides no quantitative analysis of the magnitude and biology of the environmental impacts of impingement mortality and entrainment ("IM/E") at Canal Station. Instead, Region 1 appears to have concluded that any entrainment or impingement is *per se* an "adverse environmental impact." See Response to Comments IX-24 ("EPA has read CWA § 316(b) to intend that entrainment and/or impingement should be regarded as an 'adverse impact' that must be minimized ...."). The Region's evaluation of AEI both started and stopped by finding that *some* IM/E occurs.

To put it another way, the Response to Comments shows no effort to quantify the significance of IM/E at Canal Station to the affected populations or the overall ecosystem in the specific setting of the Station. Region 1 did not, for instance, calculate what the IM/E losses mean in terms of equivalent adults or in relation to the overall population of the relevant species. This omission may have been appropriate when the Phase II rule, with its numerical performance standards, was in effect. But now that the performance standards are suspended, analyzing entrainment and impingement losses in the context of the aquatic community is important. Such analyses are specifically called for in EPA's 1977 guidance on applying CWA § 316(b). Even if CWA § 316(b) did not compel such an evaluation, the Agencies ought to perform one, so they will know what is likely to be gained by reducing IM/E and can make informed judgments about whether it is worth the adverse impacts of the various alternatives.

The Region's analysis does not include the sort of evaluation specifically called for by the draft 1977 guidance. Nor does it evaluate whether some or all of the effects of impingement and entrainment at Canal Station in fact are *de minimis*, even though (as discussed elsewhere in these comments) EPA has recognized that there may be *de minimis* impacts that do not need to be minimized. Indeed, the Response to Comments acknowledges that all impacts need not necessarily be eliminated. Response to Comments IX-24. But still the Agencies did not do any evaluation of what amount of AEI exists from IM/E at present or would exist after the proposed modifications.

As a consequence, the Response to Comments did not assess what level of impact from Canal Station's CWIS exists at present or would exist after the proposed modifications. Rather, Region 1 equated any impingement and entrainment with AEI and treated any impingement and entrainment as sufficient basis to require reducing it. The Response to Comments includes no evaluation of the impacts of such reduction on the local or regional populations after closed-cycle cooling is installed.

The Response to Comments is at variance with Region 1's own practices in other determinations. The record of the recently concluded Brayton Point NPDES permit proceeding has elaborate analyses by the Agencies of the magnitude of environmental impacts of that Station's IM/E on affected biota and of the benefits of the Agencies' selected BTA. See Responses to Comments, Public Review of Brayton Point Station, NPDES Permit No. MA 0003654, October 3, 2003, at pp. IV-4 to IV-44.

Mirant Canal does not deny that impingement and entrainment occur at Canal Station; indeed, all the Agencies' estimates for IM/E rely on information self-reported by the company. Nor does Mirant Canal dispute that some environmental impacts occur, but the most recent analysis by Normandeau indicates that such impacts are *de minimis*. See Exhibit 10 to these comments.

Whether additional measures are required to reduce the impact even further and, if so, what measures are "best technology available" cannot be determined just by concluding that IM/E exists. The Agencies must also evaluate the nature and effects of the existing IM/E in the site-specific setting to determine whether and which available technologies might be worthwhile and would work best to reduce overall environmental impacts.

The lack of an evaluation of the magnitude and nature of the biological impacts of IM/E at the Station's CWIS leaves the Agencies without a legally adequate basis for determining what specifically constitutes BTA here under CWA § 316(b). Before issuing the final permit, the Agencies must conduct a thorough evaluation of those impacts and any AEI and use the results to inform their selection of BTA.

2.8 The Agencies May Not Equate IM/E with AEI without Further Analysis

In promulgating the Phase I rules for *new* power plants, EPA used impingement mortality and entrainment as convenient metrics for adverse environmental impact but did not define IM/E as "adverse environmental impact." See 66 Fed. Reg. 65,292 (December 18, 2001). Likewise EPA used reductions in impingement and entrainment as a "quick, certain, and consistent metric" for determining performance at Phase II existing facilities. 69 Fed. Reg. 41,586 col. 1 (July 9, 2004).

With no Phase II rule in effect, the Agencies are free to assess the actual levels of AEI caused by IM/E at Canal Station and, per applicable guidance and precedent as described above, must do so.

There is no doubt that there can be levels of adverse environmental impact that are *de minimis* – that is, so low that § 316(b) requires no further "minimizing." This is clear from the principle that "minimizing" adverse environmental impact does not mean "eliminating" all impact, a principle that Region 1 agrees with. In the *Riverkeeper II* case before the Supreme Court, even the environmental groups agree that EPA has "some discretion (albeit not boundless) to determine that further differences in reduction would be so minor as to be unnecessary for compliance with the minimizing requirement." Brief for Respondents Riverkeeper, Inc., *et al.* in *Entergy Corp. v. EPA*, No. 07-588, at 29 (September 2008).

In the Phase II rule, for example, EPA concluded that whatever entrainment occurs need not be reduced for facilities with capacity utilization rates less than 15 percent or facilities withdrawing water from freshwater rivers and streams with a design intake flow five percent or less of the mean annual flow. 40 C.F.R. § 125.94(b)(2) (suspended). "Performance standards for entrainment do not apply to [certain facilities] because such facilities have a low propensity for causing significant entrainment impacts due to limited facility operation, low intake flow, or general waterbody characteristics." 69 Fed. Reg. 41,598 col. 3 (July 9, 2004). At the same time EPA concluded that reducing entrainment by 60-90% (leaving as much as 40% of the "baseline" entrainment) would satisfy § 316(b)'s requirement of "minimizing." See 40 C.F.R. § 125.94(b)(2) (suspended).

That there may be some level of impingement and entrainment that need not be further minimized has been EPA's position for decades. The 1977 draft guidance on evaluating adverse environmental impact under CWA § 316(b) said explicitly that some level of impact can be acceptable:

> The extent of fish losses of any given quantity needs to be considered on a plant-by-plant basis, in that the language of section 316(b) of P.L. 92-500 requires cooling water intakes to "minimize adverse environmental impact." Regulatory agencies should clearly recognize that some level of intake damage can be acceptable if that damage represents a minimization of environmental impact.

[Draft] Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b) P.L. 92-500 at 3 (May 1, 1977), available at http://www.epa.gov/waterscience/316b/files/1977AEIguid.pdf.

The 1977 guidance is still relevant. In 2000, while the § 316(b) rules were being written, EPA said the 1977 guidance still applied. Memorandum from Michael B. Cook, Director, EPA Office of Wastewater Management to Water Division Directors, Regions I-X and State NPDES Directors (December 28, 2000) (1977 guidance continues to be applicable while § 316(b) rules are being developed). Even when the Phase II rule was in effect, the 1977 guidance remained available as "additional guidance." Phase II Rulemaking Response to Comment 316bEFR.342.006, available at http://www.epa.gov/waterscience/316b/phase2/comments/index.html. ("State permitting agencies and permit applicants may refer to Draft Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b) P.L. 92-500 (U.S. EPA, 1977), for additional guidance"). With the suspension of the Phase II rule, the 1977 guidance is still appropriate to use in § 316(b) determinations. Indeed, it is more important than before.

Region 1 acknowledges, in the EPA Response to Kendall Comments, that "in principle … there could potentially be some de minimis threshold level of impacts below which EPA will not consider 'adverse environmental impact' to have occurred under CWA § 316(b)." EPA Response to Kendall Comments at 2-5. Even where it concludes that impingement mortality and entrainment are above *de minimis* levels, the Region distinguishes two related scenarios:

> In some cases, an adverse environmental impact may be above de minimis levels, but the technology in place may nevertheless 'minimize' adverse environmental impact because the technology is the 'best,' i.e., more effective technology for further reducing such impacts does not exist. … In other cases, an adverse environmental impact may be above de minimis levels, and the technology in place is not the best-performing technology for reducing such impacts, but there are no better-performing technologies available at the site in question because of issues such as space limitations or unacceptable non-water quality environmental impacts or energy impacts.

EPA Response to Kendall Comments at 2-5. There is, we submit, a third scenario: the technology in place is not the best-performing, but the cost of better performing technologies cannot be reasonably borne or is excessive by one of the cost-benefit standards now before the U.S. Supreme Court.

For the Canal Station, we show in these comments that the levels of impingement mortality and entrainment caused by the Station are *de minimis*. Even if they were not, closed-cycle cooling would not be "available" because of environmental impacts, energy impacts, cost-effectiveness, and the facility's inability to bear the cost. We show also that the costs of cooling towers would be "wholly disproportionate" to the benefits, an issue that will have to await the Supreme Court decision before being finally resolved.

2.9 EPA General Counsel Decisions Require an Evaluation of the Biological Impacts of IM/E

The Response to Comments relies on excerpts from Decisions of the General Counsel Nos. 41 and 63 for the proposition that a CWIS must reflect BTA to minimize AEI whether or not the AEI is significant. Response to Comments IX-9. But that does not mean EPA can ignore the magnitude of AEI in determining what constitutes BTA. Indeed, Decision of the General Counsel No. 63 *also* specifies that in conducting BPJ determinations like this one:

> EPA ultimately must demonstrate that the present value of the cumulative annual cost of modifications to cooling water intake structures is not wholly out of proportion to the magnitude of the estimated environmental gains (including attainment of the objectives of the Act and Section 316(b)) to be derived from the modifications.

In re Central Hudson Gas & Elec. Corp., Op. EPA Gen. Counsel, NPDES No. 63, 1977 WL 28250, at 381 (July 29, 1977). *Seacoast* requires that approach, as well. Accordingly, a final permit may not be issued under CWA § 316(b) without determining the environmental baseline and environmental "gains" of the proposed modification, which requires them to conduct an assessment of the impact of IM/E at Canal Station.

2.10 The Agencies Must Consider Updated Information and Determine AEI

As the Response to Comments did not evaluate the biological impacts of IM/E at Canal Station, it also did not provide any serious analysis of the data on IM/E and populations of fish that Mirant Canal has supplied from its ongoing biological monitoring program. To be sure, the 2005 Fact Sheet (at 32) addresses entrainment data, but it makes no attempt to evaluate what those data mean relative to AEI in the locality or the region. While this may have been appropriate when numerical performance standards were in effect, it no longer is appropriate now that those standards are suspended.

As shown later in these comments and the attached report (Exhibit 10), Normandeau Associates has done a recent assessment of the impact of the Canal Station on fish and lobster. Its conclusion is that the Station is unlikely to be having "adverse environmental impacts."

2.11 The Agencies Must Consider Whether Costs Are Wholly Out of Proportion to Benefits by Identifying the Baseline of AEI and the Benefits of Reducing AEI

Under EPA's draft 1977 Guidance, *Decisions of the General Counsel 41 and 63*, and the First Circuit *Seacoast* decision, the Agencies should not issue the final permit under CWA § 316(b) without evaluating whether the costs of a proposed modification are "wholly disproportionate" to the environmental benefits. To make that evaluation, Region 1 must first assess the current magnitude of AEI to establish the baseline against which to compare potential modifications. Then it must determine what type of reductions, if any, are needed so that the AEI due to IM/E reaches a *de minimis* level. Beyond the mere recitation of IM/E and a conclusory finding of AEI, the Response to Comments contains no such analysis, which the Agencies must conduct before issuing the final permit.

2.12 The Duty to Balance other BAT Factors Means the Agencies Must First Identify the Baseline of AEI and the Benefits of Reducing AEI

Similarly, in considering and reaching a reasonable balancing of the other BAT factors, the magnitude of existing AEI and potential reductions in AEI must be known. Instead, the Response to Comments simply assumes that maximal reductions in IM/E are needed and considers the other BAT factors dismissively.

Before issuing the final permit, the Agencies must balance those factors reasonably against the potential benefits of IM/E reductions. A small reduction in impingement mortality and entrainment achieved by modifying the Canal Station's CWIS, for example, may not be justifiable if the associated technology would cause adverse environmental impacts such as air pollution. But to evaluate that and similar issues, the Agencies first must determine both the baseline of AEI and the benefits of AEI reduction resulting from specific control technologies.

2.13 Duty of Full and Consistent Evaluation and Explanation

Although the Response to Comments (IX-28 to IX-46) identifies the factors that the Agencies must address for a BPJ decision, the Response to Comments does not fully evaluate each of the factors for the Canal Station. For example, in considering engineering aspects of potential control technologies, the 2005 Fact Sheet did not select fine-mesh Ristroph screens because "there are limits to what [this technology] can achieve and additional study would be needed…." 2005 Fact Sheet at 42. Similarly, the Region identified uncertainties related to adverse impacts of cooling towers (noise, fogging) but simply assumed they could be overcome.

Prior to issuing the final permit, the Agencies must fully and consistently evaluate each proposed AEI minimization approach under each of the necessary factors and explain fully how they balanced those factors in reaching their final determination of BTA.

2.14 Minimizing AEI Does Not Mean Minimizing AEI to the Exclusion of Other Considerations

The Response to Comments, citing decisions of EPA's General Counsel, asserts that the requirement in CWA § 316(b) to select the BTA to "minimize" AEI means that the permit must require Canal Station to reduce IM/E "as much as possible." Response to Comments IX-9. The Renoticed Permit seeks that result, as if CWA § 316(b) requires doing everything possible to reduce IM/E.

CWA § 316(b), however, also allows and requires a permit writer to consider additional factors, as Region 1 acknowledges: whether a technology is "available" and "best" depends on site-specific circumstances, and, by analogy, on the BAT factors. Response to Comments IX-28 to IX-46. The same decisions of EPA's General Counsel are also clear that the goal of minimizing AEI means reducing AEI as much as possible *in light of the other elements of the full standard. See Decision of the General Counsel No. 63* (*In re Central Hudson Gas & Elec. Corp., et al.*) at 380-83 (July 29, 1977); Decision of the General Counsel No. 41 (*In re Brunswick Steam Elec. Plant*) at 173-76, 182-84 (June 1, 1976).

The Response to Comments, however, stresses minimizing IM/E as all-important and shortchanges its analysis of whether the proposed technologies actually are "available" or "best" in the setting of the Canal Station.

In issuing the final permit, the Agencies must balance the goal of minimizing AEI against the other elements of the standard under CWA § 316(b) and explain fully how it does so.

2.15 "Available" and "Best" Technology Must Be Demonstrably Feasible at Canal Station

The Response to Comments at IX-23 suggests that the BTA standard under CWA § 316(b) requires the Agencies to select the technology that will reduce impingement mortality and entrainment from the Canal Station's CWIS "to the smallest possible amount."

The Agencies are not authorized, however, to select and impose technologies as BTA for Canal Station that they have not shown and documented are feasible and effective at this location. A theoretically "best" technology is not BTA if it cannot be effectively deployed at the Canal Station.

In developing the final Permit Modification, the Agencies must select as BTA only technologies that they can show would actually be feasible and effective in the particular setting of Canal Station.

2.16 The Agencies Should Consider Updated Estimates of the Costs of Cooling Towers Based on a Retrofit Component Cost Analysis

As acknowledged in the Response to Comments, it is necessary and appropriate for the Agencies to consider the cost of implementing a proposed technology to minimize AEI under CWA § 316(b). A technology that is not affordable by an ongoing business is not truly "available," and under *Seacoast* the Agencies may consider whether site-specific costs of an option are "wholly disproportionate" to the benefits. And in *Riverkeeper II*, the court agreed that EPA has authority to consider which of roughly equally beneficial alternatives is the most cost-effective. 475 F.3d at 100.

Most of the cost numbers cited in the Response to Comments are based on preliminary estimates that Alden Laboratory developed in 2003 in response to the Agencies' request for information. Those 2003 cost estimates were based on generic information provided by the Electric Power Research Institute rather than a site-specific analysis. These comments provide better and more up-to-date cost estimates for cooling towers in Exhibit 1.

2.17 The Agencies Must Consider the Impact of Costs on Mirant Canal, LLC, Not Mirant Corporation

The Response to Comments disposes of all cost considerations under CWA § 316(b) by simply comparing the preliminary cost estimates to Mirant Corporation's net income and projected profitability in that company's financial reporting for part of 2006, then determining that the parent company can afford closed-cycle cooling. That approach, however, is inappropriate under CWA § 316(b).

First, Mirant Corporation is not the permittee; Mirant Canal, LLC, is. Purely as a matter of corporate law and NPDES permitting, the financial status of Mirant Corporation is irrelevant to whether the permittee can bear the costs of the proposed technologies. This issue is addressed more fully below in section 5.2.2.

Second, Mirant Canal is a single-purpose limited liability corporation that owns and operates the Canal Station and must either achieve profitability through its operations at the Canal Station or go out of business. No investor, whether Mirant Corporation or any other person, will incur capital and operating costs to operate the Canal Station where it expects that future revenues will not allow it to recover those costs. That reality of basic economics and business prudence was not repealed by CWA § 316(b). A technology cannot be considered "available" if the associated capital and operating costs would be expected to result in the permittee having to operate at a loss.

Third, Mirant Canal is not a traditional "regulated utility" able to recover its costs under a guaranteed rate of return from a captive group of customers. Rather, it is an independent power producer in a highly competitive market. Mirant Canal's ability to sell power depends on its ability to produce it at a competitive price. Adding significant costs, whether or not mandated by regulations and permits, necessarily reduces its competitiveness.

Fourth, the Agencies are called upon to make a site-specific BPJ determination, not to evaluate whether those costs are bearable by the parent company or across the power generation industry. The generalized costs of a type of technology that might be bearable by the industry are not necessarily bearable for the specific application of that technology at a particular facility. In considering costs here, the only appropriate approach is to consider how the costs affect the ability of the particular facility, the Canal Station, to maintain profitability over time.

The recent proceedings concerning the Brayton Point Station included detailed analyses of the affordability of the Agencies' BTA proposals *for that plant*. See Responses to Comments, Public Review of Brayton Point Station, NPDES Permit No. MA 0003654, October 3, 2003, at pp. IV-41 to IV-45. And in developing the Phase I and II rules, EPA conducted a nationwide assessment of how different approaches to BTA would affect individual facilities, which led it to build cost-based flexibility into the

Phase I and II rules. *See*, *e.g.*, 67 Fed. Reg. at 17,144. While *Riverkeeper II* remanded the Phase II rule for further consideration of the standards for allowing site-specific cost-based variations, the Second Circuit acknowledged that EPA has the authority under CWA § 316(b) to allow facility specific, cost-based variation. *Riverkeeper II*, 475 F.3d at 110.

In giving the required consideration to the costs of BTA proposals as they issue the final permit, accordingly, the Agencies may not stop after noting the profitability of Mirant Corporation. Rather, they must consider the costs in relation to their affordability by Mirant Canal, LLC at Canal Station. See Section 5.2.2 below.

2.18 The Agencies Must Compare the Cost-effectiveness of Proposed Technologies

Even under the restrictive cost test endorsed by the Second Circuit in *Riverkeeper II*, the Agencies are authorized to consider the costs of potential technologies and their relative effectiveness and then to determine and select the most cost-effective of the available technologies. *Riverkeeper II*, 475 F.3d at 98-101.

In developing the final permit, the Agencies should consider cost-effectiveness among the other factors they must address. A technology should not be imposed if it costs substantially more per year than another technology that would be nearly as effective. For instance, if it would cost an additional $500,000/year to implement a technology that would prevent the loss of just 20 or 30 equivalent adult fish compared to the less costly technology, and if 20 to 30 fish are immaterial to the health of the local populations (as they are), the Agencies should choose the less costly technology.

According to the Second Circuit in *Riverkeeper II*, whether EPA should conduct a comparative analysis of the cost-effectiveness of different technologies may be optional. Mirant Canal believes, however, that such an analysis is mandatory in the current circumstances, where there are minimal impingment mortality and entrainment and such wide ranges of technologies and costs at issue.

This does not mean that it would be inappropriate for the final permit to leave some cost-effectiveness issues to the permittee. If the final permit selects a particular technology, it should be left to Mirant Canal to determine the most cost-effective way of implementing that technology.

2.19 The Agencies Must Consider the Nonaquatic Environmental Impacts of Proposed BTA Requirements

The Response to Comments acknowledges that CWA § 316(b) requires Region 1 to consider “non-water” environmental effects of potential technologies. It identifies several of those at IX-36 to IX-45. The Agencies did not analyze those effects, however, but simply concluded qualitatively that individually each impact is unlikely to be substantial or that Mirant Canal will solve the problems later. The Response to Comments contains no quantitative analysis by which a reviewer could judge whether the nonaquatic adverse impacts “outweigh” the environmental benefits of cooling towers.

Finally, as with the selection of technology, Region 1 did not assess what actually would be built (and any resulting problems).

2.20 The Region Dismisses Too Easily the Non-NPDES Permitting Issues

An intake technology (or closed-cycle cooling) is not "available" if it cannot be built. The Response to Comments dismisses too lightly the question whether cooling towers could be permitted by state and local authorities. The Region would leave permitting problems to be discovered by Mirant Canal after the final permit is effective.

Getting permits for closed-cycle cooling will pose challenges, discussed elsewhere in these comments. See Exhibit 9. Before issuing the final permit, the Agencies must determine that any required modifications can be permitted, and without unreasonable expense.

A detailed assessment of environmental impacts, aquatic and nonaquatic, could be done if Mirant Canal were permitted to do a study such as the Draft Permit proposed. Mirant Canal is helping to fund an EPRI national study of retrofitting cooling towers, the results of which should be available in 2009. Information from this EPRI study would help inform the Canal Station study.

2.21 Massachusetts Water Quality Standards Provide No Basis for Closed-Cycle Cooling

The Massachusetts Water Quality Standards ("WQS") do not provide authority for Region 1 to regulate intake structures at the Station. That is because water withdrawals in Massachusetts are regulated under the State's Water Management Act, M.G.L. c. 21G while the Massachusetts Clean Waters Act ("the Act"), under which MassDEP promulgates the WQS, only governs discharges of pollutants to surface waters. M.G.L. c. 21. In an attempt to extend its jurisdiction and the WQS to cover water withdrawals, and despite three decades of interpretating its jurisdiction under the Act as inapplicable to such withdrawals, MassDEP revised the WQS and claimed authority to regulate intake structures. See 314 C.M.R. § 4.05(3)(b)2.d., effective December 29, 2006, which baldly states that MassDEP "has the authority" to condition an intake structure to ensure that the withdrawal activity complies with the Mass WQS.

Even as amended, however, the WQS do not provide authority for either MassDEP or Region 1 to regulate the intake structures under the WQS. First, as to EPA Region 1, amendments to the Mass WQS are not "applicable" under CWA § 401(a)(1) until they have been approved under CWA § 303 and EPA has not yet approved the amendments. Second, the amendments are not authorized by Massachusetts law because the Act does not confer upon MassDEP, explicitly or implicitly, the authority to regulate water withdrawals, or the intake structures at issue here by which such withdrawals occur. MassDEP is limited to the authority conferred by the Act. Any action that goes beyond MassDEP's statutory authority is ultra vires. *See e.g. Matter of Elec. Mut. Liab. Ins. Co.*, 426 Mass. 362, 366 (1998); *Nuclear Metals, Inc. v. Low-Level Radioactive Waste Mgmt. Bd.*, 421 Mass. 196, 211 (1995). The authority granted to MassDEP by the

Act is clear: the Act governs the "discharge" of pollutants, the opposite of withdrawals. *See* M.G.L. c. 21, §§ 43(2), 44(1).

Nor is MassDEP's interpretation of the Act due any deference. *See Moot v. DEP*, 448 Mass. 340, 346 (2007) (acknowledging that an agency's technical decisions are due deference); *Goldberg v. Bd. of Health of Granby*, 444 Mass. 627, 632-33 (2005) (explaining that courts undertake a "more searching examination of whether agency action falls within the scope of its jurisdiction."). At present, the question of MassDEP's authority is under litigation in *Entergy Nuclear Generation Co. v. Massachusetts Dep't of Envtl. Protection*, No. 07-0366-H (Suffolk Super. Court).

Even were the amended WQS applicable, they do not provide any meaningful standards for water withdrawals or guidance as to what technologies are necessary to meet them. Nor has MassDEP promulgated any policies or guidance documents on the matter. Accordingly, the WQS provide no authority and no meaningful basis upon which Region 1 can base CWIS requirements for the Station.

2.22 The Final Permit Should Include a Schedule for Implementing Any Required Modifications to Canal Station's CWIS

Whatever technology is selected as BTA in the final permit, time will be required to install it. Some intake technologies will need pilot testing to determine feasibility, operability, and effectiveness at the Canal Station site. (The preamble to the Phase II rule contemplated that pilot studies would need to be done. See 69 Fed. Reg. 41,594 col. 1, 41,631 col. 1 (July 9, 2004).) Also, any modifications will entail non-NPDES-related permitting by federal, state, and local regulatory agencies. Accordingly, as Region 1 recognizes, immediate compliance will not be feasible at the time the final permit becomes effective. The suspended Phase II rule contemplated a reasonable schedule for implementation through a Comprehensive Demonstration Study, and Region 1 should likewise allow a compliance schedule for the Canal Station.

The Agencies propose, however, to address implementation exclusively through an enforcement order. Instead, the Agencies should incorporate a reasonable schedule and sequence for pilot studies (where necessary) and implementation of any modifications directly into the final permit, as they are fully authorized to do. 40 C.F.R. § 122.47; 314 C.M.R. § 3.11(10).

Mirant Canal recognizes that those regulations do not *require* the Agencies to include compliance schedules in NPDES permits, but in the circumstances of this case, it is sufficiently "appropriate" that we believe it would be arbitrary and capricious not to include an implementation program in the final permit. Otherwise, Mirant Canal would become subject to immediate citizen suit enforcement actions and unbearable pressures to accede to others' interpretations of the permit requirements.

Also, Mirant Canal's parent is a publicly held company with ongoing obligations to report material violations of environmental laws. In the circumstances here, where the Agencies know that immediate and even near-term compliance is impossible and where considerable uncertainty exists about the design and location details of closed-cycle cooling, the Agencies should set out a reasonable implementation program in the permit and thereby relieve Mirant Canal of requirements that are impossible for it to meet when the permit first becomes effective.

Region 1 asserts that a pilot testing process provided in the permit itself would, in essence, involve a compliance schedule by which the permit would essentially exempt the permittee from complying with substantive requirements of § 316(b) for part of that time. EPA Response to Kendall Comments at 4-111. But as we have argued elsewhere in these comments, Region 1 has the authority to allow for a compliance period, and a failure by Mirant Canal to comply with a compliance schedule incorporated in the permit would subject it to enforcement action.

3. The Environmental Impact of Canal Station Is *De Minimis*

The requirement of Clean Water Act § 316(b) is that the cooling water intake reflect best technology available for minimizing "adverse environmental impact." The data for the Canal Station show that the Station's present once-through cooling system is not causing "adverse environmental impact." Hence no further minimizing should be required.

The 2005 Fact Sheet reported that, while some fish species, like winter flounder, had regionally been in decline, "[t]here is no evidence to suggest that stocks in the Cape Cod Canal are in worse condition than the regional stocks." 2005 Fact Sheet at 32. As far as we are aware, nothing has occurred to change that assessment today. What has changed is that the Canal Station is having even less impact on fish than heretofore, because it is operating less.

In Exhibit 10, Normandeau Associates has evaluated whether the Canal Station intake has caused an adverse environmental impact. Normandeau used data collected at the Canal Station and the waters around it from March 1999 to February 2001, along with regional and coastal fisheries data from state and federal agencies.

Eighteen taxa are analyzed in Exhibit 10: river herring (alewife and blueback herring combined), Atlantic menhaden, Atlantic herring, fourbeard rockling, Atlantic cod, silver hake, hake (white, red, and spotted), silverside, searobin (northern and striped), grubby, cunner, tautog, sand lance, Atlantic mackerel, windowpane, American plaice, winter flounder, and American lobster. See Exhibit 10, Table 1.

The Normandeau analysis addresses three circulating water flow scenarios:

- Actual flow recorded during March 1999 - February 2001 when biological studies were conducted at the Station and in surrounding waters. At the time, circulating water flow averaged 75% of design flow.

- Recent actual flow recorded during 2006-2007, when flow was 65% of design flow.

- Maximum design flow for Unit 1 and 2 of 518 MGD.

In evaluating the adverse impacts of a cooling water intake structure, it is important to focus on populations and communities of the source waterbody and not simply the number of individuals entrained and impinged. Exhibit 10, section 1.0. It is especially inappropriate to focus on numbers of individuals where entrainment is concerned. Losses of eggs and early life stages, which have high natural mortality, should not be equated to losses of later larval stages and impinged organisms. See Exhibit 10. Many fish employ a reproductive strategy of producing large numbers of eggs, most of which do not reach adulthood. For example, 99% of winter flounder eggs die from natural causes within two months of spawning. *Id.* Despite the mortality of individual organisms as a result of recreational and commercial fishing or impingement and entrainment, populations and communities persist. Fisheries management agencies regularly employ catch quotas and size limitations to manage populations of fish, while allowing harvesting of individual fish to continue.

EPA defines adverse ecological effects as changes that alter valued structural or functional attributes of ecological entities. Exhibit 10, section 1.0. To be classified as adverse, impingement and entrainment must be sufficient to cause changes in the attributes of a population such as abundance, age and size structure, mortality, and productive potential such that its sustainability is threatened.

There are no regulatory guidelines for establishing what level of entrainment or impingement represents "adverse environmental impact." The Normandeau analysis (Exhibit 10) therefore relies on several approaches to determine if rates of entrainment and impingement appear large enough to alter the ability of populations to persist and provide their normal functions and values. Equivalent adults were calculated for each species, and when data were available, these were compared with estimates of stock size. For species targeted by commercial and recreational fisheries, equivalent harvest yield was calculated; for species that do not contribute to fisheries, equivalent yield was calculated in terms of striped bass. These two values allow foregone landings to be compared with traditional landings. Assuming adult equivalent values and equivalent yield are low relative to stock size or landings data, then it follows that an adverse impact has not occurred. One advantage of this approach is that it allows stakeholders and the public to compare the impacts of different technology alternatives.

In responding to comments on the Kendall Station, Region 1 said that EPA has determined that impingement and entrainment losses constitute adverse environmental impact that must be minimized under § 316(b). EPA Response to Kendall Comments at 2-3. The Region says that EPA expressly took this approach in both the Phase I and Phase II rules. *Id.*

It is true that EPA chose impingement mortality and entrainment as convenient metrics of adverse environmental impact. EPA used this approach for the rule because it allowed uniform nationwide performance standards and made administration of the rule convenient. Also, there was less need to determine the level of "adverse environmental impact" at the threshold, because the rule allowed for site-specific requirements as an alternative when the costs of meeting the national standards were significantly greater than the benefits. But EPA did *not* conclude that impingement and entrainment losses are the same as ("constitute") adverse environmental impact.

Now, in contrast, with no national standards and no rule for alternatives when costs are "significantly greater," an assessment of the level (or lack) of "adverse environmental impact" is appropriate and comports with EPA's still-effective 1977 draft guidance. In any event, it seems to be generally agreed that there can be some impingement mortality and entrainment at a site without necessarily triggering a requirement to modify the intake.

3.1 Field Collection and Laboratory Methods

The field collection methods and, for entrainment, laboratory methods used by Normandeau are described in the Normandeau report, Exhibit 10, sections 2.1.1 - 2.1.3, 2.2.1 - 2.2.2. Sampling of ichthyoplankton in Cape Cod Canal, Cape Cod Bay, and Buzzards Bay is described in section 2.3.

3.2 Entrainment

3.2.1 Equivalent Adults

Numbers of fish eggs and fish larvae entrained under each of three flow scenarios were converted to equivalent adult fish using stage-specific mortality rates obtained from EPA and assuming eggs and larvae did not survive passage through the circulating water system (Table 2 of the Normandeau report, Exhibit 10). Since the EPA life tables provide survival rates for each stage from beginning to end, an adjustment was made to each survival rate to account for the fact that entrained fish eggs and larvae are typically of mixed ages. Exhibit 10, section 2.1.4. It was assumed that the further along in development an entrained individual was, the greater the probability that the individual would survive to the next life stage. *Id.*

3.2.1.1. Entrainment Survival

Entrainment survival was accounted for in two ways. To represent the worst case, all fish eggs and larvae entrained were assumed to die, and equivalent adults and equivalent yield were calculated on that basis. Exhibit 10, section 2.1.4.1. In addition, because field studies show that some fish eggs and larvae do survive entrainment, empirical values were used to adjust the numbers entrained for the priority species before completing the equivalent adult and equivalent yield estimates (see sections 2.1.4.1 and 4.21 of Exhibit 10).

3.2.2 Equivalent Yield

Equivalent (harvest) yield provides a context for evaluating the data that appropriately considers causes of fish mortality in the vicinity of Mirant Canal other than entrainment and impingement. Equivalent (harvest) yield to the commercial and recreational fisheries was calculated for each taxa beginning with the estimated number of age-1 fish. Equivalent yield represents the added pounds of fish that could theoretically have been landed by fisheries if entrainment and impingement had not occurred. The calculation incorporates fishing mortality rates, vulnerability to the fishery, natural mortality rates, and average weight for each age from age 1 to the maximum expected age. Exhibit 10, section 2.1.5. It therefore represents the total pounds of fish that might be landed on a per-fish basis beginning at age 1 and extending over that fish's lifetime. For example, the harvest yield of an age-1 winter flounder was estimated to be 0.4179 pounds. Over the 16-year life span of 100 age-1 fish, four pounds would be expected to be landed by commercial and recreational fisheries.

Appendix A Table 1 to Exhibit 10 summarizes the stage-specific natural and fishing mortality rates and weight at age for each taxa. At the bottom of each table, the equivalent yield per age-1 fish is shown for harvested species.

For non-harvested species, a trophic transfer coefficient of 10% was assumed (see Exhibit 10, section 2.1.5) to estimate the amount of additional striped bass in pounds that would be produced and harvested had entrainment not occurred. A target fishing mortality rate of F = 0.3 and natural mortality rate of M = 0.15 were used to estimate pounds of striped bass resulting from the trophic transfer that would be expected to be harvested. *Id.*

3.3 Impingement

3.3.1 Equivalent Adults

Numbers of fish impinged in each taxa were adjusted as appropriate based on the observed rate of impingement survival at the Canal Station (see Table 4 of Exhibit 10). To calculate equivalent adults and equivalent yield for fish lost to impingement, it was necessary to determine the age of each collected fish. Length frequency distributions were calculated for each species in 10-mm intervals or bins. The percent of the total number of fish measured within taxa was then determined for each length bin. Length at age obtained from the scientific literature was used to assign age in years to each bin.

The total number of fish estimated to have been impinged each month for each species was then multiplied by the percent of the total represented by each bin to partition the monthly total into age classes**.** For example, the results of the length frequency distribution for butterfish showed that 86.7% of those measured were age-0 (juveniles) and 13.0% were age-1 fish. In December there was an estimated total of 90 butterfish impinged. By multiplying 90 by the respective percentages of age-0 and age-1 fish, it was determined that there were 78 age-0 and 12 age-1 butterfish impinged in December. Exhibit 10, section 2.2.3.

Since fish impinged later in any given year have a higher probability of surviving to their next birthday compared with fish impinged earlier in the year, mortality rate adjustments were made for each month that juvenile fish were impinged. This was done by dividing the EPA stage-specific instantaneous mortality rate by the respective stage duration in days to obtain a daily instantaneous rate. This daily instantaneous rate was multiplied by the number of days remaining until each fish's next birthday to derive the mortality rate expected to the end of that year. That mortality rate was converted to the corresponding survival rate ($S = e^{-M}$), then multiplied by the number of age-0 fish impinged during each respective month to estimate the number of equivalent age-1 fish. The numbers of age-1 fish expected to survive each month, had they not been impinged, were totaled to obtain an estimated annual total number of equivalent age-1 fish. All impinged fish older than age 1 were conservatively assumed to survive to their next birthday for purposes of calculating equivalent adults. Annual survival rates obtained from EPA were used to convert age-1 fish to older age classes for any species maturing at ages older than 1 (Table 5 of Exhibit 10). If specific life history information was available, age at maturity was defined as the age at which 50% of the fish begin to reproduce. If life history data were not available, only age-1 equivalents were calculated, as described above.

Information summarized below from the Normandeau report reflects one year of impingement sampling (March 1999-February 2000) and two years of entrainment sampling (1999-2001). When combined for entrainment and impingement, equivalent adult estimates were based on the average value for the two years of entrainment sampling plus the single year of impingement sampling.

3.3.2 Equivalent Yield

Equivalent yield to the commercial and recreational fisheries was calculated for each taxon beginning with the estimated number of age-1 fish. Equivalent yield represents the added pounds of fish that could theoretically have been landed by fisheries if entrainment and impingement had not occurred. Numbers of fish older than age 1 that were impinged were hindcast to age 1, using the life table survival rates. For example, if 100 age-2 fish were impinged and the age-1-to-age-2 survival rate was 0.331, then the equivalent of 302 age-1 fish were added to the age-1 equivalents.

Table 1 in Appendix A to the Normandeau report (Exhibit 10) summarizes the stage-specific natural and fishing mortality rates and weight at age for each taxon. At the bottom of each table, the equivalent yield per age-1 fish is shown for harvested species. For non-harvested species, a trophic transfer coefficient of 10% was assumed to estimate the amount of additional striped bass in pounds that would be produced and harvested by the weight of each taxon that died as a result of entrainment and impingement. A target fishing mortality rate of $F = 0.3$ and natural mortality rate of $M = 0.15$ were used to estimate pounds of striped bass resulting from the trophic transfer that would be expected to be harvested.

3.4 Cape Cod Canal Ichthyoplankton

As described in Exhibit 10, section 2.3, from late March 1999 through March 2000, ichthyoplankton sampling was completed at one location in the Cape Cod Canal opposite Mirant Canal, one location in Cape Cod Bay, and one location in Buzzards Bay. Exact locations included Station 6 (Cape Cod Canal) and Station 4 (Stony Point Dike in Buzzards Bay), both established by Collings *et al.* during earlier studies conducted for the

Canal Station. The Cape Cod Bay station was sited north of the entrance to the Cape Cod Canal in order to sample the counterclockwise current that enters the canal on the westward (ebb) tides.

These stations were sampled weekly during March through August and biweekly from September through February. Offsite sampling was coordinated with entrainment sampling, so discharge samples were collected at the same time that Station 6, opposite the Station, was sampled. Every other week from March through August, Station 6 was sampled in duplicate in the presence of Cape Cod Bay water and in duplicate in the presence of Buzzards Bay water. During opposite weeks, generally only Cape Cod Bay water was sampled, because that water mass was more common near the Canal Station. Efforts were made to capture Buzzards Bay water whenever possible. From September through February, sampling was coordinated every other week. Station 6 was sampled in the presence of Cape Cod Bay water and again in the presence of Buzzards Bay water.

At each location, samples were taken in duplicate using paired 60-cm diameter bongo nets fitted with 0.333-mm mesh and 0.505-mm mesh nets. The finer mesh ensured retention of small fish eggs and larvae, although larger mesh nets were used in earlier studies. The samples collected from the larger mesh net were archived. Each tow was oblique, with the net being raised and lowered from bottom to surface to collect fish eggs and larvae equally throughout the water column. See Exhibit 10, section 2.3.

To provide some context for the numbers of eggs and larvae entrained, samples of ichthyoplankton obtained from the Cape Cod Canal opposite the Canal Station were integrated over each species' occurrence period following the same procedures described for entrainment. Geometric mean densities were used over the two replicate samples collected on each sampling occasion. These are generally somewhat lower than the arithmetic means used for the entrainment estimates and, when compared with the arithmetic means used for the entrainment estimates, will tend to overestimate the effect of entrainment. Time-integrated values were multiplied by the volume of water passing through the Canal on two tidal cycles each day.

Following Collings *et al.* (see Exhibit 10, section 2.3), the calculated volume of the Canal is 32,284,800 m^3, a volume replaced twice each tidal cycle, suggesting a total exchange volume of 129,139,200 m^3 per day. Since the Canal Station is located near the eastern end of the Cape Cod Canal, 80% of the exchange volume (103,311,360 m^3) was attributed to Cape Cod Bay and the remaining 20% (25,827,840 m^3) to Buzzards Bay. Therefore, integrated Canal densities recorded when Buzzards Bay water was opposite the Station were multiplied by 25.8 x 10^4 hundred-cubic-meter units, and integrated densities recorded when Cape Cod Bay water was opposite the Station were multiplied by 103.3 x 10^4 100-m^3 units (Table 6 of Exhibit 10). Numbers of eggs and larvae entrained were compared with the number of eggs and larvae passing through the Canal Station.

3.5 Priority Taxa

The Normandeau assessment focused on 18 taxa of fish and one invertebrate, the American lobster. These 19 taxa were selected based on susceptibility to entrainment and/or impingement as well as ecological importance and/or commercial or recreational value to fisheries (Table 1 of Exhibit 10). Life history summaries and parameters for these species are provided in Appendix A to Exhibit 10.

3.6 Results Without Regard for Entrainment Survival

The results of the impingement and entrainment sampling are provided in the Normandeau report (Exhibit 10). Normandeau's conclusions are in section 5.0 of Exhibit 10. Based on the assessment presented in Exhibit 10, entrainment and impingement resulting from the circulating water system at the Canal Station has not been sufficient to cause changes in the attributes of any population such that its sustainability is threatened. Therefore, an adverse environmental impact has not occurred.

The basis for this conclusion is detailed in Exhibit 10, section 4. In summary, the data from entrainment and impingement sampling at the Canal Station, without accounting for entrainment survival, show the following:

River herring – River herring have demersal and somewhat adhesive eggs that are entrained in relatively low numbers by the Canal Station. Equivalent adults lost to entrainment amounted to three age-3 fish (one pound) on the 1999-2001 flow. Had entrainment and impingement of river herring not occurred, 19 additional pounds of striped bass might have been landed by recreational and commercial fisheries. The estimated entrainment and impingement losses at the Canal Station represent 0.1% or less of the commercial landings from six states reported in 1999-2001.

Atlantic menhaden – The numbers of Atlantic menhaden eggs and larvae entrained under actual plant flow represented 0.53% for eggs and 0.29% for larvae, based on the number of eggs and larvae passing the Canal Station in the Cape Cod Canal in 1999-2000. Had menhaden not been entrained and impinged, about 2000 additional pounds of fish might have been landed by the commercial and recreational fisheries combined over the eight-year lifetime of those fish.

Atlantic herring – Atlantic herring eggs are not subject to entrainment, though larvae may be. The number of larvae entrained in 1999-2000 and 2000-01 amounted to 0.05% of the larvae estimated to pass the Canal Station through the Cape Cod Canal. The combined equivalent adults lost to entrainment and impingement based on circulating water flow from 1999 to 2001 amounted to 1,358 age-3 fish weighing 410 pounds.

Fourbeard rockling – An extrapolated total of only 22 individual rockling were estimated to have been impinged in 1999-2000. The combined loss of equivalent adults from entrainment and impingement based on circulating water flow from 1999-2001 amounted to 333 age-1 fish (five pounds).

Atlantic cod – Atlantic cod were impinged in small numbers at the Canal Station in 1999-2000, with an extrapolated total of 671 fish estimated for the year. The numbers of eggs and larvae entrained under actual flow at the time of sampling represented only 0.44% and 0.46% of the number of cod eggs and larvae drifting past the Canal Station during 1999-2000.

Silver hake – A total of 332 silver hake were estimated to have been impinged on the Canal Station intake screens during 1999-2000. Losses of equivalent adults calculated for both impingement and entrainment totaled 307 age-2 fish based on 1999-2001 flow. Based on a weight of 0.242 pounds per fish, these fish would weigh 74 pounds. The potential loss of 74 pounds of equivalent adults or the harvest yield of 60 pounds is insignificant relative to reported fishery landings.

Hake – Small numbers of hake were impinged at the Canal Station in 1999-2000, an extrapolated total of 145 fish. The weight of equivalent adult fish estimated to have been lost to entrainment and impingement under actual flow amounted to 0.005% of the average of 3 million pounds of red and white hake that were landed in Massachusetts from 1999 through 2001. The harvest foregone amounted to only 226 pounds over the lifetime of the equivalent adult fish.

Silverside – Silverside eggs are rarely entrained. Equivalent yield for silversides lost to entrainment and impingement ranged from 18 to 46 pounds of striped bass, depending on the plant flow regime.

Searobin – The searobin eggs and larvae entrained under actual plant flow amounted to 1.86% and 0.61% of larvae estimated to pass the Canal Station in 1999-2000. The equivalent adults lost to entrainment and impingement combined amounted to 990 age-1 fish (60 pounds). The loss of 966 equivalent adult fish amounted to 0.57% of the average of landings by Massachusetts recreational fishermen.

Grubby – The average number of grubby larvae entrained under actual plant flow was 0.4% of the number estimated to have drifted past the Canal Station during the 1999-2000 season. In terms of forage for striped bass, had impingement and entrainment losses not occurred, six pounds of additional striped bass might have been harvested by the commercial and recreational fisheries over the life span of the grubby.

Cunner – The number of cunner eggs and larvae passing the Canal Station in 1999-2000 and not returning on subsequent tides was estimated to be 48.461 billion and 15.074 billion, respectively. The average number entrained based on 1999-2000 plant flows represented 4.04% and 0.37% of those totals. Had they not been entrained or impinged, 3,698 pounds of cunner might have been harvested by the commercial and recreational fisheries over the six-year lifespan of those fish.

Tautog – The number of tautog eggs and larvae passing the Canal Station in 1999-2000 and not returning on subsequent tides was estimated to be 2.623 billion and 815.911 million, respectively. The average number entrained based on 1999-2000 plant flows represented 4.04% and 0.62% of those totals. The weight of equivalent adults

(56 pounds) or of the foregone harvest (96 pounds) represents a very small percentage of the 1999-2001 Massachusetts commercial and recreational landings.

Sand lance – In 1999-2000 an estimated total of 27 sand lance were impinged at the Canal Station. Sand lance eggs are demersal and only rarely subject to entrainment. For example, none were collected in 1999-2000 and only three in 2000-2001.

The number of sand lance larvae passing the Canal Station in the Cape Cod Canal in 1999-2000 and not returning on subsequent tides was estimated to be 17.071 billion. The average number entrained under actual flow amounted to 0.19% of that total. Assuming sand lance entrainment and impingement had not occurred, an additional 27 pounds of striped bass might have been harvested by the recreational and commercial fisheries.

Atlantic mackerel – Atlantic mackerel are powerful swimmers and are therefore rarely impinged at coastal power facilities. None was collected during the 1999-2000 studies.

The number of mackerel eggs and larvae passing the Canal Station in 1999 and not returning on subsequent tides was estimated to be 78.857 billion and 87.958 million, respectively. The average number entrained based on 1999-2000 plant flows represented 0.24% and 10.8% of those totals. Comparing the number of larvae entrained in 1999-2000 with the number passing through the Cape Cod Canal during the same year resulted in a percentage of only 0.7.

Windowpane – Numbers of windowpane eggs entrained under the three flow scenarios amounted to between 0.47% and 0.70% of the number of windowpane eggs drifting passed the Canal Station. Numbers of windowpane larvae entrained under the three flow scenarios amounted to between 0.15% and 0.25% of the number of windowpane larvae drifting passed the Canal Station. The potential loss of less than 175 pounds of equivalent adults and less than 30 pounds of harvest is very small relative to the fishery landings.

American plaice – American plaice prefer oceanic habitats and are therefore rarely impinged at coastal power facilities. None was collected during the 1999-2000 Mirant Canal studies.

The number of American plaice eggs and larvae passing the Canal Station in 1999 and not returning on subsequent tides was estimated to be 110.379 million and 209.3878 million, respectively. The average number of eggs and larvae entrained under the 1999-2000 flow regime represented 1.30% and 0.57% of those totals, respectively.

Over their lifetime the fish potentially lost to entrainment and impingement would have been expected to contribute 21 pounds to the fishery.

Winter flounder – Numbers of winter flounder larvae entrained based on recorded 1999-2001 flow amounted to 0.7% of the larval flounder drifting past the Canal Station during the 1999-2000 season. The average weight of equivalent adults under actual flow amounted to 0.06% of the commercial and recreational landings for 1999-2001. Over the 16-year lifespan of the equivalent adults 20,161 additional pounds of winter flounder might be landed by commercial and recreational fishermen considering actual plant flow. The NOAA Northeast Fisheries Science Center (NEFSC) spring abundance index (Exhibit 10, Figure 4, top) and the MDMF spring resource assessment time series for the northern flounder stock (Figure 4, bottom) extending from the New Hampshire border to Cape Cod did not reveal a consistent downward trend that would suggest entrainment and impingement at the Canal Station have had an adverse environmental impact on winter flounder.

American lobster – Lobster are occasionally impinged at the Canal Station, an estimated total of 845 having been impinged in 1999-2000. Lobster eggs are extruded and firmly attached to the female's pleopods until they hatch, so they are not subject to entrainment. During four pelagic larval stages, lobster larvae are susceptible to entrainment. An estimated total of 512,630 and 5,430 lobster larvae were entrained in 1999-2000 and 2000-2001, respectively, providing an annual average of 259,030. Equivalent adults for entrainment amounted to six 82-mm lobsters under actual 1999-2001 plant flow.

The weight of equivalent 82-mm lobsters estimated to have been lost to entrainment and impingement amounted to 664 pounds under actual recorded flow. Foregone harvest totaled 677 pounds. The potential loss of 664 or 677 pounds represents 0.004% of the 1999-2000 Massachusetts landings.

In short, entrainment and impingement by the Canal Station in 1999 and 2000 had only a *de minimis* environmental impact.

3.7 Results Taking into Account Entrainment Survival

The data summarized above assume that all entrained organisms are killed, which is unrealistic. Field studies have shown that some fish eggs and larvae survive entrainment (Exhibit 10, section 4.2.1). Survival can be important if EPA wants to have an accurate assessment of environmental impact, especially when comparing once-through cooling with closed-cycle. Closed-cycle cooling reduces the amount of water withdrawn by 70% or more. But in that smaller volume of water there is no entrainment survival at all. All the organisms are killed.

Survival rates of entrained organisms are influenced by three main factors: thermal stress, mechanical damage, and chemical stress (use of biocides). *Id.* Each species has a different tolerance level to these factors; therefore entrainment survival rates for individual species vary, with some species having higher survival than others. For example, river herring are considered a fragile species and have been documented as being very sensitive to entrainment with a 0% survival rate, whereas cunner larvae are considered a hardier species and have been documented with a 49% survival rate. *Id.*

The survival values used to adjust the numbers entrained for the key species are shown in Table 8 of Exhibit 10. Adjusted entrainment numbers and estimated equivalent adults for the three flow scenarios are shown in Table 9.

Taking into account the expected survival of entrained organisms, Normandeau makes the following adjustments to the impacts of entrainment:

River herring – No difference.

Atlantic menhaden – Under actual flow the number of eggs lost to entrainment declined from 2,761,158 to 1,104,463 and larvae losses declined from 740,561 to 545,793. The equivalent adult losses declined from 8 to 5 age-3 fish. Compared to the number of Atlantic menhaden eggs and larvae passing the Canal Station, the survival-adjusted numbers amounted to 0.2% and 0.2%, respectively.

Atlantic herring – No difference.

Fourbeard rockling – Under actual flow the number of entrained eggs declined from 33,784,338 to 20,676,015 and equivalent adult losses declined from 311 to 252 age-1 fish. Compared to the number of rockling eggs passing the Canal Station, the survival-adjusted number amounted to 0.4%.

Atlantic cod – No difference.

Silver hake – The number of silver hake eggs lost to entrainment under actual flow declined from 3,476,071 to 2,864,283. Compared to the number of eggs passing the Canal Station, the survival-adjusted number amounted to 0.17%. The equivalent adult losses declined from 130 to 128 age-2 fish.

Hake – Under actual flow the number of eggs lost to entrainment declined from 60,271,070 to 36,885,895, and equivalent adult losses declined from 460 to 355 age-1 fish. The number of survival-adjusted eggs amounted to 0.2% of the hake eggs estimated to pass the Canal Station.

Silverside – The number of larvae lost to entrainment under actual flow declined from 688,514 to 349,077. Compared to the number of silverside larvae passing the Canal Station, the 1999-2000 survival-adjusted number amounted to 0.5%. The equivalent adult losses declined from 297 to 150 age-1 fish.

Searobin – Under actual flow, searobin eggs lost to entrainment declined from 5,019,471 to 3,859,973, and equivalent adult losses declined from 949 to 755 age-1 fish. The number of survival-adjusted eggs amounted to 1.4% of the searobin eggs estimated to pass the Canal Station.

Grubby – The number of larvae lost to entrainment under actual flow declined from 1,794,342 to 1,166,322, and equivalent adult losses declined from 1,456 to 946 age-2 fish. Compared to the number of grubby larvae passing the Canal Station, the survival-adjusted number amounted to 0.3%.

Cunner – Under actual flow, the number of eggs lost to entrainment declined from 1.96 billion to 1.33 billion, and larvae losses declined from 56.3 million to 28.5 million. The equivalent adult losses declined from 677,487 to 406,908 age-1 fish. Compared to the number of cunner eggs and larvae passing the Canal Station, the survival-adjusted numbers amounted to 2.8% and 0.2%, respectively.

Tautog – Under actual flow the number of tautog eggs lost to entrainment declined from 105,969,058 to 72,381,865, and equivalent adult losses declined from 11 to 8 age-6 fish. The number of survival-adjusted eggs amounted to 2.8% of the tautog eggs estimated to pass the Canal Station.

Sand lance – The number of sand lance eggs under actual flow lost to entrainment declined from 45,610 to 20,890, and larvae losses declined from 33,802,222 to 30,895,231. The equivalent adult losses declined from 27,431 to 25,069 age-2 fish. Compared to the number of sand lance larvae passing the Canal Station, the survival-adjusted number amounted to 0.18%.

Atlantic mackerel – Under actual flow, the number of eggs lost to entrainment declined from 186.1 million to 117.4 million, and equivalent adult losses declined from 399 to 307 age-3 fish. Compared to the number of Atlantic mackerel eggs passing the Canal Station, the survival-adjusted numbers amounted to 0.15%.

Windowpane – The number of eggs lost to entrainment under actual flow declined from 45.0 million to 37.5 million, and the equivalent adult losses declined from 422 to 382 age-3 fish. Compared to the number of windowpane eggs passing the Canal Station, the survival-adjusted numbers amounted to 0.46%.

American plaice – No difference.

Winter flounder – Under actual flow, winter flounder larvae lost to entrainment declined from 6,530,552 to 4,591,122, and equivalent adult losses declined from 5,799 to 2,950 age-3 fish. Compared to the number of winter flounder larvae passing the Canal Station, the survival-adjusted number amounted to 0.5%.

American lobster – Under actual flow the number of larvae lost to entrainment declined from 259,030 to 129,515, and equivalent adult losses declined from 6 to 3 adult (82-mm) lobsters. Compared to the number of lobster larvae passing the Canal Station, the survival-adjusted number amounted to 0.04%.

4. "Best Technology Available" for Entrainment at Canal Station Is Not Cooling Towers

4.1 The Final Permit for the Canal Station Should, Like the Draft Permit, Require a Study and an Analysis of What Intake Technology Is Best

The draft permit of 2005 proposed a study to assess the environmental impact of the Canal Station and to evaluate alternatives for reducing it. The Region felt that more information was needed.

That is still true today, even if the Region believes that the minimal impact on fish and lobster, described above, still needs to be reduced. The analysis by Shaw of the engineering issues created by closed-cycle cooling (Exhibit 8) reveals many unanswered questions about the impacts of closed-cycle cooling and about whether it is economically feasible.

Likewise the analyses by Alden of fine-mesh traveling screens show that further analysis is needed. Thus, the originally proposed solution of a study to select "best technology available" is still what is needed today.

4.2 The Permit Requirement Is Stated in a Way that Creates Unresolved Issues

The Renoticed Permit requires Canal Station to reduce "current levels of entrainment to an extent comparable to what would be achieved by the use of closed-cycle cooling for all electrical generating units, with the closed-cycle cooling system optimized to maximize cooling water intake flow reductions to the extent practicable in light of site-specific constraints…." Renoticed Permit Part I.A.13.g. The 2005 Fact Sheet and Response to Comments state that closed-cycle cooling can reduce entrainment from 70-98%. Response to Comments IX-13.

In several respects this permit standard creates uncertainty. A better solution would be for Mirant Canal to perform an assessment of technologies (as the 2005 Draft Permit proposed) to select which is best.

For "new" facilities (not the Canal Station), EPA regulations set BTA as reducing intake flow to a level commensurate with that of closed-cycle cooling. 40 C.F.R. § 125.84(b)(1). Determining what "flow" closed-cycle cooling requires is a straightforward engineering question, which requires only designing a closed-cycle system and calculating the intake flow. As the Shaw analysis (Exhibit 8) shows, designing a closed-cycle system is a complicated question that implicates condensers, turbines, piping, and other parts of the plant. But it is something engineers do routinely. By contrast the renoticed Canal Station requirement is to reduce "current levels of entrainment, which requires designing a closed-cycle cooling system *and* predicting how many organisms would be entrained. The proposed permit requirement is set in terms of "entrainment," rather than entrainment "mortality." EPA also chose entrainment as a metric in the Phase II rule. But now that § 316(b) requirements are being set on a "BPJ" basis, there is no reason not to consider organisms that survive entrainment as reducing the environmental impact.

Also, the permit would require entrainment to be reduced from "current levels," whereas the Phase II rule required reductions from a "calculation baseline." All the considerations that led EPA to define a calculation baseline have been ignored in drafting the Canal Station requirement.

These issues could be avoided, or at least analyzed systematically, if the permit provided for a study of alternative technologies rather than prescribing an uncertain standard. If necessary, entrainment survival studies could be conducted to shed light on the survival of entrained eggs and larvae.

4.3 Cooling Towers Are Not an "Available" Technology for the Canal Station

Region 1 agrees that "[c]ost is relevant for the purpose of determining the 'availability' or feasibility of various technologies." EPA Response to Kendall Comments at 2-10. In most cases, the Region says, a technology so costly that it is unaffordable by an ongoing business will not be considered "available" in a site-specific BPJ application of CWA § 316(b). *Id.* at 2-43.

Likewise Region 1 agrees that EPA may not require any technology that is not technically feasible for use at a site. A technology may not be "available" for a variety of reasons. *Id.* at 2-16. Whether the technology has been used successfully at facilities with the same or similar characteristics is one important factor for EPA to consider, though it is not an absolute requirement. *Id.*

Again, the issue of whether closed-cycle cooling has been retrofitted at plants similar to the Canal Station is an issue that deserves to be studied further.

4.3.1 Summary of Engineering Issues Retrofitting Cooling Towers at Canal Station

As discussed in Exhibit E to Mirant Canal's Reply to the Appeals Board of October 30, 2008, and in Exhibit 13 to these comments, in Alden's 2003 evaluation of the feasibility of several options for addressing impingement and entrainment at the Canal Station, the practicality and impact of backfitting Units 1 and 2 with cooling towers was evaluated only at a conceptual level. Alden used generalized assumptions about the Canal Station and a model developed by EPRI based on flow and retrofit estimates for facilities other than the Canal Station. See Exhibit 13.

Now that Region 1 has reopened the permit for comment, Mirant Canal asked Shaw to consider the Canal Station in greater detail in order to determine whether installing cooling towers would be feasible from an engineering standpoint, and, if so, to describe the extent of changes necessary to install them.

The description in Exhibit 8 and summarized below describes how a cooling tower would generally be backfit to an existing once-through cooled steam electric generating station. It explains a specific constraint at Canal Station related to the design of the original condensers. Then a workaround method that allows the reuse of the existing condensers is described, with an explanation of some specific reliability issues associated with this workaround.

4.3.1.1. Conceptual Feasibility and Typical Arrangements at New Plants

From a very conceptual level, as with most power plants, it would be possible as an engineering matter to run the Canal Station by recirculating the discharge flows into a cooling tower fill and then routing the return condenser feed line back to the condenser. In a typical cooling tower arrangement for a new power plant, one set of pumps located just upstream of the condenser and downstream of the cooling tower provides the necessary flow and head for the cooling water to pass through the condenser and up to the cooling tower fill. The hot condenser discharge flow then passes through the cooling tower fill countercurrent with the upflowing air flow so that the waste heat exits the top of the cooling tower and the condenser water falls to the cooling tower basin, where the recirculation of the flow begins again.

4.3.1.2. Infeasibility of Typical Backfitting at the Canal Station

However, this typical arrangement for backfitting a cooling tower to an existing facility is not feasible at Canal Station because the condensers are not designed to sustain the hydraulic head that the cooling water would place on the condenser tubes and condenser water boxes. These condensers and the associated large-diameter piping are designed for hydraulic pressures of approximately 20 psig. To pump the water through the condenser and up to the cooling tower fill, the pumps would require 70 to 90 psig pressure on the water side of the condenser, large-diameter connecting pipes, water boxes and heat exchange tubing. At these pressures the condenser and piping and water boxes would distort and burst, and the steam condenser would fail.

4.3.1.3. Alternative Arrangements at Canal Station Without Rebuilding Condensers: Issues and Drawbacks

There are a few alternatives to make the conventional cooling tower arrangement work at the Canal Station with the design of the existing condensers. In one potential arrangement, the elevation of the cooling tower fill would need to be at or near the existing level of the sea. That means the cooling tower basin would need to be depressed some 30 feet below the sea level to get the fill at that appropriate level. That in turn would require large-volume dewatering pumps (and a new discharge structure) to depress the groundwater levels around the basin to avoid uplift pressures on the cooling tower basin and prevent groundwater flooding of the cooling tower cavity in the land. This arrangement would also require the countercurrent air flow to pass into and around this cavity in the ground to enter the cooling tower shell. This depressed arrangement of the cooling tower would provide interference with the air flow, unless a much larger area around the basin of the tower were excavated and additional groundwater dewatering pumps were employed to dewater this larger area. These large groundwater pumps would likely have an adverse effect on local groundwater levels and intrusion of saltwater into the local aquifer, so this alternative is not considered a reasonable approach.

As an alternative, Shaw has evaluated a non-conventional arrangement of the cooling system that would allow reuse of the existing condenser, but the arrangement is not without serious drawbacks. A variation of this approach is in use now at Vermont Yankee Generating Station. This alternative arrangement requires two pump sets in separate locations (upstream and downstream of the condenser) working in series. The first pump is located between the cooling tower basin and the condenser and provides only sufficient head to pass the full condenser flows to the existing discharge canal. The design Shaw proposes would use the existing circulating water pumps for this function. The second, new set of pumps would pump, with much greater head than the first pump set, the heated condenser discharge flows from the discharge canal up to the cooling tower fill. The cooling tower discharge would flow by gravity to the existing cooling water intake structures.

This push-pull arrangement protects the condenser from hydraulic pressures that exceed the design capacity but can also create some difficult balancing issues with the pump flows and the elevations of the two water storage reservoirs in the system – the cooling tower basin and the enclosed discharge canal. This could be resolved by undersizing the volume of the new cooling tower pumps. This arrangement would require that the existing circulating water pumps draw the entire volume of cooled water from the cooling towers plus the excess volume from the Cape Cod Canal. This excess flow would be discharged to the Canal via the existing diffuser. A system of valves or gates in the intake canal dams and a weir in the discharge canal would be required to accomplish this. Although this is not an efficient way to pump the large volumes of flow required for cooling, some levels of operating efficiency would need to be sacrificed to retain the service of the existing condenser.

While this workaround should be effective, despite the inefficiency, the Canal Station cooling system will be less reliable, and the dispatch reliability of the operating units will be reduced. This is because the cooling system depends on two sets of pumps to operate the cooling system instead of just the original pumps. If the new set of pumps fails, then the steam electric generation unit will trip out as soon as the cooling water in the closed-off intake well runs below the minimum operating level of the pumps. The system can also fail if the original set of cooling water pumps fail, and this would happen with the same probability as with the previous operation. Upset conditions associated with the additional pumps will lead to additional unscheduled unit trip-outs of the steam generating unit. These trip-outs could also trip the high-pressure steam release to the atmosphere (a very loud and intrusive condition), which is used to cool the boiler and steam when the cooling system fails.

Although Shaw believes that the push-pull pump arrangement with the use of new cooling towers should be mostly reliable, the reliability of the cooling system would be considerably less (about half) than the current once-through cooling arrangement. If this unusual pumping arrangement proves in actual use to be less reliable than anticipated, then the ISO New England might be forced to limit the dispatch of Canal station even during times when it may be essential to the local electric transmission stability and reliability.

4.3.1.4. Arrangements That Include Rebuilding Condensers: Issues and Drawbacks

Replacing steam condenser shells and water boxes is very expensive in terms of capital and outage time, and, if done only to accommodate the operation of new cooling towers, the change will generate no additional plant revenue or operating margin unless other design changes are also made on the steam side equipment at the Station.

In addition to condenser replacement, most if not all existing circulating water pipes and pipeline equipment (including valves, expansion joints and other equipment) would have to be either reinforced in place or replaced to accommodate the higher pressures.

The condensers of a conventional steam electric generating plant are sized and located with respect to the elevation of the cooling water and with close proximity to the steam turbine. The condensers are typically placed immediately below the steam turbine and proximate to the foundations of the steam turbine. The condensers are the heart of the design of the power plant, as everything else is built around the design capacity and elevation and location of the condensers.

As such, condensers are extremely difficult to replace in total. The condenser tubes are relatively easily replaced, but the shells and water boxes would require a very time-consuming and delicate extraction and reinstallation process that could prevent operation of the generating units for many months. To replace the existing condenser with another capable of withstanding the higher hydraulic pressures, different types of heat exchanger metals or thicker metal piping and plate are generally required. In order for this new condenser with thicker-walled pipe and plate to provide the same rated heat exchange as the existing condenser, the new condensers would likely be larger in dimension – just to achieve the same thermal heat exchange function.

A larger-sized condenser may be difficult or impossible to place in the same location below the existing steam turbine. A larger-dimension condenser would also require that the large-diameter steam ducts from the steam turbine be expanded to spread the steam over a longer or wider condenser. This may not be possible, because the space between the turbine and condenser is very restricted. Mirant Canal would require a detailed evaluation of the feasibility of replacing the condenser, as a design or dimension change can adversely affect the function of the steam turbine and ducting.

If one were to replace the condenser to accommodate a cooling tower, that redesign would also likely greatly influence the water flow path and basic design. Once-through cooling plants typically have three (or more) parallel condenser flow paths, whereas a steam condenser for a cooling tower project typically has a series arrangement of the shells and the water flow path. This series arrangement will generally reduce the size and capital cost of the cooling tower, since the series condenser will generally deliver a higher temperature and smaller flow than a once-through condenser for the same steam condensing capacity. As a part of the evaluation of the cooling tower cost alternatives, Shaw has considered two arrangements of the flow through the existing condensers that can be used to reduce the size and cost of the cooling towers. The two arrangements considered only changes in the rate of flow through the condensers, not a conversion of the flow path. However, for neither arrangement did Shaw consider a complete redesign of the condensers, because the resulting costs would be extremely high, and such a design may not be possible with the continued use and location of the existing steam turbine and large-diameter steam ducts.

4.3.1.5. Costs of a Cooling Tower Backfit Cannot Be Recovered Unless Other Plant Changes Are Incorporated

A redesign of the condenser would require a detailed engineering and economic evaluation of the cooling and steam systems. With a planned condenser replacement, one would generally reconsider the optimization of the steam and cooling systems to extract additional energy from the existing equipment. However, in the case of adding a cooling tower and potentially replacing a condenser, the new system will only achieve less generation and will do so with less thermal efficiency than the existing operation. Therefore no opportunity will exist to recover the additional capital costs ($182.3 to 224.5 million) of the cooling tower through additional new generation.

But if one is going to the expense of adding a cooling tower and also modifying the condenser to accommodate the higher water pressures for a conventional cooling tower single pump set flow arrangement, then one would also want to look at the blading and efficiency of the steam turbine connected to the replaced condenser. The redesigned condenser may allow for an economically advantageous replacement of the turbine or reblading of the steam turbine to recover some of the costs of the redesigned cooling system. Although this adds additional capital costs, it may allow recovery of some of the costs associated with the condenser replacement.

But if the steam turbine is resized, replaced, or rebladed to accommodate the condenser, then it would be foolish to ignore the steam supply from the boiler. If that older boiler is generating steam by the simple cycle conversion of fossil fuel to electric energy, then it would be wise to consider replacing the fuel and steam supply side with the cooling tower condenser and steam turbine. Replacing an older fossil fuel-fired boiler with gas- or distillate-fired combustion turbines and an HRSG or with a supercritical unit may greatly increase the energy conversion efficiency of the overall power plant. And the conversion may also help to recover the capital costs of the cooling tower, new condenser, and new or rebladed steam turbine.

Shaw's discussion, above and in Exhibit 8, of why *not* to replace the condenser is important for this reason: If a cooling tower could easily be incorporated into the design of an existing steam electric generator without the need to replace or work around a deficiency in the condenser design, then that site would be reasonably suited to accommodate the change with existing plant equipment. But when the replacement of once-through cooling with a cooling tower requires work-arounds for operation of existing equipment, as is the case at the Canal Station, or when the backfit affects the reliability of operation, it generally requires complete rethinking of the optimal operation and strategic competitive placement of the plant in the competitive ISO New England dispatch process and the resulting potential recovery of capital expenses.

4.3.1.6. Conclusion on Practicability of Backfitting Cooling Towers

Unless the Canal Station is completely redesigned with major changes to the boiler and steam side of the plant, then the capital costs of the cooling tower backfit will only add to the overall dispatch cost of operating the Station. If cooling towers are constructed, then Mirant Canal would need to either contract long-term power sales at higher rates or bid into the ISO New England auction at higher rates to recover the capital costs of the new cooling towers. Existing and expected market conditions will not sustain either approach. The higher dispatch cost resulting from a backfit of cooling towers would then likely further limit the capacity utilization of the Station compared to other generating facilities with which the Canal Station competes. Given the low current level of plant utilization, it is likely the capital costs of a cooling tower backfit would eliminate the Canal Station from the competitive electric generation market.

4.3.1.7. Capital and Operating Costs of Cooling Towers

The existing conditions (existing equipment designs and plant arrangements) were examined to determine the impacts that new cooling towers would have on the Canal Station. As discussed in Exhibit 1 to these comments, factored engineer’s estimates were developed to estimate the capitals costs for installing the closed-cycle circulating water system at the Canal Station. Four conditions were examined in an attempt to bracket the potential costs associated with installing cooling towers at the Canal Station. The four conditions consist of either natural draft hyperbolic towers or plume-abated mechanical draft towers for circulating water rates that match the current flow rates, or the minimum circulating water flow rates that could be used with the existing steam turbines in an attempt to minimize the size of the cooling towers.

The factored estimates were all based on the following major assumptions:

- The cooling towers would be located to the east of Unit 2 on Station property (currently used for laydown) with the required demolition of existing rail spurs as well as other structures. This arrangement would allow for missing the existing rail spur servicing the ammonia storage tanks and the ammonia storage tanks themselves, which are located near the location for the cooling towers. Alternative arrangements would likely require additional demolition costs.

- Pile foundations would be required for the hyperbolic cooling towers due to the existing site conditions.
- The new circulating water system would be based on reusing the existing equipment to the maximum extent practical (costs would increase if it was not possible to reuse the equipment):
  - reusing the existing condensers (for the minimum circulating water flow rate case this may not be easily achievable due to flow paths within the existing condenser),
  - matching the requirements of the existing condensers in the design of the cooling towers and new circulating water system components,
  - reusing the existing discharge flume and adding new circulating water pumps to supply heated water from the existing discharge flume to the new cooling towers,
  - reusing the existing discharge for blowdown,
  - reusing the existing circulating water pumps by constructing a water conveyance from the new cooling towers to the existing circulating water pumps, and
  - reusing the existing Unit 2 intake structure with the addition of new makeup water pumps after the intake structure is isolated from the existing circulating water pumps.
- Noise barrier walls located on the property lines to the west, north, and east of the new cooling towers would be required. See Exhibit 6.
- Chemical feed systems would be required.
- For the mechanical cooling tower option, a plume-abated arrangement tower would be required to minimize potential fogging of the Cape Cod Canal.
- Equipment laydown and construction parking will be problematic and will likely impact worker productivity due to the limited space at the Station (if alternative space at or near the plant could be found, this cost would be less).

Shaw, which prepared the analysis in Exhibit 1, notes that the validity of these assumptions will have to be determined through detailed study of the plant operation, equipment adequacy and condition, etc. Using those assumptions, the costs are as follows:

Total Installed Cost Units 1 and 2

Cooling Tower Type	Matched Circulating Water Flow	Minimum Circulating Water Flow
Natural Draft Hyperbolic Cooling Towers	$224.5 M	$183.3 M
Plume Abated Mechanical Draft Cooling Towers	$217.7 M	$182.8 M

Operating and maintenance costs consist primarily of the lost capacity of the plant, additional electrical load required to operate the new closed-cycle circulating water system, additional chemical costs to treat the circulating water, and maintenance costs for the new equipment. Those O&M costs are as follows:

Total Annual Operating and Maintenance Costs Units 1 and 2

	Matched Circulating Water Flow		**Minimum Circulating Water Flow**	
	Natural Draft	Mechanical draft	Natural Draft	Mechanical draft
Operating Cost – Additional Load[1]	$1.7 M	3.1 M	$1.1 M	$2.0 M
Operating cost - Lost Power[2]	$1.0 M	$1.0 M	$2.7 M	$2.7 M
Maintenance cost[3]	$0.3 M	$0.5 M	$0.3 M	$0.5 M
Total O&M cost	$3.0 M	$4.6 M	$4.1 M	$5.2 M

4.4 Other Issues

In addition to threatening the economic competitiveness of the Canal Station, a backfit of cooling towers causes other potential adverse effects on the natural and human environment that should cause concern and prompt additional study before such a change is made. Some of the environmental impacts associated with the backfit of cooling towers that should be considered more carefully include:

- Visual impacts of the cooling tower structure
- Noise during construction and operation
- Heat rate penalties – which are in addition to the capital cost competitiveness issues described above
- Loss of plant generating capacity – associated with additional electrical use of plant operation
- Cooling tower plume effects
- Potential fogging and icing effects on local area, roads, and bridges
- Salt drift from the cooling tower on native vegetation and local infrastructure
- Suitability of soils to support the cooling tower structures
- Traffic impacts during construction

[1] Operating costs associated with the additional load are based on the 2007 plant operation statistics using the average anticipated 2009 cost of power.

[2] Operating costs associated with the heat rate penalty are based on the hours the Units operated at or near 100% capacity in 2007.

[3] Maintenance costs include yearly pump maintenance and periodic pump overhauls, yearly fan maintenance for the mechanical draft cooling towers, and yearly cooling tower water basin cleaning and fill maintenance.

Each of these human and natural environment potential impacts also requires more detailed study to identify the level of impact, cumulative effects of these impacts, need for mitigation for these impacts, and costs of impact mitigation.

The impacts on capital and operating costs, the competitiveness of the Canal Station with the reconfigured operation with cooling towers, and the many potential natural and human environment impacts must be considered collectively and with respect to the existing entrainment and impingement mortality impacts of the current operation. Without such a set of comprehensive reviews and consideration of all the potential plant economic and environmental effects, decision making on the suitability of addition of a cooling tower is not reasonable.

4.5 Visual Impacts

Available space at the Canal Station site for new cooling towers is limited to plant property located east of Unit 2. This area, approximately 11 acres, is currently used for ammonia storage for the Station's selective catalytic reduction nitrogen removal systems and general lay down area and provides rail access to the plant. The existing circulating water discharge flume is located in the west portion of this part of the Station. Of the three rail tracks located within this area, the most southern one is constantly used for supplies of ammonia, while the other two are not currently used. Considerations in siting the towers within the available space include the installation of noise barrier walls on the plant boundary adequate space between the walls and the cooling towers and between the two units' cooling towers themselves for air flow requirements.

The Cape Cod Commission has explained the local concern about the visual impact of cooling towers. Letter, Paul Niedzwiecki, Executive Director, Cape Cod Commission, to David Webster, EPA Region 1 at 1-2 (undated; received January 12, 2009). The Commission says that the sight of cooling towers may adversely impact two National Register Historic Districts and may be incompatible with plans to redevelop the Sandwich Marina for mixed residential and commercial uses. *Id.* at 2. The permit requirement for closed-cycle cooling "may adversely impact many Cape towns and the ability of the Cape as a region to attract tourism, as well as the ability of the Town of Sandwich to stimulate its economy." *Id*.

4.6 Heat Rate Penalties

4.6.1 Preliminary Analysis of Heat Rate Penalties

Shaw has performed a preliminary review of the heat rate penalties associated with adding cooling towers to the summer operation of the Canal Station. See Exhibit 2. This review is conceptual in nature, since a detailed analysis has not been performed. The basis for this review is reusing as much of the existing equipment as possible and matching the cooling towers to the existing plant conditions. The reuse of existing equipment may not be the most economic solution for the plant if a closed-cycle system is installed.

Two cases were examined that would generally bound an economic evaluation of cooling towers. Both cases assume the reuse of existing equipment to the maximum extent practical. The first case matches the existing circulating water flow, while the second reduces the circulating water flow to the back-pressure alarm setpoint on the steam turbines. To reuse the existing condensers at the reduced flow would require a detailed evaluation to determine their adequacy.

The results of this preliminary analysis are shown in Exhibit 2, as follows:

Parameter	**Summer Unit 1**	**Summer Unit 2**	**Summer Unit 1**	**Summer Unit 2**	**Notes**
	Match Current Circulating Water Flows		**Minimize Circulating Water Flows**		
Unit Design					
Design generation, kw	571,958	578,002	571,958	578,002	Ref. 1, 2 (Includes corrections based on assumed winter back pressure without cooling towers)
Design turbine heat rate, Btu/kw hr	7188	8032	7188	8032	Ref. 1, 2
Design condenser pressure, inch Hg A	1.50	2.00	1.50	2.00	Ref. 1, 2
Climate					
Design CW cold temperature, ^{O}F	70	70	70	70	Assumed based on temperature in Cape Cod Bay
Expected ambient Tdb, ^{O}F	77.8	77.8	77.8	77.8	Ref. 3
Expected ambient Twb, ^{O}F	73.4	73.4	73.4	73.4	Ref. 3
Expected recirculation allowance, ^{O}F	0	0	0	0	Assumed as for Natural Draft tower in a recent study for another site in the Northeast
Expected approach to ambient Twb, ^{O}F	15	15	15	15	Assumed as for salt-water Natural Draft tower in a recent study for another site in the Northeast
Expected CW cold temperature, ^{O}F	88.4	88.4	88.4	88.4	In winter, tower is operated to keep CW cold above 40 F and avoid freezing

Parameter	**Summer Unit 1**	**Summer Unit 2**	**Summer Unit 1**	**Summer Unit 2**	**Notes**
	Match Current Circulating Water Flows		**Minimize Circulating Water Flows**		
Condenser Calculations					
BP at design CW cold temp, inch Hg A	2.30	2.58	2.58	0.00	As shown on 85% clean curve for design CW [Ref 4]; at 578,002 kw, Unit 2 is off-design
BP at expected CW cold temp, inch Hg A	3.57	3.93	3.93	0.00	Extrapolated based on 85% clean condenser curve [Ref. 4]
Change of BP, inch Hg A	1.27	1.35	1.35	0.00	Expected - design
Corrections					
Expected condenser pressure, inch Hg A	2.77	3.35	5.00	5.00	Assumes condensers are both designed for summer operation
% Design Duty	100	#N/A	100	#N/A	Assume the Unit 1 condenser designed for the design back pressure
Steam flow, 10^6 lb/hr	#N/A	2.38	#N/A	2.38	Assume the Unit 2 condenser designed for the "guaranteed" steam flow, operating off-design for 5% overpressure
Correction to load, %	-3.00%	-2.08%	-8.86%	-4.60%	Ref. 1, 2; read from sheet "Corrections"
Correction to heat rate, %	3.11%	2.26%	9.72%	5.00%	Ref. 1, 2; read from sheet "Corrections"
Expected load, kw	554,772	566,005	521,260	551,414	
Expected heat rate, Btu/kw hr	7411	8213	7887	8434	
Lost plant output from cooling towers, MW	17.2	12.0	50.7	26.6	(positive indicates "derate")
Total Plant lost output MW	29.2		77.3		

4.6.2 Additional Studies Needed

As Exhibit 2 points out, to better define the actual heat rate penalty, a series of studies would be required, including but not limited to:

1. Economic optimization study to consider alternative flow rates and cycles of concentration, including alternate cooling tower sizes and condenser re-optimization.

2. Annual seawater temperature profile (temperatures in each month of the year or at shorter time-intervals if needed).

3. Seawater side water balance to determine the cycle of concentration of the cooling water circulated between the cooling towers and the units and year-around flow at the canal intake and discharge structure.

4. Heat balance (year-around) to determine new plant output and identify the temperature of the seawater returned to the cooling towers and temperature of the blowdown return to the canal, etc.

5. Existing steam turbines will require a thermal design review to identify new limiting turbine exhaust parameters.

6. Annual profiles of wet-bulb and dry-bulb temperatures and annual profiles of wind speed and direction.

4.7 Plant Energy Penalties

The total energy penalty from cooling towers is a combination of the loss of plant efficiency (addressed in Exhibit 3) and additional electrical loads to operate the additional equipment, including additional circulating water pumps for both types of towers and additional fans for the mechanical draft cooling towers. The plant efficiency penalties are based on review of the Canal Station condenser designs, while the lost power is based on input from cooling tower manufacturers and circulating water pump manufacturers.

Preliminary estimates for these penalties are included in the following table from Exhibit 3. This preliminary estimate is the minimum expected during summer operation. Based on detailed economic analyses to determine the most economic option for the Canal Station, the energy penalty could be greater than 4% of plant output.

	Matched Circulating Water Flow		Minimum Circulating Water Flow	
	Natural Draft	Mechanical Draft	Natural Draft	Mechanical Draft
Lost Power – minimum Heat Rate Penalty both units – summer (see Exhibit 2)	29.2 MW	29.2 MW	77.3 MW	77.3 MW
Lost Power Additional Plant Loads – circulating water pumping both units	6.1 MW	6.1 MW	4 MW	4 MW
Lost Power – Additional Plant Load – Cooling Tower Fans both units, plume abatement pumps, both units		5.5 MW		3.6 MW
Total Lost Power minimum– Summer	35.3 MW	40.8 MW	81.4 MW	84.9 MW
Percent of Plant output lost- Summer minimum	3.1%	3.5%	7.1%	7.4%

4.8 Geotechnical Investigations for Design of Cooling Tower Foundations

4.8.1 Why an Analysis of Soil Conditions Is Needed

As stated in Exhibit 4, foundation design for cooling towers, or other commercial structures, must comply with Massachusetts Building Code/International Building Code requirements. Natural draft cooling towers are very large and heavy concrete structures, on the order of 500 feet high and supported on a ring beam foundation up to 300 feet in diameter. Mechanical draft cooling towers are not as large or heavy and are typically founded on concrete slabs or footings. In either case, detailed geotechnical information on the mechanical properties of subsurface soils and rock and their vertical and lateral variations are needed to properly design the foundations and prepare an Engineering Report, as required by the Code. Bedrock at the Canal Station site is thought to be deep (>200 feet), and soils are primarily sands, possibly overlying marine clay. Ground water is encountered a few feet above sea level and is expected to fluctuate with the tides, due to the close proximity of the site to the Cape Cod Canal.

Geotechnical engineering analysis must evaluate soil bearing capacity and estimated settlement (both total and differential settlement) for either type of cooling tower. This may pose significant challenges for natural draft towers, which cannot tolerate large differential settlement, in part due to their great height. Because the foundations will be supported on saturated granular soils, the potential for soil liquefaction during an earthquake must be evaluated, and the foundation design must have an adequate factor of safety against failure due to liquefaction. Liquefaction occurs when ground shaking causes the pore water pressure in a soil to increase to the point where the soil loses its shear strength and temporarily behaves like a liquid. The risk of liquefaction is greatest in fine grained sandy and silty soils located below the water table and can cause catastrophic failure of structural foundations. Detailed geotechnical investigations and laboratory testing of soil samples from various depths are needed to support the required analysis and Engineering Report. Boring logs and laboratory test data previously conducted for design of the power plant should be reviewed for applicability; however, new investigations and testing will be needed at the specific site of the cooling towers.

If soil conditions require use of deep foundations (piles or caissons), the code requires special inspections and testing (*e.g.*, a pile load test) before the foundation is constructed.

4.8.2 Recommended Geotechnical Investigations

The following recommended scope, set out in Exhibit 4, is applicable to natural draft cooling towers. For mechanical draft towers, the overall scope is conservative and might be reduced by approximately one-third in terms of the number of borings and quantity of laboratory tests.

Shaw recommends approximately ten test borings beneath each cooling tower. Four or five of the borings should be drilled and sampled to the depth of the first competent founding layer (possibly 150 – 200 feet). Standard Penetration Tests should be taken every five feet or at identified strata changes. Undisturbed tube samples should be taken in any layers of cohesive soil encountered. Three or four of the borings at each cooling tower location should be completed as observation wells to allow measurement of the depth to ground water on a periodic basis for at least a one-month duration. Cone penetrometer tests (CPTs) may be substituted for five of the test borings at each cooling tower. The CPTs should be pushed to the same depth as the borings or to refusal of the equipment. Seismic CPTs are recommended in order to provide measurement of the shear wave velocity of the soil, as well as penetration resistance and sleeve friction, and pore pressure.

Each boring or CPT location would be surveyed to accurately determine location coordinates and ground surface elevation. Assuming two cooling towers (20 test borings/CPTs), the effort to plan the program, let subcontracts and perform the field work, would take approximately two months. If soil conditions are such that deep foundations are required, a pile load test would require about 2 ½ months for planning, subcontracting, and execution.

Geotechnical laboratory testing of soil samples should include the following tests and approximate quantities (see Exhibit 4):

Laboratory Test	ASTM Standard	Approximate Quantity
Natural Moisture Content	ASTM D 2216	30
Specific Gravity	ASTM D 854	4
Sieve Analysis	ASTM D 6913	30
Hydrometer Analysis	ASTM D 422	5
Atterberg Limits	ASTM D 4318	10
Unit Weight	*	
One-Dimensional Consolidation	ASTM D 2435	6
Consolidated Undrained Triaxial Compression	ASTM D 4767	4
Unconfined Compressive Strength	ASTM D 2166	4
Standard Compaction	ASTM D 698	6
pH	ASTM G 51	6
Unified Soil Classification	ASTM D 2487	30

* Unit Weight in accordance with ASTM D 2435 or ASTM D 4767 when performed in conjunction with Consolidation or CU Triaxial Compression tests.

The laboratory testing and final report for the testing would be completed four to six weeks following completion of the test borings.

Preparation of geotechnical analysis, calculations, and a foundation engineering report to address key geotechnical parameters (bearing capacity, settlement, liquefaction analysis) and recommended foundation type and design criteria would require about two months following laboratory testing.

The overall investigation, analysis, and report could be completed in approximately 20 - 26 weeks.

4.9 Cooling Tower Plume and Salt Drift Analysis

Before cooling towers are required, specific analyses should be completed with site-specific design information and local meteorological data to estimate the cooling tower impacts. Visible plumes typically can reach lengths of up to 10 kilometers downwind and heights of 1,000 meters under high ambient humidity conditions, especially in winter. Mechanical draft towers can cause ground-level fogging near the tower and ground-level icing in cold climates. Salt drift deposition is another potential impact of cooling towers that should be considered.

To aid in determining these impacts, an analysis of the potential environmental impacts caused by the operation of a natural draft cooling tower or mechanical draft cooling towers at the Canal Station could be performed, as described in Exhibit 5, using the Electric Power Research Institute-sponsored Seasonal/Annual Cooling Tower Impact

(SACTI) Program. This model is considered a state-of-the-art cooling tower impact model by EPRI and the electric power industry. It was developed by Argonne National Laboratory using knowledge obtained from extensive research on cooling tower environmental effects. The SACTI model provides salt drift deposition pattern (*i.e.*, kg/km^2 per month) as a function of distance and direction from the cooling towers, as well as the frequency of occurrence of visible plumes, hours of plume shadowing, and ground-level fogging and icing occurrences by season resulting from the operation of cooling towers.

The SACTI analyses would include three cooling tower options: natural draft cooling towers, mechanical draft cooling towers without plume abatement, and mechanical draft cooling towers with plume abatement. Cooling tower design information such as tower dimensions, tower layout, air mass flow rate (*i.e.*, assumed to be saturated), drift rate and heat rejection rate, along with meteorological information consisting of hourly surface meteorological observations and seasonal mixing height data, are used as input data to the SACTI model.

The cooling tower input parameters needed for the analyses are summarized as follows in Exhibit 5:

- Tower type (*i.e.*, linear mechanical, circular mechanical, or natural draft);
- Number of towers;
- Tower orientation relative to true north;
- Tower height above plant grade (m);
- Tower length (m);
- Tower width (m);
- Number of cells/tower;
- Cell exit diameter (m);
- Heat dissipation rate/tower (MW);
- Total airflow rate/tower (kg/sec);
- Drift rate (% circulating water and g/sec);
- Cooling water total dissolved solids (TDS) concentration (g TDS/g solution) considering cycles of concentration;
- Drift droplet size distribution, if available. Otherwise, a default distribution can be used.

The SACTI model requires hourly surface meteorological data in a format provided by the U.S. National Climatic Data Center (NCDC) in Asheville, North Carolina, or in Nuclear Regulatory Commission format for onsite meteorological data. The nearest National Weather Service (NWS) station to the site that has measured all of the necessary parameters for the SACTI must be purchased from the NCDC. The meteorological parameters required by the model include wind speed, wind direction, dry-bulb temperature, an atmospheric moisture parameter (*i.e.*, dew point temperature, relative humidity, or wet-bulb temperature), and an atmospheric stability indicator. Any missing parameter values would be filled in using a U.S. EPA-recommended procedure. In addition to the surface observations, morning and afternoon seasonal mixing height values from the nearest upper air observation location to the site (Chatham, Massachusetts) would be used in the SACTI model, as well as the monthly clearness index to help determine plume shadowing impacts.

The cooling tower impacts are then estimated using the SACTI program, along with the cooling tower operational parameters, the hourly surface meteorological observations, and morning and afternoon seasonal mixing height values, by executing in sequence the three codes that compose the SACTI program as follows:

- The PREP program is executed first, as that is the preprocessor code that reads the meteorological data files, eliminates unusable records, adds cooling tower exit conditions for each hour of meteorological data, calculates required non-dimensional variables, determines the plume categories, generates representative cases for each category, and generates an output file summarizing the meteorological data.

- The MULT program is then executed using the output of the PREP program along with the cooling tower drift emission rate, drift droplet size spectrum, and cooling tower arrangement information. The MULT program calculates the plume and drift impacts for representative cases for each plume category and generates an output file containing the plume properties for each plume category.

- The TABLES program is then executed. It uses the output of the MULT program to produce tables of predicted impacts by downwind distance and wind direction for each season of the year and for the annual period.

Upon completion of these analyses, a more informed determination of plume impacts and methods to reduce them at the Canal Station can be ascertained.

4.10 Noise

In order to review Region 1's noise analysis and develop actual design requirements, Shaw in-house and Edison Electric Institute data were used to preliminarily investigate the noise impacts cooling towers would have on the nearest houses on Briarwood Road south of the plant. See Exhibit 6. These houses were defined as the nearest noise receptors in the noise analysis included in the EPA 2008 responses to comments documents. This preliminary analysis was based on using natural draft cooling towers, which are slightly quieter than mechanical draft cooling towers. It should be noted that one of the reasons Brayton Point selected natural draft cooling towers over mechanical draft towers was that it was easier to mitigate potential noise impacts. See 'EPA Region 1 Preamble to Brayton Point Station: Final NPDES Permit,' http://www.epa.gov/NE/braytonpoint/index.html.

Based on approximate distances of 600 feet and 1100 feet from the rim of the two natural draft cooling towers, a total unmitigated level of 63 dBA was calculated at the nearest receptor. If we assume a significant level of mitigation of 10 dBA applied to the cooling towers at this location, the combined levels would be 53 dBA, which, when added to the EPA analysis-quoted ambient of 50 dBA, would result in a total of about 55 dBA. This increase of 5 dBA is higher than the 3 dBA quoted in the Region 1 Table 1, and the cooling towers may therefore have more impact on the community than Region 1 is suggesting. As a minimum to support the mitigation assumed in Exhibit 6, the Canal Station will require noise barrier walls close to the base of the towers to avoid adverse impact at nearby receptors. Additional noise mitigation measures could be needed, especially if mechanical draft towers are selected.

Also, the background data in the Region 1 analysis relies on a report published eight years ago and hence may not represent the current situation. A new baseline ambient noise survey could show a lower sound level, which would cause the impact of any cooling towers in the community to be greater than is implied by Region 1.

4.10.1 MassDEP Policy

The Response to Comments refers to MassDEP's policy on noise. MassDEP has the authority to regulate noise under 310 C.M.R. § 7.10, which is part of the Commonwealth's air pollution control regulations. Under the MassDEP regulations, noise is considered to be an air contaminant and, thus, 310 C.M.R. § 7.10 prohibits "unnecessary emissions" of noise. MassDEP administers this regulation through Noise Policy DAQC 90-001, dated February 1, 1990. The policy limits a source to a 10-dBA increase in the measured ambient sound level (L90) at the nearest residences. Ambient is defined as the background sound level without the source operating, although it is noted that in this case the ambient sound level may be taken to include the existing plant because it is a longstanding existing facility.

In the 1970s, Stone & Webster (now Shaw) quantified the ambient sound levels, as well as the Canal Station Unit 1 sound levels for the addition of Canal Unit 2 to the Station. At that time there was no acoustical room left in the MassDEP ambient + 10 noise requirements for Unit 2 without modification to Unit 1, which was undertaken. Subsequently, Units 1 and 2 combined consumed the entire 10 dBA noise budget allowed under the MassDEP Code.

MassDEP is quoted in the Response to Comments as considering a 3 dB increase on this budget as being "barely perceptible" and "would satisfy MassDEP's sound impact criteria," but it is unclear whether this is a personal opinion expressed by a member of staff at MassDEP or if this is MassDEP policy.

4.10.2 Detailed Noise Study

Exhibit 6 points out that, in light of the MassDEP noise policy summarized above, the following detailed noise study should be performed to assess the viability of the cooling towers at the Canal Station. Here (and in Exhibit 6) is a listing of likely work that would form the basis of such a study:

- Identify key receptors on all sides of the Plant;

- Measure the day-time and night-time sound levels to establish existing ambient levels in terms of Leq and L90;
- Measure the sound power of the existing Station using walk-away data at increasing distances from the Station;
- Discuss with MassDEP what criterion should be adopted for the cooling towers at these receptors;
- Incorporate the existing plant into a SoundPlan computer model and calibrate to the measured values;
- Incorporate the cooling tower options of natural draft cooling towers and mechanical draft cooling towers into the model and predict increases at the key receptors;
- Identify mitigation options required to meet Code levels at the receptors; and
- Estimate the cost of this mitigation.

4.11 Cooling Tower Makeup and Blowdown

Shaw's preliminary analysis, shown in Exhibit 7, is that, on average at 100 percent capacity, the Canal Station will require makeup water to the circulating water system as set out in the table below:

	Unit 1	**Unit 2**
Evaporation	4,120 gpm	4,582 gpm
Blowdown @ 1.5 cycles	8,240 gpm	9,163 gpm
Total for unit	12,360 gpm	13,745 gpm
Total Plant	26,105 gpm (37.6 MGD)	

This requirement is based on 1.5 cycles of concentration, which is consistent with the Brayton Point Station NPDES permit. Final blowdown and evaporation would be determined based on development of final heat balances and cooling tower vendor information.

Chemical treatment systems would be required to ensure the efficient and reliable performance of the cooling water system. The new chemical feed systems would be focused on the new requirements of cooling tower service. They would be essentially independent of the existing chlorination system, which would be retained to serve the continuing needs of the condensers.

The chemical treatment systems would provide for receiving, storage distribution and injection of the following chemicals:

Biocide (in addition to condenser chlorination)
Anti-foaming agent
Anti-scaling agent
Dispersant agent.

The requirement for these chemical additions would depend on seasonal issues as well as the operation of the plant.

4.12 Required Permits

As Exhibit 9 points out, a natural draft cooling tower at the Canal Station could potentially have an adverse effect on the existing air quality impacts of the Station due to the size of the tower. A 500-foot tall cooling tower with a diameter of 255 feet could cause additional building downwash effects on the plant stack, depending on its proximity, causing higher ground-level emissions concentrations. If required, the analysis of these downwash effects may require a detailed wind tunnel study or computational fluid dynamics study to establish the cooling tower dimensions to use in the analysis due to the smooth hyperbolic shape of the tower.

In addition, the cooling tower drift emissions would cause an increase in particulate matter (PM) emissions that would need to be analyzed for ground-level impacts and might trigger the need for a Prevention of Significant Deterioration (PSD) permit application, in addition to Massachusetts DEP Comprehensive Air Plan Approval, depending on the actual emissions increase. Using seawater as make-up would most likely result in this outcome.

In all, it is expected that the following permitting/licensing requirements would be required for the cooling tower project:

- MassDEP Comprehensive Air Plan Approval;
- U.S. EPA Prevention of Significant Deterioration (PSD);
- Federal Aviation Administration Structure Height approval;
- Massachusetts Environmental Policy Act Office (without and with an EIR);
- Construction NPDES Permit;
- Operating NPDES Permit Modifications;
- Chapter 91 (Massachusetts waterways licensing requirements) permit modification;
- Army Corps of Engineers Section 404 permit;
- Massachusetts Water Quality Certification
- Massachusetts Wetland Protection Act NOI (including Riverfront) and Order of Conditions;
- Wastewater Treatment System modification approval;
- Massachusetts Coastal Zone Management review;
- Local Planning Board approval such as the Cape Cod Commission; and
- Local Zoning Approvals (as necessary).

As a general matter, EPA agrees that if applicable law prohibits installation of a CWIS technology, or if a government agency whose permission is required in order to install that technology denies permission, then the technology is not "available." EPA Response to Kendall Comments at 2-55. This may be the case for noise or other impacts at the Canal Station, but further study is needed.

5. Economic Analysis of Closed-Cycle Cooling for the Mirant Canal Station

Mirant Canal has asked Veritas to analyze the economics of retrofitting closed-cycle cooling at the Canal Station. The results are in Exhibit 12, and the conclusions are summarized below.

5.1 The Meaning of "Wholly Disproportionate"

In the *Seacoast* decision, discussed above, the First Circuit Court of Appeals affirmed EPA's refusal to require an intake modification where the costs were "wholly disproportionate" to the benefits. How big would costs have to be to be "wholly disproportionate" to benefits? This can be inferred from several court decisions, not all of them in the area of environmental law.

A few cases interpret "wholly disproportionate" or similar terms. In *Ohio v. U.S. Department of the Interior*, 880 F.2d 432, 444 (D.C. Cir. 1989), *reh. denied en banc*, 897 F.2d 1151 (1989), the D.C. Circuit suggested in *dictum* that "grossly disproportionate" might mean, for example, that damages were three times the amount of use value, that is, a ratio of 3-to-1. In *General Ry. Signal Co. v. Washington Metropolitan Area Transit Authority*, 875 F.2d 320, 326 (D.C. Cir. 1989), *cert. denied*, 494 U.S. 1056 (1990), the court concluded that line item figures of $1.3 million were "grossly disproportionate" to estimates of actual costs ranging from $566,000 to $650,000, a ratio of 2.3-to-1 or less. The court also said that a 161.5% markup to cover profits and indirect costs was "wholly disproportionate" to the relatively modest indirect costs and the 9.73% profit figure contained in an estimate of the costs of the work that included these elements. And in *Strong v. Bellsouth Telecoms., Inc.*, 173 F.R.D. 167, 172-73 (W.D. La. 1997), the court concluded that $6 million in costs and attorneys' fees was "grossly disproportionate" to the $2 million in benefits rendered by the attorneys.

Based on these precedents, it appears that a cost is "wholly disproportionate" if it is two or three times benefits. That is consistent with plain English. Most people asked to pay twice what a house or car was worth would agree that the price was wholly disproportionate to the value.

5.2 The Costs of Closed-Cycle Cooling Cannot Reasonably Be Borne by Either the Industry or the Canal Station

5.2.1 The Industry Cannot Reasonably Bear the Cost of a Retrofit Requirement

At the national level, EPA has twice concluded after rulemakings that closed-cycle cooling is not best technology for existing facilities generally. See 41 Fed. Reg. 17,388 col. 3 (April 26, 1976), 69 Fed. Reg. 41,605 col. 1 (July 9, 2004). The basis for this decision was essentially that the cost was too high, making closed-cycle cooling "impracticable" industry-wide.

Similarly, using the Second Circuit's "reasonably borne" test, the electric power industry as a whole could not reasonably bear the cost of closed-cycle cooling. Studies conducted by government agencies and researchers evaluate the cost impact to industry by applying standard financial decision making scenarios. These studies reason that should the new capital and higher operating costs of the retrofit result in facilities becoming unprofitable, they will shut down, rather than bear the costs of the retrofit.

In 2008 the Department of Energy (DOE) conducted an analysis that evaluated the impact of § 316(b) regulation on U.S. generation facilities subject to that regulation. DOE identified the financially marginal plants by using capacity factor as a proxy. DOE determined that the U.S. would lose between 38,000 and 75,000 MW of generation capacity as a result of a retrofit requirement. DOE concluded that "older units may not have sufficient useful operating life remaining to recover the retrofit investment. Also, less efficient generation facilities may not be operated enough hours of the year … to justify the retrofit investment" (p. iv). DOE's study identifies New England as a region where the cost impacts are likely to be more severe, with potentially as much as an 18 percent reduction in capacity (p. 28). See http://www.oe.energy.gov/information_center/reports.htm#de.

On October 23, 2008, NERC issued its Long-Term Reliability Assessment (LTRA) for the 2008-2017 period. See the 2008 Assessment at www.nerc.com/files/LTRA2008.pdf. Pages 29-31 of the report address cooling water intakes. The NERC report concludes that a number of ongoing environmentally driven regulatory issues could, in sum, have a significant effect on resource adequacy in the U.S., namely greenhouse gas reductions and climate change initiatives, cooling water intake structures, and the interstate and mercury rules.

The NERC report notes that requiring units to retrofit with closed-loop cooling systems may result in some units retiring earlier than expected. Further, for plant retrofitting, there is an ancillary load imposed by the closed-loop cooling equipment, resulting in a derating of the unit's net output capability.

NERC concluded that, based on a worst-case view, NERC-U.S. Adjusted Potential Resources may be reduced by over 48,000 MW, approximately 39,000 MW due to retirements and 9,000 MW due to increased unit auxiliary loads. This reduction has the effect of lowering the Adjusted Potential Resource Capacity Margin by 4.3 percent. The most significant reductions in capacity margin occur in California, ERCOT, New England, and the Delta Subregion of SERC, with each of these areas experiencing more than a 10 percent reduction in their capacity margins. These regions may require additional resources to accommodate the potential retirements and retrofits. See pp. 29-31 of the 2008 Long-Term Reliability Assessment.

5.2.2 Affordability Should Be Evaluated at the Facility Level

Region 1 has considered affordability at the corporate parent level. But, as Exhibit 12 points out, the affordability of facility-specific regulatory requirements should reflect the individual facility's ability to bear costs and its viability rather than the corporate parent's. Both regulatory guidance and the realities of corporate finance support this position. In its guidance document for evaluating water quality standards variances, EPA notes that the financial impacts analysis of compliance costs is to be conducted at the facility level. See EPA, *Interim Economic Guidance for Water Quality Standards* at 3-1 (March 1995), http://www.epa.gov/waterscience/standards/econworkbook/pdf/complete.pdf. Region 1 should consider the Canal Station's specific financial situation when evaluating affordability under CWA § 316(b).

As Exhibit 12, section 2, explains, if the stream of future profits from a facility is not expected to exceed the stream of costs, the responsible choice is to close the facility. Mirant's annual report (2007) contains a discussion of the impact of environmental regulations on plant operation decisions: "To comply with these legal requirements and the terms of our operating permits, we must spend significant sums … we may be required to shutdown facilities if we are unable to comply with the requirements, … or if we determine the expenditures required to comply are uneconomic." This consideration of profitability at the facility level is consistent with profit-maximizing corporate behavior, in which responsibility to shareholders dictates that investments with negative expected returns not be undertaken.

In the EPA Response to Kendall Comments, Region 1 reasons that when assessing penalties for Clean Water Act violations, EPA is not restricted to considering the finances of the immediate owner. EPA Response to Kendall Comments at 2-45. Region 1 also mentions "ability to pay" standards in penalty provisions of other statutes. *Id*.

However, the considerations of "ability to pay" when deciding how much penalty to impose for violations and the "reasonably borne" test for determining the level of control technology that can be afforded are different in concept. In the penalty context, the purpose is deterrence of improper behavior and the permittee has no choice about paying the penalty. The "reasonably borne" test by contrast involves a voluntary choice to be made by the permittee, whether to incur the additional cost imposed by a new permit requirement. A cost cannot be considered "reasonably borne" if incurring that cost would be an economically irrational decision by the permittee.

In particular, determining on a BPJ basis whether a facility can reasonably bear (afford) the cost of cooling towers inherently focuses on the economics of the facility itself. The issue is whether the additional costs will make the facility unprofitable and force it to shut down or whether the facility owner can reasonably expect to be able to recover the cost through the future operation of the facility, and these are facility-specific issues, because the relevant question is whether the facility can remain profitable. The profitability or viability of the parent corporation is not relevant. To make it relevant, one would have to assume that the corporate parent will inject money into an unprofitable facility for some reason. A corporation's responsibility to its shareholders dictates against such decision making.

The reasonably borne affordability test must assess the viability of the facility if the cost at issue is imposed, whereas the "ability to pay" test for penalties is aimed at affecting the behavior of company decisionmakers, who may well be at the corporate parent level, by punishing past behavior. In essence the goal is to make the penalty large enough so that decisionmakers avoid violations in the future.

In the EPA Response to Kendall Comments, EPA has said it disagrees that the financial status of a parent company is irrelevant, and it posed the following question:

> If a facility's owner has structured its corporate arrangements so that the facility is owned by a corporation which is in turn wholly owned by another corporation, may EPA consider the finances of the parent corporation, or must it treat the (non-publicly-held) immediate owner of the facility as if it were a standalone entity?

EPA Response to Kendall Comments at 2-44.

In answering this question, Region 1 noted that there is no determinative law on this point and drew an analogy to the CWA's civil penalty policy under § 309(d), where EPA must consider "the economic impact of the penalty on the violator." 33 U.S.C. § 1319(d). EPA further observed that "it is *not* restricted to considering the finances of the immediate owner" in assessing penalties and cited various cases under the CWA and other environmental statutes, including *Atl. States Legal Found., Inc. v. Universal Tool & Stamping Co.*, 786 F. Supp. 743, 753 (N.D. Ind. 1992) (in a CWA § 309(d) case, the court may consider the parent corporation's finances in evaluating the impact of the penalty on a violator). Region 1 believes there is an "undeniable similarity" between the "ability to pay" and "reasonably borne" inquiries.

But upon closer examination, the "undeniable similarity" is, at best, superficial, causing the resulting analysis to be arbitrary and capricious. The two concepts are substantively very different. As discussed above, one is intended to punish and deter, and the other is intended to establish a substantive standard of economic viability.

As the court stated in one of the cases Region 1 cites as support for considering parent company finances under § 309(d), a civil penalty is intended to "curtail the pollution of this nation's waterways by discouraging future violations." *Atl. States*, at 753. The court further stated:

> To further the objective of the Act, the amount of the civil penalty must be high enough such that the penalty does not merely become a cost of doing business. If not, it becomes more profitable to pay the penalty rather than incur the costs of compliance…. Further, a substantial penalty reduces the likelihood that polluters will choose accepting the risk that non-compliance will go unpunished.

Id. (citations omitted).

By contrast, the costs of the "best technology available" standard in § 316(b) are intended to be the "cost of doing business" and are used in an evaluation of whether the technology at issue is economically viable in the sense that facility owners will be willing to adopt the technology rather than choosing to go out of business to avoid incurring a cost they have no ability to recover. Such costs are not meant to be punitive or to deter non-compliance. In fact, to the contrary, these costs are intended to encourage compliance by being reasonably within the financial means of most individual facilities so that they may continue to operate as economically viable commercial entities.

Legislative history for § 316(b) states that "'best technology available' is intended to be interpreted to mean the best technology available commercially at an economically practicable cost." 118 Cong. Rec. 33,762 (1972), reprinted in 1 *Legislative History of the Water Pollution Control Act Amendments of 1972*, at 264 (1973) (Statement of Representative Don H. Clausen). Although the Second Circuit in *Riverkeeper II* discounted this history, it should not be ignored. "Economically practicable" certainly suggests that the cost of the technology should not make a facility unprofitable.

In the Phase II rule EPA itself provided for mitigating measures where compliance costs are significantly greater than agency estimates of costs or environmental benefits:

> Under § 125.94(a)(5) (i) or (ii), if the Director determines that a facility's costs of compliance would be significantly greater than the costs considered by the Administrator for a like facility to meet the applicable performance standards, or that the costs of compliance would be significantly greater than the benefits of meeting the applicable performance standards at the facility, the Director must make a site-specific determination of best technology available for minimizing adverse environmental impact.

69 Fed. Reg. 41,576, 41,591 (Jul. 9, 2004). In the Phase II rulemaking EPA assessed the economic practicability of requiring cooling towers by looking at per-facility capital costs ($130 to $200 million) and at the total social cost ($3.5 billion per year, 2.4-4.0 percent less energy for existing fossil-fuel facilities as a whole). 69 Fed. Reg. 41,605 (July 9, 2004). EPA did not look at costs on a corporate parent level.

Even the EPA's NPDES Permit Writer's Manual offers evidence that assessing the costs of a substantive standard under the CWA is far different from the punitive standards set forth in *Atl. States*. *See* NPDES Permit Writer's Manual, http://www.epa.gov/npdes/pubs/owm0243.pdf, at 71 ("'Reasonable' means that the conditions are achievable at a cost that the facility can afford").

Indeed, the very act of applying for a permit for a point source discharge under the CWA is an explicit attempt to eliminate the risks of noncompliance and *avoid* the assessment of a penalty. Given these differences, EPA's analogy to penalty policy and its contention that it can apply the same criteria it uses to assess civil penalties to its consideration of costs in setting substantive compliance standards is arbitrary and capricious and not supported by the CWA, applicable case law, or the Agency's own practices.

Apart from EPA's questionable analogy to penalties for violations, other reasons warrant not considering the financial status of the parent company when determining best technology available under § 316(b).

Mirant Corporation, the parent company of Mirant Canal, is not the permittee, as indicated on the face of the Draft Permit. This is entirely reasonable, given that the CWA's substantive standards are intended to regulate point sources at the facility level.

Furthermore, subsidiaries such as Mirant Canal can be and frequently are sold or spun off as independent entities, which would undermine what at one time may have been considered a "reasonable" consideration of costs for an entire corporate family. A power company, subsidiary or otherwise, cannot, under virtually any circumstance, operate at a loss and expect to remain in existence, thus making facility-level inquiries into financial status the only accurate measure of what may be "reasonably borne by the industry."

Finally, even if it were possible to include an assessment of the financial status of Mirant Corporation when considering costs for Mirant Canal, such consideration would have to take into account the fact that Mirant Corporation owns multiple subsidiaries. Its financial status would thus need to be assessed on a proportional basis, which would likely produce the same result if the inquiry was limited to Mirant Canal's individual financial status. After all, the costs of new requirements imposed at one of Mirant Corporation's subsidiaries could not be so great as to prevent it from meeting comparable costs for the same or similar requirements at each of its other subsidiaries.

Region 1 also argues, with respect to the Kendall Station, that the permittee is obligated to present enough financial information to show that it cannot "reasonably bear" the cost of an intake technology. Mirant Canal provides in these comments facility-specific information showing that the cost of retrofitting the Station with closed-cycle cooling would be an unreasonable burden that would, absent some cost-recovery mechanism, force the plant to shut down. Mirant Canal also offers to provide more detailed information, subject to treatment as confidential business information, if Region 1 needs it for its review.

5.2.3 The Canal Station Cannot Bear the Costs of a Cooling Tower Retrofit and Will Become Uneconomic If a Retrofit Is Required

As already noted, in the *Riverkeeper II* decision, one of the factors the Second Circuit identified for EPA's consideration when determining BTA on a nationwide basis is whether the costs of a cooling tower retrofit can be "reasonably borne by the industry." *Riverkeeper II*, 475 F.3d at 99.

Although Region 1 contends that Mirant can afford the cost of the retrofit, Mirant Canal's projected future revenues are insufficient to support the capital investment necessary to backfit cooling towers to the Canal Station. With the addition of closed-cycle cooling, model simulations project that the Canal Station's net present value is negative $180 million. See Exhibit 12, section 2.2. Absent a cost-recovery mechanism, cooling towers would be uneconomic and will not be installed.

In the EPA Response to Kendall Comments, Region 1 compared the relatively large cost of $120 million for cooling towers at the Brayton Point Station with the smaller cost of $1.9 million for a fine-mesh barrier net at the Kendall Station. EPA Response to Kendall Comments at 2-49. For the Canal Station, however, the estimated cost of cooling towers is $182.8 to $224.5 million. See Exhibit 1.

5.3 Without More Transmission or Generating Capacity for Cape Cod, the Shutdown of the Canal Station Would Affect Electricity Reliability

Another factor that the Second Circuit indicated that EPA should consider in determining BTA is the impact of a retrofit requirement on energy production and efficiency ("energy requirements," in the words of CWA § 304(b)(2)(B)). See Exhibit 12, section 3. An important aspect of energy production relates to the reliability of the bulk power system. Reliability is the ability of the electric system to supply electricity, taking into account planned and forced outages, and its ability to withstand sudden disturbances, such as unanticipated loss of system facilities. The North American Electric Reliability Corporation's (NERC's) mission is to ensure the bulk power system in North America is reliable. To achieve this objective, NERC develops and enforces reliability standards. As of June 18, 2007, the U.S. Federal Energy Regulatory Commission (FERC) granted NERC the legal authority to enforce reliability standards with all U.S. owners, operators, and users of the bulk power system and made compliance with those standards mandatory.

When New England's wholesale market does not satisfy NERC's reliability requirements, ISO-NE takes additional steps to ensure that the electrical system is reliable. ISO-NE has issued reliability agreements and supplemental commitments to generators to ensure reliability. Both the agreements and the commitments keep uneconomic units in service. Owners receive payments that are recovered from market participants. See Exhibit 12, section 3. Thus, in order to meet NERC's reliability requirements, some uneconomic units will be kept on line.

Since 2006 the Canal Station has provided supplemental commitment to ISO-NE as a part of the contingency plan for reliable service. *Id.* Because there are no other large power plants within the region, nearly all the electricity consumed on Cape Cod, Martha's Vineyard, and Nantucket is supplied by the Canal Station during the summer peak. Thus the location of the Station relative to the transmission system makes the plant uniquely able to fulfill ISO-NE's reliability requirements. *Id.*

The Canal Station is also important during other times of the year in the case of certain transmission outages. The loss of both of the two transmission lines serving the area would require generation from the Canal Station to re-establish electrical service during almost all time periods. During many time periods, the loss of a single line would require generation from the Canal Station to maintain reliability. For example, during 2002 a fire at the Canal Station occurred when a transmission line was out of service. As a result 300,000 electricity customers in southeastern Massachusetts lost service.

To better understand the reliability impacts of closing the Canal Station, Mirant Canal engaged PwrSolutions to do an independent analysis. See Exhibit 12, section 3, and Exhibit 15. The results indicate that closing the Canal Station would pose serious threats to the reliability of the lower SEMA transmission system. Exhibit 12, section 3.

5.4 Closed-Cycle Cooling Would Negatively Affect the Local Community

If the Canal Station closes because it cannot afford a cooling tower retrofit, the result would be negative impacts to the local economy in the form of job losses, reduced local spending, decreased tax revenues, and, potentially, tax increases for some residents. See Exhibit 12, section 4.

With plant closure, most of the employees at the Station would lose their jobs. Additional impacts in the local community would occur as the unemployed would no longer have income to spend on local goods and services. Local economic impacts are commonly evaluated using input/output models of the regional economy under consideration. Exhibit 12 describes an economic impact study of the 1992 closure of the Yankee Plant in Rowe, Massachusetts. The authors determined that for every 1.8 jobs lost at the plant, another job was lost in the local economy. In that community the decreased local spending resulted in the closure of the town's only grocery store, and other retail stores suffered as well. A local economic impact study has not been conducted for the Canal Station. However, the closure of the Canal Station could have similar effects on the local community.

Sandwich, like many small towns in Massachusetts, relies on property tax revenues to provide local funding for schools, public safety, and other public services. The Canal Station's continuing presence provides an important source of tax revenue for the community, and closing the Station would have tax repercussions for the town. Exhibit 12, section 4.

5.5 The Economic Benefits of the Cooling Tower Retrofit Do Not Justify the Costs

As the Veritas report on economic issues (Exhibit 12) concludes, the benefits of retrofitting closed-cycle cooling at the Canal Station do not justify the costs. On December 2, 2008, the U. S. Supreme Court heard arguments on the legality of benefit-cost analysis as part of the § 316(b) Phase II Rule. The Court's decision is anticipated in early to mid-2009.

Since Region 1 will probably make its decision after the Supreme Court's decision is announced, it is appropriate to understand how the benefits of the cooling tower retrofit at the Canal Station compare to the costs of the retrofit. Even if the

Supreme Court rules *against* cost-benefit analysis, costs and benefits will still be relevant because of the Second Circuit's "reasonably borne" and "cost-effectiveness" analyses.

5.5.1 Dynamic Population Models Simulate Catch Changes

As reported in Exhibit 12, section 5.1, Veritas developed preliminary bio-economic impact estimates based on dynamic population simulations for selected species in the Canal Station's entrainment data. Age-structured population models are the most sophisticated models typically employed to evaluate changes in recreational and commercial catch. This analytical approach is consistent with the one used by EPA in developing the Phase II rule. As Veritas reports in Exhibit 12, Leslie's model is frequently used in fisheries management and has long been an important component of best professional judgment § 316(b) assessments under EPA's 1977 draft guidance.

Measuring the benefits associated with a cooling tower retrofit requires distinguishing the current level of entrainment for the Canal Station from the level of entrainment that would occur with the retrofit. For purposes of this assessment, Veritas evaluated the entrainment impacts based on the full design flow for the Canal Station. Although the plant is not currently operating at full design flow, using design flow as the basis of benefits results in a larger benefits estimate. If the Canal Station operates at a level less than design flow, the resulting benefits will be smaller, potentially much smaller, than those reported in Exhibit 12. For the retrofit scenario, Veritas assumed that entrainment is reduced by 92.8 percent from the current level (Exhibit 12, section 5.1). This difference in entrainment impacts corresponds to the benefits of the retrofit.

For the species identified in Tables 1 and 2 in Exhibit 12, Veritas developed estimates of changes in recreational and commercial harvests associated with the retrofit. Because these changes are derived from age-structured dynamic population models, the changes vary from year to year. For species that are harvested both commercially and recreationally, Veritas allocated catch across the two categories in the same proportion reflected in the 2007 National Marine Fisheries Service (NMFS) data.

5.5.2 The Recreational Benefits of the Retrofit Are Less than $600 Thousand

Veritas proceeded in its economics assessment by developing the estimated benefits, in dollars, associated with the changes in catch that result from the population dynamic models. Estimating recreational benefits requires a simulation of angler behavior and changes in social welfare resulting from reductions in entrainment and the associated increases in expected catch. Important factors that should be accounted for include the number and quality of substitute fishing sites, the popularity of the impacted species, and the number of trips with improved catch rates. See Exhibit 12, section 5.2.

Random utility analysis is the accepted method for valuing IM&E reductions on recreational fishing. The environmental economics literature contains numerous examples of random utility models (RUMs) for assessing recreational fishing values. *Id.*

Veritas selected a recreational fishing study conducted by Hicks *et al.* This study covers marine recreational fishing in the northeastern United States, using data from the 1994 Marine Recreational Fisheries Statistics Survey (National Marine Fisheries Service). These data were collected on-site by interviewing anglers at the conclusion of their fishing trips and via telephone. EPA used this study as the basis for its North Atlantic regional case study in the Phase II rulemaking. In terms of similarity, the marine fisheries in the Hicks *et al.* study contain similar species of fish that are prevalent in coastal Massachusetts waters, such as winter flounder, tautog, and Atlantic cod.

Veritas used available information on recreation in the area and typical travel distances to develop an appropriate radius for substitute sites, generally within 100 miles of the affected site (see Figure 4 of Exhibit 12). Although the actual number of substitute sites can be in the hundreds, most RUMs based on original data do not include nearly that many. For this assessment, the selected substitute sites were Massachusetts Bay, Salem Harbor, Mount Hope Bay, Plymouth Bay, and Narragansett Bay (in Rhode Island).

Based on publicly available information about typical travel distances, Veritas identified the likely users of the affected site within a 50-mile radius. For the affected site, it fixed the number of trips to correspond to the best available visitation information for the Cape Cod area. Within these constraints, the remaining trips were distributed among the substitute sites in an appropriate manner, also based on available visitation information. Trips to Cape Cod and the selected substitute sites were based on a customized compilation of the NMFS data, performed by the NMFS staff in the Fisheries Statistics Division. Veritas' calibration reflects distances from all angler origins (zip codes) to the sites within the calibrated model. Exhibit 12, section 5.2.

Veritas simulated changes in trip patterns that anglers make in response to changes in catch rates for the Cape Cod area. It developed the travel cost calibration, using income information for the affected population of anglers, from the travel cost function in the original model.

The calibrated model evaluates whether a pattern of trips different from the current pattern maximizes angler satisfaction. Subtracting the angler satisfaction under current conditions from the (presumably higher) angler satisfaction under alternative conditions provides the change in value associated with higher catch rates for anglers using Cape Cod Bay. Veritas calculated changes in values within an explicit Monte Carlo framework.

The analysis in Exhibit 12 reveals that the discounted present value over 20 years of reducing entrainment at the Canal Station, based on a 3% discount rate, is $583,600.

5.5.3 The Commercial Benefits of a Retrofit Are Less than $400 Thousand

Commercial benefits from entrainment reductions accrue primarily to commercial fishermen as increased profit attributable to the higher catch per unit effort (CPUE) associated with increases in fish populations. See Exhibit 12, section 5.3. The ability of commercial fishermen to realize sustained increased profits depends on the responsiveness of market prices to higher CPUE. Market extremes determine the upper and lower bounds on commercial benefits.

For purposes of this assessment, Veritas assumed that all increases in commercial catch are caught by commercial fishermen who dock in Massachusetts, without any additional fuel or labor expenses. Veritas assumed these additional catch increases had no effect on 2007 dockside prices.

Calculated in this manner, over 20 years, the discounted present value of commercial fishing benefits associated with a retrofit is $358,000. *Id*.

5.5.4 The Costs of the Retrofit Are Wholly Disproportionate

As report in Exhibit 12, section 5.4, the total benefits of reducing entrainment are estimated at less than $1.0 million.

According to Exhibit 1, the capital costs of a cooling tower at the Canal Station range from about $182 million to about $225 million. If a retrofit were economically feasible, Mirant Corporation would likely finance the capital costs of the cooling towers. To accurately reflect the cost to Mirant Corporation of borrowing funds, Veritas constructed a company-specific weighted cost of capital. This cost of capital assumes a 50/50 debt-equity structure. The debt portion comprises a weighted average of the debts and interest rates reported in Mirant Corporation's most recent 10-Q. The equity portion is based on the capital asset pricing model. Sources that provide the data inputs for this model include Standard & Poors (2008), Bankrate, Inc. (2008), Nasdaq (2008), and Bloomberg (2008). See Exhibit 12, section 5.4.

The resulting cost of capital is adjusted to reflect the federal corporate tax rate. The capital cost is amortized over 20 years, reflecting an annual cost of $20.1 to $24.7 million. Veritas added the annual operating and maintenance cost estimated by Shaw (see Exhibit 1) to the annual loan amount and discounted the total at 7 percent, consistent with OMB recommendations. Over 20 years, the discounted present value of the costs is $225–264 million. The ratio of costs to benefits exceeds 200-to-1. *Id.*

By any reasonable standard, the ratio of cost to benefits for retrofitting cooling towers at the Canal Station is dramatic. The benefits of reducing entrainment at the Canal Station simply do not justify the costs of the retrofit.

Even if the Supreme Court rules *against* cost-benefit analysis, cooling towers cannot be justified under a "reasonably borne" or "cost-effectiveness" analysis. And if the Supreme Court rules *in favor of* cost-benefit analysis, the "wholly disproportionate" analysis in Exhibit 12 would be dispositive and rule out closed-cycle cooling for the Canal Station. The Supreme Court decision will have to be taken into account before the final decision is made on § 316(b) compliance for the Canal Station.

5.6 Cost-Effectiveness Analysis Is Likely to Eliminate a Cooling Tower Retrofit from Consideration

In its January 2007 decision, the Second Circuit Court of Appeals recognized the option of using "cost-effectiveness" analysis to identify the Best Technology Available. *Riverkeeper II*, 475 F.3d at 99-100. The role of cost-effectiveness analysis depends on whether a standard is in place. When a standard is in place, cost-effectiveness analysis is cost minimization with some allowance for uncertainty. *Id.* Consistent with the Second Circuit decision, consideration of technologies with lower costs and higher or lower effectiveness is warranted. See Exhibit 12, section 6.

Applying cost-effectiveness analysis in this manner presumes a standard. When there is no standard, incremental cost-effectiveness analysis is the appropriate methodology. *Id.*

Exhibit 12, section 6, reports on a preliminary cost-effectiveness analysis performed by Veritas for the Canal Station, comparing 0.5-mm mesh traveling screens and closed-cycle cooling. It estimates that closed-cycle cooling would result in additional fish but at a cost per fish more than an order of magnitude greater than that for screens. Moreover, if entrainment survival were taken into account, the effectiveness of screens might approach that of cooling towers. *Id.* Based on this analysis, further evaluation of alternate technologies is called for, just as the 2005 Draft Permit would have required.

5.7 The 2009 Cost Estimates Are the Best Available

The cost estimates submitted with these comments, though still preliminary, are significantly better than the estimates in the 2003 Alden Laboratory Report relied on in the Response to Comments.

As Alden explains in Exhibit 13, the 2003 report provided only a "conceptual level" analysis based on a generic EPRI cost model. Alden concludes: "the Alden (2003) report is outdated and does not reflect the current operating conditions of Canal Station, current installation costs, or current energy costs" (Exhibit 13 at 2).

Accordingly, Region 1 should base decisions on the cost information in these comments (including Exhibit 1) instead of the 2003 Alden Report.

5.8 The Cost of Cooling Towers Is "Wholly Disproportionate" to EPA's Estimate of the Cost of Compliance with the Phase II Rule

The now-suspended Phase II rule contained a "cost-cost" test. 40 C.F.R. § 125.94(a)(5)(i) (suspended). EPA, in developing the national cost of implementing the rule, estimated the cost for each Phase II facility to comply with the rule. The rule provided that if the *actual* cost for a facility to meet the performance standard (based on a site-specific analysis) was "significantly greater than" the cost estimated by EPA for the facility, the facility would not have had to install that technology. If no technology could meet the performance standard at a cost not significantly greater than the benefit, the facility could have a less stringent, site-specific requirement. This standard would be based on the technology or operational measures or both that were as close to the performance standard as possible for a cost not significantly greater than the benefit.

The Canal Station is identified by EPA as facility number DNU2015 in Appendix B to the Phase II rule. See 69 Fed. Reg. 41,681 (July 9, 2004). Canal's modeled technology in Appendix A is "N/A." 69 Fed. Reg. 41,677. EPA in the preamble of the rule explains that it assumed such facilities would already meet the applicable performance standards and should use "zero" as the value of the costs considered by EPA. 69 Fed. Reg. 41646 col. 3 (July 9, 2004).

In *Riverkeeper II* the Second Circuit did not invalidate the "cost-cost" test in the Phase II rule. The court remanded it because of inadequate notice and opportunity for public comment, but the court did not even imply that the test was inconsistent with the Clean Water Act, at least if EPA used a "wholly disproportionate" rather than a "substantially greater than" standard. *Riverkeeper II*, 475 F.3d at 113 n.25.

Accordingly, Region 1 should not require a technology the cost of which is wholly disproportionate to zero. Cooling towers, at a cost of some $200 million, should be ruled out on this basis.

5.9 Brayton Point Is Different from the Canal Station

In its Response to Comments, Region 1 cited the Brayton Point Station several times to support requiring closed-cycle cooling for the Canal Station, a facility different from Brayton Point in important ways.

As the Appeals Board said in the Brayton Point decision, Brayton Point is a facility and an ecosystem with "fairly unique attributes." *In re Dominion Energy Brayton Point, L.L.C.*, NPDES Permit No. MA 0003654, NPDES 03-12, 2006 EPA App. LEXIS 9, *15 (February 1, 2006). The case involved an important estuarine ecosystem "whose fisheries have shown huge decreases in productivity…, a decline that began to become manifest around the same time that the facility's withdrawals from and discharges into the Bay appreciably increased." *Id.* Brayton Point is the largest fossil-fuel burning electric power plant in New England. *Id.* at *31. Before the current permit was issued, Brayton Point was permitted to withdraw 1,452.5 MGD of water. *Id.* at *33. The Canal Station withdraws only about 518 MGD (see December 2008 Fact Sheet at 5) at the maximum and in practice much less.

Thus Region 1's reliance on the facts of Brayton Point is misguided. Here are the ways in which the Region used the Brayton Point plant and site to draw conclusions about the Canal Station:

> At Brayton Point Station, mass mortalities of Atlantic menhaden occurred in the discharge canal when water temperature exceeded 95°F. Hence a daily average limit of 107°F at Mirant Canal could trigger a mass mortality of Atlantic menhaden (Response to Comments III-19).

That a mechanical draft cooling tower at Canal Station would be 60-70 feet tall is consistent with EPA's analysis of Brayton Point. Natural draft cooling towers at Brayton Point may be up to 500 feet high (Response to Comments IX-37).

Most emissions from cooling towers should not significantly contribute to fogging or icing because draft eliminators can achieve a draft rate of 0.0005%, as shown in Region 1's analysis of Brayton Point (Response to Comments IX-38).

It might be feasible to develop an early warning system to trigger road salting or lighting cautionary signs when cooling tower operations are likely to contribute to potentially hazardous fog or ice. See EPA Region 1 Draft Permit Determinations Document for Brayton Point Station at 7-48. (Response to Comments IX-39).

Adding plume abatement capability could more than double the capital cost of cooling towers. See EPA Region 1 Draft Permit Determinations Document for Brayton Point Station at 7-49. (Response to Comments IX-39).

Any increase of fog or icing caused by cooling towers at Canal Station is likely to be well within the range of natural fluctuations in background conditions. See EPA Region 1 Draft Permit Determinations Document for Brayton Point Station at 7-51 (Response to Comments IX-40).

Salt emissions should not be a significant problem at Canal Station because draft eliminators can reduce draft to 0.0005%. See EPA Region 1 Draft Permit Determinations Document for Brayton Point Station at 7-52 to 7-53. (Response to Comments IX-40).

MassDEP has regulations and policies directly pertaining to noise emissions. See EPA Region 1, Determination on Remand for Brayton Point Station Permit (November 30, 2006), at 46-54 (Response to Comments IX-42).

MassDEP will review noise impacts of cooling towers at Canal Station, examining several factors. See EPA Region 1, Determination on Remand for Brayton Point Station Permit (November 30, 2006), at 53-54 (Response to Comments IX-43).

EPA used the available Canal Station data in conjunction with information from its noise analysis for mechanical draft cooling towers at Brayton Point to conduct the noise analysis for Canal Station (Response to Comments IX-43).

EPA's contractor's analysis of octave band data at Brayton Point indicated that a pure tone condition would not be created by mechanical draft cooling towers, and similarly no adverse impact would be expected at Canal Station (Response to Comments IX-44).

In light of EPA's analysis for Brayton Point, Mirant Canal's contractor's suggestion that mitigating noise might add 25 percent to the capital cost may be a fair, albeit rough estimate for this stage of the analysis (Response to Comments IX-44).

Brayton Point has an extensive monitoring program far greater in scope and cost than the requirements in Mirant Canal's permit (Response to Comments IX-69).

The species of fish most likely to trigger this provision would be one of the schooling bait fish, which have in the past experienced cases of mass mortality in Mount Hope Bay from the combination of high temperature and chlorine discharged by Brayton Point (Response to Comments IX-74).

EPA biologists have observed herring gulls congregating by the outfall points at Brayton Point and Salem Harbor and scooping up fish as they emerge (Response to Comments IX-83).

Some of these observations have to do with the biology of Mt. Hope Bay. Normandeau's more pertinent analysis of the environmental impact in the Cape Cod Bay (Exhibit 12) is better evidence of the impact of the Canal Station. Some of the Region's observations based on Brayton Point have to do with the visual impact of cooling towers, fogging and icing, and air particulate pollution. Again, site-specific information for the Canal Station provided in these comments is better evidence.

Moreover, some of these impacts need to be studied further, again at the Canal Station site and not some other. That is one reason Mirant Canal recommends a study of alternatives.

6. A Study Is Needed to Assess Site Conditions, the Current Need for the Station to Maintain Electric Reliability, Updated Costs, and New Technical Information on Intake Technologies

In 2005 Region 1 proposed a detailed study of alternative intake technologies. That study still needs to be done for the same reasons that applied then. In addition, circumstances have changed and new information is available that was not available in 2005.

A number of intake technologies should be assessed or the previous assessment updated, such as fine-mesh screens. Alden Research Laboratory has done a new analysis of fine-mesh (0.5 to 2.0 mm) traveling screens with fish protection features (Exhibit 11 to these comments). Because the performance of fine-mesh screens is species-, lifestage-, and site-specific, Alden recommends pilot studies and screen optimization to better estimate the performance that could be achieved at the Canal Station.

The total efficacy by species is given in Table 2 of the Alden analysis, and post-impingement survival of juvenile and adult fish in Table 3. The estimated total capital costs are $5,174,000 (Table 6). Annualized costs, including both annualized capital costs and annual operation and maintenance, would be $1,047,000. A pilot study test facility would cost $650,000. See Table 6.

One reason to allow Mirant Canal to perform a study and analysis of intake technologies, such as fine-mesh traveling screens, is to allow it to take account of new data that are expected in 2009. EPRI, for example, has an ongoing project to evaluate fine mesh screens in the laboratory. EPRI is building a database on survival of early life stages (eggs and larvae) of fish collected off different types of traveling water fine mesh screens. EPRI's laboratory testing began in 2006, and a second phase of testing was done in 2007 and reviewed in 2008. Testing continued in 2008, and a new technical update is expected in March 2009. This new information could be valuable for assessing fine-mesh traveling screens as a possible intake technology for the Canal Station.

There is considerable uncertainty about the biological performance that could be achieved with fish protection technologies at Canal. Broadly, these uncertainties fall into three categories: biological, technological, and site-specific.

Biologically, the sizes of the entrained organisms are unknown. For technologies that use narrow openings to physically exclude passage into the facility, the size of the organisms is critical in predicting how well they will perform. In addition, these technologies often use low, through-opening velocities to allow motile lifestages to swim away from the device. Since length frequency distributions of the entrainable larvae were not available for the Canal Station, it is not possible to estimate what portion of the larvae might have sufficient motility (*i.e.*, swimming ability) to avoid involvement. In addition, there are several species entrained at the Canal Station for which there are no larval post-collection survival data. In these cases, surrogate species were selected, which necessarily increases the uncertainty of the estimates. Without Canal Station entrainment survival data, it was not possible to look at trade-offs of using larger fine mesh, mesh sizes that would reduce the through-screen velocities for the screens to optimize performance.

Technologies have continued to develop and improve since Alden assessed technologies for application at Canal in 2003. For modified traveling screens, much of the data used to estimate biological performance with larval fish in the 2003 report were based on older screen designs. Advances in Ristroph screen design have been developed through extensive laboratory and field experimentation. Hydraulic buffeting in the fish lifting buckets, identified as injurious to fish by Fletcher (1990), was reduced through improvements in bucket design during the 1980s and 90s. Evaluations of the latest generation of modified traveling screens have generally shown improved survival of juvenile and adult fish over previous screen designs. Since most fine-mesh screening installations were prior to these enhancements to the technology (*e.g.*, Big Bend, Prairie Island, Brayton Point, Somerset), the impact of improved screen designs has not been observed with fish eggs and larvae. In addition, there are whole classes of screens that have not yet been tested or are in the preliminary stages of testing with early lifestages of fish (*e.g.*, Passavant-Geiger rotary-disc screens, Hydrolox polymer belt screens, Beaudrey water intake protection (WIP) screens) that were not considered in 2003. Finally, the methods used to hold fish and assess mortality have improved since the earlier fine-mesh screen studies were conducted, which further reinforces the need for more current assessments.

Lastly, there can be considerable site-specificity in the performance of fish protection technologies. For some technologies (such as fine-mesh traveling screens) there is a very limited dataset of biological performance. There may be considerable differences in the design and operation of the existing fine-mesh facilities and what would be designed and operated at Canal. There could also be differences in local hydraulics, debris loading, proximity to spawning, nursery, or foraging habitats. Each such difference could also impact the potential for larval fish involvement and the sizes of those fish entrained.

For these reasons, additional evaluation of the biological performance of selected fish protection technologies is warranted at Canal.

7. Example of How a Cost-Effectiveness Analysis Could Be Done

One advantage of a study of intake technologies would be to allow Mirant Canal to perform, and Region 1 to review, an assessment of cost-effectiveness using updated costs. Veritas has provided an example, Exhibit 14, of the type of analysis that could be done. Exhibit 14 is meant only as an illustration and not as an opinion of actual costs for or benefits of alternative technologies for the Canal Station.

7.1 Integrating Benefit-Cost and Cost-Effectiveness Comparisons

While cost-effectiveness and wholly-disproportionate analysis provide a means of evaluating and comparing alternatives, they also lead to the identification of an individual option whose costs are not wholly disproportionate to the corresponding environmental effects. This does not mean that the corresponding economic benefits of this option exceed the costs. Benefit-cost analysis gives context to the results of a cost-effectiveness and wholly-disproportionate analysis.

Figures 1.3 and 1.4 of Exhibit 14 provide an illustrative example of estimating and comparing the benefits and costs associated with each of the options illustrated in Figure 1.2. In addition, to provide context for the results of the cost-effectiveness analysis presented in Figure 1.2, Figures 1.3 and 1.4 also present and compare the costs of each option to its corresponding environmental effect. The vertical axis on the left side of Figure 1.3 depicts the annual costs and benefits of each option, measured in dollars, and the vertical axis on the right side illustrates the corresponding environmental effect, measured in annual increase in the steady state population. The annual cost of the IM&E reduction option is represented by the red bars on the left of each option, the annual economic benefits are represented by the black bars in the middle of each option, and the increase in the steady state population is represented by the blue bars on the right of each option. Comparing the height of the red bars in Figure 1.3 to the height of the black bars reveals that costs exceed economic benefits many times over for every IM&E reduction option.

To compare the corresponding environmental effect for each option, Figure 1.3 displays the IM&E reduction options in order of increase in the steady state population. "Barrier Net" is on the left in Figure 1.3 because it provides the smallest increase in the steady state population for the IM&E reductions shown in this example. Wedgewire screens or cooling towers are on the right in Figure 1.3 because each has the highest increase in the steady state population, compared to the other options. Specifically, the IM&E reduction associated with 0.5-mm wedgewire screens and both types of cooling towers is estimated to yield more than 650,000 fish per year. The natural draft cooling tower is at the far right of these three because it is the most expensive.

Ordering the options in this manner illustrates the variation in both the costs and effectiveness across options. For example, the costs of installing an aquatic filter barrier are over $3 million per year, versus approximately $2 million per year for 2-mm wedgewire screens. However, the 2-mm wedgewire screens option results in nearly 525,000 fish per year, while the aquatic filter barrier option results in approximately 440,000 fish per year.

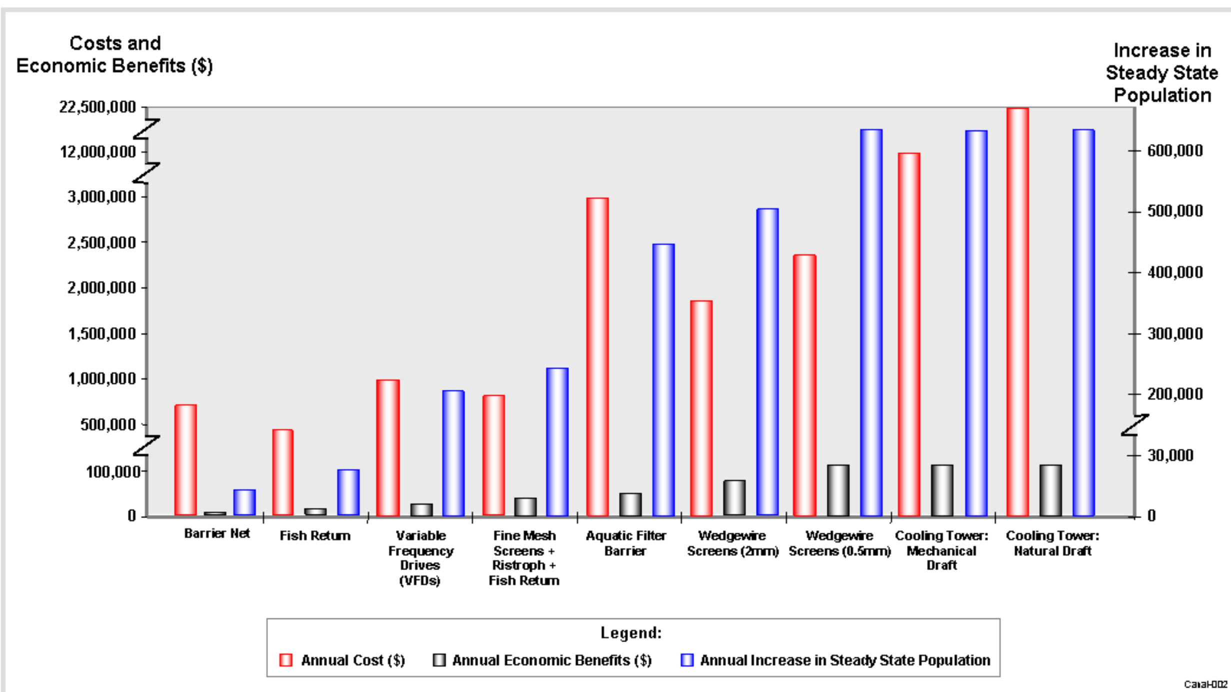

Figure 1.3 Costs, Benefits, and Increase in Steady State Population

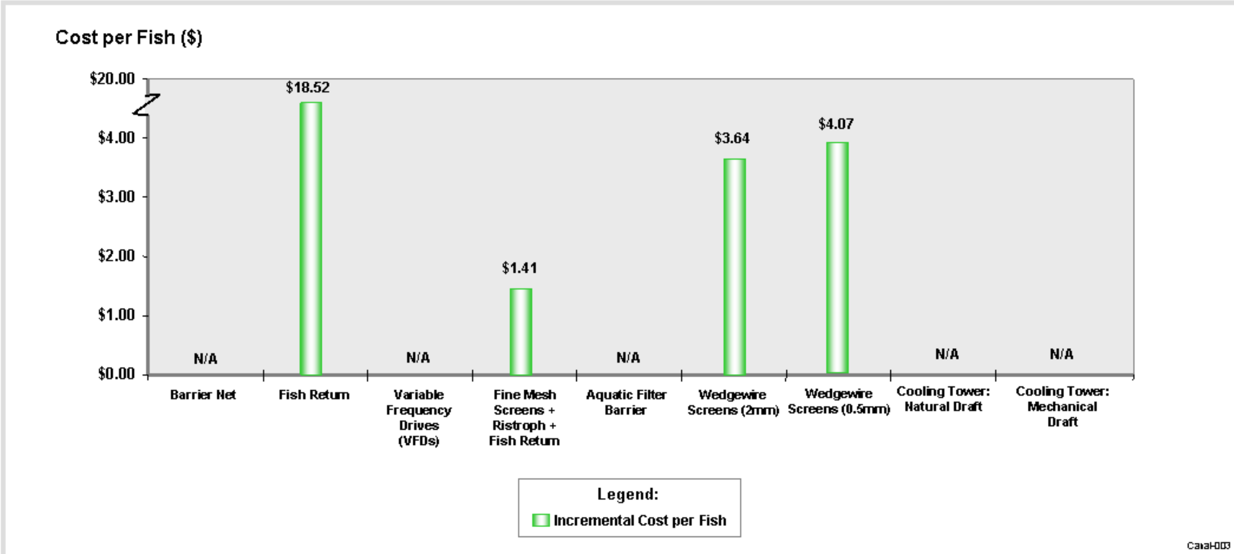

Figure 1.4 Incremental Cost per Fish

Ordering the options in this manner also illustrates the relationship between the incremental costs of the various IM&E reduction options and the corresponding incremental environmental effect of each option. For example, comparing the 0.5-mm wedgewire screens to the next option in Figure 1.3, a mechanical draft cooling tower, shows that while the cooling tower has an incremental cost of nearly $10 million over the wedgewire screens, it does not produce more fish than the wedgewire screens. Both produce approximately 660,000 fish. This incremental comparison of costs and corresponding increase in the steady state population illustrates the relative effect of each option.

For the example in Exhibit 14, as Figure 1.4 shows, the fine mesh traveling screens with Ristroph and a fish return have the lowest incremental cost per fish at $1.41. In addition, the figure also shows that the results have the same pattern as the incremental cost-effectiveness and wholly disproportionate analyses illustrated in Figure 1.2. The incremental cost per fish decreases as we move from the fish return option to the fine mesh traveling screen with Ristroph and fish return option. From that point the incremental cost per fish increases for the 2-mm and 0.5-mm wedgewire screen options.

8. Limits on Cooling Tower Blowdown (Part I.A.2.f)

The Final Permit contains a new Part I.A.2.f that was not in the draft permit. It requires that cooling tower blowdown (if cooling towers are installed) be limited and monitored for flow rate, free available chlorine, the 126 priority pollutants, total recoverable chromium, and total recoverable zinc.

Mirant Canal did not comment on this requirement earlier because it was not proposed in the 2005 Draft Permit. Instead, it grows out of the new, now renoticed requirement that Mirant Canal install closed-cycle cooling or a comparable technology, which was also not proposed in the Draft Permit. EPA's explanation is as follows:

In addition to the effluent monitoring requirements for the open discharge flume (outfall 001) and consistent with the use of closed-cycle cooling (as discussed in response to comment IX.A), the Final Permit includes limits on cooling tower blowdown, only if the Permittee chooses to comply with Part I.A.13.g of the Final Permit by using closed-cycle cooling to reduce the impacts of impingement and entrainment. See Part I.A.2.f of the Final Permit. The description of outfall serial number: 001 has been changed to reflect that cooling tower blowdown may also discharge at this location by removing the term "once-through" from: "once-through non-contact condenser cooling water" in Part I.A.2 of the Final Permit. Furthermore, the TRO limit of 0.2 mg/L is required for once-through cooling water pursuant to 40 C.F.R. 423.13(b)(1) at outfall 001 while cooling tower blowdown is not subject to this limit. Therefore, footnote 1 of Part I.A.2 of the Final Permit has been supplemented with the following: "This limit only applies to the extent that the Permittee utilizes once-through cooling water." If, for instance, the Permittee decides to convert the entire Station to closed-cycle cooling (i.e., cooling towers) to meet the BTA requirements of Part I.A.13.g of the Final Permit, the 0.2 mg/L TRO limit does not apply to the cooling tower blowdown. The limit does apply, however, to the outfall 001 discharge to the extent that the Permittee employs an alternative method of complying with Part I.A.13.g of the Final Permit (e.g., partial conversion to closed-cycle cooling, flow reduction, etc.) that continues to generate once-through cooling water.

Response to Comments III-25.

Mirant Canal asks the Region to delete Part I.A.2.f because it is arbitrary, capricious, and without adequate basis in the record. The following specific permit requirements on cooling tower blowdown should be deleted from the permit:

1. Continuous monitoring of flow rate

2. Limit on free available chlorine of 0.2mg/l (monthly average) and 0.5 mg/l (daily maximum)

3. Daily measurement of free available chlorine

4. No detectable concentrations of 126 priority pollutants

5. Yearly measurement of composite sample for priority pollutants

6. Limit on total recoverable chromium of 0.2 mg/l (monthly average) and 0.2 mg/l (daily maximum)

7. Total recoverable chromium measured two times a month using a composite sample

8. Limit on total recoverable zinc of 1.0 mg/l (monthly average) and 1.0 mg/l (daily maximum)

9. Total recoverable zinc measured two times a month using a composite sample

Limits on cooling tower blowdown are unnecessary if there are no cooling towers. If the Region decides, as we urge in these comments, that a study of alternative technologies, rather than cooling towers, is required, then the limits on blowdown would be at best premature. Even if the final permit retains the requirement of closed-cycle cooling or a "comparable" technology, there is the theoretical possibility that something other than cooling towers would comply. Either way, the limits on cooling tower blowdown are premature, and out of place in this permit.

Even if cooling tower blowdown limits were to be included in the final permit, no monitoring for priority pollutants should be required provided that Mirant Canal can show that the cooling tower maintenance chemicals it uses do not contain priority pollutants.

9. Metal Cleaning Wastes and Outfalls 011 and 012 (Permit I.A.5)

Internal Outfall 011 (metal cleaning waste systems) consists of air preheater wash, boiler fireside wash, precipitator wash, boiler chemical cleaning, stack and breach wash, equipment cleaning and feed water heater chemical cleaning, and metal cleaning sludge dewatering filtrate.

9.1 Report on Flow at Outfall 011 (Permit I.A.5)

The Draft Permit proposed average monthly and maximum daily limits on flow rate. The August 2008 Final Permit changed this to a report on the average monthly and maximum daily flow rate (Part I.A.5) plus limits on the combined flow from outfalls 011 and 012 (Parts I.A.5.d, I.A.6.b).

Mirant Canal accepts the limits on combined flow but objects to the requirement to report average monthly and maximum daily flow for 011. Since the combined flow from Outfalls 011 and 012 is subject to permit limits, there is no purpose to reporting the separate flow of Outfall 011 alone. This requirement is arbitrary and capricious, lacks basis in the record, and has no apparent purpose. Mirant Canal had inadequate opportunity to comment on it.

In truth, it would be better to leave the current limits on Outfalls 011 and 012 separate and monitor them separately. But if the Region insists on having a combined limit, monitoring separately makes no sense.

9.2 Segregating Metal Cleaning Wastes and Reclassifying Low Volume Wastes (Permit I.A.5.b)

Both the Draft and the Final Permits have identical limits on total copper and total iron at Outfall 011. These are taken from the "best available technology" requirements for "chemical metal cleaning wastes" in EPA's effluent limitations guidelines.

Outfall 011 discharges a combination of ash sluice, low volume waste (known as "equipment washes"), and chemical cleaning waste. These waste streams are co-mingled and treated in Waste Ponds A, B, C, or D before being discharged.

The Draft and Final Permits imposed a new requirement Part I.A.5.b that "[l]ow volume or fly ash wastewater shall not be combined with metal cleaning wastewater prior to discharge to the final effluent flume." Hence Mirant Canal must now redesign its wastewater system to segregate the ash sluice water from (1) the chemical metal cleaning waste and (2) those parts of the "equipment washes" that the Region classifies as (non-chemical) "metal cleaning waste." The iron and copper limits would be applied separately to the chemical and non-chemical metal cleaning wastes instead of to the combined stream, and daily composite sampling would be required for the metal cleaning streams instead of the weekly grab sampling now required.

The Region's decision depends on an interpretation of the effluent limitations guidelines. The BAT iron and copper limits are for "chemical" metal cleaning wastes. 40 C.F.R. § 423.13(e). In the guidelines, BAT guidelines for "non-chemical" metal cleaning wastes are expressly "reserved" (presumably for future rulemaking). As Region 1 explains (Response to Comments VI-6), EPA's reason for reserving non-chemical requirements was uncertainty over the differences between oil-burning and coal-burning plants and "the cost and economic impact that would result from requiring that nonchemical metal cleaning wastes satisfy the same limits that had been set for chemical metal cleaning wastes." 47 Fed. Reg. 52,297 (Nov. 19, 1982).

At Mirant Canal the "cost and economic impact" of the Region's changes would approach half a million dollars, and more if an additional clarifier is needed (Response to Comments VI-3). Nevertheless, Region 1 resolved the issue EPA Headquarters "reserved"; the Region concludes that the BAT standard for chemical metal cleaning wastes applies to non-chemical metal cleaning wastes as well. Response to Comments VI-6.

The Region also rejected the guidance of the "Jordan Memorandum." The Jordan Memorandum explained the best practicable control technology ("BPT") limits on metal cleaning wastes for iron and copper, which were adopted in the 1970s. Mr. Jordan explained that "metal cleaning wastes" means *chemical* cleaning wastes. When EPA updated the effluent limitations guidelines in 1982, it adopted a new definition "clarifying" that metal cleaning wastes means *all* metal cleaning wastes, except for facilities that had permits based on the Jordan Memorandum. EPA said "the previous guidance policy may continue to be applied in those cases in which it was applied in the past." 47 Fed. Reg. 52,297 col. 3 (Nov. 19, 1982).

One reason Region 1 gives for rejecting the Jordan Memorandum is that the author of the guidance is an engineer, not a lawyer. Response to Comments VI-8. However, the policy in the Jordan Memorandum was adopted *by EPA itself* -- "EPA adopted the policy," 45 Fed. Reg. 68,328, 68,333 (Oct. 14, 1980).

Another reason was that, in the Region's view, EPA rejected the Jordan Memorandum for BAT purposes in the 1980 proposed amendments. Response to Comments VI-9, *citing* 45 Fed. Reg. 68,328, 68,333 (Oct. 14, 1980). But EPA did so only for those facilities that had not relied on it.

Although Region 1 says it is not clear the Jordan Memorandum was applied to Mirant Canal in the past, the fact is that past permit conditions were consistent with it, until now. The Region has not explained why, assuming EPA meant what it said in the 1982 preamble about applying the Jordan Memorandum to non-chemical metal cleaning wastes where it had been applied in the past, the definitions applied to the permit for the Canal Station should not be interpreted consistent with that instruction.

Region 1 acknowledges that, even after determining the Jordan Memorandum was incorrect, it still allowed it to be used where it had been followed before due to equitable considerations. These same equitable considerations apply to the Canal Station, where the copper and iron limits have been applied to the combined wastestream at Outfall 011 since the 1989 permit was issued and where segregating ash sluice water from chemical and non-chemical cleaning wastes would be burdensome and expensive.

The new interpretation will require a redesign and reconstruction of a waste treatment system at a cost of more than a half million dollars, even though the copper and iron limits already apply to the combined waste stream of which the metal cleaning wastes (both chemical and non-chemical) are a part.

Moreover, the Region's conclusion that the iron and copper limits should apply to non-chemical metal cleaning wastes heretofore classified as "equipment washes" is based on an elaborate "best professional judgment" analysis purporting to apply the statutory factors for BAT requirements. *See* Response to Comments VI-12 to -16. This analysis goes through the factors of age of equipment, process employed, engineering aspects, process changes, cost, and environmental impacts. But Mirant Canal had no opportunity to comment on this analysis, since it appeared for the first time in the Response to Comments. For the reasons given above, Mirant Canal submits that the Region's abandonment of the Jordan Memorandum for this particular facility, without regard to the equities and the Canal Station's longstanding reliance on the Memorandum, was an error.

Accordingly, Mirant Canal objects to the ban on combining metal cleaning wastewater with the other waste streams discharged through Outfall 001.

9.3 Monitoring and Reporting Total Average Monthly Combined Flow From Outfalls 011 and 012 Separately (Permit I.A.5, I.A.5.d & I.A.6.b)

The Draft Permit would have required limits on flow rate at Outfall 011 and continuous monitoring using the pump capacity curve and operational hours. The August 2008 Final Permit retains the monitoring requirement and requires reporting of, but no limits on, Outfall 011 flow.

For Outfall 012 the Draft Permit would have required the same monitoring (using pump capacity curve and operational hours) and flow limits. The Final Permit requires the same monitoring and a report instead of flow limits on Outfall 012 alone.

After comments on the draft permit were filed, Region 1 added limits on the *combined flow* from Outfalls 011 and 012:

> I.A.5.d. The total average monthly combined flow from outfall locations 011 and 012 shall not exceed 0.32 MGD and total maximum daily combined flow from outfall locations 011 and 012 shall not exceed 0.52 MGD.

Final Permit p. 7 of 21.

In short, after the comments were filed the Region replaced separate flow limits on Outfalls 011 and 012 with flow limits on their total combined flow. But the Region retained the requirement that flows for the two outfalls be monitored separately.

There appears to be no rational basis for measuring flow on the two components of the combined flow. Since the limits apply to the combined streams, it should be enough for Mirant Canal to monitor and report the combined flow. On this ground, Mirant Canal objects to the requirement that it monitor and report the flow rate at Outfalls 011 and 012 separately.

10. Annual Heat Load Reports Unless Closed-Cycle Cooling Is Operating (Permit I.A.7)

Both the Draft and the August 2008 Final Permits require annual Heat Load Reports for three years (Part I.A.7). Mirant Canal did not object to the gist of this proposal (Mirant Canal Comments at 19). However, Mirant Canal does object to this requirement on the ground that the permit does not allow enough time for compliance. It will take time to install equipment necessary to report annual heat load. Region 1 should allow six months before the requirement takes effect.

11. Source Water Physical Data and Cooling Water Intake Structure Data (Permit I.A.8)

Part I.A.8 of the Draft Permit required, first, that Mirant Canal submit the Proposal for Information Collection ("PIC") and Comprehensive Demonstration Study

("CDS") that were required by EPA's intake structures rule for existing facilities, 40 C.F.R. § 125.95. That regulation is now suspended while the U.S. Supreme Court reviews EPA's Phase II rule for cooling water intake structures. Second, the draft required Mirant Canal to submit source water physical data, cooling water intake structure data, and cooling water system data required by 40 C.F.R. §§ 122.21(r)(2), (3), and (5). The August 2008 Final Permit keeps the second requirement but eliminates the (r)(5) requirement for cooling water system data.

Section 122.21(r)(5) is suspended. 72 Fed. Reg. 37,109 col. 2 (July 9, 2007). So is § 122.21(r)(1)(ii), which required Phase II facilities to submit the information required by (r)(2), (3), and (5). *Id.* Hence the regulatory basis for the permit requirement is no longer in effect.

These requirements would be appropriate if Mirant Canal were to perform a CDS as proposed in the Draft Permit. They are unnecessary, however, if the facility must install closed-cycle cooling (or comparable technology), as the Renoticed Permit would require.

Therefore these requirements are arbitrary and unnecessary *if* the closed-cycle cooling requirement remains in the permit. Moreover, Region 1 has not explained why these requirements are in the permit.

12. Region 1's Evaluation of Best Technology Available for Impingement

Several portions of the Renoticed Permit collectively address Canal Station's CWISs and the associated Outfall 002. Canal Station's existing CWISs consists of several components, chiefly:

- two intake flumes from the Cape Cod Canal, one each for Units 1 and 2 at the Station;
- chlorination equipment, which chlorinates the intake water for up to two hours/day/unit in order to protect the condenser piping from biofouling; and
- two screen houses, one for each Unit, containing intake screens, associated pumps and spray wash equipment, and debris removal and fish return troughs.

Outfall 002 is an open air flume connected to the Cape Cod Canal and placed between the two intake flumes. Discharges at Outfall 002 chiefly consist of:

- fish returning from the intake screens;
- debris washed off the intake screens and associated spray wash water; and

- a portion of the condenser cooling water discharge, some of which is diverted from the channel to Outfall 001 in order to provide adequate flow within Outfall 002 to return fish and debris to the Cape Cod Canal.

The Renoticed Permit imposes numerous new requirements for the CWISs and Outfall 002, falling into several categories:

- physical modifications to the CWISs, intended to reduce the effects of impingement;

- modifications to the Station's operating practices at the CWISs, also intended to reduce the effects of impingement; and

- new limitations and monitoring requirements on the discharge from Outfall 002.

Importantly, the Renoticed Permit imposes all of the requirements addressed in this section of comments irrespective of its separate, entrainment-related requirements for the CWISs. As discussed below, those separate, entrainment-related requirements, however, require cooling towers (or their equivalent) that would drastically alter Canal Station's current operating practices upon which the Agencies justify the impingement-related provisions.

12.1 Relation to Entrainment-Reduction Provisions

In the Draft Permit, the Agencies proposed many of the same non-entrainment related requirements for the CWISs and Outfall 002 that they have now included in the Renoticed Permit in somewhat modified form. The Draft Permit also proposed to require Mirant Canal to conduct the extensive studies then required under the § 316(b) Phase II rule. Those studies would have involved an evaluation of both the entrainment-related and the impingement-related effects of the existing CWISs at Canal Station. Mirant Canal commented on the Draft Permit, and is now renewing those comments here, that the Agencies should not require any modification to the CWISs until Mirant Canal could complete those studies and propose modifications sufficient to constitute BTA for minimizing any adverse environmental impacts.

In the Renoticed Permit, the Agencies nevertheless imposed major modifications to the CWISs and related operations designed to reduce impingement impacts, even though the Renoticed Permit still did not fully or adequately resolve what modifications to Canal Station's operations and/or its CWISs are required to address potential entrainment issues. What is abundantly clear, however, is that any future modifications to Canal Station's operations and/or its CWISs intended to address entrainment impacts certainly would affect whatever modifications, if any, are then needed in order to reduce any remaining impingement impacts, particularly where the most likely modifications to reduce entrainment impacts would largely obviate and could actually conflict with the impingement-reductions provisions proposed in the Renoticed Permit. In other words, a strong possibility exists that whatever technology is ultimately selected as BTA for reducing entrainment impacts, will also be sufficient to address any impingement impacts as well.

The Renoticed Permit even recognizes how its impingement-reduction provisions are likely inextricably intertwined with the entrainment-reduction provisions and that whatever changes are implemented to address entrainment may obviate the need for the Renoticed Permit's current provisions addressing impacts from impingement. See Part I.A.13.g(iii). But despite this recognition, the Renoticed Permit would only allow for Mirant Canal to seek a permit modification to "remove any unnecessary requirements" that are no longer needed to address impingement impacts. But the Agencies should not require major modifications to the CWISs that they acknowledge may not be needed depending on the later resolution of other required modifications, and offer to resolve that tension only through the vagaries of a permit amendment process. Rather, all modifications to the CWISs should be addressed concurrently.

12.2 Impact of Entrainment-Reduction Provisions in the Renoticed Permit

As stated above, the Renoticed Permit contains several provisions to reduce impingement mortality. But the Renoticed Permit's provisions relating to entrainment reduction would require Canal Station to install closed-cycle cooling, which the Agencies recognized could reduce overall intake flows between 70-98%. Response to Comments IX-28. This reduction in intake flows associated with installing closed-cycle cooling would be sufficient to reduce any adverse impacts from impingement. As EPA noted in the Phase II rulemaking, a facility reducing intake flow commensurate with a closed-cycle recirculating cooling system was deemed to meet the performance standards for both impingement mortality and entrainment. 40 C.F.R. § 125.94(a)(1)(i) (suspended).

Such a reduction in intake flows of 70-98% would be expected to reduce impingement of fish by at least 70-98% as well. Response to Comments IX-28-29. In fact, reductions in impingement would likely approach 100% because any remaining flows will result in approach velocities to Canal Station's CWISs that have been found by EPA to be protective of most species of fish.

If closed-cycle cooling is required at Canal Station and the existing intakes remain in operation, then the flow and velocity through the traveling water screens would be reduced proportionally to the flow. Using the low end of achievable flow reductions with closed-cycle cooling (70% reduction), Alden estimates that the velocity at the face of the intake flumes will be 0.4 ft/sec for Unit 1 and 0.3 ft/sec for Unit 2. The maximum velocity within the intake flumes would be 0.6 ft/sec for both Units 1 and 2. The velocity approaching the traveling water screens would be 0.2 ft/sec for both units. At these velocities most motile organisms entering the intake flumes should be able to escape. In addition, using a conservative estimate of the open area of the existing screens (50%), the through mesh velocity of the screens would be under 0.5 ft/sec.

In its Phase II rulemaking, EPA found that fish swim speed data:

> showed that the species and life stages evaluated could endure a velocity of 1.0 ft/s. To develop a threshold that could be applied nationally and is effective at preventing impingement of most species of fish at their different life stages, EPA applied a safety factor of two to the 1.0 ft/s threshold to derive a threshold of 0.5 ft/s. This safety factor, in part, is meant to ensure protection when screens become partly occluded by debris during operation and velocity increases through portions of the screen that remain open.

66 Fed. Reg. at 65,274; *see also* 65 Fed. Reg. at 49,088. There are several reasons why this finding is significant and applicable to the Renoticed Permit. First, it demonstrates that even the maximum velocity within the intake flume (0.6 ft/sec) falls below the 1.0 fps that EPA found most of the studied species could resist. Second, velocity approaching the traveling water screens (0.2 ft/sec) is well below the velocity that EPA established even after applying a safety factor of two. Canal Station's intake velocities resulting from the Renoticed Permit's entrainment-reduction provisions, therefore, are well within the range of velocities that EPA determined fish could endure with respect to impingement. Third and finally, EPA's articulated reason for requiring a safety factor of two (*i.e.*, provision for possible debris loading on the screen) are not applicable to Canal Station's traveling screens that are already rotated and washed in a frequent manner in order to prevent any significant debris loading.

Finally, the Response to Comments states more than once that closed-cycle cooling – by itself – represents BTA for minimizing adverse environmental impacts at Canal Station. Response to Comments IX-7, IX-19. This determination that closed-cycle cooling – by itself – would be sufficient to minimize all adverse environmental impacts is inconsistent with the Renoticed Permit's provisions that would require additional and costly modifications to address impacts from impingement. In other words, the Renoticed Permit's impingement-reduction provisions are not consistent with the Agencies' findings in the Response to Comments that closed-cycle cooling (and nothing else) is sufficient to minimize any adverse environmental impacts from Canal Station's intake. Once the Agencies determine a technology is BTA and require installation of that technology in a NPDES permit, no further permit provisions can be justified on the basis of § 316(b).

12.3 Adverse Environmental Impacts Analysis

In the Fact Sheet accompanying the Draft Permit, as well as in the Response to Comments, the Agencies determined that the existing CWISs are having unacceptable adverse impacts as a result of impingement, chiefly by citing Mirant Canal's reported impingement numbers.

Mirant Canal commented on the Draft Permit that the Agencies' determination that impingement was of concern was not based on any meaningful substantive analysis. Nevertheless, in the Response to Comments the Agencies continued to avoid any serious analysis under § 316(b) of whether the numbers of impinged fish, the seasonal pattern of impingement, or the value of the impacted species warrant the finding of unacceptable impact, and ignored evidence in the record that those impacts are *de minimis* and certainly do not warrant the costly and difficult modifications proposed in the Draft Permit and now in the Renoticed Permit. Nor did the Agencies consider whether less drastic modifications also would be sufficient. And they did not consider whether the entrainment-related requirements would obviate most of those small impingement effects, thus obviating the need for the impingement-related improvements.

12.3.1 Applicable Standard

Section 316(b) requires that CWISs reflect BTA for "minimizing adverse environmental impacts." As discussed in more detail in Section 2 above, it is significant to note that the statute does not require the minimization or elimination of *all* impacts, nor does it even mandate the elimination of *all* adverse impacts. Rather, it only requires the minimization of adverse impacts. A proper BTA analysis under § 316(b), therefore, should begin with a complete, well-reasoned finding that adverse environmental impacts exist by doing something more than noting the mere existence of impingement.

In order to reach the conclusion that the level and magnitude of impingement mortality at Canal Station constitutes such an adverse impact, it is necessary to quantify the actual significance of impingement mortality at Canal Station to the affected populations and their overall ecosystem in the specific setting of Canal Station, as Normandeau Associates has done, as discussed above in Section 3.

But the Agencies did not perform such an analysis that would, for instance, examine the impingement mortality estimates in connection with the overall population of the relevant species, or the estimated number of such organisms that reside in or pass by the vicinity of the Station. This is despite the fact that such analyses are specifically identified in EPA's guidance for issuing BPJ determinations under § 316(b). [Draft] Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b) P.L. 92-500 at 3 (May 1, 1977), available at http://www.epa.gov/waterscience/316b/files/1977AEIguid.pdf.

12.3.2 Raw Impingement Numbers

All the Agencies rely upon in reaching their conclusion that impingement at Canal Station is causing adverse environmental impacts are the raw estimates of impingement mortality. After citing to these numbers, the Agencies do nothing more than determine that the current CWISs "caused substantial adverse environmental impact from entrainment and impingement." Response to Comments IX-10. But simple reliance on these raw estimates, without anything more, constitutes an incomplete adverse impacts analysis under § 316(b) and renders the result arbitrary and capricious.

If the Agencies had conducted a proper and thorough adverse impacts analysis with respect to impingement at Canal Station, they would have reached the same conclusions as Normandeau, discussed in detail above in Section 3, after its analysis of impingement data, which is that the circulating water system at Mirant Canal has not resulted in an "adverse environmental impact" to the population of 17 taxa of fish and one important macroinvertebrate, the American lobster, which together, represent 95.5% of the fish impinged during field studies conducted at the facility.

Mirant Canal hereby incorporates into these comments the Normandeau Adverse Environmental Impact Assessment for Mirant Canal Station (Exhibit 10), and expects the Agencies to respond to each portion of the Normandeau analysis that analyzes the impact of impingement at Canal Station.

Even if the Agencies had properly concluded that impingement mortality constitutes an adverse environmental impact at the Canal Station, they would have also had to evaluate whether those adverse impacts were greater than the *de minimis* levels that the Agencies recognize need not be addressed or minimized. As set out in Section 3, the impacts of impingement mortality and entrainment together are *de minimis*, making the impacts of impingement mortality alone clearly *de minimis*.

12.3.3 Estimates of Impingement Mortality

In the Fact Sheet, the Agencies specifically noted that the *estimate* of 71,623 organisms lost to impingement was based on the *assumption* of "complete mortality for all impinged organisms." (Fact Sheet, 39). Despite this recognition that impingement mortality is likely less than this number, the Agencies nevertheless base their entire "adverse impact" analysis on nothing more than bald references to this 71,000 number (most of which were juveniles with relatively high natural mortality rates) that they know does not accurately calculate actual impingement mortality.

12.4 Impingement Mortality Reduction Analysis

Even had the Agencies correctly determined that impingement mortality at Canal Station was causing more than *de minimis* adverse environmental impacts, it failed to take the next logical step in the § 316(b) analysis by determining what amount of impingement reductions would be required. As the Agencies recognized, *de minimis* adverse impacts do not need to be reduced. The Agencies, therefore, should have, but did not, analyze how much reduction in impingement mortality would be necessary to bring such mortality down to the *de minimis* level.

12.5 Scope and Extent of Engineering Changes

Both the Fact Sheet and the Response to Comments contain an incomplete BTA analysis with respect to the Renoticed Permit's impingement-related provisions.

The changes required by the Renoticed Permit present significantly greater engineering and structural additions than what the Agencies seemed to assume, and these changes would cost more than the Agencies seemed to assume. For example, the NPDES permit would require, at a minimum, the following engineering and structural changes to the existing structures:

- Installation of new pumps and piping to provide Outfall 002 with sufficient flow;

- Installation of new traveling screens with both a low- and high-pressure spray system;

- New pumps and piping to provide the new spray system with a source of water;

- Enlargement and modification to the existing intake bays to accommodate new screens; and

- Construction of an entirely new fish-return system consisting of two different outfalls.

The Agencies never fully considered the scope of engineering changes and challenges, and the accompanying costs, required to comply with the Renoticed Permit's provisions, despite recognizing that these two factors – by virtue of the fact that they are considered as part of the BAT analysis – are relevant to its BTA analysis.

12.6 Proposed Prohibitions of Discharge at Outfall 002

The Renoticed Permit contains several requirements imposing operational changes to the current practice of discharging some amounts of condenser water through Outfall 002. The purpose of these provisions is to reduce impingement-related impacts. The following comments address these provisions.

12.6.1 Discharge of Condenser Water at Outfall 002 During Screen Wash

Part I.A.3.b prohibits discharge of condenser water at Outfall 002 during times that the screen wash is in operation within a screen house, at least until the required upgrades to the fish return system are made pursuant to Part I.A.13.e.

The stated purpose of this provision is to prevent impinged fish that are being returned to the Cape Cod Canal through Outfall 002 from being exposed to elevated water temperatures as they are washed out of the screens into the Cape Cod Canal. There is no rational basis in the record for that requirement, however, for the following reasons.

The Agencies did not analyze whether the amount of temperature elevation, and the duration of exposure to those elevated temperatures, would have any impact on returning fish. Pursuant to the existing permit, as well as the Renoticed Permit, the discharge temperature within Outfall 002 is limited to 90° F as well as to a Δ T of 33° F. The Agencies supplied no explanation of why the brief exposure of the returning fish to temperatures so limited would have any adverse impact, especially where the Agencies have already concluded that 107° F is an acceptable limit for discharge to the Canal through Outfall 001, Part I.A.2, and where the Agencies' only specific analysis on possible adverse impacts on fish from temperature identifies 95° F as only being *potentially* problematic. Response to Comments III-19.

Furthermore, this requirement is in conflict with the separate requirement at Part I.A.3.d for the Outfall 002 discharge flow to provide sufficient water depth to return impinged organisms to the Cape Cod Canal. The Agencies do not assess whether or to what extent it is feasible to obtain such flow without using a portion of the condenser cooling water discharge as is done now.

Finally, given the fact that Alden estimates that the upgrades to the fish return system contemplated by the Renoticed Permit would take only approximately three months to construct, it is not reasonable to require any costly or extensive interim changes that may very well take almost as long to install as the improvements to the fish return system, and that would only provide for a very brief and very limited – if any – benefit.

12.6.2 Discharge of Condenser Water at Outfall 002 During Chlorination

Part I.A.3.c of the Renoticed Permit prohibits the discharge of condenser water at Outfall 002 during the chlorination of any Unit condensers. The Agencies included this provision in the Draft Permit with the explanation that it would "obviat[e] the need for TRC monitoring." Fact Sheet, p. 13. The Agencies provided a different rationale in the Response to Comments, stating that the purpose of this provision is to protect fish from harmful exposure to chlorine. Response to Comments IV-5. But neither rationale provides sufficient support for the provision.

With respect to the current permit, Canal Station samples for compliance with the chlorine limit only about 300 feet from the point of application, so there is virtually no chance that the concentration of chlorine in Outfall 002 would differ from the levels in Outfall 001. In other words, there is no reason to monitor for chlorine at Outfall 002, regardless of whether there is a prohibition on the discharge of chlorinated waters there.

The newer rationale contained within the Response to Comments is likewise inadequate. The Agencies' conclusion that exposure to the chlorine levels present in the condenser discharge during chlorination is harmful to fish is not based on any data or information suggesting that an exposure of impinged fish for brief times to the low levels of residual chlorine still present in the condenser cooling water as discharged through Outfall 002 is likely to have any impacts whatsoever, harmful or otherwise. In fact, any organisms in Outfall 002 would not be subject to any chlorine levels beyond the limits that the Agencies previously believed were acceptable for discharge back into the Cape Cod Canal because, as discussed above, Canal Station monitors for chlorine compliance within 300 feet of injection, which is prior to discharge into Outfall 002.

Prohibiting the discharge of condenser cooling water through Outfall 002 during chlorination would prevent the facility from providing the necessary flow to return impinged organisms to the Cape Cod Canal during low tide. The Agencies do not assess whether or to what extent it is feasible to obtain such flow without using a portion of the condenser cooling water discharge as is done now.

Moreover, prohibitions on discharge in order to protect the fish returning through Outfall 002 to the Cape Cod Canal are not necessary once the Renoticed Permit's requirements to upgrade the fish return system are implemented. Given the fact that Alden estimates that the upgrades to the fish return system contemplated by the Renoticed Permit would take only approximately three months to construct, it is not reasonable to require any costly or extensive interim changes that may very well take almost as long to install as the improvements to the fish return system, and that would only provide for a very brief and very limited – if any – benefit.

12.7 Flume Water Depth

Part I.A.3.d requires that the Outfall 002 discharge flume have sufficient water depth to return impinged organisms to the Cape Cod Canal with "minimal stress." Part I.A.13.e requires the water level in the newly constructed fish return system to also be sufficient to cause "minimal stress."

12.7.1 "Minimal Stress"

The primary problem with this proposed requirement is that "minimal stress" is vague and undefined and gives no notice of what is required for compliance, nor is there an adequate record on how much depth is needed for minimal stress. Furthermore, nothing in the record suggests or indicates that the current flows in Outfall 002 are insufficient to be protective of fish returning to the Cape Cod Canal.

Also, as noted above, there is tension between this requirement and the prohibitions on discharge of condenser water at Outfall 002 under certain conditions. The Agencies have not considered how flows in the discharge flume are to be maintained without the ability to discharge condenser waters during screen-washing and chlorination.

Finally, Part I.A.13.d proposes construction of two new fish return troughs above and below the CWISs to deliver fish in line with the tidal flow. If those return troughs are installed, then Part I.A.3.d is not even necessary because there will not be any fish in Outfall 002 to transport back to the Cape Cod Canal. To the extent that the Renoticed Permit would only require sufficient water depth in Outfall 002 until a new fish return system is constructed, such a requirement is still not justified given the fact that Alden estimates that the upgrades to the fish return system contemplated by the Renoticed Permit would take only approximately three months to construct. It is not reasonable to require any costly or extensive interim changes that may very well take almost as long to install as the improvements to the fish return system, and that would only provide for a very brief and very limited – if any – benefit.

12.7.2 Maintenance of Minimum Depth and Proposed Flow Limits

Part I.A.3 of the Renoticed Permit contains a limit on the amount of water that can be discharged through Outfall 002. But the Agencies have failed to analyze whether this new proposed flow limitation is consistent with the proposed requirement that Canal Station maintain a minimum depth in Outfall 002. In other words, it is possible that in order to maintain a sufficient depth in Outfall 002 to comply with Part I.A.3, Canal

Station will be in violation of Part I.A.3.d, which limits the total amount of flow from Outfall 002. The Agencies must ensure that these two permit provisions are not in conflict, and the current record contains no basis for such a determination.

12.8 Proposed Fish Return System.

Part I.A.13.e of the Renoticed Permit proposes the construction of a new fish return system. But nothing in the record supports a conclusion that the current fish return system is causing any adverse impacts or mortality to fish, let alone any unacceptable impacts or mortality. The proposed fish return does nothing but address theoretical or speculative harms to fish that do not have any support in the record.

12.8.1 Two Outfalls

The Renoticed Permit's provisions requiring construction of an entirely new fish return system cannot be justified on the current record, and is based on inapplicable analyses. The Response to Comments indicates that the new fish return system requires two different outfalls so that the previously impinged organisms are discharged down current from the intake structures. Response to Comments IX-32 to -33.

As a result, the Renoticed Permit requires fish to be "transported away from any intake structure based on the tidal flow in the Cape Cod Canal." (Part I.A.13.e). The Agencies recognize that Canal Station's current permit essentially contains an identical requirement by mandating that fish be returned at a sufficient distance from the intakes to avoid re-impingement. Response to Comments IX- 32. And the Agencies do not rely upon any analysis or anything else in the record indicating that this current provision has somehow proven inadequate at ensuring that any re-impingement occurs in *de minimis* numbers.

The Agencies, therefore, have not provided any rational basis for changing this permit requirement. In other words, absent any record support, the Agencies' concerns about re-impingement are speculative and cannot be the basis for this new provision, especially where a perfectly effective provision is presently in place for protecting against this speculative harm, and there has never been a finding or even a suggestion that Canal Station's past discharge somehow violates this existing provision.

12.8.2 No Vertical Drop

The new fish return system must also have a new discharge point to prevent any vertical drop of organisms back into the Cape Cod Canal. The Agencies' justification for such a requirement is not rational. The Agencies state that the vertical drop will subject returning fish to increased predation by gulls that will congregate at the outfall. Response to Comments IX-83. The sole basis for this conclusion is that certain unidentified biologists said that they have observed how gulls congregate around the fish-return at a completely different power plant (with a much higher rate of water withdrawal and discharge) and attempt to capture fish as they are returned to the water. Response to Comments IX-83 to -84.

First, evidence of these anecdotal observations at another power plant with a different intake and outfall are not part of the administrative record and appeared for the first time in the Response to Comments, long after the opportunity to address them in comments on the Canal Station permit. If the Agencies wish to rely upon such anecdotal observations, Mirant Canal should have been given the opportunity to address them with Canal-specific information. Second, anecdotal observations of predation during low tides at another facility with different withdrawal and discharge and very different outfall cannot serve as a rational basis for determining that such predation occurs at Canal Station in sufficiently high numbers so as to require construction of a completely new discharge location. If the Agencies have the resources to send unidentified biologists out to other power stations to observe impacts from predation at their outfall, they should do the same at Canal Station if they want to base permit provisions on such observations, rather than rely on inapplicable observations at other facilities.

12.9 Proposed Operation of Upgraded Intake Screens

The Renoticed Permit contains various provisions that would alter the current operation of Canal Station's intake screens. For the reasons discussed below, none of these provisions has sufficient support in the record.

12.9.1 "Minimal Stress"

Part I.A.13.c requires the installation of a low-pressure screen spray wash engineered to deliver aquatic organisms from the fish holding buckets to the return trough with "minimal stress." The problem with this proposed requirement is that "minimal stress" is vague and undefined and gives no notice of what is required for compliance.

12.9.2 Continuous Rotation of Screens

Part I.A.13.f requires continuous operation of the intake screens once the fish return system has been reconfigured in accordance with the foregoing requirements, whenever the corresponding intake pumps are operating. If by continuous operation the permit means to require continuous rotation of the screens, Mirant Canal objects because the record provides no adequate basis for any determination that continuous rather than periodic rotation will have material benefits.

12.9.3 Using Non-Chlorinated Water for Screen Washes

Part I.A.13.d requires continued rotation of the intake screens during chlorination, and also, with respect to screen wash water, requires use of non-chlorinated water sources or dechlorination of screen wash water prior to discharge. The asserted basis for these requirements is to reduce or eliminate exposure of impinged fish to chlorination in the screen wash water and the Outfall 002 discharge.

There is no adequate basis in the record, however, for these requirements because the Agencies have not analyzed whether the low levels of chlorine in the screen wash water and its discharge, given the brief duration of exposure to the impinged organisms, has had or is likely to have any adverse impact. The required changes would be extremely expensive and burdensome to implement, and should be required only upon an adequate record that they are necessary and would bring actual benefits.

12.10 Sorting Fish and Natural Debris from Other Debris

Part I.A.14.b of the Renoticed Permit requires that all live organisms and natural debris that are freed from the traveling screens be returned to the Cape Cod Canal, and that all unnatural debris be removed from the screens and disposed of in a manner so that it is not returned to the Canal. Specifically, the Renoticed Permit states:

> All live fish, shellfish, and other aquatic organisms collected or trapped on the intake screens shall be returned to their natural habitat with minimal stress. All other material, except natural debris (e.g., seaweed), shall be removed from the intake screens and disposed of….

(Part I.A.14.b). Neither Mirant Canal nor Alden is aware of any "available" technologies or manual methods capable of separating live fish and natural debris from dead fish and unnatural debris. Moreover, neither Mirant Canal nor Alden is aware of any other plant with this type of § 316(b) requirement. Because there is no available technology to satisfy this permit provision, it cannot be imposed under § 316(b).

In fact, the only way to even attempt to comply with this permit provision would be to require continuous manual sorting of fish and debris. Even then, manual sorting would not be able to definitively identify live organisms from dead organisms as the screens are continuously rotated, given that impinged organisms can often be extremely small and even microscopic, and that it is impossible to definitively determine if some forms of larvae are alive or dead. Moreover, the process of manually sorting would subject the live organisms to additional stress that would likely cause mortality, especially among the younger life stages. Furthermore, with respect to debris, a substantial majority of the debris currently collected on the intake screens is natural so there is no rational basis for proposing a costly and novel manual sorting method in order to remove the very minimal unnatural debris that is removed from Canal Station's intake screens.

Moreover, such a provision does not do anything to minimize any adverse environmental impacts from Canal Station's intake because it cannot be reasonably concluded that releasing unnatural debris back into the Cape Cod Canal is an adverse impact caused by Canal Station's intake. In other words, whatever adverse impacts caused by unnatural debris already in the Cape Cod Canal cannot be addressed by § 316(b), which is focused on adverse impacts caused specifically by intake technologies.

Alden has estimated that even attempting to comply with this provision would require construction of a large and costly sorting facility with multiple sorting flumes. It is not even clear to Alden whether sufficient and adequate space exists at Canal Station for constructing such a facility and its accompanying piping and flumes. Finally, the *annual* costs of operating such a manual sorting facility would approach $6 million.

12.11 Compliance Schedule

The Renewal Permit's impingement-related provisions require substantial and costly changes to Canal Station, and yet do not provide any reasonable time schedule for Canal Station to accomplish these changes. The Agencies certainly have the ability to analyze and discern how long compliance with the Renewal Permit's various provisions would take, and also had the ability to reach out to Mirant Canal to open a dialogue on the issue prior to the issuance of the permit. But the Agencies did not do so here. Rather, they claimed that they can issue a permit with an indeterminate compliance timeline so long as they simultaneously issue an administrative order that contains that timeline.

But the Agencies cannot undermine the process for issuing permits by including critical aspects of the permit in a separate administrative order. While issuing an administrative order containing the compliance timeline would indisputably be more convenient for the Agencies, convenience is not a basis for avoiding its obligations to issue a permit that provides sufficient notice to the permittee and a reasonable time to comply with its requirements. The Agencies lack the authority to transfer substantive permit provisions that directly impact the permittee's ability to comply – such as those establishing a compliance deadline – out of the permitting process (and its attendant checks and balances including the public comment period) and into an administrative order. The Agencies cannot exempt certain permit requirements from the requisite public comment period by including those provisions in a separate administrative order. Such a practice exceeds the Agencies' permitting authority.

13. Biological Monitoring and Reporting Requirements

13.1 Proposed Requirements Are Inextricably Intertwined with the Withdrawn Provisions

The Agencies did not withdraw the Permit provisions covering biological monitoring and reporting requirements, but, as the Agencies recognized, some non-withdrawn provisions are inextricably intertwined with the withdrawn provisions and merit the Agencies' further consideration. The array of biological monitoring and reporting requirements proposed by the Agencies can only be justified to the extent that they are designed to evaluate Canal Station's compliance with the performance requirements in the Renoticed Permit. Until an available entrainment-reduction technology is chosen, if any, the Agencies cannot reasonably determine the proper scope of the biological monitoring and reporting requirements. Because the biological and reporting provisions in the Permit must be tailored to the withdrawn provisions, they are "inextricably intertwined" with them.

13.2 Proposed Requirements Exceed the Agencies' Authority

As Mirant Canal has acknowledged, the Agencies wield considerable discretion to impose monitoring requirements as part of their permitting process. But discretion is not synonymous with absolute authority, because monitoring and reporting requirements must be "based upon [Canal Station's] impact[.]" 40 C.F.R. § 122.48. That is true whether monitoring and reporting requirements are focused on adverse environmental impacts or state water quality standards.

Yet, as discussed below, the Agencies propose monitoring and reporting requirements more expansive and more expensive than are justified by Canal Station's historical or anticipated operations and impacts.

The Agencies have not explained this decision to arbitrarily impose an extensive set of monitoring obligations without regard to Canal Station's impacts, nor even explained why such monitoring is needed. The Agencies' failure to explain their approach to biological monitoring stands in stark contrast to the approach prescribed by the Phase II rule. While Mirant Canal acknowledges that the rule has been suspended and, therefore, the Agencies are not bound by it, Mirant Canal submits that the Phase II rule reflected EPA's reasoned judgment as informed by the public comment and shaped by the rulemaking process, and Mirant Canal notes that neither the industry or the environmental groups challenged those aspects of the Phase II rule. The Phase II rule contemplated that monitoring requirements would begin *following* the design and installation of the entrainment-reduction technology. And then, the scope of any monitoring would be limited to that required to verify performance of the selected technology. 69 Fed. Reg. 41,690 col. 3 (July 9, 2004). Similarly, under the Phase II rule, the duration of any monitoring would have been limited to two years, rather than imposed for the life of the permit as the Agencies now propose. 69 Fed. Reg. 41,620 col. 1 (July 9, 2004). The Agencies in issuing the final permit should reduce and reformulate the monitoring requirements accordingly.

13.3 Proposed Biological Monitoring Is Not Justified When Measured Against Historical or Anticipated Impacts

Mirant Canal previously commented that 40 years of operations at Canal Station do not support the type of biological monitoring scheme the Agencies have proposed. Nor have the Agencies explained why the Station's expected future operations warrant such extensive monitoring requirements. To the extent that the Agencies are concerned about variability in entrainment rates, Mirant Canal has explained that such variability is naturally occurring and seasonal rather than attributable to the Station's impacts. Consequently, based on Canal Station's historical operations, a lesser degree of monitoring than that proposed would satisfy the Agencies' obligations to verify compliance with the Renoticed Permit.

Once Mirant Canal implements an available § 316(b) technology, the minimized impacts from its intake will support only a minimal degree of monitoring. Moreover, under the Renoticed Permit, there is little or no need for the entrainment monitoring required by Parts I.A.9.b.i. through I.A.9.b.vi. given the requirement for Mirant Canal to install cooling towers or an equivalent technology. Similarly, there is only a minimal need for Mirant Canal to conduct impingement monitoring if it installs cooling towers or an equivalent technology. Parts I.A.9.c.i. through I.A.9.c.vi. The Station would require much less water and, therefore, the intakes would draw substantially fewer fish towards the Station. Of those fish, the reduced velocity would mean that more fish could swim away from the intakes, further reducing impingement.

13.4 The Permit Should Provide More Time for Compliance

The Renoticed Permit requires that Mirant Canal commence biological studies 30 days after the effective date of the Permit. Part I.A.9.a. Mirant Canal reiterates that the Agencies should not set monitoring requirements until an entrainment-reduction technology is chosen, but if the Agencies continue on their present course, they should acknowledge that the monitoring and sampling required by the Permit necessitates physical construction, organizational and contracting work, as well as potential staffing arrangements that Mirant Canal cannot reasonably be expected to complete in such a short timeframe. The proposed timeframe is especially troubling given the uncertainty of what type of exclusion device Mirant Canal will install. New and additional apparatus could require that Canal Station staff and contractors alter their sampling methods. That would take some time, so Mirant Canal requests 90 days to implement any monitoring program required by the Permit.

13.5 Full-scale Monitoring Should Not Be Required for the Life of the Permit

The Agencies have not identified a high risk associated with Canal Station's historical or anticipated operations that justifies the high cost of the proposed biological monitoring and reporting requirements, expected to be $125,000 to $180,000 per year.

So, while Mirant Canal agrees that some additional study would be appropriate in order to evaluate the impingement and entrainment impacts of the selected technology, an additional year or two of studies would supply ample data for measuring the degree of minimization achieved. Also, to the extent that the Agencies contend that existing data fail to account for the year-to-year and season-to-season variation in Mirant Canal's 1999-2001 study period, an additional year or two of study would adequately explain any such variation.

13.6 Entrainment Sampling Should Be Performed in the Discharge

Part I.A.9.b.iii requires Mirant Canal to conduct entrainment sampling in the Station's intake structures. Mirant Canal comments that its earlier sampling activities were performed in the discharge flume and, to the extent that the Permit retains an entrainment sampling requirement, the Permit should require sampling in the discharge flume. Sampling for entrainment in the discharge makes sense once any technologies are installed to minimize entrainment pursuant to § 316(b); at that point in time, it will be especially important to accurately determine which organisms have actually passed through the Station.

Sampling in the discharge will also yield a more accurate result because sampling at the intakes is affected by the tides and is best performed at low tide. The Renoticed Permit includes designated times for entrainment sampling that will not always coincide with low tides. Part I.A.9.b.ii. If Mirant installs cooling towers, then intake flow will be so low, even at low tide, as to preclude the use of 0.333-mm mesh nets. Finally, sampling in the discharge carries the added benefit of reducing the Permit's entrainment monitoring costs by half, because there is only one discharge compared to two intake units.

13.7 The Agencies Should Correct Ambiguous Provisions Regarding Operation of Circulating Pumps During Sampling

As the Agencies know, Canal Station sometimes operates only one pump and sometimes neither pump is active, depending on the Station's generation status. Consequently, Part I.A.9.b.ii. of the Renoticed Permit may require that Mirant Canal activate idle circulating pumps solely for the purpose of conducting monitoring activities. If so, then the Renoticed Permit requirements would produce impingement and entrainment mortality solely for the purpose of measuring impingement and entrainment, not for the purpose of measuring Canal Station's real operational impacts.

In addition, the calculations and estimates required by Parts I.A.9.b.vi and I.A.9.c.vi. would be rendered worthless if based on data manufactured by permit requirements rather than the Station's actual operations. The Permit should require only that the status of the circulating pumps be reported if either pump is idle during sampling.

Parts I.A.9.b.ii. and I.A.9.c.ii. also create confusion when read together. As discussed above, the former requires both cooling water circulating pumps for each unit to operate during the sample period; the latter requires impingement sampling only when both pumps are operating. It is not clear whether the Agencies intended these to be parallel provisions and, if so, whether Mirant Canal must activate both pumps prior to sampling or whether no sampling is required *unless* both pumps are activated pursuant to normal operations.

13.8 Provisions Related to Unusual Impingement Events Are Unnecessary

Given the greatly reduced levels of impingement that would result under the Renoticed Permit, the Unusual Impingement Event ("UIE") provisions in Part I.A.12 would be practically superfluous. Currently, the Station rarely comes close to or exceeds 40 dead fish during an eight-hour period and then only during the annual migration of menhaden and river herring in November and December. Mirant Canal comments that the definition of UIE should exclude November and December. Furthermore, given that a UIE would be caused by seasonal variation rather than Canal Station's operation, it would be unreasonable to require Mirant Canal to undertake an analysis of the Station's operations or the dead fish. Consequently, the UIE provisions should be deleted from the Permit.

13.9 Marine Mammal Protocol Requirements Should Be Deleted

Part I.A.10 of the Renoticed Permit would require Mirant Canal to submit to EPA and to adhere to a Marine Mammals Reporting Program and Response Protocol ("Protocol"), but the Agencies do not offer any evidence that Canal Station has in the past or will in the future cause adverse impacts to marine mammals or marine turtles ("marine species"). EPA previously determined that Canal Station would have no significant adverse impact on endangered species that migrate through or inhabit areas in the vicinity of the Station. Similarly, the National Marine Fisheries Service ("NMFS") found that impingement of sea turtles and marine mammals on the Station's intakes was unlikely because they are "able to readily avoid" it. NMFS Letter, dated January 25, 2006, at p. 3 (A.R. 175). Given the Renoticed Permit's proposal to install cooling towers, there is even less potential for the Station to cause adverse impacts to marine species. Mirant Canal requests that the Agencies delete Part I.A.10 from the Permit.

13.10 Discharge-Related Monitoring Should Be Tailored to Canal Station's Actual Impacts

The Agencies have not shown that Canal Station's discharge produces fish kills in the Cape Cod Canal. Nevertheless, the Renoticed Permit would require that Mirant Canal conduct daily visual inspections of the shoreline adjacent to the Station for dead fish. Part I.A.11.a. The Region points to a single instance in which a chlorination error may have impacted fish mortality, Response to Comments IX.C.3.1, but that problem was corrected and, in fact, Mirant Canal reported that incident as a result of observed impingement, not because it spotted fish floating in the Cape Cod Canal. Mirant Canal Permit Application; Attachment C.1, Appendix 1, pg. A1-8. The Permit's discharge mortality provisions are especially superfluous given the Renoticed Permit's proposal to install cooling towers because the Station's discharge would be significantly reduced. As discussed above, any discharge-related monitoring should be tailored to reflect the actual operation of Canal Station once a technology is chosen and implemented.

13.11 Permit Requires Overly Burdensome Response to Fish Mortalities

Given the reduction in Canal Station's discharge that will result under the Renoticed Permit, the Agencies cannot justify the requirement that Mirant Canal collect and analyze dead fish and curtail the Station's operations if it identifies 25 or more dead fish in a 24-hour period. Parts I.A.11.b. and I.A.11.c. It is of no comfort to Mirant Canal that, as the Agencies have claimed, fish collection is only required for fish linked to Canal Station's discharge or thermal plume. Response to Comments IX.C.3.1. The Cape Cod Canal is not a closed water body and, consequently, is affected by numerous factors. It would be nearly impossible for Mirant Canal to determine whether dead fish are attributable to the Station's operations or some other occurrence.

Yet, in order to comply with the Renoticed Permit, Mirant Canal would be required to arrange for the dead fish to be measured and identified by species, to collect water samples and suspend chlorination for at least 24 hours, and to undertake monitoring activities that are not otherwise required, including monitoring of dissolved oxygen levels. All of that would be required even though there is no basis for assuming that an occurrence of 25 or more dead fish has anything to do with operations at Canal Station. Under existing conditions, these requirements are overly burdensome and unreasonable.

14. Conclusion

A study to find the best technology available for the Canal Station is needed as surely today as it was when the Draft Permit was proposed in 2005. Then, as now, § 316(b) requirements were set using "best professional judgment" under the same statute as today.

The *facts* have changed, to be sure, but the principal change has been that the Canal Station is impinging and entraining fewer organisms than in 2005. Also, research on intake technologies has produced new information. Mirant Canal is providing in these comments updated information on virtually every aspect of the analysis that must be done to determine "best technology available." But more analysis is needed.

For these reasons, Mirant Canal asks Region 1 to do what it originally proposed and provide for a study of alternative technologies.

Attachments

Shaw Exhibits (2009)

Exhibit 1 Capital and Operating Cost Impacts
Exhibit 2 Heat Rate Penalties
Exhibit 3 Plant Energy Penalties
Exhibit 4 Geotechnical Investigations for Design of Cooling Tower Foundations
Exhibit 5 Cooling Tower Plume and Salt Drift Analysis
Exhibit 6 Noise Issues
Exhibit 7 Cooling Tower Makeup and Blowdown
Exhibit 8 Engineering Issues Related to Retrofitting Cooling Towers at Canal Station
Exhibit 9 Permitting Issues

Exhibit 10 Normandeau Associates, Adverse Environmental Impact Assessment for Mirant Canal Station (January 2009)

Exhibit 11 Alden Research Laboratory, Inc., Mirant Canal Generating Station Alternative Technology Considerations Fine-mesh Screen Proposal (January 26, 2009)

Exhibit 12 Veritas, Economic Issues Regarding BTA for Mirant's Canal Generating Plant (January 2009)

Exhibit 13 Alden Research Laboratory, Inc., Closed-cycle Cooling and the Alden 2003 Report (January 6, 2009)

Exhibit 14 Veritas, Using Benefit-Cost, Cost-Effectiveness, and Wholly Disproportionate Analyses to Evaluate and Compare Alternative IM&E Reduction Options: Technical Overview (January 2009)

Exhibit 15 PwrSolutions Inc., Assessment of Impact of Closure of Canal Plant on the Reliability of Transmission System in the South-Eastern Massachusetts (SEMA) Load Zone and New England Control Area (January 21, 2009)

Exhibit 1 – Capital and Operating Cost Impacts

The existing conditions (existing equipment designs and plant arrangements) were examined to determine the impacts new cooling towers would have on the Station. Factored engineer's estimates were developed to estimate the capitals costs for installing the closed cycle circulating water system at Canal Station. A total of four conditions were examined in an attempt to bracket the potential costs associated with installing cooling towers at the Canal plant. The four conditions consist of either natural draft hyperbolic towers or plume abated mechanical draft towers for circulating water rates that match the current flow rates, or the minimum circulating water flow rates that could be used with the existing steam turbines in an attempt to minimize the size of the cooling towers.

The factored estimates were all based on the following major assumptions. In general these assumptions if found not to be correct will affect the cost:

- The cooling towers would be located to the east of Unit 2 on Station property (currently used for laydown) with the required demolition of existing rail spurs as well as other structures. The arrangement would allow for missing the rail spur servicing the ammonia storage tanks and the ammonia storage tanks which are located in the proximity of the location for the cooling towers. Alternative arrangements would likely require additional demolition costs
- Pile foundations would be required for the hyperbolic cooling towers due to the existing site conditions
- The new circulating water system would be based on reusing the existing equipment to the maximum extent practical (costs would increase if the assumed reused equipment was not possible):
    - reusing the existing condensers, (for the minimum circulating water flow rate case this may not be easily achievable due to flows paths within the existing condenser)
    - matching the requirements of the existing condensers in the design of the cooling towers and new circulating water system components,
    - reusing the existing discharge flume and adding new circulating water pumps to supply heated water from the existing discharge flume to the new cooling towers
    - reusing the existing discharge for blow down,
    - reusing the existing circulating water pumps by constructing a water conveyance from the new cooling towers to the existing circulating water pumps, and
    - reusing the existing unit 2 intake structure with the addition of new makeup water pumps after the intake structure is isolated from the existing circulating water pumps.
- Noise barrier walls located on the property lines to the west, north and east of the new cooling towers would be required, see Exhibit 6
- Chemical feed systems would be required

- For the mechanical cooling tower option a plume abated arrangement tower would be required to minimize potential fogging of the Cape Cod Canal
- Equipment laydown and construction parking will be problematical impacting worker productivity due to the limited space at the Station (if alternative space at or adjacent to the plant could be located, this cost would be mitigated)

It should be noted that validity of these assumptions will have to be determined through detailed study of the plant operation, equipment adequacy and condition, etc.

Total Installed Cost Units 1 and 2

Cooling Tower Type	Matched Circulating Water Flow	Minimum Circulating Water Flow
Natural Draft Hyperbolic Cooling Towers	$224.5 M	$183.3 M
Plume Abated Mechanical Draft Cooling Towers	$217.7 M	$182.8 M

Operating and maintenance costs consist primarily of the lost capacity of the plant, additional electrical load required to operate the new closed cycle circulating water system, additional chemical costs to treat the circulating water, and maintenance costs for the new equipment.

Total Annual Operating and Maintenance Costs Units 1 and 2

	Matched Circulating Water Flow		**Minimum Circulating Water Flow**	
	Natural Draft	Mechanical draft	Natural Draft	Mechanical draft
Operating Cost – Additional Load (1)	$1.7 M	3.1 M	$1.1 M	$2.0 M
Operating cost - Lost Power (2)	$1.0 M	$1.0 M	$2.7 M	$2.7 M
Maintenance cost (3)	$0.3 M	$0.5 M	$0.3 M	$0.5 M
Total O&M cost	$3.0 M	$4.6 M	$4.1 M	$5.2 M

Notes:

1. Operating costs associated with the additional load (see Exhibit 3) are based on the 2007 plant operation statistics using the average anticipated 2009 cost of power
2. Operating costs associated with the heat rate penalty, calculated in Exhibit 2 are based on the hours of operation the Units operated at or near 100 % capacity in 2007.
3. Maintenance costs include yearly pump maintenance and periodic pump overhauls, yearly fan maintenance for the mechanical draft cooling towers, and yearly cooling tower water basin cleaning and fill maintenance.

Exhibit 2 –Heat Rate Penalties

A preliminary review of the heat rate penalties associated with adding cooling towers to the summer operation of the Canal plant was performed. This is conceptual in nature since a detailed analysis has not been performed. The basis for this review is reusing as much of the existing equipment as possible and matching the cooling tower to the existing plant conditions. The reuse of existing equipment may not be the most economic solution for the plant if a closed cycle system were installed.

Two cases were examined that would generally bound an economic evaluation of cooling towers. Both cases assume the reuse of existing equipment to the maximum extent practical. The first case matches the existing circulating water flow while the second case reduces the circulating water flow to the back pressure alarm set point on the steam turbines. The reuse the existing condensers at the reduced flow would require a detailed evaluation to determine their adequacy (i.e., the assumption used herein may be optimistic).

Parameter	**Summer Unit 1**	**Summer Unit 2**	**Summer Unit 1**	**Summer Unit 2**	**Notes**
	Match Current Circulating Water Flows		**Minimize Circulating Water Flows**		
Unit Design					
Design generation, kw	571,958	578,002	571,958	578,002	Ref. 1, 2 (Includes corrections based on assumed winter back pressure without cooling towers)
Design turbine heat rate, Btu/kw hr	7188	8032	7188	8032	Ref. 1, 2
Design condenser pressure, inch Hg A	1.50	2.00	1.50	2.00	Ref. 1, 2
Climate					
Design CW cold temperature, ^{O}F	70	70	70	70	Assumed based on temperature in Cape Cod Bay
Expected ambient Tdb, ^{O}F	77.8	77.8	77.8	77.8	Ref. 3
Expected ambient Twb, ^{O}F	73.4	73.4	73.4	73.4	Ref. 3
Expected recirculation allowance, ^{O}F	0	0	0	0	Assumed as for Natural Draft tower in a recent study for another site in the Northeast

Parameter	Summer Unit 1	Summer Unit 2	Summer Unit 1	Summer Unit 2	Notes
	Match Current Circulating Water Flows		Minimize Circulating Water Flows		
Expected approach to ambient Twb, ^{O}F	15	15	15	15	Assumed as for salt-water Natural Draft tower in a recent study for another site in the Northeast
Expected CW cold temperature, ^{O}F	88.4	88.4	88.4	88.4	In Winter, tower is operated to keep CW cold above 40 F and avoid freezing
Condenser Calculations					
BP at design CW cold temp, inch Hg A	2.30	2.58	2.58	0.00	As shown on 85% clean curve for design CW [Ref 4]; at 578,002 kw, Unit 2 is off-design
BP at expected CW cold temp, inch Hg A	3.57	3.93	3.93	0.00	Extrapolated based on 85% clean condenser curve [Ref. 4]
Change of BP, inch Hg A	1.27	1.35	1.35	0.00	Expected - design
Corrections					
Expected condenser pressure, inch Hg A	2.77	3.35	5.00	5.00	Assumes condensers are both designed for summer operation
% Design Duty	100	#N/A	100	#N/A	Assume the Unit 1 condenser designed for the design back pressure
Steam flow, 10^6 lb/hr	#N/A	2.38	#N/A	2.38	Assume the Unit 2 condenser designed for the "guaranteed" steam flow, operating off-design for 5% overpressure
Correction to load, %	-3.00%	-2.08%	-8.86%	-4.60%	Ref. 1, 2; read from sheet "Corrections"
Correction to heat rate, %	3.11%	2.26%	9.72%	5.00%	Ref. 1, 2; read from sheet "Corrections"
Expected load, kw	554,772	566,005	521,260	551,414	
Expected heat rate, Btu/kw hr	7411	8213	7887	8434	

Parameter	Summer Unit 1	Summer Unit 2	Summer Unit 1	Summer Unit 2	Notes
	Match Current Circulating Water Flows		Minimize Circulating Water Flows		
Lost plant output from cooling towers, MW	17.2	12.0	50.7	26.6	(positive indicates "derate")
Total Plant lost output MW	29.2		77.3		

References:

1. Unit 1 data from Siemens "Thermal Performance Data for Canal #1" dated 1 May 2008 Heat Balance Diagram WB-11228, 4/29/08 SAC "100% Load, VWO Rated Pressure, Not Guaranteed" (TC4F-32.4 I), Curve WV-0919-1, SAC 28 Apr 2008, "LP Turbine Exhaust Pressure Correction to Load", Curve WV-0920-1, SAC 28 Apr 2008, "LP Turbine Exhaust Pressure Correction to Heat Rate"
2. Unit 2 data from Westinghouse "Thermal Performance Data for 529619 kw Turbine-Generator" dated 11/28/72, [2.a] Heat Balance Diagram AB998-0964, 4/2/7x, "529619 kW Net Load, Maximum Guaranteed" [superseded], [2.b] Heat Balance Printout, 4/1/71, "578002 kW Net Load, Maximum Calculated - 5% overpressure - not guaranteed", [2.b] Assumes same back-pressure as [2.a], therefore it represents a different condenser. We have approximated the condenser, as if it were designed for 2.0 inches at condition [2.a], but operated off-design (110% of design duty) for conditions [2.b] Curve AV076-0345, WC/DJD 12/19/72, "LP Turbine Exhaust Pressure Correction to Load, TC4F-28.5 inch", Curve AV076-0344, WC/DJD 12/19/72, "LP Turbine Exhaust Pressure Correction to Heat Rate, TC4F-28.5 inch"
3. ASHRAE 2005, Otis ANGB, Massachusetts, 1% exceedence WB/MCDB
4. Condenser curves provided in spreadsheet "canal 1 condenser graphs.xls", no number, date or base data

In order to better define the actual heat rate penalty a series of studies would be required including but not limited to:

1. Economic optimization study to consider alternative flow rates and cycles of concentration including alternate cooling tower sizes and condenser re-optimization
2. Annual sea water temperature profile (temperatures in each month of the year, or at shorter time-intervals if needed)
3. Seawater side Water balance to determine the cycle of concentration of the cooling water circulated between the CT and the units and year around flow at the canal intake and discharge structure.
4. Heat balance (year around) to determine new plant output, and identify the temperature of the Seawater returned to the CT and temperature of the blowdown return to the canal, etc.

5. Existing steam turbines will require a thermal design review to identify new limiting turbine exhaust parameters.
6. Annual profiles of wet-bulb and dry-bulb temperature. Annual profiles of wind speed and direction.

Exhibit 3 –Plant Energy Penalties

The total energy penalty to the Canal plant operation is a combination in the loss of plant efficiency addressed in Exhibit 2 and additional electrical loads to operate the additional equipment including additional circulating water pumps for both types of towers and additional fans for the mechanical draft cooling towers. The plant efficiency penalties are based on review of the Canal Station condensers designs while the lost power is based on input from the cooling tower manufacturers and circulating water pump manufacturers

Preliminary estimates for these penalties are included in the following table. This preliminary estimate is the minimum expected during summer operation. Based on detailed economic analyses to determine the most economic option for the Canal Station the energy penalty could be greater than 4% of plant output.

	Matched Circulating Water Flow		**Minimum Circulating Water Flow**	
	Natural Draft	Mechanical Draft	Natural Draft	Mechanical Draft
Lost Power – minimum Heat Rate Penalty both units – summer (see Exhibit 2)	29.2 MW	29.2 MW	77.3 MW	77.3 MW
Lost Power Additional Plant Loads – circulating water pumping both units	6.1 MW	6.1 MW	4 MW	4 MW
Lost Power – Additional Plant Load – Cooling Tower Fans both units, plume abatement pumps, both units		5.5 MW		3.6 MW
Total Lost Power minimum– Summer	35.3 MW	40.8 MW	81.4 MW	84.9 MW
Percent of Plant output lost- Summer minimum	3.1%	3.5%	7.1%	7.4%

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Exhibit 4 – Geotechnical Investigations for Design of Cooling Tower Foundations

Statement of Problem

Foundation design for cooling towers, or other commercial structures, must comply with Massachusetts Building Code/International Building Code requirements. Natural draft cooling towers are very large and heavy concrete structures, on the order of 500 ft high and supported on a ring beam foundation up to 300 ft in diameter. Mechanical draft cooling towers are not as large or heavy and are typically founded on concrete slabs or footings. In either case, detailed geotechnical information on the mechanical properties of subsurface soils and rock, and their vertical and lateral variations are needed to properly design the foundations and prepare an Engineering Report, as required by the Code. Bedrock at the Canal Station site is thought to be deep (>200 ft) and soils are primarily sands, possibly overlying marine clay. Ground water is encountered a few ft above sea level and is expected to fluctuate with the tides, due to the close proximity of the site to the Cape Cod Canal.

Geotechnical engineering analysis must evaluate soil bearing capacity and estimated settlement (both total and differential settlement) for either type of cooling tower. This may pose significant challenges for natural draft towers, which cannot tolerate large differential settlement, in part due to their great height. Because the foundations will be supported on saturated granular soils, the potential for soil liquefaction during an earthquake must be evaluated and the foundation design must have an adequate factor of safety against failure due to liquefaction. Liquefaction occurs when ground shaking causes the pore water pressure in a soil to increase to the point where the soil loses its shear strength and temporarily behaves like a liquid. The risk of liquefaction is greatest in fine grained sandy and silty soils located below the water table and can cause catastrophic failure of structural foundations. Detailed geotechnical investigations and laboratory testing of soil samples from various depths are needed to support the required analysis and Engineering Report. Boring logs and laboratory test data previously conducted for design of the power plant should be reviewed for applicability; however, new investigations and testing will be needed at the specific site of the cooling towers.

If soil conditions require use of deep foundations (piles or caissons), the code requires special inspections and testing (e.g., a pile load test) before the foundation is constructed.

Scope of Recommended Geotechnical Investigations

The following recommended scope is applicable to natural draft cooling towers. For mechanical draft towers, the overall scope is conservative and might be reduced by approximately 1/3, in terms of the number of borings and quantity of laboratory tests.

Approximately ten (10) test borings are recommended beneath each cooling tower. Four or five of the borings should be drilled and sampled to the depth of the first competent founding layer (possibly 150 – 200 ft). Standard Penetration Tests (SPTs) should be taken every 5 ft, or at identified strata changes. Undisturbed tube samples should be taken in any layers of cohesive soil encountered. Three or four of the borings at each cooling tower location should be completed as observation wells to allow measurement of the depth to ground water on a periodic basis for at least one month duration. Cone penetrometer tests (CPTs) may be substituted for five of the test borings at each cooling tower. The CPTs should be pushed to the same depth as the borings, or to refusal of the equipment. Seismic CPTs are recommended in order to provide measurement of the shear wave velocity of the soil, as well as penetration resistance and sleeve friction, and pore pressure. Each boring or CPT location would be surveyed to accurately determine location coordinates and ground surface elevation. Assuming two cooling towers (20 test borings/CPTs), the effort to plan the program, let subcontracts and perform the field work would take approximately two months. If soil conditions are such that deep foundations are required, a pile load test would require about 2 1/2 months for planning, subcontracting, and execution.

Geotechnical laboratory testing of soil samples should include the following tests and approximate quantities:

Laboratory Test	ASTM Standard	Approximate Quantity
Natural Moisture Content	ASTM D 2216	30
Specific Gravity	ASTM D 854	4
Sieve Analysis	ASTM D 6913	30
Hydrometer Analysis	ASTM D 422	5
Atterberg Limits	ASTM D 4318	10
Unit Weight	*	
One-Dimensional Consolidation	ASTM D 2435	6
Consolidated Undrained Triaxial Compression	ASTM D 4767	4
Unconfined Compressive Strength	ASTM D 2166	4
Standard Compaction	ASTM D 698	6
pH	ASTM G 51	6
Unified Soil Classification	ASTM D 2487	30

* Unit Weight in accordance with ASTM D 2435 or ASTM D 4767 when performed in conjunction with Consolidation or CU Triaxial Compression tests.

The laboratory testing and final report for the testing would be completed 4-6 weeks following the completion of the test borings.

Geotechnical analysis and calculations and a foundation engineering report, to address key geotechnical parameters (bearing capacity, settlement, liquefaction analysis), and recommended foundation type and design criteria would require about 2 months following the completion of the laboratory testing.

The overall investigation, analysis, and report could be completed in approximately 20 – 26 weeks.

Exhibit 5 – Cooling Tower Plume and Salt Drift Analysis

Specific analyses should have been completed with site-specific design information and local meteorological data to estimate the cooling tower impacts. Visible plumes typically can reach lengths of up to 10 kilometers downwind and heights of 1,000 meters under high ambient humidity conditions, especially in winter. Mechanical draft towers can cause ground level fogging near the tower and ground level icing in cold climates. Salt drift deposition is another potential impact of cooling towers that should be considered.

To aid in determining the potential impacts of cooling towers at the Canal Station, an analysis of the potential environmental impacts caused by the operation of a natural draft cooling tower or mechanical draft cooling towers at the Mirant Canal Station could have been performed using the Electric Power Research Institute (EPRI) sponsored Seasonal/Annual Cooling Tower Impact (SACTI) Program. This model is considered a state-of-the-art cooling tower impact model by EPRI and the electric power industry. It was developed by Argonne National Laboratory (ANL) using the knowledge obtained from extensive research conducted on cooling tower environmental effects. The SACTI model provides salt drift deposition pattern (i.e., kg/km^2 per month) as a function of distance and direction from the cooling towers as well as the frequency of occurrence of visible plumes, hours of plume shadowing, and ground level fogging and icing occurrences by season resulting from the operation of the cooling towers.

The SACTI analyses would include three cooling tower options: natural draft cooling towers, mechanical draft cooling towers without plume abatement; and mechanical draft cooling towers with plume abatement. Cooling tower design information such as tower dimensions, tower layout, air mass flow rate (i.e., assumed to be saturated), drift rate and heat rejection rate, along with meteorological information consisting of hourly surface meteorological observations and seasonal mixing height data, would be used as input data to the SACTI model.

The cooling tower input parameters needed for the analyses are summarized as follows:

- Tower type (i.e., linear mechanical, circular mechanical, or natural draft);
- Number of towers;
- Tower orientation relative to true north;
- Tower height above plant grade (m);
- Tower length (m);
- Tower width (m);
- No. of cells/tower;
- Cell exit diameter (m);
- Heat dissipation rate/tower (MW);
- Total airflow rate/tower (kg/sec);
- Drift rate (% circulating water and g/sec);
- Cooling water total dissolved solids (TDS) concentration (g TDS/g solution) considering cycles of concentration;

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- Drift droplet size distribution, if available. Otherwise, a default distribution can be used.

The SACTI model requires hourly surface meteorological data in a format provided by the U.S. National Climatic Data Center (NCDC) in Asheville, NC or in Nuclear Regulatory Commission (NRC) format for on-site meteorological data. The nearest National Weather Service (NWS) station to the site that has measured all of the necessary parameters for the SACTI will be purchased from the NCDC. The meteorological parameters required by the model include wind speed, wind direction, dry-bulb temperature, an atmospheric moisture parameter (i.e., dew point temperature, relative humidity, or wet-bulb temperature), and an atmospheric stability indicator. Any missing parameter values would be filled in using a U.S. EPA recommended procedure. In addition to the surface observations, morning and afternoon seasonal mixing height values the nearest upper air observation location to the site (i.e., Chatham, MA), would be used in the SACTI model as well as the monthly clearness index to help determine plume shadowing impacts.

The cooling tower impacts are then estimated using the SACTI program, along with the cooling tower operational parameters and the hourly surface meteorological observations and morning and afternoon seasonal mixing height values, by executing in sequence the three codes that comprise the SACTI program as follows:

- The PREP program is executed first as that is the preprocessor code that reads the meteorological data files, eliminates unusable records, adds cooling tower exit conditions for each hour of meteorological data, calculates required non-dimensional variables, determines the plume categories, generates representative cases for each category, and generates an output file summarizing the meteorological data;

- The MULT program is then executed using the output of the PREP program along with the cooling tower drift emission rate, drift droplet size spectrum, and cooling tower arrangement information. The MULT program calculates the plume and drift impacts for representative cases for each plume category and generates an output file containing the plume properties for each plume category; and

- The TABLES program is then executed which uses the output of the MULT program to produce tables of predicted impacts by downwind distance and wind direction for each season of the year and for the annual period.

Upon completion of these analyses a more informed determination as to plume impacts and methods to reduce those impacts at the Canal Station can be ascertained.

Exhibit 6 – Noise Issues

In order to review EPA provided analysis and develop actual design requirements, Shaw in-house and Edison Electric Institute data were used to preliminarily investigate the noise impacts cooling towers would have on the nearest houses on Briarwood Road south of the plant. These houses were defined as the nearest noise receptors in the noise analysis included in the EPA 2008 responses to comments documents. This preliminary analysis was based on using natural draft cooling towers which in our experience are slightly quieter than mechanical draft cooling towers. It should be noted that one of the reasons Brayton Point selected natural draft cooling towers over mechanical draft towers was that is was easier to mitigate potential noise impacts. (See 'EPA Region 1 Preamble to Brayton Point Station: Final NPDES Permit' - http://www.epa.gov/NE/braytonpoint/index.html .)

Based on approximate distances of 600 feet and 1100 feet from the rim of the two Natural Draft cooling towers, a total unmitigated level of 63 dBA was calculated at the nearest receptor. If we assume a significant level of mitigation of 10 dBA applied to the cooling towers at this location, the combined levels would be 53 dBA which, when added to the EPA analysis quoted ambient of 50 dBA, would result in a total of about 55 dBA. This increase of 5 dBA is higher than the 3 dBA quoted in the EPA Table 1 and the cooling towers may therefore have more impact on the community than EPA is suggesting. As a minimum to support the mitigation assumed above the Canal Station will require noise barrier walls close to the base of the towers to avoid adverse impact at nearby receptors. Additional noise mitigation measures could be needed, especially if mechanical draft towers are selected.

It is also noted that the background data in the EPA analysis relies on a report published eight years ago and hence may not represent the current situation. A new base line ambient noise survey could show a lower sound level which would result in the impact of any cooling towers in the community to be greater than is implied by EPA.

MassDEP Policy

The EPA document refers to MassDEP's policy on noise. The Mass DEP has the authority to regulate noise under 310 CMR 7.10, which is part of the Commonwealth's air pollution control regulations. Under the DEP regulations, noise is considered to be an air contaminant and, thus, 310 CMR 7.10 prohibits "unnecessary emissions" of noise. Mass DEP administers this regulation through Noise Policy DAQC 90-001 dated February 1, 1990. The policy limits a source to a 10-dBA increase in the measured ambient sound level (L90) at the nearest residences. Ambient is defined as the background sound level without the source operating, although it is noted that in this case this may be taken to include the existing plant because it is a longstanding existing facility.

In the 1970s Stone & Webster (now Shaw Environmental) quantified the ambient sound levels, as well as the Canal Station Unit 1 sound levels for the addition of Canal Unit 2 to the station. At that time there was no acoustical room left in the MassDEP ambient + 10 noise requirements for Unit 2 without modification to Unit 1, which was undertaken. Subsequently, the two combined Units 1 and 2 consumed the entire 10 dBA noise budget allowed under the MassDEP Code. We now note that MassDEP is quoted in the EPA response as considering a 3 dB increase on this budget as being “barely perceptible” and “would satisfy MassDEP’s sound impact criteria” but are unclear whether this is a personal opinion expressed by a member of staff at MassDEP or if this is MassDEP policy.

Detailed Noise Study

Therefore, in the light of the above, it is envisaged that the following detailed noise study should have been performed by EPA to consider the viability, or otherwise, of the cooling towers at the Canal Station. This is a listing of likely work that would form the basis of that study EPA should have performed.

- Identify key receptors on all sides of the Plant;
- Measure the day-time and night-time sound levels to establish existing ambient levels in terms of Leq and L90;
- Measure the sound power of the existing plant using walk-away data at increasing distances from the plant;
- Discuss with MADEP what criterion should be adopted for the cooling towers at these receptors;
- Incorporate the existing plant into a SoundPlan computer model, and calibrate to the measured values;
- Incorporate the cooling tower options of natural draft cooling towers and mechanical draft cooling towers into the model and predict increases at the key receptors;
- Identify mitigation options required to meet Code levels at the receptors;
- Estimate the cost of this mitigation;

Exhibit 7 – Cooling Tower Makeup and Blowdown

Preliminary, on average at 100 percent capacity the Canal Station will require the following for makeup water to the circulating water system. This requirement is based on a 1.5 cycles of concentration which is consistent with the Brayton Point Station NPDES permit. Final blowdown and evaporation would be determined based on development of final heat balances and cooling tower vendor information.

	Unit 1	Unit 2
Evaporation	4,120 gpm	4,582 gpm
Blowdown @ 1.5 cycles	8,240 gpm	9,163 gpm
Total for unit	12,360 gpm	13,745 gpm
Total Plant	26,105 gpm (37.6 MGD)	

Chemical treatment systems will be required to ensure an efficient and reliable performance of the cooling water system. The new chemical feed systems would be focused on the new requirements of cooling tower service. It will be essentially independent of the existing chlorination system, which will be retained to serve the continuing needs of the condensers.

The chemical treatment systems will provide for receiving, storage distribution and injection of the following chemicals:

Biocide (in addition to condenser chlorination)
Anti-foaming agent
Anti-scaling agent
Dispersant agent

The requirement for these chemical additions will depend on seasonal issues as well as the operation of the plant.

Exhibit 8 – Engineering Issues Related to Retrofitting Cooling Towers at Canal Station

In Alden's 2003 evaluation of the feasibility of several options for addressing impingement and entrainment at the Canal Station, the practicality and impact of backfitting Units 1 and 2 with cooling towers was evaluated only at a very conceptual level. Alden used vague assumptions about site equipment to factor typical costs developed in an EPRI 2002 report "Investigating Site Specific Factors for Retrofitting Recirculating Cooling Towers" to estimate the costs for cooling towers at the Canal station. Now that US EPA Region I has issued a Final NPDES permit with a requirement to reduce entrainment to the same level as that for the closed-cycle cooling option, Mirant Canal has asked Shaw to consider in greater detail the approach used in the original conceptual level evaluation in order to determine whether installation of cooling towers would be feasible from an engineering standpoint, and, if so, to describe the extent of changes (and their consequences) necessary to install them.

The description below describes how a cooling tower would generally be backfit to an existing once through cooled steam electric generating station. The section then explains a specific constraint at Canal Station related to the design of the original condensers. Then a workaround method that allows the reuse of the existing condenser is described which also explains some specific reliability issues associated with this workaround. Finally, there is discussion of other environmental impacts of the cooling tower backfits as well as the need for a comprehensive review of environmental impacts, the economic impact of the backfit of a cooling tower, and the potential consequences to the ISO New England transmission system and generation bidding system.

Conceptual Feasibility and Typical Arrangements at New Plants

From a very conceptual level, as with most power plants, it would be possible as an engineering matter to run the Canal Station by recirculating the discharge flows into a cooling tower fill and then routing the return condenser feed line back to the condenser. In a typical cooling tower arrangement for a new power plant, one set of pumps located just upstream of the condenser and downstream of the cooling tower provides the necessary flow and head for the cooling water to pass through the condenser and up to the cooling tower fill. The hot condenser discharge flow then passes through the cooling tower fill countercurrent with the upflowing air flow so that the waste heat exits the top of the cooling tower and the condenser water falls to the cooling tower basin where the recirculation of the flow begins again.

Infeasibility of Typical Arrangements to Backfit at Canal Station

However, this typical arrangement of backfit of a cooling tower is not a feasible arrangement at Canal Station as the condensers are not designed to sustain the hydraulic head that the cooling water would place on the condenser tubes and condenser water boxes. These condensers and the associated large diameter piping are designed for hydraulic pressures of approximately 20 psig. To pump the water through the condenser and up to the cooling tower fill the pumps would require 70 to 90 psig pressure on the water side of the condenser, large diameter connecting pipes, water boxes and heat exchange tubing. At these pressures the condenser and piping and water boxes would distort and burst and the steam condenser would fail.

Alternative Arrangements at Canal Station without Rebuilding Condensers; Issues and Drawbacks

There are a few alternatives to make the conventional cooling tower arrangement work at Canal with the design of the existing condensers. In one potential arrangement, the elevation of the cooling tower fill would need to be at or near the existing level of the sea. That means the cooling tower basin would need to be depressed some 30 feet below the level of the sea to get the fill at that appropriate level. That in turn would require large volume dewatering pumps (and a new discharge structure) to depress the ground water levels around the basin to avoid uplift pressures on the cooling tower basin and prevent groundwater flooding of the cooling tower cavity in the land. This arrangement would also require the countercurrent air flow to pass into and around this cavity in the ground to enter the cooling tower shell. This depressed arrangement of the cooling tower would provide interference with the air flow unless a much larger area around the basin of the tower were excavated and additional groundwater dewatering pumps were employed to dewater this larger area. These large groundwater pumps would likely have an adverse effect on local groundwater levels and intrusion of saltwater into the local aquifer so this alternative is not considered a reasonable approach.

As an alternative, Mirant has evaluated a non-conventional arrangement of the cooling system which would allow reuse of the existing condenser but the arrangement is not without some serious drawbacks. A variation of this approach is in use now at Vermont Yankee Generating Station. This alternative arrangement requires two pump sets in separate locations (upstream and downstream of the condenser) working in series. The first pump is located between the cooling tower basin and the condenser and provides only sufficient head to pass the full condenser flows to the existing discharge canal. Shaw proposes to use the existing circulating water pumps for this function. The second, and new set of pumps, will pump, with much greater head than the first pump set, the heated condenser discharge flows from the discharge canal up to the cooling tower fill. The cooling tower discharge would flow by gravity to the existing cooling water intake structures.

This push-pull arrangement protects the condenser from hydraulic pressures that exceed the design capacity but can also create some difficult balancing issues with the pump flows and the elevations of the two water storage reservoirs in the system – the cooling tower basin and the enclosed discharge canal. This could be resolved by under sizing the volume of the new cooling tower pumps. This arrangement would require that the existing circulating water pumps draw the entire volume of cooled water from the cooling towers plus the excess volume from the Cape Cod Canal. This excess flow would be discharged to the canal via the existing diffuser. A system of valves or gates in the intake canal dams and a weir in the discharge canal would be required to accomplish this.

Although this is not an efficient way to pump the large volumes of flow required for cooling, some levels of operating efficiency would need to be sacrificed to retain the service of the existing condenser.

Even with this workaround, which should be effective, despite the inefficiency, the Canal cooling system will be less reliable and will reduce the dispatch reliability of the operating units. This is because the cooling system is dependent on two sets of pumps to operating the cooling system instead of just the original pumps. If the new set of pumps fail, then the steam electric generation unit will trip out as soon as the cooling water in the closed off intake well runs below the minimum operating level of the pumps. The system can also fail if the original set of cooling water pumps fail and this would happen with the same probability as with the previous operation. Upset conditions associated with the additional pumps will lead to additional unscheduled unit trip outs of the steam generating unit. These trip outs could also trip the high pressure steam release to the atmosphere (a very loud and intrusive condition) which is used to cool the boiler and steam when the cooling system fails.

Although Shaw believes that the push-pull pump arrangement with the use of new cooling towers should be mostly reliable, the reliability of the cooling system would be considerably less (about half) than the current once through cooling arrangement. If this unusual pumping arrangement proves in actual use to be less reliable than anticipated, then the ISO New England might be forced to limit the dispatch of Canal station even during times when Canal may be essential to the local electric transmission stability and reliability.

Arrangements that include Rebuilding Condensers; Issues and Drawbacks

Replacing steam condenser shells and water boxes is very expensive in terms of capital and outage time and if done only to accommodate the operation of new cooling towers, the change will generate no additional plant revenue or operating margin unless other design changes are also made on the steam side equipment at the plant.

In addition to condenser replacement, most if not all existing circulating water pipe and pipeline equipment including valves, expansion joints and other equipment would either have to be reinforced in place or replaced to accommodate the higher pressures.

The condensers of a conventional steam electric generating plant are sized and located with respect to the elevation of the cooling water and with close proximity to the steam turbine as a first step in both the design and with the construction of the power plant. The condensers are typically placed immediately below the steam turbine and proximate to the foundations of the steam turbine. The condensers are the heart of the design of the power plant, as everything else is built around the design capacity and elevation and location of the condensers.

As such, condensers are extremely difficult to replace in total. The condenser tubes are relatively easily replaced but the shells and water boxes would require a very time consuming and delicate extraction and reinstallation process that could prevent operation of the generating unit for many months. To replace the existing condenser with another capable of withstanding the higher hydraulic pressures, different types of heat exchanger metals or thicker metal piping and plate are generally required. In order for this new condenser with thicker walled pipe and plate to provide the same rated heat exchange as the existing condenser, the new condensers would likely be larger in dimension – just to achieve the same thermal heat exchange function.

A larger sized condenser may be difficult or impossible to place in the same location below the existing steam turbine. A larger dimension condenser would also require that the large diameter steam ducts from the steam turbine be expanded to spread the steam over a longer or wider condenser. The space between the turbine and condenser is very restricted and this may not be possible. Mirant would require a detailed evaluation of the feasibility of replacement of the condenser, as a design or dimension change can adversely affect the function of the steam turbine and ducting.

If one were to replace the condenser to accommodate a cooling tower, that redesign would also likely greatly influence the water flow path and basic design. Once through cooling plants typically have three (or more) parallel condenser flow paths whereas a steam condenser for the cooling tower project typically has a series arrangement of the shells and the water flow path. This series arrangement will generally reduce the size and capital cost of the cooling tower since the series condenser will generally deliver a higher temperature and smaller flow than a once through condenser for the same steam condensing capacity. As a part of the evaluation of the cooling tower cost alternatives, Shaw has considered two arrangements of the flow through the existing condensers that can be used to reduce the size and cost of the cooling towers. The two arrangements only considered changes in the rate of flow through the condensers – not a conversion of the flow path. However, neither arrangement considered a complete redesign of the condensers to do this because the costs are extremely high and may not be possible with the continued use and location of the existing steam turbine and large diameter steam ducts.

Costs of Cooling Tower Backfit Cannot be Recovered Unless Other Plant Changes are Incorporated

A redesign of the condenser would require a detailed engineering and economic evaluation of the cooling and steam systems. With a planned condenser replacement, one would generally reconsider the optimization of the steam and cooling systems to extract additional energy from the existing equipment. However, in the case of adding a cooling tower and potentially replacing a condenser, the new system will only achieve less generation and will do so with less thermal efficiency than the existing operation. There is no opportunity to recover the additional capital costs ($182.3 to 224.5 million) of the cooling tower with additional new generation.

But if one is going to the expense of adding a cooling tower and also modifying the condenser to accommodate the higher water pressures for a conventional cooling tower single pump set flow arrangement, then one would also want to look at the blading and efficiency of the steam turbine connected to the replaced condenser. The redesigned condenser may allow for an economically advantageous replacement of the turbine or reblading of the steam turbine to recover some of the costs of the redesigned cooling system. Although this adds additional capital costs it may allow recovery of some of the costs associated with the condenser replacement.

But if the steam turbine is resized, replaced or rebladed to accommodate the condenser, then it would be foolish to ignore the steam supply from the boiler. If that older boiler is generating steam by the simple cycle conversion of fossil fuel to electric energy, then it would be wise to consider replacement of the fuel and steam supply side once the cooling tower condenser and steam turbine. Replacing an older fossil fired boiler with gas or distillate fired combustion turbines and a HRSG or with a supercritical unit may greatly increase the energy conversion efficiency of the overall power plant. And the conversion may also help to recover the capital costs of the cooling tower, new condenser, and new or rebladed steam turbine.

Why go to all this length to explain why not to replace the condenser? Because if a cooling tower could easily be incorporated into the design of an existing steam electric generator without the need to replace or work around a deficiency in the condenser design, then that site is reasonably suited to accommodate the change with existing plant equipment. But when the replacement of once through cooling with a cooling tower requires work-arounds for operation of existing equipment, as is the case here at Canal, or when the backfit affects the reliability of operation, it generally requires complete rethinking of the optimal operation and strategic competitive placement of the plant in the competitive ISO New England dispatch process of recovery of capital expenses.

Conclusions of Practicability of Backfit of the Cooling Tower

Unless the Canal plant is completely redesigned with major changes to the boiler and steam side of the plant, then the capital costs of the cooling tower backfit will only add to the overall dispatch cost of operation of the station. If cooling towers are constructed, then Mirant would need to either contract long term power sales at higher rates or bid into the ISO New England auction at higher rates to recover the capital costs of the new cooling towers. This higher dispatch costs will then likely further limit the capacity utilization of the station with respect to other generating facilities with which Canal competes. Given the low current level of plant utilization, it is likely the capital costs of a cooling tower backfit will eliminate the Canal station from the competitive electric generation market.

Exhibit 9 –Permitting Issues

The construction of a natural draft cooling tower at the Canal site could potentially have an adverse effect on the existing air quality impacts of the station due to the size of the tower. A 500 ft tall cooling tower with a diameter of 255 ft could cause additional building downwash effects on the plant stack, depending on its proximity, causing higher ground-level pollutant concentrations. If required, the analysis of these downwash effects may require a detailed wind tunnel study or computational fluid dynamics (CFD) study to establish the cooling tower dimensions to use in the analysis due to the smooth hyperbolic shape of the tower.

In addition, the cooling tower drift emissions will cause an increase in particulate matter (PM) emissions that will need to be analyzed for ground level impacts and may trigger the need for a Prevention of Significant Deterioration (PSD) permit application, in addition to the Massachusetts DEP Comprehensive Air Plan Approval, depending on the actual emissions increase. Using sea water as make-up would most likely result in this outcome.

In all, it is expected that the following permitting/licensing requirements will be required for the cooling tower project:

- Massachusetts DEP Comprehensive Air Plan Approval;
- USEPA Prevention of Significant Deterioration (PSD);
- FAA Structure Height approval;
- MEPA (without and with an EIR);
- Construction NPDES Permit;
- Operating NPDES Permit Modifications;
- Chapter 91 permit modification;
- Army Corps of Engineers Section 404 permit;
- Massachusetts Water quality Certification
- Massachusetts Wetland Protection Act NOI (including Riverfront) and Order of Conditions;
- Wastewater Treatment System modification approval;
- Coastal Zone Management review
- Local Planning Board approval such as the Cape Cod Commission, and;
- Local Zoning Approvals (as necessary).

Adverse Environmental Impact Assessment for Mirant Canal Station

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EXECUTIVE SUMMARY

EPA and the Massachusetts Department of Environmental Protection issued a National Pollutant Discharge Elimination System (NPDES) Permit for Mirant Canal Station (Mirant Canal) located in Sandwich, Massachusetts in December 2008. The permit requires construction of cooling towers or a technology achieving comparable reductions in entrainment and impingement of fish eggs, fish larvae, juvenile and adult fish. In addition the permit requires an improved fish handling system consisting of reduced chlorine exposure, fish buckets on the intake screens, low pressure spray wash headers, and an improved fish return system.

In its review of available information EPA concluded that the cooling water intake system at Mirant Canal caused substantial adverse environmental impact. That conclusion was based on annual entrainment estimates of approximately 2.6 to 3.6 billion eggs and 187 to 318 million larvae over a two-year study period and the annual impingement of approximately 71,000 juvenile and adult fish based on a single year of data. This report provides estimates of entrainment and impingement levels under three circulating water flow scenarios and seeks to determine whether levels of entrainment and impingement observed at Mirant Canal are sufficient to impair the ability of populations to persist and perform their normal functions and values i.e. whether an adverse impact is occurring. In doing so the data presented reflect realistic current circulating water flow levels at Mirant Canal.

Eighteen taxa are addressed in this assessment: river herring (alewife and blueback herring combined), Atlantic menhaden, Atlantic herring, fourbeard rockling, Atlantic cod, silver hake, hake (white, red, and spotted hake), silverside, searobin (northern and striped), grubby, cunner, tautog, sand lance, Atlantic mackerel, windowpane, American plaice, winter flounder and American lobster. These taxa accounted for 95.6% of the fish eggs entrained, 75.5% of the larvae entrained and 95.5% of the fish impinged during field studies conducted at the facility. For each taxa the estimated number entrained and impinged for each flow scenario is presented. Equivalent adults and equivalent yield are then calculated because fish produce vast numbers of eggs and larvae very few of which survive to become adults.

These estimates are presented separately for entrainment and impingement as EPA has requested separate changes in Station design to reduce levels of both. Some species examined are not subject to entrainment in large numbers but they are susceptible to impingement while others are entrained but not often impinged. The relative benefits of entrainment and impingement reduction technologies can therefore readily be compared for each taxa.

The analysis of entrainment and impingement data presented in this report indicates that operation of the circulating water system at Mirant Canal has not resulted in an adverse environmental impact to the population of 17 taxa of fish and one important macroinvertebrate, the American lobster. Numbers of eggs and larvae entrained, expressed as a percentage of the number of eggs and larvae passing by Mirant Canal, was 1% or less for all types of eggs and larvae with the exception of cunner and tautog eggs which were 4%. Foregone harvest yield resulting from entrainment and impingement for commercially and recreationally landed species was small in absolute terms but also when compared with landings data. Equivalent yield in terms of striped bass was also very small (<30 pounds) for each of five taxa having no commercial or recreational value. Numbers of equivalent adults and yield are even less when entrainment survival is included in the assessment.

Based on the assessment presented here entrainment and impingement resulting from the circulating water system at Mirant Canal has not been sufficient to cause changes in the attributes of any population such that its sustainability is threatened. Therefore, an adverse environmental impact has not occurred.

GLOSSARY AND ACRONYMS

Adverse Environmental Impact (i.e., "AEI"): Mortality in susceptible populations caused by entrainment or impingement at the Mirant Canal Generating Station cooling water intake structure, either alone or in combination with natural (such as predation) and human-induced sources of mortality (such as harvesting), sufficient to impair the ability of these populations to maintain themselves and perform their normal ecological functions.

Atlantic States Marine Fisheries Commission (i.e., "ASMFC"): The Atlantic States Marine Fisheries Commission was formed by the 15 Atlantic coast states in 1942 in recognition that fish do not adhere to political boundaries. The Commission serves as a deliberative body, coordinating the conservation and management of the states shared near shore fishery resources – marine, shell, and anadromous fisheries – for sustainable use.

Buzzards Bay: A long bay of the western Atlantic Ocean that is enclosed by the Massachusetts mainland to the northwest, Cape Cod to the east, and the Elizabeth Islands to the southeast. It has a surface area of approximately 550 km^2 and an average depth of 11 m (Howes and Goehringer 1996). For stocks managed by the Atlantic States Marine Fisheries Commission, Buzzards Bay is the northwest portion of statistical reporting area 538.

Cape Cod Bay: The roughly circular bay of the western Atlantic Ocean located northwest of Cape Cod, Massachusetts with a surface area of about 1300 km^2, a bottom area of about 1600 km^2, and an average depth of 30 m (Emberton 1981). For stocks managed by the Atlantic States Marine Fisheries Commission, Cape Cod Bay is the southern portion of statistical reporting area 514.

Community: An assemblage of species populations that occur together in space and time.

Cooling Water Intake Structure (i.e., "CWIS"): The total physical structure and any associated constructed waterways used to withdraw cooling water from waters of the United States. The cooling water intake structure extends from the point at which water is withdrawn from the surface water source up to, and including, the intake pumps.

Early life stage: The collective term for the eggs, yolk sac larvae, post yolk sac larvae, and early juvenile life stages of fishes of a size subjected to entrainment.

Entrainment: The drawing of ichthyoplankton and other small aquatic organisms through a cooling water intake structure into the cooling system of a power plant.

Equivalent Adult (i.e., "EA"): Estimated number of entrained or impinged organisms extrapolated to the numbers or production of older reproductive age organisms that would have survived to some future age.

Generating Unit (i.e., "Unit"): Consists of the sum and total of all equipment necessary for the production of electricity including the boilers, turbine generators, and two circulating water intake pumps with each pump protected by one traveling intake screen. Each generating unit can operate independently to be brought online or taken offline as demand fluctuates in the system.

Gulf of Maine (i.e., "GOM"): The Atlantic Ocean bight from Nantucket Shoals and Cape Cod (Massachusetts) on the southwest to Cape Sable (Nova Scotia) on the northeast. These coastal waters are arbitrarily limited offshore by the 150 fathom (300 m) depth contour (Collette and Klein-MacPhee 2002).

Harvest: All fish kept as an outcome of fishing.

Ichthyoplankton: Eggs and larvae of fish with limited swimming abilities that float in the water-column and are passively transported by currents.

Impingement: The trapping of fish and other aquatic organisms against intake screens by the force of the water being drawn through a cooling water intake structure.

Individual: A single organism.

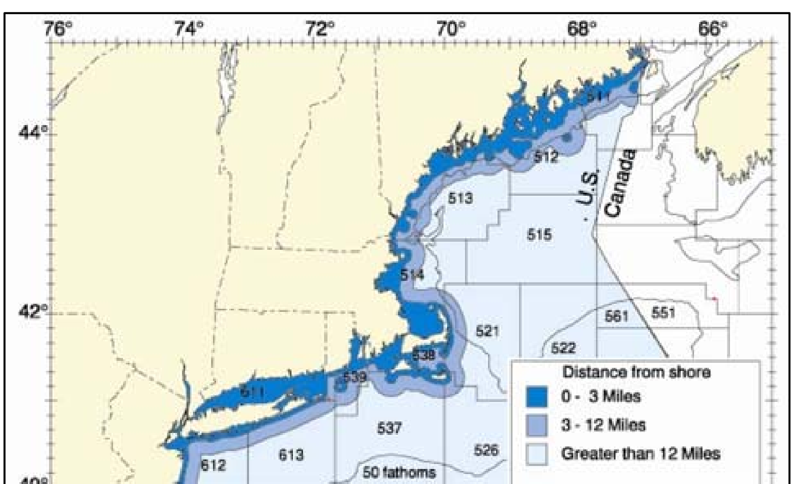
Magnuson-Stevens Fishery Conservation and Management Act (i.e., "Magnuson Act"): The primary law governing marine fisheries management in the U.S. The law is named after Warren G. Magnuson, former U.S. Senator from Washington state, and Ted Stevens, the current senior Senator from Alaska.

Massachusetts Division of Marine Fisheries (i.e., "MDMF"): The state agency managing the Commonwealth's living marine resources and the harvesting of those resources by the commercial and recreational fisheries, while maintaining a diverse number of self-sustaining fish populations at healthy levels of abundance in balance with the ecosystem.

Millions of Gallons per Day (i.e., "MGD"): Unit of measurement for cooling water intake flow.

Mirant Canal Generating Station (i.e., "Mirant Canal"): Electric power generating station located in Sandwich, Massachusetts. Mirant Canal began commercial operation in 1968, capable of generating at a rated capacity of 1,112 Megawatt electric, and withdraws source water from Cape Cod Bay and Buzzard Bay via a once-through cooling water intake structure.

NOAA Statistical Area 514 (i.e., Area 514): The statistical area used to report commerical catches that covers Cape Cod Bay and Massachusetts Bay.



Northeast Fisheries Science Center (i.e., "NEFSC"): The research arm of NOAA Fisheries in the northeast region. The NEFSC plans, develops, and manages a multidisciplinary program of basic and applied research to: (1) better understand living marine resources of the Northeast Continental Shelf Ecosystem from the Gulf of Maine to Cape Hatteras, and the habitat quality essential for their existence and continued productivity; and (2) describe and provide to management, industry, and the public, options for the conservation and utilization of living marine resources, and for the restoration and maintenance of marine environmental quality.

Overfished: The condition of a fish stock where the spawning stock biomass drops below a threshold level and may not be able to adequately replenish the population. The threshold level is determined by biological reference points including fishing mortality and stock biomass.

Overfishing: Fishing with a sufficiently high intensity to reduce the spawning stock biomass to a level that will not support a sufficient quantity of fish to sustain a commercial or recreational harvest.

Population: A group of plants, animals, or other organisms, all of the same species, that live together and reproduce.

Post Yolk-Sac Larvae (i.e., "PYSL"): Fish larvae that have absorbed the yolk and obtain nutrition by feeding but have not developed their full complement of juvenile features.

Recruit: A fish that has grown large enough to be caught in commercial fishing gear or other equipment used by agencies performing stock assessments for harvested fish species.

Susceptible: Characteristic of one or more life stages of an aquatic species that, due to life history and/or habitat preferences , are subject to entrainment and/or impingement.

Stock: The part of a fish population which is under consideration from the point of view of actual or potential utilization.

Unit: See Generating Unit

United States Environmental Protection Agency (i.e., "USEPA"): The U.S. Environmental Protection Agency (EPA or sometimes USEPA) is an agency of the federal government of the United States charged with protecting human health and with safeguarding the natural environment: air, water, and land.

Yolk-Sac Larvae (i.e., "YSL"): Fish larvae that have recently hatched and are still receiving nutrition from yolk deposited in the eggs before they were spawned.

Young-of-the-year (i.e., "YOY"): Fish that have completed the transformation from the larval to the juvenile stage and have grown large enough to be impinged on the traveling screens of the cooling water intake structure.

1.0 INTRODUCTION

EPA and the Massachusetts Department of Environmental Protection issued a National Pollutant Discharge Elimination System (NPDES) Permit for Mirant Canal Station (Mirant Canal) located in Sandwich, Massachusetts. The permit requires construction of cooling towers or a technology achieving comparable reductions in entrainment and impingement of fish eggs, fish larvae, juvenile and adult fish. In addition the permit requires an improved fish handling system consisting of reduced chlorine exposure, fish buckets on the intake screens, low pressure spray wash headers, and improved fish return. In its review of available information EPA concluded that the cooling water intake system at Mirant Canal caused substantial adverse environmental impact. That conclusion was based on annual entrainment estimates of approximately 2.6 to 3.6 billion eggs and 187 to 318 million larvae over a two-year study period and the annual impingement of approximately 71,000 juvenile and adult fish.

This report provides estimates of entrainment and impingement levels and seeks to determine whether levels of entrainment and impingement observed at Mirant Canal are sufficient to impair the ability of populations to persist and perform their normal functions and values. Three circulating water flow scenarios are considered:

- Actual flow recorded during March 1999 – February 2001 when biological studies were conducted at the Station and in surrounding waters. During those years circulating water flow averaged 75% of design flow.
- Recent actual flow recorded during 2006-2007 which was 65% of design flow.
- Maximum design flow for Unit 1 and 2 of 518 MGD.

Data collected at Mirant Canal and from the waters adjacent to it from March 1999 to February 2001 along with regional and coastal fisheries data from state and federal agencies were used in the assessment.

Eighteen taxa are addressed in this assessment: river herring (alewife and blueback herring combined), Atlantic menhaden, Atlantic herring, fourbeard rockling, Atlantic cod, silver hake, hake (white, red, and spotted hake), silverside, searobin (northern and striped), grubby, cunner, tautog, sand lance, Atlantic mackerel, windowpane, American plaice, winter flounder and American lobster (Table 1). For each taxa the estimated number entrained and impinged for each flow scenario is presented. Equivalent adults are then calculated because fish produce vast numbers of eggs and larvae very few of which survive to become adults.

These estimates are presented separately for entrainment and impingement as EPA has requested separate changes in Station design to reduce levels of both. Some species such as river herring, Atlantic menhaden, and silversides are not subject to entrainment in large numbers but they are susceptible to impingement. Similarly fourbeard rockling, hake, searobin, sand lance, and Atlantic mackerel are species not often impinged. The relative benefits of entrainment and impingement reduction technologies can therefore readily be compared.

To evaluate any adverse impacts of a CWIS, it is important to focus on populations and communities of the source water body not simply the number of individuals entrained and impinged. That is because many fish employ a reproductive strategy involving the production of large numbers of eggs most of which fail to reach adulthood. For example, 99% of winter flounder eggs die from natural causes within two months of spawning. Less than two out of every 100,000 winter flounder eggs is expected to survive to age 1 and only 12% of those survive to age 3 when maturity typically begins. As a result of these high mortality rates only one or two age 3 winter flounder are produced from every million eggs (LWB and Normandeau 2008).

Despite the mortality of individual organisms as the result of recreational and commercial fishing or impingement and entrainment, populations and communities persist. The removal of individuals in a manner that allows populations to persist is the cornerstone of fisheries management. Fisheries management agencies regularly employ catch quotas and size limitations to manage populations of fish while allowing harvesting of individual fish to continue (Restrepo et al. 1998).

Sustainability is determined by a population's abundance, age and size structure, and the ability of the members of the population to reproduce and replace themselves. An adverse impact results in measurable reductions in abundance and changes in the age and size dynamics of the population. Increased mortality rates and reduced reproductive rates in severe cases can cause the population to collapse.

EPA defines adverse ecological effects as changes that alter valued structural or functional attributes of ecological entities (USEPA 1998). To be classified as adverse impingement and entrainment must be sufficient to cause changes in the attributes of a population such as abundance, age and size structure, mortality, and reproductive potential such that its sustainability is threatened.

There are currently no regulatory guidelines for establishing what level of entrainment or impingement represents adverse environmental impact. This report therefore relies on several approaches to determine if rates of entrainment and impingement appear large enough to alter the ability of populations to persist and provide their normal functions and values. Equivalent adults were calculated for each species and when data are available these are compared with estimates of stock size. For species targeted by commercial and recreational fisheries equivalent harvest yield was calculated and for species that do not contribute to fisheries, equivalent yield was calculated in terms of striped bass. These two values allow foregone landings to be compared with traditional landings. Where adult equivalent values and equivalent yield are low relative to stock size or landings data than it follows that an adverse impact has not occurred. For harvested stocks it is also valuable to note if management agencies consider a stock to be overfished. If not, than available data indicate that the stock is at sustainable levels and therefore that no adverse impact is occurring.

2.0 METHODS

2.1 Entrainment

2.1.1 Field Collections Methods

Fish eggs and larvae entrained through the cooling water system at the Mirant Canal Generating Station Units 1 and 2 were sampled weekly during the months of March through August, twice per month during the months of February and September through January. Sampling began in late February 1999 and continued through February 2002, however samples were processed through June 15, 2001. Three samples were taken during each collection week. Each of the three samples was taken on a different day of the sampling week timed to distribute sampling in such a way that each of the primary water masses passing the Station (Buzzards Bay and Cape Cod Bay) was sampled.

All samples were collected with a 60-cm diameter plankton net, with 0.333-mm mesh, streamed in the discharge channel approximately 20 meters downstream from the head wall. Each sample represented approximately 100 m^3 of water. Exact filtration volumes were determined from a General Oceanics 2030 R2 digital flowmeter mounted in the mouth of the net. All samples were preserved in a 10% formalin-seawater solution and returned to the laboratory for microscopic examination to determine taxon, life stage, and number collected.

2.1.2 Laboratory Methods

Fish eggs and larvae were identified to the lowest distinguishable taxonomic category and counted. In most cases entire samples were examined for fish larvae and the less common types of fish eggs. When a particular species was especially abundant, aliquot subsamples were taken with a plankton splitter modified from Motoda (1959; see also Van Guelpen et al. 1982). Such subsamples contained 100 or more specimens of a given species or grouping. Studies have indicated that subsampling error can be maintained at a low level if numbers of specimens in an aliquot increase as the fraction represented by the aliquot grows smaller, e.g., 100 larvae are sufficient in a one-half split, but 200 should be present in a one-quarter split.

Nearly 100 published sources are available to identify the ichthyoplankton of coastal Massachusetts, many of which have been summarized in Jones et al. (1978), Hardy (1978a,b), Johnson (1978), Fritzsche (1978), Martin and Drewry (1978), Elliott and Kushlan (1980), Shaw (1980), and Fahay (1983). Due to the literature available, species were usually identifiable. However, certain eggs, particularly in the early stages of development, cannot be consistently identified to species in the preserved samples. These eggs were classified in species groupings in the earlier stages or in some cases throughout their development if necessary. A brief description of each grouping follows.

Gadidae-*Glyptocephalus* group (Atlantic cod, *Gadus morhua*; haddock, *Melanogrammus aeglefinus*; pollock, *Pollachius virens*, and witch flounder, *Glyptocephalus cynoglossus*) (egg diameters overlap, no oil globule present): Stage 3 eggs (those containing embryos whose tails have grown free of the yolk) were separated based on relative size and pigmentation combinations. Because haddock eggs are difficult to identify until shortly before hatching (late stage 3), some early stage 3 haddock eggs may have been identified as cod eggs; however, this error should be small based on the relatively low numbers of late stage 3 haddock eggs and haddock larvae typically collected in the coastal waters near Mirant Canal.

Enchelyopus-Urophycis-Peprilus group (fourbeard rockling, *Enchelyopus cimbrius*; hake, *Urophycis* spp.; and butterfish, *Peprilus triacanthus*) (egg and oil globule diameters overlap): Stage 3 eggs were separated based on differences in embryonic pigmentation. Prior to May 1 all eggs of this type were classified as *E. cimbrius* since the other two species are unlikely to spawn prior to that date.

Merluccius-Stenotomus-Cynoscion group (silver hake, *Merluccius bilinearis*; scup, *Stenotomus chrysops*; and weakfish, *Cynoscion regalis*) (egg and oil globule diameters overlap): Stage 3 eggs were separated based on differences in pigmentation of the embryo and oil globule.

Labridae- Limanda (Pleuronectes) group (tautog, *Tautoga onitis*; cunner, *Tautogolabrus adspersus*; and yellowtail flounder, *Limanda ferruginea* formerly *Pleuronectes ferrugineus*) (no oil globule present, egg diameters overlap): Stage 3 eggs were separated into labridae and yellowtail flounder based on differences in embryonic pigmentation. A high percentage of these two species of labrid eggs are distinguishable, but only with careful, time-consuming measurement (Williams 1967; Scherer 1984). Therefore, no attempt was made to separate cunner from tautog eggs to reduce sample analysis time. Prior to May 1 all eggs of this type were classified as yellowtail since the labrid species are unlikely to spawn prior to that date. For purposes of this analysis numbers of labrid-Limanda eggs were separated into labrid and Limanda based on their respective larval ratios collected in the Cape Cod Canal ichthyoplankton samples. Labrid eggs were separated into tautog and cunner based on their respective larval ratios collected in the Cape Cod Canal ichthyoplankton samples.

Paralichthys-Scophthalmus group (fourspot flounder, *Paralichthys oblongus*, and windowpane, *Scophthalmus aquosus*): oil globule and egg diameters as well as pigmentation similar): Separation of these two species even at stage 3 remains uncertain. Consequently they were grouped in all cases.

Several other groups of eggs and larvae were not identified to species level because adequate descriptions of each species are not available. These groupings are as follows:

Anchoa spp. - Bay anchovy (*Anchoa mitchilli*) and striped anchovy (*A. hepsetus*) eggs are easily distinguishable but their larvae are not. Eggs of these fishes were therefore listed by species while the larvae were listed simply as *Anchoa* spp.

Anchovies large enough to have developed median fins were identified to species following Lippson and Moran (1974).

Urophycis spp. - consists of the red hake (*U. chuss*), the spotted hake (*U. regia*), and the white hake (*U. tenuis*). Most larvae (and eggs) in this genus were probably the red hake (see summary in Hardy 1978a).

Menidia spp. - consists of the inland silverside (*M. beryllina*) and the Atlantic silverside (*M. menidia*). Atlantic silverside larvae are probably more likely to occur in the area of the Cape Cod Canal based on impingement collections at Mirant Canal. In a few cases, silverside prejuveniles were obtained in entrainment samples. If anal ray counts could be obtained, they were identified to species.

Ammodytes sp. - No species designation was assigned to the sand lance because considerable taxonomic confusion exists in the literature (see for example Richards et al. 1963; Scott 1968, 1972; Winters 1970; Fahay 1983; Dalley and Winters 1987). Meyer et al. (1979) examined adults collected on Stellwagen Bank and classified them as *A. americanus* = (*A. hexapterus*). Recently Nizinski et al. (1990) concluded that adult *A. americanus* occur in shallow coastal waters and protected bays and estuaries; *A. dubius* is found in deeper, open waters.

Prionotus spp. - consists of the northern searobin (*P. carolinus*) and the striped searobin (*P. evolans*).

All larval gobies were classified as the seaboard goby (*Gobiosoma ginsburgi*) based on habitat characteristics. The sympatric, naked goby (*G. bosc*) is reported to occur in waters of generally lower salinity than the seaboard goby (Fritzsche 1978).

Due to their abundance and economic importance, winter flounder larvae (*Pseudopleuronectes americanus*) were classified into four developmental stages. These stages were defined as follows; corresponding length ranges are included:

Stage 1 - from hatching until the yolk sac is fully absorbed (2.3-2.8 mm TL).
Stage 2 - from the end of stage 1 until a loop or coil forms in the gut (2.6-4.0 mm TL).
Stage 3 - from the end of stage 2 until the left eye migrates past the midline of the head during transformation (3.5-8.0 mm TL).
Stage 4 - from the end of stage 3 onward (7.3-8.2 mm TL).

All ichthyoplankton samples collected from May through October 1999 and May through October 2000 were also examined thoroughly for lobster larvae. They only occur in New England waters during those months. No subsampling was done for this species since larvae are uncommon. Lobster larvae were classified by developmental stage following Herrick (1911).

2.1.3 Analytical Methods

Egg and larvae counts by taxa were standardized to densities per 100 m^3 of water using simultaneously obtained flow meter information (Appendix B). Larval lobster were an exception in that densities were standardized to 1000 m^3 of water since they are far less common than fish eggs and larvae (Appendix C). Each time sampling was conducted at Mirant Canal the water mass (Cape Cod Bay, Buzzards Bay, or mixed water) entering the Station was determined using published tide charts for the Cape Cod Canal. Densities determined for each taxa by water mass on each sampling day were multiplied by estimated plant flow and the proportion of cooling water originating from Cape Cod Bay (80%) and Buzzards Bay (20%) to derive daily total entrainment estimates. For example, on June 9, 2000 a density of 92.14 mackerel eggs per 100 m^3 of water was obtained in the Mirant Canal discharge canal while Cape Cod Bay water was adjacent to the Station. Average Station flow recorded in June 2000 was 462.77 MGD. The June 9 density was multiplied by Cape Cod Bay plant flow converted to 100 m^3 units [(462,770,000 gals * 0.8)/26417.205) = 14,014.2,100 m3 units] to estimate the daily total number of mackerel eggs entrained on June 9. Whenever entrainment samples were collected as mixed Cape Cod Bay and Buzzards Bay water was entering the Station densities were divided evenly between Cape Cod Bay and Buzzards Bay. Daily total entrainment estimates were integrated over time using trapezoidal integration to derive monthly and annual total entrainment estimates for each of the priority taxa collected from March 1999 through February 2000 and from March 2000 through February 2001 (see example in Appendix B). Estimates for the two years were averaged (Table 2)

Three plant flow scenarios were considered (Table 3):

- Design flow = 800 cubic feet per second (cfs; 518 million gallons per day, MGD).
- Actual plant flow recorded from March 1999 through February 2001 when entrainment sampling was completed.
- Average plant flow recorded during 2006 and 2007.

Percent of total figures provided in the text were calculated from the actual plant flow data based on means over the two sampling years.

2.1.4 Equivalent Adults

Numbers of fish eggs and fish larvae entrained under each of the three Station flow scenarios were converted to equivalent adult fish using stage-specific mortality rates obtained from EPA (2004) and assuming eggs and larvae did not survive passage through the circulating water system (Table 2). Equivalent adults are a useful tool for interpreting the context of what are often large numbers of entrained eggs and larvae. The procedure employs estimates of mortality rates to estimate how many adult fish might have been produced had entrainment not occurred. When data were available, age at maturity was defined as the age at which 50% of the fish begin to reproduce. In addition to numbers of fish, equivalent adults were expressed on a weight basis by multiplying by the average weight of an equivalent adult fish. For example, Atlantic mackerel weigh approximately

0.639 pounds at age 3 when they begin to mature so the number of age 3 equivalent adults was multiplied by 0.639. It is important to bear in mind that not all those fish would be caught so the equivalent adult weight does not represent a loss to commercial and recreational fisheries. That is properly assessed by calculating equivalent yield (see below).

Since the EPA life tables provide survival rates for each stage from beginning to end an adjustment was made to each survival rate following EPRI (2004) to account for the fact that entrained fish eggs and larvae are typically of mixed ages. It was assumed that the further along in development an entrained individual was the greater the probability that the individual would survive to the next life stage.

The EPA (2004) life table for the fourbeard rockling, a species for which many important life history variables such as fecundity are unknown, is inconsistent with other members of the cod family. For every one million eggs the rockling life table results in 572 age 1 fish. For Atlantic cod one million eggs produce 9 age 1 fish. Similarly for haddock, silver hake and the other hakes (red, white, and spotted) 9, 3, and 2 age 1 fish are produced. Since the rockling data were inconsistent the hake life table was used for rockling. Similarly life tables for searobin and grubby produced very high numbers of age 1 fish from one million eggs, 1,032 and 906, respectively. Although also exceptionally high (685 age 1 fish) the sand lance life table was used for these two species as a conservative compromise.

To calculate equivalent adults for American lobster instantaneous natural mortality was obtained from French McCay et al. (2003). The daily larval morality rate was 0.147 (French McCay et al. 2003). Larval stage durations were based on MacKenzie and Moring (1985) and a 28-day larval period (French McCay et al. 2003). Stage-specific instantaneous fishing mortality (commercial and recreational combined) was obtained from Dean et al. (2004, 2005) and Dean et al. (2006). Proportion vulnerable to fishing is based on the current Massachusetts minimum legal size of 82 mm carapace length (CL) (Dean et al. 2004, 2005 and Dean et al. 2006). American lobster are harvestable in Gulf of Maine for the commercial and recreational fisheries to a maximum size of 127 mm CL.

In calculating equivalent adults no attempt was made to adjust for density dependence or the ability of populations to compensate for the loss of some individuals (Rose et al. 1993, Tyler et al. 1997 among others). Variation in growth and mortality rates during the early life history stages in marine fish populations is very large. As numbers decline, in this case due to entrainment and impingement, growth can increase and mortality may decrease among the remaining individuals. As a result the ultimate affect of entrainment and impingement is diminished.

2.1.4.1 Entrainment Survival

Entrainment survival was accounted for two ways. First to represent the worst case, all fish eggs and larvae entrained were assumed to die, and equivalent adults and equivalent yield (see below) were calculated on that basis. Secondly, fish eggs and larvae entrained were assumed to have some entrainment survival since field studies at numerous facilities including Mirant Canal have shown that some fish eggs and larvae do survive entrainment (EPRI 2000, Collings et al. 1981). Empirical entrainment survival values were used to adjust the numbers entrained for the priority species before completing the equivalent adult and equivalent yield estimates (see Section 4.21).

2.1.5 Equivalent Yield

Equivalent (harvest) yield provides a context for evaluation of the available data that appropriately considers causes of fish mortality in the vicinity of Mirant Canal other than entrainment and impingement. Equivalent (harvest) yield to the commercial and recreational fisheries was calculated for each taxa beginning with the estimated number of age 1 fish. Equivalent yield represents the added pounds of fish that could theoretically have been landed by fisheries if entrainment and impingement had not occurred. The calculation incorporates fishing mortality rates, vulnerability to the fishery, natural mortality rates, and average weight for each age from age 1 to the maximum expected age. It therefore represents the total pounds of fish that might be landed on a per fish basis beginning at age 1 and extending over that fish's lifetime. For example, the harvest yield of an age 1 winter flounder was estimated to be 0.4179 pounds. Over the 16-year life span of 100 age 1 fish, 4 pounds would be expected to be landed by commercial and recreational fisheries.

Appendix A Table 1 summarizes the stage-specific natural and fishing mortality rates, and weight at age for each taxa. At the bottom of each table the equivalent yield per age 1 fish is shown for harvested species.

For non-harvested species a trophic transfer coefficient of 10% was assumed (Pauly and Christensen 1995) to estimate the amount of additional striped bass in pounds that would be produced and harvested had entrainment not occurred. Natural mortality rates at age provided by EPA (2004) were used to calculate the weight of fish in pounds that would have died over the lifetime of each age 1 fish. For example, over the ten-year lifespan of an age 1 sand lance 0.0061 pounds of fish would have died (all due to natural mortality since sand lance are not harvested). The loss of 10,000 age 1 sand lance as a result of entrainment would result in the loss of 61 pounds of fish and therefore 6 pounds of striped bass would have been produced. A target fishing mortality rate of $F = 0.3$ and natural mortality rate of $M = 0.15$ (exploitation rate = 0.24158) was used to estimate pounds of striped bass resulting from the trophic transfer that would be expected to be harvested. In this example 1.4 pounds.

2.2 Impingement, 1999-2000

2.2.1 Field Collection Methods

The Mirant Canal Generating Station consists of two generating units, each with two circulating water pumps. Each pump is protected by one traveling intake screen constructed of 3/8-inch (9.5 mm) mesh. Under normal plant operations screens rotate automatically triggered by head-loss pressure switches. Additional manual washes were typically made every eight hours around the time of shift change. Impingement sampling began on February 26, 1999 and continued until March 31, 2000. Sampling occurred three times a week: once in the morning, once in the afternoon, and once at night. Each unit was sampled separately. Typically both a unit's screens were sampled simultaneously. Occasionally, if a pump was out of service, only the screen in front of the operating pump was sampled.

Impingement collections were made by placing a 3/8-inch (9.5 mm) stainless steel basket in the screenwash return sluiceway while the screens were operating. Sampling time was typically a minimum of two hours as recorded from the end of the previous wash to the end of the current wash. Occasionally, such as during high fish impingement events, the screens were operated continuously. On these occasions a one-hour sample was collected.

Upon completion of each collection the basket contents were examined. Amounts of mixed wet algae were approximated in gallons. All fish and macroinvertebrates in each sample were collected, identified, and enumerated. Fish were measured to the nearest millimeter total length and all lobster were measured to the nearest millimeter carapace length. In large collections, 25 individuals per species were measured, the remainder counted. All fish were immediately examined for initial condition (live, dead, injured) by placing them in a bucket of ambient seawater. Any fish that was alive or injured at the time of collection were placed in 20 gallon holding tanks supplied with continuously running ambient seawater. Latent survival was determined after 48 hours. Fish classified as injured after 48 hours were tallied with dead fish to provide conservative estimates of the impingement survival rate. Large fish such as striped bass and skates were too large to be held in the tanks, so only initial survival was determined. Latent survival was calculated by species by dividing total number alive after 48 hours by the total initial number (not including fish immediately released and those not found in the holding tanks after 48 hours). Lobster were counted, measured (carapace length) and recorded as alive, injured, or dead. Lobsters were not held in the holding tanks after several disappeared. Lobster had an initial survival rate of 94%

Each generating unit is also fitted with a trash rack ahead of the traveling screens. These were cleaned with a mechanical trash rack rake during each screenwash sample. The contents were unloaded into a sluiceway and examined for any fish, mammals, reptiles, and invertebrates. Any fish or lobster sampled from the trash racks were not included in this analysis because Mirant Canal log books did not document trash rack wash times. Only 26 fish (10 species) were impinged on the trash racks producing an extrapolated total of 45 fish. Cunner and winter flounder were the only priority species collected with estimated annual totals of 22 and 4 fish, respectively, both less than 1% of their estimated traveling screen totals.

2.2.2 Analytical Method

For each Unit collection, numbers of fish impinged in the 24-hour period represented by each sample was calculated by species based on the sampling interval. For example, if two cunner were collected in a two-hour screen wash, an estimated 24-hour total of 24 was calculated (see example of calculation at end of Appendix D). From the 24-hour estimates, extrapolated totals were expanded to weekly totals. Typically this involved scaling by a factor of 2.33 to account for three sampling days in every week. Unit totals were summed to produce weekly Station totals. The weekly Station totals were added to produce monthly estimates and an annual estimate.

To derive impingement estimates for design flow and for 2006-2007 plant flow, monthly impingement estimates obtained in 1999-2000 were scaled up or down as appropriate based on direct proportion assuming that impingement is directly related to flow (Table 3).

On four days in June 1999 the plant experienced problems with chlorine injections with the result that several species of fish were impinged in unusual numbers. These included cunner, pollock, Atlantic cod, winter flounder, sand lance, white hake, and scup. Estimated numbers impinged and impingement survival rates were calculated after excluding that anomaly. The lengths of these species impinged in the chlorine events were used in data analysis.

2.2.3 Equivalent Adults

Numbers of fish impinged within each taxa were adjusted as appropriate based on the observed rate of impingement survival at Mirant Canal (Table 4). To calculate equivalent adults and equivalent yield (see below) for fish lost to impingement, it was necessary to determine the age of each collected fish. Length frequency distributions were calculated for each species in 10 mm intervals or bins. The percent of the total number of fish measured within taxa was then determined for each length bin. Length at age obtained from the scientific literature was used to assign age in years to each bin. The total number of fish estimated to have been impinged each month for each species was then multiplied by the percent of total represented by each bin to partition the monthly total into age classes. For example the results of the length frequency distribution for butterfish showed that 86.7% of those measured were age-0 (juveniles) and 13.0% were age-1 fish. In December there was an estimated total of 90 butterfish impinged. By multiplying 90 by the respective percentages of age-0 and age-1 fish it was determined that there were 78 age-0 and 12 age-1 butterfish impinged in December.

Since fish impinged later in any given year have a higher probability of surviving to their next birthday compared with fish impinged earlier in the year, mortality rate adjustments were made for each month that juvenile fish were impinged. This was done by dividing the EPA stage-specific instantaneous mortality rate by the respective stage duration in days to obtain a daily instantaneous rate. This daily instantaneous rate was multiplied by the number of days remaining until each fish's next birthday to derive the mortality rate expected to the end of that year. That mortality rate was converted to the corresponding survival rate ($S = e^{-M}$), then multiplied by the number of age 0 fish impinged during each respective month to estimate the number of equivalent age 1 fish. The numbers of age 1 fish expected to survive each month, had they not been impinged, were totaled to obtain an estimated annual total number of equivalent age 1 fish. All impinged fish older than age 1 were conservatively assumed to survive to their next birthday for purposes of calculating equivalent adults. Annual survival rates obtained from EPA (2004) were used to convert age 1 fish to older age classes for any species maturing at ages older than 1 (Table 5). If specific life history information was available, age at maturity was defined as the age at which 50% of the fish begin to reproduce. If life history data were not available, only age 1 equivalents were calculated as described above.

Information summarized below reflects one year of impingement sampling (March 1999-February 2000) and two years of entrainment sampling (1999-2001). When combined for entrainment and impingement, equivalent adult estimates were based on the average value for the two years of entrainment sampling plus the single year of impingement sampling.

2.2.4 Equivalent Yield

Equivalent yield to the commercial and recreational fisheries was calculated for each taxa beginning with the estimated number of age 1 fish. Equivalent yield represents the added pounds of fish that could theoretically have been landed by fisheries if entrainment and impingement had not occurred. Numbers of fish older than age 1 that were impinged were hindcast to age 1 using the life table survival rates. For example, if 100 age 2 fish were impinged and the age 1 to age 2 survival rate was 0.331 than the equivalent of 302 age 1 fish were added to the age 1 equivalents.

Appendix A Table 1 summarizes the stage-specific natural and fishing mortality rates, and weight at age for each taxa. At the bottom of each table the equivalent yield per age 1 fish is shown for harvested species. For non-harvested species a trophic transfer coefficient of 10% was assumed (Pauly and Christensen 1995) to estimate the amount of additional striped bass in pounds that would be produced and harvested by the weight of each taxa that died as a result of impingement. A target fishing mortality rate of $F = 0.3$ and natural mortality rate of $M = 0.15$ was used to estimate pounds of striped bass resulting from the trophic transfer that would be expected to be harvested.

2.3 Cape Cod Canal Ichthyoplankton

From late March 1999 through March 2000 ichthyoplankton sampling was completed at one location in the Cape Cod Canal opposite Mirant Canal, one location in Cape Cod Bay, and one location in Buzzards Bay. Exact locations included Station 6 (Cape Cod

Canal) and Station 4 (Stony Pont Dike in Buzzards Bay) both established by Collings et al. (1981) during earlier studies conducted for the Canal Plant. The Cape Cod Bay station was sited north of the entrance to the Cape Cod Canal in order to sample the counterclockwise current which enters the canal on the westward (ebb) tides. These stations were sampled weekly during March through August and biweekly from September through February. Offsite sampling was coordinated with entrainment sampling, so discharge samples were collected at the same time that Station 6, opposite the plant, was sampled. Every other week from March through August Station 6 was sampled in duplicate in the presence of Cape Cod Bay water and in duplicate in the presence of Buzzards Bay water. During opposite weeks, generally only Cape Cod Bay water was sampled because that water mass was more common near Mirant Canal (see discussion below); efforts were made to capture Buzzards Bay water whenever possible. From September through February, sampling was coordinated every other week. Station 6 was sampled in the presence of Cape Cod Bay and again in the presence of Buzzards Bay water.

At each location samples were taken in duplicate using paired 60-cm diameter bongo nets fitted with 0.333-mm mesh and 0.505-mm mesh nets. The finer mesh insured retention of small fish eggs and larvae, although larger mesh nets were used in earlier studies (Collings et al. 1981). The samples collected from the larger mesh net were archived. Each tow was oblique with the net being raised and lowered from bottom to surface to collect fish eggs and larvae equally throughout the water column.

To provide some context for the numbers of eggs and larvae entrained samples of ichthyoplankton obtained from the Cape Cod Canal opposite Mirant Canal were integrated over each species occurrence period following the same procedures described for entrainment. Geometric mean densities were used over the two replicate samples collected on each sampling occasion. These are generally somewhat lower then the arithmetic means used for the entrainment estimates and, coupled with the arithmetic means used for the entrainment estimates, will tend to over-estimate the effect of entrainment. Time-integrated values were multiplied by the volume of water passing through the Canal on two tidal cycles each day. Following Collings et al. (1981), the calculated volume of the Canal is 32,284,800 m^3 a volume replaced twice each tidal cycle suggesting a total exchange volume of 129,139,200 m^3 per day. Since Mirant Canal is located near the eastern end of the Cape Cod Canal 80% of the exchange volume (103,311,360 m^3) was attributed to Cape Cod Bay and the remaining 20% (25,827,840 m^3) to Buzzards Bay. Therefore, integrated Canal densities recorded when Buzzards Bay water was opposite the Plant were multiplied by 25.8E4 100-m^3 units and integrated densities recorded when Cape Cod Bay water was opposite the Plant were multiplied by 103.3E4 100-m^3 units (Table 6). Numbers of eggs and larvae entrained were compared with the number of eggs and larvae passing through the Canal.

3.0 PRIORITY TAXA

This assessment focused on 18 taxa of fish and one invertebrate: river herring (alewife and blueback herring combined), Atlantic menhaden, Atlantic herring, fourbeard rockling, Atlantic cod, silver hake, hake (white, red, and spotted hake), Atlantic silverside, searobin (northern and striped), grubby, cunner, tautog, sand lance, Atlantic mackerel, windowpane, American plaice, winter flounder and American lobster. These 19 taxa were selected based on susceptibility to entrainment and/or impingement as well as ecological importance and/or commercial, recreational value to fisheries (Table 1). Life history summaries and parameters for these species are provided in Appendix A.

4.0 RESULTS

Estimated numbers for entrainment and impingement and the corresponding equivalent adults presented in numbers and weights under each of the three flow scenarios for the eighteen taxa assessed are shown in Tables 2 and 4. These estimated numbers are shown to the nearest whole individual to make it easier to follow the calculations. Individual taxa are discussed in context of regional and coastal fisheries data whenever possible.

4.1 River Herring (Alewife and Blueback Herring)

River herring spawn demersal and somewhat adhesive eggs in freshwater; as a result relatively low numbers of eggs and larvae are entrained at Mirant Canal (Table 2). These numbers along with the corresponding equivalent adults are summarized in the following table for each of the three flow scenarios. Based on the recorded 1999-2001 circulating water flow, river herring accounted for 0.002% of the total number of eggs entrained and 0.01% of the larvae entrained. Equivalent adults lost to entrainment amounted to 3 age 3 fish (1 pound) based on the recorded 1999 to 2001 flow.

River Herring Entrained				
Plant Flow	Average Number Entrained		Equivalent Adults (Age 3 Fish)	
	Eggs	Larvae	Number	Pounds
Maximum	61,694	25,494	4	1
1999 – 2001	56,923	22,288	3	1
2006 – 2007	43,352	18,262	3	1
Weight based on age 3 alewife.				

As a result of their anadromous reproductive life style the number of eggs and larvae entrained and the number of equivalent adults is very low and does not to represent an adverse impact to river herring populations in the vicinity of Mirant Canal.

River herring accounted for 35% of the estimated annual impingement during 1999-2000 with a combined species total of 25,779 fish (Table 4). The majority of impinged fish were young-of-the-year (Figure 1) and they were about evenly distributed between alewife and blueback herring.

River Herring Impinged			
Plant Flow	**Total Number Impinged**	**Equivalent Adults (Age 3 Fish)**	
		Number	**Pounds**
Maximum	63,866	5,311	1,159
1999 – 2001	25,779	2,234	487
2006 – 2007	38,200	2,399	688
Weight calculated separately for age 3 alewife and blueback herring.			

Combined River Herring		
Equivalent Adults (Age 3 Fish)		**Equivalent Yield (lbs)**
Number	**Pounds**	
5,315	1,160	46
2,237	488	19
2,402	689	28
Estimated entrainment and impingement equivalent adult weights added together.		

Juvenile herring impinged at Mirant Canal may come from a number of river systems in Buzzards Bay and Cape Cod Bay as these fish move offshore for several years to grow and mature before spawning. Similarly the small number of eggs and larvae that drift from freshwater spawning habitat may disburse many miles during early development. Two herring runs in Buzzards Bay, the Mattapoisett and Sippican Rivers have electronic fish counters that allow run size to be estimated although the Sippican counter was not installed until 2005. The Bournedale run in the Cape Cod Canal is also monitored with an electronic counter. The 1999 and 2000 Mattapoisett River run consisted of approximately 107,000 and 130,000 adults, respectively while the Bournedale run for those two years consisted of 213,000 and 672,000 fish, respectively. Based on the Mattapoisett and Bournedale herring run counts an average of 561,000 adults were in the local area in 1999 and 2000 and represent only two of the local populations. Based on the average run size for 1999 and 2000 the estimated loss of equivalent adults under the three flow scenarios would range from 0.4% to 1%.

Comparing the average number entrained with the estimated number of river herring larvae passing Mirant Canal in 1999-2000 (Table 7) suggested that 0.26% of the total were entrained. Since 2000, river herring have declined sharply along the eastern US coast and presumably any corresponding declines in egg and larval abundance were reflected in lower levels of entrainment in years following those in which studies were done. Had entrainment and impingement of river herring not occurred at the recorded levels 19 additional pounds of striped bass might have been landed by the recreational and commercial fisheries.

River herring are managed by the Atlantic States Marine Fisheries Commission (ASMFC). Adults are harvested recreationally and commercially, the latter in the ocean and in their natal rivers. However, in response to stock declines harvest moratoria were established in Massachusetts, Rhode Island, Connecticut, and North Carolina beginning in 2006 and extending through at least 2011. Due to this moratorium river herring were treated as a forage species and expressed in terms of equivalent striped bass yield. In 1999, 2000, and 2001 when studies were conducted at Mirant Canal six states reported commercial landings, most from Maine, North and South Carolina. Totals were 1.33 million pounds in 1999, 1.25 million pounds in 2000, and 1.53 million pounds in 2001. The estimated entrainment and impingement losses at Mirant Canal represent 0.1% or less of those landings.

Based on the small numbers of eggs and larvae entrained and the impingement results compared with stock size and landings data during the years when studies were completed no adverse impact to river herring populations is expected. River herring stocks have declined in recent years as has water usage at Mirant Canal suggesting that overall impacts have not increased since studies were done.

4.2 Atlantic Menhaden

Atlantic menhaden represented 0.1% of the eggs and 0.4% of the larvae entrained at Mirant Canal. An average of 2,761,158 menhaden eggs and 740,561 larvae were estimated to have been entrained during studies completed from 1999 to 2001. Based on the number of menhaden eggs (520.2 million) and larvae (257.9 million) passing Mirant Canal in the Cape Cod Canal in 1999-2000, numbers entrained under actual plant flow represented 0.53% of menhaden eggs and 0.29% of the larvae.

Equivalent adults lost to entrainment amounted to 8 age 3 fish (3 pounds) based on circulating water flow recorded from 1999 to 2001. If entrainment had not occurred the estimated 8 age 3 equivalent adults would have produced an estimated 8 pounds of harvestable menhaden over the lifespan of the individuals. The following table summarizes numbers entrained, equivalent adults, and harvest yield for each of the three flow scenarios.

Atlantic Menhaden Entrained					
Plant Flow	Average Number Entrained		Equivalent Adults (Age 3 Fish)		Harvest Yield (lbs)*
	Eggs	Larvae	Number	Pounds	
Maximum	3,163,620	1,095,581	11	4	10
1999 – 2001	2,761,158	740,561	8	3	8
2006 – 2007	2,120,663	686,947	7	3	6
* Over an 8- year lifespan.					

The numbers of equivalent adults lost to entrainment is very low and the number entrained represents a small percentage of the number drifting through the Cape Cod Canal therefore no adverse impact to the Atlantic menhaden populations in the vicinity of Mirant Canal is occurring.

Atlantic menhaden juveniles (Figure 2) represented 32% of the fish impinged at Mirant Canal. 23,901 juvenile menhaden were estimated to have been impinged during the study completed in 1999 and 2000. The estimated equivalent adults for impingement amounted to 2,090 age 3 fish (840 pounds). If impingement had not occurred the estimated 2,090 age 3 equivalent adults would have produced an estimated 1,970 pounds of harvestable menhaden over the lifespan of the individuals. The combined equivalent adults for entrainment and impingement amounted to 2,098 age 3 fish based on circulating water flow recorded in 1999 to 2001. Corresponding values for maximum flow and 2006-2007 flow were 4,620 and 2,731 respectively.

Atlantic Menhaden Impinged					Combined Atlantic Menhaden		
Plant Flow	Total Number Impinged	Equivalent Adults (Age 3 Fish)		Harvest Yield (lbs)*	Equivalent Adults (Age 3 Fish)		Harvest Yield (lbs)*
		Number	Pounds		Number	Pounds	
Maximum	52,582	4,609	1,853	4,344	4,620	1,857	4,354
1999 – 2001	23,896	2,090	840	1,970	2,098	843	1,977
2006 – 2007	31,162	2,724	1,095	2,566	2,731	1,098	2,573

* Over an 8-year lifespan.

Atlantic menhaden is a migratory fish consisting of a single spawning population without regional subpopulations (ASMFC 2006a). Age 3 abundance in 1999 and 2000 was estimated to be 240 and 220 million fish, respectively. The combined number of equivalent adults resulting from entrainment and impingement under actual flow amounted to only 0.001% of the estimated average spawning stock. Had menhaden not been entrained and impinged about 2,000 pounds of fish might have been landed by the commercial and recreational fisheries combined over the 8-year lifetime of those menhaden.

Atlantic menhaden are managed by the ASMFC and have supported one of the largest fisheries in the United States since colonial times. This fishery is comprised of two components, a reduction fishery that produces fishmeal and fish oil and a bait fishery. The majority of landings in New England are for the bait fishery. Annual bait landings along the Atlantic coast averaged approximately 80.5 million pounds from 1999-2001, and approximately 80.7 million pounds from 2001-2005, representing approximately 17% of the total landings (ASMFC 2006a). The ASMFC currently does not consider Atlantic menhaden overfished nor is overfishing occurring (ASMFC 2006a).

The numbers of equivalent adults and harvest yield lost to plant operations is low and current regulatory agency data suggests that the Atlantic menhaden population is currently sustainable and not overharvested therefore Mirant Canal plant operations are not having an adverse impact on the Atlantic menhaden population.

4.3 Atlantic Herring

Atlantic herring eggs are adhesive, spawned on offshore banks, and not subject to entrainment. Entrainment of herring larvae accounted for 0.5% of the average number of larvae entrained during the 1999-2000 and 2000-2001 sampling seasons. The number of Atlantic herring larvae entrained based on actual plant flow represented 0.05% of the estimated 1.9 billion larvae passing by Mirant Canal through the Cape Cod Canal.

Equivalent adults lost to entrainment amounted to 1,060 age 3 fish (320 pounds) based on the circulating water flow recorded from 1999 to 2001. If entrainment had not occurred the estimated 1,060 equivalent adults would have produced an estimated 388 pounds of harvestable Atlantic herring over the lifespan of the individuals. The following table summarizes numbers entrained, equivalent adults, and harvest yield for each of the three flow scenarios.

Atlantic Herring Entrained					
Plant Flow	Average Number Entrained		Equivalent Adults (Age 3 Fish)		Harvest Yield (lbs)*
	Eggs	Larvae	Number	Pounds	
Maximum	0	1,624,877	1,766	533	647
1999 – 2001	0	975,579	1,060	320	388
2006 – 2007	0	1,043,520	1,134	342	415
* Over a 16-year lifespan.					

The numbers of equivalent adults lost to entrainment is low and should not represent an adverse impact to the Atlantic herring populations in the vicinity of Mirant Canal.

Atlantic herring impingement totaled an estimated 1,230 fish and accounted for 2% of the estimated annual total in 1999-2000. All the sampled individuals were juveniles (Figure 3). Estimated equivalent adults for impingement amounted to 298 age 3 fish (90 pounds). If impingement had not occurred an estimated 51 pounds of harvestable herring would have been produced over the lifespan of the 298 equivalent adults. The combined equivalent adults for entrainment and impingement based on circulating water flow recorded from 1999 to 2001 amounted to 1,358 age 3 fish (410 pounds). The following table summarizes numbers impinged, equivalent adults, and harvest yield for each of the three flow scenarios.

Atlantic Herring Impinged					Combined Atlantic Herring		
Plant Flow	Total Number Impinged	Equivalent Adults (Age 3 Fish)		Harvest Yield (lbs)*	Equivalent Adults (Age 3 Fish)		Harvest Yield (lbs)*
		Number	Pounds		Number	Pounds	
Maximum	1,686	408	123	70	2,174	657	716
1999 – 2001	1,230	298	90	51	1,358	410	439
2006 – 2007	1,090	264	80	45	1,398	422	460
* Over a 16-year lifespan.							

Atlantic herring are managed as the Gulf of Maine-Georges Bank stock complex. This complex contains three distinct but seasonally intermixing components, the coastal Gulf of Maine, Nantucket Shoals, and Georges Bank. Total landings for the stock complex declined from 470,000 mt in 1968 to 36,000 mt in 1983, then gradually increased during the late 1980s and 1990s, peaked at 133,000 mt in 2001, and then decreased slightly from 2002 through 2005 (Overholtz 2006). NEFSC spring and autumn research survey biomass indices were low in the 1960s and 1970s, and declined further in the 1980s when the offshore component collapsed. As the stock complex recovered the biomass indices increased in the late 1980s and 1990s and have remained relatively high but variable (Overholtz 2006). Based on the latest stock assessment (TRAC 2006) the Gulf of Maine-Georges Bank stock complex had an age 2 + stock biomass of 1.0 million metric tons (mt) in 1999, 1.3 million mt in 2000, and 1.0 million mt in 2005. The coastal Gulf of Maine component represents approximately 25% of the stock complex in both numbers and biomass (Overholtz et al. 2004) accounting for approximately 250,000 mt in 1999 and 325,000 mt in 2000. Currently the Atlantic herring stock complex is not considered overfished (Overholtz 2006).

The potential annual loss of 1,358 age 3 fish weighing 410 pounds (0.19 mt) to plant operations is low and current regulatory agency data suggests that the Atlantic herring stock complex is currently sustainable and not overharvested. Based on these data Mirant Canal plant operations are not expected to result in an adverse impact on the Atlantic herring population.

4.4 Fourbeard Rockling

Rockling spawn pelagic eggs that are subject to entrainment as are individuals in the larval stage. An estimated 33.7 million rockling eggs and 8.1 million larvae were entrained based on the recorded 1999-2001 flow. Their eggs accounted for 1.3% of all eggs entrained and their larvae accounted for 4.3% of all larvae entrained. The numbers of rockling eggs and larvae estimated to have passed Mirant Canal during the 1999-2000 study were 5.63 and 2.52 billion, respectively suggesting that rockling are abundant. The average number of each life stage entrained under actual circulating water flow therefore amounted to less than 0.6% and 0.3 % of these respective totals. Based on the circulating water flow recorded from 1999 to 2001 equivalent adults lost to entrainment amounted to

311 age 1 fish (4 pounds). The numbers entrained and equivalent adults for each the three flow scenarios are summarized in the following table.

Fourbeard Rockling Entrained				
Plant Flow	**Average Number Entrained**		**Equivalent Adults (Age 1 Fish)**	
	Eggs	**Larvae**	**Number**	**Pounds**
Maximum	43,775,959	9,848,308	390	6
1999 – 2001	33,784,338	8,115,074	311	4
2006 – 2007	28,095,951	6,654,402	257	4

The numbers of equivalent adults lost to entrainment are low and should not represent an adverse impact to the rockling populations in the vicinity of Mirant Canal.

Rockling were uncommon in Mirant Canal impingement samples probably because they are a bottom fish that burrows into soft sediments. An extrapolated total of 22 individuals was estimated to have been impinged in 1999-2000 representing 0.03% of the year's total. The combined equivalent adults for entrainment and impingement based on circulating water flow recorded from 1999 to 2001 amounted to 333 age 1 fish (5 pounds). The following table summarizes numbers impinged, equivalent adults, and equivalent yield for each of the three flow scenarios.

Fourbeard Rockling Impinged				**Combined Fourbeard Rockling**		
Plant Flow	**Total Number Impinged**	**Equivalent Adults (Age 1 Fish)**		**Equivalent Adults (Age 1 Fish)**		**Equivalent Yield (lbs)***
		Number	**Pounds**	**Number**	**Pounds**	
Maximum	25	25	0.4	415	6	0.5
1999 – 2001	22	22	0.3	333	5	0.4
2006 – 2007	17	17	0.2	274	4	0.3
* Over a 9-year lifespan.						

As a result of their small size rockling have no commercial or recreational value and no stock size data are currently available.

Equivalent yield for rockling amounted to less than one pound of striped bass. Based on these data the potential annual loss of small numbers of rockling to plant operations should not result in an adverse impact to the population.

4.5 Atlantic Cod

Atlantic cod eggs accounted for an average of 0.05% of all eggs entrained and their larvae accounted for an average of 0.6% of all larvae entrained. The numbers of eggs and larvae entrained under actual flow at the time of sampling represented only 0.44 and 0.46% of the number of cod eggs and larvae drifting past Mirant Canal during 1999-2000. Equivalent adults lost to entrainment amounted to 1,750 age 2 fish (429 pounds) based on the circulating water flow recorded from 1999 to 2001. If entrainment had not occurred the estimated 1,750 equivalent adults would have produced an estimated 931 pounds of harvestable Atlantic cod over a 6-year lifespan of an adult. The following table summarizes numbers entrained, equivalent adults, and harvest yield for each of the three flow scenarios.

Atlantic Cod Entrained					
Plant Flow	Average Number Entrained		Equivalent Adults (Age 2 Fish)		Harvest Yield (lbs)*
	Eggs	Larvae	Number	Pounds	
Maximum	1,597,157	1,357,940	2,153	527	1,145
1999 – 2001	1,135,277	1,105,005	1,750	429	931
2006 – 2007	1,021,503	951,029	1,507	369	802
* Over a 6-year lifespan.					

The numbers of equivalent adults lost to entrainment are low and unlikely to represent an adverse impact to the Atlantic cod populations in the vicinity of Mirant Canal.

Cod were impinged in small numbers at Mirant Canal in 1999-2000 with an extrapolated total of 671 fish being estimated for the year. This number represented 0.9% of the year's total. Equivalent adults lost to impingement amounted to 211 age 2 fish (52 pounds) based on the recorded 1999 to 2001 circulating water flow. If impingement had not occurred the 211 equivalent adults would have produced an estimated 112 pounds of harvestable cod over the lifespan of the individuals. The combined equivalent adults lost to plant operations amounted to 1,961 age 2 fish (481 pounds). The table below summarizes numbers impinged, equivalent adults, and harvest yield under the three flow scenarios.

Atlantic Cod Impinged					Combined Atlantic Cod		
Plant Flow	Total Number Impinged	Equivalent Adults (Age 2 Fish)		Harvest Yield (lbs)*	Equivalent Adults (Age 2 Fish)		Harvest Yield (lbs)*
		Number	Pounds		Number	Pounds	
Maximum	937	306	75	163	2,459	602	1,308
1999 – 2001	671	211	52	112	1,961	481	1,043
2006 – 2007	604	196	48	104	1,703	417	906
* Over a 6-year lifespan.							

Atlantic cod are managed as two spawning stocks consisting of the Gulf of Maine which includes Cape Cod Bay, and Georges Bank which includes inland waters such as Vineyard Sound, Buzzards Bay, Block Island Sound and Narragansett Bay. Commercial landings in the Gulf of Maine declined from 17,781 mt in 1991 to 1,380 mt in 1999, increased to 4,280 mt in 2001, declined to 3,028 mt in 2006, and increased slightly to 3,989 mt in 2007. NOAA Statistical Area 514 commercial landings peaked at 14,124,290 pounds in 1983, gradually declined to a low of 385 pounds in 1999, and then increased to 3,429,011 pounds in 2006. The commercial landings averaged 20,699 pounds from 1999-2001. Georges Bank landings declined from 12,889 mt in 2001 to 3,384 mt in 2005, and then increased slightly to 5,957 mt in 2007 (NEFSC 2008).

According to the latest stock assessment (NEFSC 2008) the Gulf of Maine spawning stock consisted of an annual average of 15.8 million fish from 1999 through 2001 when the Mirant Canal studies were conducted. Of those fish, 4.5 million were age 2 fish. Corresponding estimates for the Georges Bank stock were 22.8 million and 2.6 million. Based on these data the potential annual loss of 1,703 to 2,459 age 2 fish from plant operations is negligible compared to stock size and landings and therefore should not result in an adverse impact to the Atlantic cod population.

4.6 Silver Hake

Silver hake spawn pelagic eggs and those accounted for an average of 0.1% of the total number of entrained eggs. Numbers of silver hake larvae were also entrained accounting for an average of 3.4% of the total. The estimated number of silver hake eggs and larvae drifting passed Mirant Canal in 1999-2000 was 1.710 and 1.602 billion, respectively. Silver hake eggs and larvae entrained under actual flow amounted to 0.20 and 0.40% of those respective estimates. The table below summarizes the number of silver hake eggs and larvae entrained and their corresponding equivalent adults for the three flow scenarios.

Silver Hake Entrained				
Plant Flow	Average Number Entrained		Equivalent Adults (Age 2 Fish)	
	Eggs	Larvae	Number	Pounds
Maximum	4,380,541	9,980,770	198	48
1999 – 2001	3,476,071	6,418,642	130	31
2006 – 2007	2,906,820	6,240,371	125	30

Equivalent adults calculated for entrainment losses totaled 130 age 2 fish (31 pounds) based on 1999-2001 flow. The entrainment of such a small percentage of silver hake is not expected to cause an adverse impact to the local hake populations.

A total of 332 silver hake were estimated to have been impinged on the Mirant Canal intake screens during 1999-2000 accounting for 0.5% of the annual total. Equivalent adults calculated for impingement losses totaled 177 age 2 fish based on 1999-2001 flow. The combined equivalent adults calculated for both entrainment and impingement losses totaled 307 age 2 fish based on 1999-2001 flow. Based on a weight of 0.242 pounds per fish (EPA 2004a) these fish would weigh 74 pounds. If entrainment and impingement had not occurred an estimated 60 pounds of harvestable silver hake would have been produced over the 12-year lifespan of the 307 adults. Corresponding estimates for maximum flow and flow recorded in 2006-2007 are shown below.

Silver Hake Impinged				Combined Silver Hake		
Plant Flow	Total Number Impinged	Equivalent Adults (Age 2 Fish)		Equivalent Adults (Age 2 Fish)		Harvest Yield (lbs)*
		Number	Pounds	Number	Pounds	
Maximum	775	413	100	611	148	119
1999 – 2001	332	177	43	307	74	60
2006 – 2007	473	252	61	377	91	74

* Over a 12-year lifespan.

The U.S. silver hake fishery is currently managed assuming there are two stocks (NEFSC 2006). The northern stock area includes northern Georges Bank and the Gulf of Maine while the southern stock area includes southern Georges Bank, southern New England, and the Mid-Atlantic Bight. Biologically silver hake along the northeast coast are likely one population with incomplete mixing between northern and southern areas (NEFSC 2001). Annual landings during the 1999-2001 period averaged 28.2 million pounds, 7.28 million from the northern stock and 20.89 million pounds from the southern stock. Commercial landings in the northern stock have declined from 7.6 million pounds (3,446 mt) in 2001 to a historic low of 0.5 million pounds (240 mt) in 2005 (NEFSC 2006, Col and Traver 2006). The NEFSC spring and autumn bottom trawl survey biomass and abundance indices declined steeply in the early 1960s and then increased from the late 1960's through 2002 (Sosebee and Cadrin 2006). The northern stock was not considered overfished in 1999-2001 period (NEFSC 2006) and is currently not considered overfished (Col and Traver 2006). Landings in the southern stock in 2004 amounted to 18.6 million pounds. The southern stock was considered overfished during 1999-2001 but an increase in abundance during 2002 -2004 led to revision of the status (NEFSC 2006).

Compared to the reported annual silver hake landings during the 1999-2001 period for the northern and southern stocks, the potential loss of 74 pounds of equivalent adults or the harvest yield of 60 pounds is insignificant. Based on these data and current regulatory agency data suggests that the northern silver hake stock is currently sustainable and not overharvested; therefore Mirant Canal plant operations are not having an adverse impact on the silver hake population.

4.7 Hake

Hake consist of three species, the red, white, and spotted hake. Egg and larval hakes are difficult if not impossible to speciate, however spotted hake were easily separated from red and white hake in Mirant Canal impingement samples. This assessment therefore considers all three species combined for entrainment and the white and spotted hake combined for impingement. No red hake were impinged at Mirant Canal from 1999-2000.

All three hake species spawn pelagic eggs that may be entrained, as may the larvae of all three species. The table below summarizes numbers entrained and the corresponding equivalent adults under each of the three flow scenarios.

Hake Entrained				
Plant Flow	**Average Number Entrained**		**Equivalent Adults (Age 1 Fish)**	
	Eggs	**Larvae**	**Number**	**Pounds**
Maximum	77,900,563	11,963,458	584	135
1999 – 2001	60,271,070	9,675,631	460	106
2006 – 2007	52,173,826	8,025,435	391	90

An estimate of the number of hake eggs and larvae drifting passed Mirant Canal in 1999-2000 amounted to 17.373 and 1.792 billion, respectively. The number of eggs and larvae entrained under actual 1999-2001 flow amounted to 0.35 and 0.54% of those respective estimates. An estimated 460 age 1 equivalent adult hake would have been lost to entrainment under actual plant flow. The entrainment of such a small percentage should not cause an adverse impact to the local hake populations.

Small numbers of hake were impinged at Mirant Canal in 1999-2000, an extrapolated total of 145 fish being obtained. This number accounted for 0.2% of the year's total. Equivalent adults lost to impingement amounted to 130 age 1 fish (30 pounds) based on the recorded 1999 to 2001 water flow. The combined equivalent adults lost due to plant operations amounted to 590 age 1 fish (136 pounds). If entrainment and impingement had not occurred an estimated 226 pounds of harvestable hake would have been produced over the 10-year lifespan of the equivalent age 1 adults. The table below summarizes numbers impinged, equivalent adults, and harvest yield under the three flow scenarios.

Hake Impinged				Combined Hake		
Plant Flow	Total Number Impinged	Equivalent Adults (Age 1 Fish)		Equivalent Adults (Age 1 Fish)		Harvest Yield (lbs)*
		Number	Pounds	Number	Pounds	
Maximum	181	164	38	748	173	286
1999 – 2001	145	130	30	590	136	226
2006 – 2007	119	108	25	499	115	190

* Over a 10-year lifespan.

Red hake are managed as two stocks, northern (Gulf of Maine to Northern Georges Bank) and southern (Southern Georges Bank to the Mid-Atlantic Bight region). The northern red hake stock commercial landings peaked at 15,281 mt in 1973 and then have progressively declined to a historical low of 130 mt in 2005 (Traver and Col 2006). The NEFSC autumn bottom trawl survey data suggest a gradual increase in the northern stock biomass from the 1970's through 2002 and then a steady decline. The 2005 biomass index (1.274 kg/tow) was the lowest since 1974 (Traver and Col 2006). NOAA Statistical Area 514 red hake commercial landings have declined from 391,144 pounds in 2002 to 114,032 pounds in 2006. Commercial landings in both the northern and southern stocks have declined due to the withdrawal of and restrictions on the distant water fleets. Currently, the northern red hake stock is not considered overfished (Traver and Col 2006). Southern stock landings in the United States reached their lowest level in 2005 when 441,000 pounds were landed. The southern stock is currently not considered in an overfished condition (Traver and Col 2006).

The U.S. white hake commercial landings have increased from 2,225 mt in 1997 to 4,435 mt in 2003. However, in NOAA Statistical Area 514 white hake commercial landings have steadily declined from 353,238 pounds in 2002 to 81,877 pounds in 2006. The NEFSC spring and autumn bottom trawl survey white hake biomass and abundance indices increased in the 1960s and then fluctuated without a trend during the 1970s and 1980s. The indices declined in the 1990s reaching a historic low in 1997, and then increased through 2002 due to the strong 1998 year class. The Massachusetts inshore spring and autumn bottom trawl survey biomass and abundance indices declined from 1978 through 2001, the abundance index increased slightly in 2002 (Sosebee and Cadrin 2006). Based on current available data the Georges Bank and Gulf of Maine white hake stock is currently considered overfished, which is a reversal from the previous assessment conducted in 2005 (NEFSC 2008).

From 1999 through 2001 when studies at Mirant Canal were performed an annual average of 3 million pounds of red and white hake were landed in Massachusetts. The 590 equivalent age 1 fish weighing 136 pounds (based on a weight of 0.231 pounds per age 1 fish) estimated to have been lost to entrainment and impingement under actual flow amounted to 0.005% of those landings. The harvest foregone amounted to only 226 pounds over the lifetime of the equivalent adult fish. Based on these data and the current regulatory agency assessments of red and white hake stocks it is unlikely that Mirant Canal plant operations are having an adverse impact on the hake populations.

4.8 Silverside

Silverside eggs are adhesive and deposited on vegetation in tidal marsh habitat so they are rarely entrained. Numbers of larvae were entrained with a two-year average of 688,514 individuals which accounted for 0.4% of the larval total. An estimated 12.552 million silverside larvae drifted passed Mirant Canal in 1999-2000. The two-year average number of larvae entrained under actual plant flow amounted to 5.5% of that estimate. It is important to note however that the number of silverside larvae entrained in 1999-2000 (112,848, actual plant flow) when sampling was conducted in the adjacent Canal waters amounted to only 9% of the number entrained in 2000-2001 (1,264,180, actual plant flow). Presumably greater numbers of larvae passed through the Canal during the second year of entrainment sampling when collections were not made in the adjacent waters. Comparing numbers entrained only in 1999-2000 with the number passing by Mirant Canal during the same season provided an estimate of only 0.9%.

Equivalent adults lost to entrainment amounted to 297 age 1 fish (6 pounds) based on the circulating water flow recorded from 1999 to 2001. Numbers entrained and equivalent adult values for each of the three flow scenarios are tabulated below. The numbers of equivalent adults lost to entrainment are low and do not represent an adverse impact to the silverside populations in the vicinity of Mirant Canal.

Silverside Entrained				
Plant Flow	Average Number Entrained		Equivalent Adults (Age 1 Fish)	
	Eggs	Larvae	Number	Pounds
Maximum	0	765,366	330	7
1999 – 2001	0	688,514	297	6
2006 – 2007	0	528,351	228	5

Silverside represented 17% of the 1999-2000 impingement total with an estimated extrapolated total of 12,742 fish. Equivalent adults calculated for these losses totaled 3,240 age 1 fish based on 1999-2001 flow. The combined equivalent adults calculated for both entrainment and impingement losses totaled 3,537 age 1 fish based on 1999-2001 flow. Impingement numbers, equivalent adults, and equivalent yield values under the three flow scenarios are shown below.

Silverside Impinged				Combined Silverside		
Plant Flow	Total Number Impinged	Equivalent Adults (Age 1 Fish)		Equivalent Adults (Age 1 Fish)		Equivalent Yield (lbs)*
		Number	Pounds	Number	Pounds	
Maximum	28,812	7,044	144	7,374	151	46
1999 – 2001	12,742	3,240	66	3,537	72	22
2006 – 2007	16,937	4,116	84	4,344	89	18
* Over a 2-year lifespan.						

Equivalent yield for silversides lost to entrainment and impingement ranged from 18 to 46 pounds of striped bass depending on the plant flow regime.

Although stock size data are not available for silversides an estimate of 42 million fish was obtained based on 10% of the area of Buzzards Bay and Cape Cod Bay and reported production of silversides in the scientific literature (1 gram per m^2, Conover 1985) and assuming 5 grams per individual. Based on that estimate the potential losses due to entrainment and impingement appear negligible and do not represent an adverse impact on the local silverside population.

4.9 Searobin

Searobin eggs are pelagic and accounted for 0.2% of the total number of eggs entrained. Searobin larvae were also entrained and accounted for 0.07% of the larval total. Based on the number of searobin eggs (269.861 million) and larvae (22.015 million) drifting passed Mirant Canal in 1999-2000, the number of eggs and larvae entrained under actual plant flow represented 1.86% of searobin eggs and 0.61% of larvae.

Searobin equivalent adults lost to entrainment amounted to 949 age 1 fish (57 pounds) based on recorded 1999 to 2001 water flow. The following table summarizes the numbers entrained and equivalent adults under each of the three flow scenarios.

Searobins Entrained				
Plant Flow	Average Number Entrained		Equivalent Adults (Age 1 Fish)	
	Eggs	Larvae	Number	Pounds
Maximum	6,111,503	152,914	1,147	69
1999 – 2001	5,019,471	134,225	949	57
2006 – 2007	4,169,753	107,296	785	47

The numbers of equivalent adults lost to entrainment are low and should not represent an adverse impact to the searobin populations in the vicinity of Mirant Canal.

Searobin are a bottom fish and not often impinged on intake screens. In 1999-2000 an extrapolated annual total of 41 fish was obtained based on sampling at Mirant Canal. This represented 0.06% of the annual impingement total. The equivalent adults lost to entrainment and impingement combined amounted to 990 age 1 fish (60 pounds). If these losses had not occurred an estimated 74 pounds of harvestable searobins would have been produced over an 8-year lifespan of the adults. Numbers impinged and equivalent adults under the three flow scenarios are summarized below.

Searobins Impinged				Combined Searobins		
Plant Flow	Total Number Impinged	Equivalent Adults (Age 1 Fish)		Equivalent Adults (Age 1 Fish)		Harvest Yield (lbs)*
		Number	Pounds	Number	Pounds	
Maximum	74	74	4	1,221	74	90
1999 – 2001	41	41	2	990	60	74
2006 – 2007	45	45	3	830	50	61

* Over an 8-year lifespan.

Searobins have limited commercial value and as a result commercial landings in Massachusetts averaged only 1,488 pounds from 1991 to 1999 with only 11 pounds being reported in 1999. Massachusetts recreational fishermen however landed 59,767 and 276,514 fish in 1999 and 2000, respectively. The loss of 966 equivalent adult fish amounted to 0.57% of the average of those landings. Based on these data entrainment and impingement at Mirant Canal should not result in an adverse impact on the local searobin populations.

4.10 Grubby

Grubby produce highly demersal, adhesive eggs that are not subject to entrainment but their larvae are pelagic and are entrained. The two-year average of 1,794,000 larvae accounted for 0.9% of all larvae entrained. An estimated 448.5 million grubby larvae drifted past Mirant Canal during the 1999-2000 season. The average number of larvae entrained under actual plant flow was 0.4% of that estimate. Numbers entrained and equivalent adults for entrainment losses under the three flow scenarios are tabulated below.

Grubby Entrained				
Plant Flow	Average Number Entrained		Equivalent Adults (Age 2 Fish)	
	Eggs	Larvae	Number	Pounds.
Maximum	0	4,560,695	3,700	43
1999 – 2001	0	1,794,342	1,456	17
2006 – 2007	0	2,783,920	2,259	26

Grubby equivalent adults lost to entrainment amounted to 1,456 age 2 fish (17 pounds) under actual flow. The small percentage of grubby lost to entrainment should not adversely impact the grubby populations in the vicinity of Mirant Canal.

Grubby impinged at Mirant Canal accounted for 1.5% of the fish impinged on the intake screens with an estimated annual total of 1,083 fish. Equivalent adults calculated for these losses totaled 650 age 2 fish based on 1999-2001 flow. The combined equivalent adults calculated for both entrainment and impingement losses totaled 2,106 age 2 fish based on 1999-2001 flow. Impingement numbers, equivalent adults, and equivalent yield values under the three flow scenarios are shown below.

Grubby Impinged				Combined Grubby		
Plant Flow	Total Number Impinged	Equivalent Adults (Age 2 Fish)		Equivalent Adults (Age 2 Fish)		Equivalent Yield (lbs)*
		Number	Pounds	Number	Pounds	
Maximum	1,364	818	9	4,518	52	6
1999 – 2001	1,083	650	7	2,106	24	2
2006 – 2007	946	568	7	2,827	33	4

* Over an 9-year lifespan.

Since they have no commercial or recreational value, stock size data are not available for the grubby.

In terms of forage for striped bass, had entrainment and impingement losses not occurred 6 pounds of additional striped bass might have been harvested by the commercial and recreational fisheries over the life span of the grubby. Based on these data potential annual loss of small numbers of grubby to plant operations should not result in an adverse impact to the population.

4.11 Cunner

Cunner eggs and larvae accounted for 77.4 and 29.7%, respectively of the entrainment totals. The rocky shoreline of the Cape Cod Canal, the three bridges spanning the Canal and the numerous piles and piers in the area provide ideal habitat for these reef fish, hence their considerable abundance. Cunner eggs and larvae were also among the numerical dominants in studies conducted at Mirant Canal in 1966 and 1967 (Fairbanks et al. 1971) and from 1976-1979 (Collings et al. 1981). The following table summarizes numbers entrained, equivalent adult information and harvest yield for each of the three plant flow scenarios.

Cunner Entrained					
Plant Flow	Average Number Entrained		Equivalent Adults (Age 1 Fish)		Harvest Yield (lbs)*
	Eggs	Larvae	Number	Pounds	
Maximum	2,189,321,006	64,923,636	764,987	18,819	4,176
1999 – 2001	1,958,253,694	56,306,380	674,142	16,584	3,680
2006 – 2007	1,515,565,234	45,517,033	532,856	13,108	2,909
* Over a 6-year lifespan.					

The number of cunner eggs and larvae passing Mirant Canal in 1999-2000 and not returning on subsequent tides was estimated to be 48.461 billion and 15.074 billion, respectively. The average number entrained based on 1999-2000 plant flows represented 4.04 and 0.37% of those totals.

Cunner accounted for 5.4% of the fish impinged in 1999-2000. Estimated numbers impinged, equivalent adult information and harvest yield for each of the three plant flow scenarios are summarized below.

Cunner Impinged					Combined Cunner		
Plant Flow	Total Number Impinged	Equivalent Adults (Age 1 Fish)		Harvest Yield (lbs)*	Equivalent Adults (Age 1 Fish)		Harvest Yield (lbs)*
		Number	Pounds		Number	Pounds	
Maximum	6,384	5,364	132	29	770,351	18,951	4,205
1999 – 2001	3,977	3,345	82	18	677,487	16,666	3,698
2006 – 2007	3,979	3,341	82	18	536,197	13,190	2,927
* Over a 6-year lifespan.							

Had they not been entrained or impinged the number of cunner lost would have been expected to contribute 3,698 pounds of cunner to the commercial and recreational fisheries over the 6-year lifespan of those fish the majority of that total due to entrainment of eggs and larvae. Massachusetts commercial cunner landings averaged 0.25 mt during the 1999-2000 period, with no commercial landings reported in 2001. Cunner recreational landings for Massachusetts averaged 53,404 fish from 1999-2001.

As described in Appendix A cunner are sedentary and occupy a very small home range measured in a few hundred to a few thousand square meters. Since they spawn enormous numbers of eggs in the Cape Cod Canal and have ranked among the numerical dominants each time studies were done there while Mirant Canal has been in operation (Fairbanks et al. 1971, Collings et al. 1981, Mirant 2003) an adverse environmental impact is has not occurred.

4.12 Tautog

Tautog, like the cunner, is a coastal species typically occurring nearshore in association with rocks, pilings, and jetties. An estimated 105.97 million tautog eggs and 5.1 million larvae were entrained based on the recorded 1999-2001 flow. Tautog eggs and larvae accounted for 4.2 and 2.7%, respectively, of the early life history stages entrained. The number of tautog eggs and larvae passing Mirant Canal in 1999-2000 and not returning on subsequent tides was estimated to be 2.623 billion and 815.911 million, respectively. The average number entrained based on 1999-2001 plant flows represented 4.04 and 0.62% of those totals. The percentages of cunner and tautog passing through the Canal are the same, this is an artifact caused by the way we apportioned labrid-Limanda eggs and labrid eggs (see Methods). The following table summarizes numbers entrained and equivalent adult information for each of the three plant flow scenarios.

Tautog Entrained				
Plant Flow	Average Number Entrained		Equivalent Adults (Age 6 Fish)	
	Eggs	Larvae	Number	Pounds
Maximum	118,466,497	5,662,312	12	23
1999 – 2001	105,969,058	5,068,342	11	20
2006 – 2007	82,009,700	3,942,433	8	16

Equivalent adults lost to entrainment amounted to 11 age 6 fish (20 pounds) based on the circulating water flow recorded from 1999 to 2001. The numbers of equivalent adults lost to entrainment are low and should not represent an adverse impact to the tautog populations in the vicinity of Mirant Canal.

Tautog accounted for 0.3% of the number of fish impinged at Mirant Canal with an annual estimated total of 217 fish. Equivalent adults lost to impingement amounted to 19 age 6 fish (36 pounds) based on recorded 1999-2001 flow. The combined equivalent adults lost to both entrainment and impingement totaled 30 age 6 fish based on 1999-2001 flow. If entrainment and impingement had not occurred an estimated 96 pounds of harvestable tautog would have been produced over the 24-year lifespan the equivalent adults. The table below summarizes numbers impinged, equivalent adults, and harvest yield values for each of the three plant flow scenarios.

Tautog Impinged				Combined Tautog		
Plant Flow	Total Number Impinged	Equivalent Adults (Age 6 Fish)		Equivalent Adults (Age 6 Fish)		Harvest Yield (lbs)*
		Number	Pounds	Number	Pounds	
Maximum	396	37	70	49	93	158
1999 – 2001	217	19	36	30	56	96
2006 – 2007	248	23	43	31	59	103

* Over a 24-year lifespan.

Tautog are managed by individual states under the Atlantic States Marine Fisheries Commission. Commercial landings in Massachusetts peaked at160.7 mt in 1991, declined to 14.8 mt in 1996, increased to 67.2 mt in 2002 and then declined to 40 mt in 2004. The 1999-2001 Massachusetts commercial landings averaged 38.7 mt (85,319 pounds). Recreational landings in Massachusetts peaked at 1,980,719 fish in 1986, declined to 25,034 in 1998, and then increased to 115,658 in 2001. In 2003 more restrictive recreational fishery regulations were adopted as a result catches dropped to 20,000 fish in 2004 (ASMFC 2006b). Massachusetts recreational landings averaged 431,326 pounds during the 1999-2001 period. During that same period commercial landings in NOAA Statistical Area 514 averaged 24,703 pounds. The coastwide tautog stock is currently considered in an overfished condition although overfishing did not occur in 2005 (ASMFC 2006b).

The weight of the equivalent adults (56 pounds) or of the harvest foregone (96 pounds) represents a very small percentage of the 1999-2001 Massachusetts commercial and recreational landings. Based on these data the potential annual loss of small numbers of tautog to plant operations should not result in an adverse impact to the population.

4.13 Sand Lance

Sand lance eggs are demersal and only rarely subject to entrainment. For example none were collected in 1999-2000 and only 3 were collected in 2000-2001. Larvae can be abundant in coastal waters during winter and early spring and overall they accounted for 18% of the larvae entrained during the two-year study. The number of sand lance larvae passing Mirant Canal in the Cape Cod Canal in 1999-2000 and not returning on subsequent tides was estimated to be 17.071 billion. The average number entrained (33.8 million) under actual 1999-2001 flow amounted to 0.19% of that total. Equivalent adults potentially lost to entrainment amounted to 27,431 age 2 fish (200 pounds). The number of sand lance eggs and larvae entrained and the corresponding equivalent adults for each of the three flow scenarios are summarized in the table below.

Sand Lance Entrained				
Plant Flow	Average Number Entrained		Equivalent Adults (Age 2 Fish)	
	Eggs	Larvae	Number	Pounds
Maximum	67,444	58,299,458	47,309	345
1999 – 2001	45,610	33,802,222	27,431	200
2006 – 2007	35,975	39,065,960	31,700	231

Sand lance are relatively small, thin fish found over sandy bottom into which they burrow for protection. As a result of their life history not many are impinged. In 1999-2000 an estimated total of 27 were impinged at Mirant Canal. This total accounted for 0.04% of the annual total of all fish. The combine equivalent adults lost to plant operations amounted to 27,456 age 2 fish. The average number of fish impinged and equivalent adults are summarized below.

Sand Lance Impinged				Combined Sand Lance		
Plant Flow	Total Number Impinged	Equivalent Adults (Age 2 Fish)		Equivalent Adults (Age 2 Fish)		Equivalent Yield (lbs)*
		Number	Pounds	Number	Pounds	
Maximum	32	17	0.1	47,326	345	46
1999 – 2001	27	25	0.1	27,456	200	27
2006 – 2007	24	14	0.1	31,714	231	31
* Over a 11-year lifespan.						

Assuming sand lance entrainment and impingement had not occurred 27 pounds of striped bass might have been harvested by the commercial and recreational fisheries as a result of conversion of those sand lance.

Sand lance have no commercial or recreational value therefore no population size information is available for them. They are abundant as the numbers of larvae would suggest and have been observed in schools of various sizes ranging up to tens of thousands of individuals (Meyer et al. 1979). Based on these low numbers it is unlikely that Mirant Canal has had an adverse impact on the sand lance population.

4.14 Atlantic Mackerel

Atlantic mackerel eggs and larvae accounted for 9 and 5% of the eggs and larvae entrained during the 1999-2000 and 2000-2001 sampling seasons. An estimated 186.1

million mackerel eggs and 9.5 million larvae were entrained based on recorded 1999-2001 flow. Equivalent adults potentially lost to entrainment amounted to 399 age 3 fish (255 pounds). The average number of eggs and larvae entrained and the equivalent adults are summarized below.

Atlantic Mackerel Entrained				
Plant Flow	Average Number Entrained		Equivalent Adults (Age 3 Fish)	
	Eggs	Larvae	Number	Pounds
Maximum	281,290,293	10,713,066	546	349
1999 – 2001	186,119,583	9,458,078	399	255
2006 – 2007	183,936,409	7,477,925	365	233

The number of mackerel eggs and larvae passing Mirant Canal in 1999 and not returning on subsequent tides was estimated to be 78.857 billion and 87.958 million, respectively. The average number entrained based on 1999-2000 plant flows represented 0.24 and 10.8% of those totals. As described for silversides the relatively high percentage for mackerel larvae is an anomalous result of comparing a two-year entrainment average with a single year of Cape Cod Canal data. The number of mackerel larvae entrained under actual plant flow varied a great deal, by a factor of 40, between 1999-2000 (591,955) and 2000-2001 (18,324,201). Comparing the number of larvae entrained in 1999-2000 with the number passing through the Cape Cod Canal during the same year resulted in a percentage of only 0.7.

Atlantic mackerel are powerful swimmers and are therefore rarely impinged at coastal power facilities. None were collected during the 1999-2000 studies.

Atlantic Mackerel Impinged				Combined Atlantic Mackerel		
Plant Flow	Total Number Impinged	Equivalent Adults (Age 3 Fish)		Equivalent Adults (Age 3 Fish)		Harvest Yield (lbs)*
		Number	Pounds	Number	Pounds	
Maximum	0	0	0	546	349	235
1999 – 2001	0	0	0	399	255	172
2006 – 2007	0	0	0	365	233	157

* Over a 14-year lifespan.

Atlantic mackerel undergo extensive seasonal migrations with a northern and southern component so that entrainment at Mirant Canal should not affect a local subpopulation. They were heavily exploited by distant-water fleets at non-sustainable rates during the 1970’s but with development of the Exclusive Economic Zone in 1982 spawning stock biomass has increased steadily from a low of 663,000 mt in 1976 to 2.3 million mt in

2004 (NFSC 2006). The spawning stock in 1999 and 2000 when studies were done at Mirant Canal was 1.3 million mt (2.9 billion pounds). U.S. annual landings averaged 11,443 mt (25.2 million pounds) during the 1999-2001 period (NEFSC 2006). Based on these data the potential annual loss of 399 age 3 fish weighing 255 pounds or the loss of 172 pounds of foregone harvest is negligible and does not represent an adverse impact to the Atlantic mackerel population.

4.15 Windowpane

Windowpane eggs and larvae accounted for 2 and 1%, respectively, of the early life history stages entrained. An estimated 45.0 million windowpane eggs and 2.1 million larvae were entrained based on the recorded 1999-2001 flow. Equivalent adults potentially lost to entrainment amounted to 442 age 3 fish (117 pounds). Numbers of eggs and larvae entrained and corresponding equivalent adults are summarized below.

Windowpane Entrained				
Plant Flow	Average Number Entrained		Equivalent Adults (Age 3 Fish)	
	Eggs	Larvae	Number	Pounds
Maximum	57,304,807	3,153,391	581	154
1999 – 2001	45,056,160	2,093,238	442	117
2006 – 2007	38,213,544	1,945,035	381	101

Numbers of windowpane eggs entrained under the three flow scenarios amounted to between 0.47 and 0.70% of the number of windowpane eggs drifting passed Mirant Canal. Numbers of windowpane larvae entrained under the three flow scenarios amounted to between 0.15 and 0.25% of the number of windowpane larvae drifting passed Mirant Canal.

Windowpane accounted for 0.2% of the fish impinged in 1999-2000 with an annual estimated total of 143 fish. Numbers of fish impinged and the corresponding equivalent adults are summarized below.

Windowpane Impinged				Combined Windowpane		
Plant Flow	Total Number Impinged	Equivalent Adults (Age 3 Fish)		Equivalent Adults (Age 3 Fish)		Harvest Yield (lbs)*
		Number	Pounds	Number	Pounds	
Maximum	163	32	8	613	162	28
1999 – 2001	143	31	8	473	125	21
2006 – 2007	119	30	8	411	109	18

* Over a 10-year lifespan.

Windowpane are managed as two stocks: the Gulf of Maine-Georges Bank and Southern New England-Mid-Atlantic Bight. Gulf of Maine-Georges Bank windowpane catches from 1975-2007, peaked in 1991 at 3,645 mt (8,035,840 pounds) and then declined to a low of 105 mt (231,485 pounds) in 1999. No direct windowpane fishery has existed since 1994; however catches have increased since 2002 due to increased discarding in the large mesh bottom trawl fleet. The 2007 catch was 1,032 mt (2,275,168 pounds), the highest since 1997 (NEFSC 2008). Annual landings during the 1999-2001 period were 176,370 pounds (80 mt) from the Gulf of Maine-Georges Bank and 277,782 pounds (126 mt) from the Southern New England-Mid-Atlantic Bight (NEFSC 2008). The Gulf of Maine-Georges Bank windowpane stock was not considered overfished during the 1999-2001 period when entrainment and impingement studies were conducted at Mirant Canal (NEFSC 2002). The current stock assessment (NEFSC 2008) suggests that in 2007 the Gulf of Maine-Georges Bank windowpane stock was overfished and that overfishing was occurring.

The potential loss of less than 175 pounds of equivalent adults and less than 30 pounds of harvest is very small relative to these fishery landings and not expected to represent an adverse impact.

4.16 American Plaice

American plaice spawn pelagic eggs that are subject to entrainment along with their larvae. Overall they accounted for 0.06% and 0.2% of the eggs and larvae entrained. Numbers of each life stage entrained as well as equivalent adults in number of fish and pounds are tabulated below.

American Plaice Entrained				
Plant Flow	**Average Number Entrained**		**Equivalent Adults (Age 3 Fish)**	
	Eggs	**Larvae**	**Number**	**Pounds**
Maximum	2,040,221	660,647	89	17
1999 – 2001	1,433,222	423,565	58	11
2006 – 2007	1,198,909	401,410	54	10

The number of American plaice eggs and larvae passing Mirant Canal in 1999 and not returning on subsequent tides was estimated to be 110.379 million and 209.3878 million, respectively. The average number of eggs and larvae entrained under the 1999-2000 flow regime represented 1.30 and 0.57% of those totals, respectively.

American plaice are right-eyed benthic flatfish that prefer oceanic habitats and are therefore rarely impinged at coastal power facilities. None were collected during the 1999-2000 Mirant Canal studies.

American Plaice Impinged				Combined American Plaice		
Plant Flow	Total Number Impinged	Equivalent Adults (Age 3 Fish)		Equivalent Adults (Age 3 Fish)		Harvest Yield (lbs)*
		Number	Pounds	Number	Pounds	
Maximum	0	0	0	89	17	32
1999 – 2001	0	0	0	58	11	21
2006 – 2007	0	0	0	54	10	19
* Over a 25-year lifespan.						

American plaice are managed as a single Gulf of Maine-Georges Bank stock. Spawning stock biomass increased from 8,014 mt in 1995 to 10,648 mt in 2001, then declined to 8,560 mt in 2004, and has increased to 15,659 mt in 2007. Spawning stock biomass was 21.5 million pounds (9,764 mt) in 1999 and 23.1 million pounds (10,512 mt) in 2000. U.S. annual landings in the Gulf of Maine and Georges Bank during the 1999-2001 period averaged 8.5 million pounds (3,854 mt; NEFSC 2008). The Gulf of Maine-Georges Bank plaice stock was considered overfished in 2001 (NEFSC 2002) and 2004 (NEFSC 2005). The current stock assessment (NEFSC 2008) suggests that in 2007 the Gulf of Maine-Georges Bank American plaice was not overfished.

Over their life time the fish potentially lost to entrainment and impingement would have been expected to contribute 21 pounds to the fishery. Based on these data the potential annual loss of at most 17 pounds of age 3 fish is negligible and does not represent an adverse impact to the American plaice population.

4.17 Winter Flounder

Winter flounder eggs are demersal and adhesive but because of the dynamic environment in the Cape Cod Canal highly variable numbers of them were collected in the entrainment samples. Flounder eggs accounted for 0.8% of all eggs entrained and 4% of the larvae entrained. Numbers of winter flounder larvae entrained based on recorded 1999 to 2001 flow amounted to 0.7% of the 942.324 million larval flounder drifting passed Mirant Canal during the 1999-2000 season. Equivalent adults lost to entrainment amounted to 5,799 age 3 fish (5,782 pounds) based on the circulating water flow recorded from 1999 to 2001. If entrainment had not occurred the 5,799 equivalent adults would have produced an estimated 20,041 pounds of harvestable winter flounder over the 16-year lifespan of the individuals. The following table summarizes winter flounder numbers entrained, equivalent adults, and harvest yield for each of the three flow scenarios.

Winter Flounder Entrained					
Plant Flow	Average Number Entrained		Equivalent Adults (Age 3 Fish)		Harvest Yield (lbs)*
	Eggs	Larvae	Number	Pounds	
Maximum	23,434,479	10,368,117	8,369	8,344	28,920
1999 – 2001	16,636,274	6,530,552	5,799	5,782	20,041
2006 – 2007	14,643,576	6,541,899	5,409	5,393	18,691
* Over a 16- year lifespan.					

Winter flounder accounted for 0.8% of the fish impinged in 1999-2000 with an annual estimated total of 575 fish. Estimated numbers impinged and corresponding equivalent adults for each of the three flow scenarios are shown below.

Winter Flounder Impinged					Combined Winter Flounder		
Plant Flow	Total Number Impinged	Equivalent Adults (Age 3 Fish)		Harvest Yield (lbs)*	Equivalent Adults (Age 3 Fish)		Harvest Yield (lbs)*
		Number	Pounds		Number	Pounds	
Maximum	782	47	47	161	8,416	8,391	29,081
1999 – 2001	575	37	37	121	5,836	5,819	20,161
2006 – 2007	509	31	31	107	5,440	5,424	18,798
* Over a 16-year lifespan.							

Winter flounder are managed as three stocks – southern New England, Gulf of Maine, and Georges Bank although fisheries managers believe considerable interaction occurs between stocks. Massachusetts commercial and recreational landings for 1999-2001 averaged 9.4 million pounds. The average weight of equivalent adults under actual flow amounted to 0.06% of those landings. Over the 16-year lifespan of the equivalent adults calculated under observed flow 20,161 pounds of winter flounder might be landed by commercial and recreational fishermen or an average of 1,260 pounds per year.

A review of the NOAA Northeast Fisheries Science Center (NEFSC) spring abundance index (Figure 4, top) and the MDMF spring resource assessment time series for the northern flounder stock (Figure 4, bottom) extending from the New Hampshire border to Cape Cod (Howe et al. 1994, Paul Nitschke, NMFS, personal communication, Matthew Camisa, MDMF, personal communication) have not shown a consistent downward trend that would suggest entrainment and impingement at Mirant Canal has had an adverse environmental impact on winter flounder.

4.18 American Lobster

American lobster supports one of the most valuable fisheries along the east coast of the United States and the most economically valuable one in Massachusetts. Lobster eggs are extruded and firmly attached to the female's pleopods until they hatch. They are therefore not subject to entrainment. Following hatch the prelarval phase remains attached to the female until they molt to the first larval stage at which point they are released from the female. During four pelagic larval stages lobster larvae are susceptible to entrainment. An estimated total of 512,630 and 5,430 lobster larvae were entrained in 1999-2000 and 2000-2001, respectively, providing an annual average of 259,030. Equivalent adults for entrainment amounted to 6, 82 mm lobsters under actual 1999-2001 plant flow. The table below shows the numbers of larvae entrained, equivalent adults, and harvest yield for each of the three flow scenarios.

American Lobster Entrained					
Plant Flow	Average Number Entrained		Equivalent Adults (82 mm)		Harvest Yield (lbs)*
	Eggs	Larvae	Number	Pounds	
Maximum	NA	271,193	6	6	7
1999 – 2001	NA	259,030	6	6	7
2006 – 2007	NA	189,842	4	5	5
* Over the years of harvest until the lobster reaches 127 mm carapace length.					

The average number of American lobster larvae entrained under actual plant flow amounted to 0.08% of the number of lobster larvae drifting passed Mirant Canal in the Cape Cod Canal during 1999-2000. The small percentage of larvae entrained compared to the numbers present in the Canal and the low numbers of equivalent adults lost to entrainment should not represent an adverse impact to the American lobster population in the vicinity of Mirant Canal.

American lobsters are occasionally impinged at Mirant Canal, an estimated total of 845 being impinged in 1999-2000. Equivalent adults for impingement amounted to 591, 82 mm lobsters under actual 1999-2001 plant flow. The numbers of lobster impinged, equivalent adults, and harvest yield for each of the three flow scenarios are summarized below.

American Lobster Impinged					Combined American Lobster		
Plant Flow	Total Number Impinged	Equivalent Adults (82 mm)		Harvest Yield (lbs)*	Equivalent Adults (82 mm)		Harvest Yield (lbs)*
		Number	Pounds		Number	Pounds	
Maximum	1,197	838	934	951	844	940	957
1999 – 2001	845	591	658	671	597	664	677
2006 – 2007	755	528	588	599	532	593	604
* Over the years of harvest until the lobster reaches 127 mm carapace length.							

American lobster are managed as three stocks: Gulf of Maine, Georges Bank, and Southern New England. The Gulf of Maine supported 74% of the US landings from 1981 to 2003. Landings in the Gulf of Maine were stable and averaged 14,700 mt from 1981 to 1989, then increased sharply from 1990 (19,200 mt) to 1999 (30,000 mt), and continue to remain at record levels (ASMFC 2006c). Total Gulf of Maine lobster landings totaled 66.2 million pounds in 1999 and 70.2 million pounds in 2000, with 15.9 million pounds and 15.0 million pounds landed in Massachusetts, respectively (Dean et al. 2005). The current stock assessment (ASMFC 2006c) suggests that the Gulf of Maine American lobster stock is not overfished. The weight of equivalent 82 mm lobsters estimated to have been lost to entrainment and impingement amounted to 664 pounds under actual recorded flow. Foregone harvest totaled 677 pounds. The potential loss of 664 or 677 pounds represents 0.004% of the 1999-2000 Massachusetts landings. Based on these data the potential annual loss of lobsters at Mirant Canal is negligible and does not represent an adverse impact to the American lobster population.

4.19 Total Entrainment

Based on recorded 1999 to 2001 circulating water flow 2.5 billion eggs and 1.9 million larvae are estimated to have been lost to entrainment (Table 2). The following table summarizes the number of eggs and larvae entrained for all species combined including the priority species for each of the three flow scenarios. The entrained eggs and larvae comprised 24 species of eggs and 40 species of larvae. Priority species accounted for 95.6% of the fish eggs entrained and 75.5% of the larvae entrained under recorded 1999 to 2001 flow.

All Species Entrained						
Plant Flow	Average Number Entrained For Priority Species		Average Number Entrained For All Species		Priority Species as a Percentage of All Species	
	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
Maximum	2,808,915,785	195,156,032	2,933,812,730	247,042,844	95.7	78.9
1999 – 2001	2,420,017,911	143,352,238	2,531,474,684	189,778,331	95.6	75.5
2006 – 2007	1,926,135,215	131,931,229	2,007,738,989	168,014,037	95.9	78.5

4.20 Total Impingement

A total of 74,242 fish (all species) were estimated to be impinged at Mirant Canal from 1999 to 2000 based on recorded flow. The following table summarizes the number of fish impinged for all species for each of the three flow scenarios. The impinged fish contained 45 species. Priority species accounted for 95.5% of the fish impinged under recorded 1999 to 2001 flow.

All Species Impinged			
Plant Flow	Average Number Impinged For Priority Species	Average Number Impinged For All Species	Priority Species as a Percentage of All Species
Maximum	158,059	163,499	96.7
1999 – 2001	70,880	74,242	95.5
2006 – 2007	94,472	97,878	96.5

4.21 Entrainment Survival

Field studies have shown that some fish eggs and larvae survive entrainment (EPRI 2000). Survival rates of entrained organisms are influenced by three main factors: thermal stress (discharge temperature), mechanical damage, and chemical stress (use of biocides). Each species has a different tolerance level to these factors therefore entrainment survival rates for individual species vary, with some species having higher survival than others (EPA 2004b, EPRI 2000). For example, river herring are considered a fragile species and have been documented as being very sensitive to entrainment with a 0% survival rate, whereas cunner larvae are considered a hardier species and have been documented with a 49% survival rate (EPRI 2000). The survival values used to adjust the numbers entrained for the key species are shown in Table 8. Many of the survival values in Table 8 came from Collings et al. 1981. The eggs and larvae studied in Collings et al. (1981) were collected with a plankton net streamed in the intake water and not a more sophisticated method such as larval tables or barrel samplers. These devices remove eggs and larvae from ambient water in a very gentle way so as not to introduce mortality as eggs and larvae are collected. As a result the survival rates in that study could be conservative. Adjusted entrainment numbers and estimated equivalent adults for each of the three flow scenarios are shown in Table 9.

River herring generally experience 100% egg and larvae mortality in cooling water intake structures (Table 8), as a result adjusting entrainment for survival produces no difference between entrainment numbers and survival adjusted entrainment numbers.

Atlantic menhaden eggs and larvae have been shown to have some entrainment survival (Table 8) therefore the following table summarizes estimated entrainment and equivalent adult numbers when entrainment survival is considered. Under actual flow the number of eggs lost to entrainment declined from 2,761,158 to 1,104,463 and larvae losses declined from 740,561 to 545,793. The equivalent adult losses declined from 8 to 5 age 3 fish. Compared to the number of Atlantic menhaden eggs and larvae passing Mirant Canal the survival adjusted numbers amounted to 0.2 and 0.2%, respectively.

Atlantic Menhaden with Entrainment Survival

Plant Flow	Adjusted Average Number Entrained		Equivalent Adults (Age 3 Fish)		Harvest Yield (lbs)*
	Eggs	Larvae	Number	Pounds	
Maximum	1,265,448	807,443	6	3	6
1999 – 2001	1,104,463	545,793	5	2	4
2006 – 2007	848,265	506,280	4	2	4

* Over an 8 year lifespan.

Atlantic herring larvae are fragile and sensitive to entrainment with a mortality rate of 100% as a result adjusting entrainment for survival produces no difference between entrainment numbers and survival adjusted entrainment numbers.

Fourbeard rockling eggs have been shown to have some entrainment survival, however larval survival rates are currently unavailable (Table 8). The following table summarizes estimated entrainment and equivalent adult numbers when entrainment survival for eggs is considered. Under actual flow the number of entrained eggs declined from 33,784,338 to 20,676,015 and equivalent adult losses declined from 311 to 252 age 1 fish. Compared to the number of rockling eggs passing Mirant Canal the survival adjusted number amounted to 0.4%.

Fourbeard Rockling with Entrainment Survival					
Plant Flow	**Adjusted Average Number Entrained**		**Equivalent Adults (Age 1 Fish)**		**Equivalent Yield (lbs)**
	Eggs	**Larvae**	**Number**	**Pounds**	
Maximum	26,790,887	9,848,308	313	4	0.4
1999 – 2001	20,676,015	8,115,074	252	4	0.3
2006 – 2007	17,194,722	6,654,402	208	3	0.3

Atlantic cod have 100% mortality in cooling water intake structures when temperatures exceed 12° C (Table 8). Therefore adjusting entrainment for survival produces no difference between entrainment numbers and survival adjusted entrainment numbers.

Silver hake eggs have been documented to have some entrainment survival, however currently larval survival rates are unknown (Table 8). The following table summarizes estimated entrainment and equivalent adult numbers when entrainment survival is considered. The number of silver hake eggs lost to entrainment under actual flow declined from 3,476,071 to 2,864,283. Compared to the number of eggs passing Mirant Canal the survival adjusted number amounted to 0.17%. The equivalent adult losses declined from 130 to 128 age 2 fish.

Silver Hake with Entrainment Survival					
Plant Flow	**Adjusted Average Number Entrained**		**Equivalent Adults (Age 2 Fish)**		**Harvest Yield (lbs)***
	Eggs	**Larvae**	**Number**	**Pounds**	
Maximum	3,609,566	9,980,770	196	47	38
1999 – 2001	2,864,283	6,418,642	128	31	25
2006 – 2007	2,395,220	6,240,371	123	30	24
* Over a 12 year lifespan.					

Hake eggs have been documented to have some entrainment survival, however larval survival rates are currently unavailable (Table 8). The following table summarizes estimated entrainment and equivalent adult numbers when entrainment survival is considered for hake eggs. Under actual flow the number of eggs lost to entrainment declined from 60,271,070 to 36,885,895 and equivalent adult losses declined from 460 to 355 age 1 fish. The number of survival adjusted eggs amounted to 0.2% of the hake eggs estimated to pass Mirant Canal.

Hake with Entrainment Survival					
Plant Flow	Adjusted Average Number Entrained		Equivalent Adults (Age 1 Fish)		Harvest Yield (lbs)*
	Eggs	Larvae	Number	Pounds	
Maximum	47,675,145	11,963,458	449	104	136
1999 – 2001	36,885,895	9,675,631	355	82	107
2006 – 2007	31,930,382	8,025,435	301	69	91
* Over a 10 year lifespan.					

Some silverside larvae have been shown to survive entrainment (Table 8) therefore the following table summarizes estimated entrainment and equivalent adult numbers when entrainment survival is considered. The number of larvae lost to entrainment under actual flow declined from 688,514 to 349,077. Compared to the number of silverside larvae passing Mirant Canal the 1999-2000 survival adjusted number (57,214 larvae) amounted to 0.5%. The equivalent adult losses declined from 297 to 150 age 1 fish.

Silverside with Entrainment Survival					
Plant Flow	Adjusted Average Number Entrained		Equivalent Adults (Age 1 Fish)		Equivalent Yield (lbs)
	Eggs	Larvae	Number	Pounds	
Maximum	0	388,041	167	3	1
1999 – 2001	0	349,077	150	3	1
2006 – 2007	0	267,874	115	2	1

Searobin eggs have been shown to have some entrainment survival; however larval survival rates are currently unavailable (Table 8). The following table summarizes estimated entrainment and equivalent adult numbers when entrainment survival is considered. Under actual flow eggs lost to entrainment declined from 5,019,471 to 3,859,973 and equivalent adult losses declined from 949 to 755 age 1 fish. The number of survival adjusted eggs amounted to 1.4% of the searobin eggs estimated to pass Mirant Canal.

Searobins with Entrainment Survival					
Plant Flow	Adjusted Average Number Entrained		Equivalent Adults (Age 1 Fish)		Harvest Yield (lbs)*
	Eggs	Larvae	Number	Pounds	
Maximum	4,699,746	152,914	911	55	70
1999 – 2001	3,859,973	134,225	755	45	58
2006 – 2007	3,206,540	107,296	624	38	48
* Over an 8 year lifespan.					

Grubby larvae have been shown to have some entrainment survival (Table 8) therefore the following table summarizes estimated entrainment and equivalent adult numbers when entrainment survival is considered. The number of larvae lost to entrainment under actual flow declined from 1,794,342 to 1,166,322 and equivalent adult losses declined from 1,456 to 946 age 2 fish. Compared to the number of grubby larvae passing Mirant Canal the survival adjusted number amounted to 0.3%.

Grubby with Entrainment Survival					
Plant Flow	Adjusted Average Number Entrained		Equivalent Adults (Age 2 Fish)		Equivalent Yield (lbs)
	Eggs	Larvae	Number	Pounds	
Maximum	0	2,964,452	2,405	28	4
1999 – 2001	0	1,166,322	946	11	2
2006 – 2007	0	1,809,548	1,468	17	2

Some cunner eggs and larvae have been shown to survive entrainment (Table 8) therefore the following table summarizes estimated entrainment losses and equivalent adult numbers when entrainment survival is considered. Under actual flow the number of eggs lost to entrainment declined from 1.96 billion to 1.33 billion and larvae losses declined from 56.3 million to 28.5 million. The equivalent adult losses declined from 677,487 to 406,908 age 1 fish. Compared to the number of cunner eggs and larvae passing Mirant Canal the survival adjusted numbers amounted to 2.8 and 0.2%, respectively.

Cunner with Entrainment Survival					
Plant Flow	Adjusted Average Number Entrained		Equivalent Adults (Age 1 Fish)		Harvest Yield (lbs)*
	Eggs	Larvae	Number	Pounds	
Maximum	1,495,306,247	32,916,284	456,905	11,240	2,494
1999 – 2001	1,337,579,610	28,547,335	403,563	9,928	2,203
2006 – 2007	1,035,131,055	23,077,136	317,963	7,822	1,736
* Over a 6 year lifespan.					

Tautog eggs have been shown to have some entrainment survival however larval survival rates are currently unavailable (Table 8). The following table summarizes estimated entrainment and equivalent adult numbers when entrainment survival is considered. Under actual flow the number of tautog eggs lost to entrainment declined from 105,969,058 to 72,381,865 and equivalent adult losses declined from 11 to 8 age 6 fish. The number of survival adjusted eggs amounted to 2.8% of the tautog eggs estimated to pass Mirant Canal.

Tautog with Entrainment Survival					
Plant Flow	Adjusted Average Number Entrained		Equivalent Adults (Age 6 Fish)		Harvest Yield (lbs)*
	Eggs	Larvae	Number	Pounds	
Maximum	80,912,618	5,662,312	9	17	22
1999 – 2001	72,381,865	5,068,342	8	15	20
2006 – 2007	56,012,625	3,942,433	6	12	15
* Over a 24 year lifespan.					

Some sand lance eggs and larvae have been shown to survive entrainment (Table 8) therefore the following table summarizes estimated entrainment and equivalent adult numbers when entrainment survival is considered. The number of sand lance eggs under actual flow lost to entrainment declined from 45,610 to 20,890 and larvae losses declined from 33,802,222 to 30,895,231. The equivalent adult losses declined from 27,431 to 25,069 age 2 fish. Compared to the number of sand lance larvae passing Mirant Canal the survival adjusted number amounted to 0.18%.

Sand Lance with Entrainment Survival					
Plant Flow	**Adjusted Average Number Entrained**		**Equivalent Adults (Age 2 Fish)**		**Equivalent Yield (lbs)**
	Eggs	**Larvae**	**Number**	**Pounds**	
Maximum	30,889	53,285,704	43,235	316	42
1999 – 2001	20,890	30,895,231	25,069	183	24
2006 – 2007	16,477	35,706,288	28,971	211	28

Atlantic mackerel eggs have been shown to have some entrainment survival however larval survival rates are currently unavailable (Table 8). The following table summarizes estimated entrainment and equivalent adult numbers when entrainment survival is considered. Under actual flow the number of eggs lost to entrainment declined from 186.1 million to 117.4 million and equivalent adult losses declined from 399 to 307 age 3 fish. Compared to the number of Atlantic mackerel eggs passing Mirant Canal the survival adjusted numbers amounted to 0.15%.

Atlantic Mackerel with Entrainment Survival					
Plant Flow	**Adjusted Average Number Entrained**		**Equivalent Adults (Age 3 Fish)**		**Harvest Yield (lbs)***
	Eggs	**Larvae**	**Number**	**Pounds**	
Maximum	177,494,175	10,713,066	407	260	175
1999 – 2001	117,441,457	9,458,078	307	196	132
2006 – 2007	116,063,874	7,477,925	274	175	118
* Over a 14 year lifespan.					

Windowpane eggs have been shown to have some entrainment survival however larval survival rates are currently unavailable (Table 8). The following table summarizes estimated entrainment and equivalent adult numbers when entrainment survival is considered. The number of eggs lost to entrainment under actual flow declined from 45.0 million to 37.5 million and the equivalent adult losses declined from 422 to 382 age 3 fish. Compared to the number of windowpane eggs passing Mirant Canal the survival adjusted numbers amounted to 0.46%.

Windowpane with Entrainment Survival					
Plant Flow	**Adjusted Average Number Entrained**		**Equivalent Adults (Age 3 Fish)**		**Harvest Yield (lbs)***
	Eggs	**Larvae**	**Number**	**Pounds**	
Maximum	47,734,904	3,153,391	506	134	23
1999 – 2001	37,531,781	2,093,238	382	101	17
2006 – 2007	31,831,882	1,945,035	331	88	15
* Over a 10 year lifespan.					

American plaice eggs and larvae have 100% mortality in cooling water intake structures when temperatures exceed 14° C (Table 8). Therefore adjusting entrainment for survival produces no difference between entrainment numbers and survival adjusted entrainment numbers.

Winter flounder eggs, stage 1 and stage 2 larvae appear to have 100% mortality in cooling water intake structures. Stage 3 and stage 4 winter flounder larvae have been shown to have some entrainment survival (Table 8) therefore the following table summarizes estimated entrainment and equivalent adult numbers when entrainment survival is considered. Under actual flow winter flounder larvae lost to entrainment declined from 6,530,552 to 4,591,122 and equivalent adult losses declined from 5,799 to 2,950 age 3 fish. Compared to the number of winter flounder larvae passing Mirant Canal the survival adjusted number amounted to 0.5%.

Winter Flounder with Entrainment Survival					
Plant Flow	**Adjusted Average Number Entrained**		**Equivalent Adults (Age 3 Fish)**		**Harvest Yield (lbs)***
	Eggs	**Larvae**	**Number**	**Pounds**	
Maximum	23,434,479	7,335,997	4,263	4,250	14,813
1999 – 2001	16,636,274	4,591,122	2,950	2,941	10,252
2006 – 2007	14,643,576	4,615,734	2,755	2,747	9,570
* Over a 16 year lifespan.					

Some American lobster larvae have been shown to survive entrainment (Table 8) therefore the following table summarizes estimated entrainment and equivalent adult numbers when entrainment survival is considered. Under actual flow the number of larvae lost to entrainment declined from 259,030 to 129,515 and equivalent adult losses declined from 6 to 3 adult (82 mm) lobsters. Compared to the number of lobster larvae passing Mirant Canal the survival adjusted number amounted to 0.04%.

American Lobster with Entrainment Survival					
Plant Flow	Adjusted Average Number Entrained		Equivalent Adults (82 mm)		Harvest Yield (lbs)*
	Eggs	Larvae	Number	Pounds	
Maximum	NA	135,597	3	3	0
1999 – 2001	NA	129,515	3	3	0
2006 – 2007	NA	94,921	2	2	0
* Over the years of harvest until the lobster reaches 127 mm carapace length.					

5.0 CONCLUSIONS

The analysis of entrainment and impingement data presented in this report indicates that operation of the circulating water system at Mirant Canal has not resulted in an adverse environmental impact to the population of 17 taxa of fish and one important macroinvertebrate, the American lobster. These taxa accounted for 95.6% of the fish eggs entrained, 75.5% of the larvae entrained and 95.5% of the fish impinged during field studies conducted at the facility.

Numbers of eggs and larvae entrained, expressed as a percentage of the number of eggs and larvae passing by Mirant Canal, was 1% or less for all types of eggs and larvae with the exception of cunner and tautog eggs which were 4%. These two species are very abundant in and around the Cape Cod Canal because of the rock lining the Canal along with several bridge abutments and marinas that create habitat for them.

Foregone harvest yield resulting from entrainment and impingement for commercially and recreationally landed species was small in absolute terms but also when compared with landings data. Equivalent yield in terms of striped bass was also very small (<30 pounds) for each of five taxa having no commercial or recreational value.

Based on the assessment presented here entrainment and impingement resulting from the circulating water system at Mirant Canal has not been sufficient to cause changes in the attributes of any population such that its sustainability is threatened. Therefore, an adverse environmental impact has not occurred.

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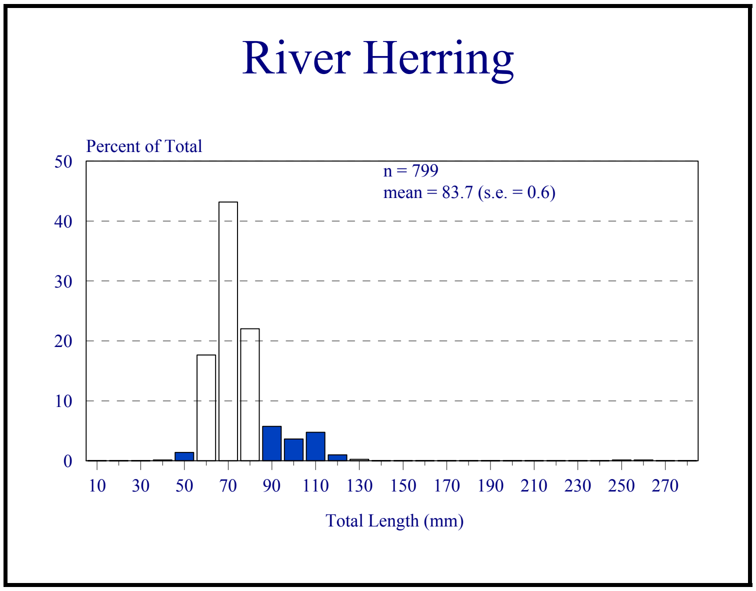


Figure 1. Total length frequency distribution for alewife and blueback herring impinged on the intake screens at Mirant Canal, March 1999 - February 2000.

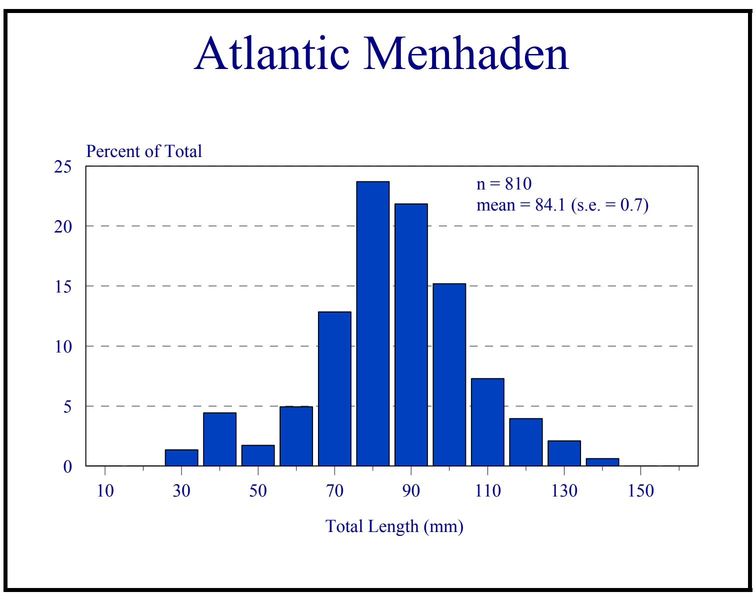


Figure 2. Total length frequency distribution for Atlantic menhaden impinged on the intake screens at Mirant Canal, March 1999 - February 2000.

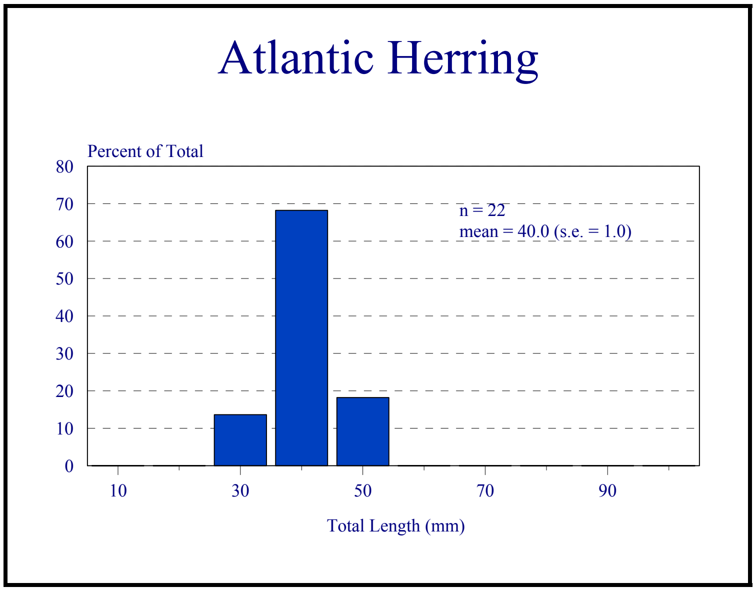
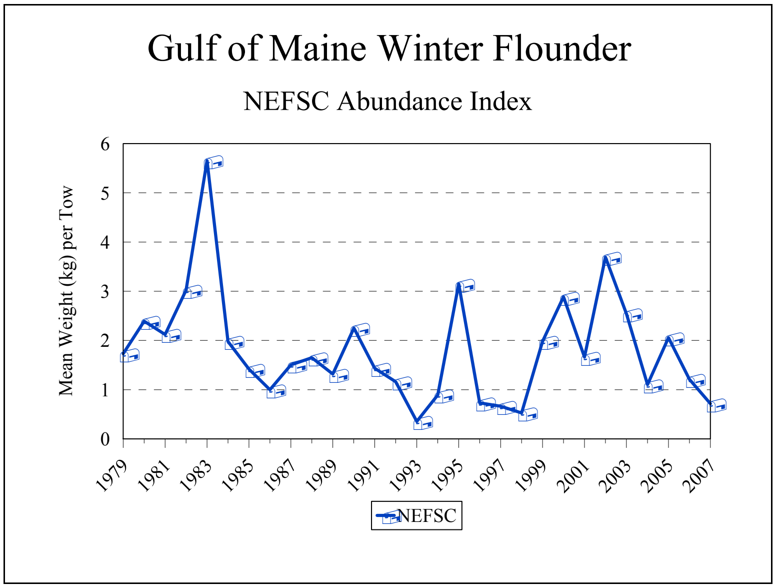


Figure 3. Total length frequency distribution for Atlantic herring impinged on the intake screens at Mirant Canal, March 1999 - February 2000.



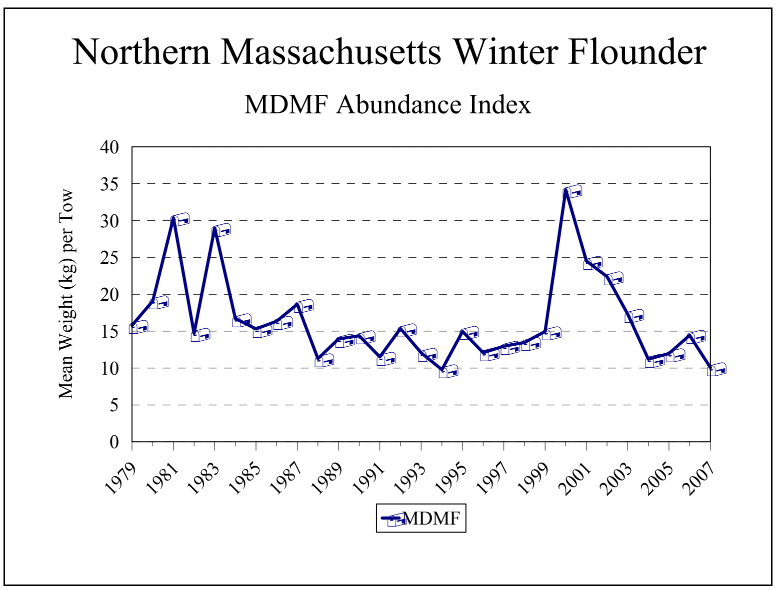


Figure 4. Northeast Fisheries Science Center (NEFSC) Gulf of Maine (top) and Massachusetts Division of Marine Fisheries (MDMF; bottom) northern stock spring abundance indices for winter flounder stocks, mean weight (kg) per tow, 1979-2005.

Table 1. Priority species assessed for adverse environmental impact at Mirant Canal.

Species	**Family**	Susceptible to				
		Entrainment		**Impingement**	**Harvest**	
		Eggs	Larvae		Commercial	Recreational
Alewife	Herring (Clupeidae)	No	Yes	Yes	No	No
Blueback Herring		No	Yes	Yes	No	No
Atlantic Menhaden		Yes	Yes	Yes	Yes	Yes
Atlantic Herring		No	Yes	Yes	Yes	Yes
Fourbeard Rockling	Cod (Gadidae)	Yes	Yes	Yes	No	No
Atlantic Cod		Yes	Yes	Yes	Yes	Yes
Silver Hake		Yes	Yes	Yes	Yes	Yes
Hake		Yes	Yes	Yes	Yes	Yes
Silversides	Atherinidae	No	Yes	Yes	No	No
Searobin	Triglidae	Yes	Yes	Yes	Yes	Yes
Grubby	Cottidae	No	Yes	Yes	No	No
Cunner	Wrasses (Labridae)	Yes	Yes	Yes	Yes	Yes
Tautog		Yes	Yes	Yes	Yes	Yes
Sand Lance	Ammodytidae	No	Yes	Rarely	No	No
Atlantic Mackerel	Scombridae	Yes	Yes	Rarely	Yes	Yes
Windowpane	Scopthalmidae	Yes	Yes	Yes	Yes	No
American Plaice	Righteye Flounders (Pleuronectidae)	Yes	Yes	Rarely	Yes	No
Winter Flounder		Rarely	Yes	Yes	Yes	Yes
American lobster	Nephropidae	No	Yes	Yes	Yes	Yes

Table 2. Estimated numbers entrained and equivalent adults for eggs and larvae of priority species collected at Mirant Canal for a representative year[1] based on three flow scenarios; actual recorded 1999-2001, maximum rated flow, and average recorded 2006-2007 flows. Weights are also shown.

	Actual Recorded Flow 1999 - 2001				Maximum Rated Flow (518 MGD)				Average Recorded Flow 2006 - 2007			
Species	Eggs	Larvae	EA Lost	Weight (lbs)	Eggs	Larvae	EA Lost	Weight (lbs)	Eggs	Larvae	EA Lost	Weight (lbs)
River Herring	56,923	22,288	3	1	61,694	25,494	4	1	43,352	18,262	3	1
Atlantic Menhaden	2,761,158	740,561	8	3	3,163,620	1,095,581	11	4	2,120,663	686,947	7	3
Atlantic Herring	0	975,579	1,060	320	0	1,624,877	1,766	533	0	1,043,520	1,134	342
Fourbeard Rockling	33,784,338	8,115,074	311	4	43,775,959	9,848,308	390	6	28,095,951	6,654,402	257	4
Atlantic Cod	1,135,277	1,105,005	1,750	429	1,597,157	1,357,940	2,153	527	1,021,503	951,029	1,507	369
Silver Hake	3,476,071	6,418,642	130	31	4,380,541	9,980,770	198	48	2,906,820	6,240,371	125	30
Hake	60,271,070	9,675,631	460	106	77,900,563	11,963,458	584	135	52,173,826	8,025,435	391	90
Silverside	0	688,514	297	6	0	765,366	330	7	0	528,351	228	5
Searobin	5,019,471	134,225	949	57	6,111,503	152,914	1,147	69	4,169,753	107,296	785	47
Grubby[2]	0	1,794,342	1,456	17	0	4,560,695	3,700	43	0	2,783,920	2,259	26
Tautog	105,969,058	5,068,342	11	20	118,466,497	5,662,312	12	23	82,009,700	3,942,433	8	16
Cunner	1,958,253,694	56,306,380	674,142	16,584	2,189,321,006	64,923,636	764,987	18,819	1,515,565,234	45,517,033	532,856	13,108
Sand Lance[2]	45,610	33,802,222	27,431	200	67,444	58,299,458	47,309	345	35,975	39,065,960	31,700	231
Atlantic Mackerel	186,119,583	9,458,078	399	255	281,290,293	10,713,066	546	349	183,936,409	7,477,925	365	233
Windowpane	45,056,160	2,093,238	442	117	57,304,807	3,153,391	581	154	38,213,544	1,945,035	381	101
American Plaice	1,433,222	423,565	58	11	2,040,221	660,647	89	17	1,198,909	401,410	54	10
Winter Flounder	16,636,274	6,530,552	5,799	5,782	23,434,479	10,368,117	8,369	8,344	14,643,576	6,541,899	5,409	5,393
American Lobster	na	259,030	6	6	na	271,193	6	6	na	189,842	4	5
Total	2,531,474,684	189,778,331			2,933,812,730	247,042,844			2,007,738,989	168,014,037		

[1]Representative year denotes that the data provided are the average of two annual estimates based on data collected from March 1999 through February 2000 and March 2000 - February 2001.

[2] Grubby and sand lance spawn in winter, therefore to obtain two complete year classes entrainment numbers were based on December 1999 - June 2000, and December 2000 - June 2001.

Table 3. Monthly circulating water flow at Mirant Canal used to calculate entrainment for maximum flow, actual 1999-2001 flow, and average flow for 2006-2007.

	Maximum Flow			Average of 2006 and 2007 Flows	
	MGD	100 m^3		MGD	100 m^3
JAN	518.00	19,572.70	JAN	414.52	15,691.14
FEB	518.00	19,572.70	FEB	375.00	14,195.29
MAR	518.00	19,572.70	MAR	348.39	13,187.89
APR	518.00	19,572.70	APR	280.00	10,599.15
MAY	518.00	19,572.70	MAY	333.87	12,638.39
JUN	518.00	19,572.70	JUN	363.33	13,753.66
JUL	518.00	19,572.70	JUL	345.16	13,065.78
AUG	518.00	19,572.70	AUG	377.42	14,286.88
SEP	518.00	19,572.70	SEP	305.00	11,545.51
OCT	518.00	19,572.70	OCT	277.42	10,501.47
NOV	518.00	19,572.70	NOV	315.00	11,924.05
DEC	518.00	19,572.70	DEC	275.81	10,440.41

	Recorded Monthly Flows, 1999 through 2001					
	1999		2000		2001	
	MGD	100 m^3	MGD	100 m^3	MGD	100 m^3
JAN	470.71	17,818.30	441.03	16,694.89	475.35	17994.14
FEB	502.11	19,006.82	446.14	16,888.16	502.50	19021.69
MAR	464.19	17,571.64	224.19	8,486.65	285.81	10818.95
APR	422.50	15,993.36	128.73	4,873.09	142.07	5377.81
MAY	377.74	14,299.09	273.13	10,339.06	467.68	17703.52
JUN	498.00	18,851.35	462.77	17,517.62	475.90	18014.77
JUL	491.35	18,599.80	438.13	16,584.99	379.65	14,371.13
AUG	491.35	18,599.80	406.26	15,378.54	506.87	19,187.15
SEP	289.30	10,951.20	458.03	17,338.45	No Data	
OCT	182.29	6,900.44	479.74	18,160.21	277.00	10,485.59
NOV	181.97	6,888.19	470.80	17,821.72	486.90	18,431.17
DEC	349.68	13,236.73	493.16	18,668.19	471.19	17,836.62

MGD = millions of gallons per day.
100 m^3 = 100 cubic meter units.

Table 4. Estimated numbers and equivalent adults of priority species impinged at Mirant Canal based on actual 1999-2000, scaled to maximum flow, and scaled to 2006-2007 flow scenarios. Equivalent adult weight is also shown.

	Actual Flow (Mar 1999-Feb 2000)				Maximum Flow (518 MGD)				Scaled to 2006-2007 Mean Flow			
Species	Total Impinged	Survival Adjusted	EA Lost	Wt (lbs)	Total Impinged	Survival Adjusted	EA Lost	Wt (lbs)	Total Impinged	Survival Adjusted	EA Lost	Wt (lbs)
Alewife	13,065	13,065	515	136	32,748	32,748	1,253	331	19,688	19,688	753	199
Atlantic Cod	671	611	211	52	937	853	306	75	604	550	196	48
Atlantic Herring	1,230	1,230	298	90	1,686	1,686	408	123	1,090	1,090	264	80
Atlantic Menhaden	23,896	23,896	2,090	840	52,582	52,582	4,609	1,853	31,162	31,162	2,724	1,095
Atlantic Silverside	12,742	12,742	3,240	66	28,812	28,812	7,044	144	16,937	16,937	4,116	84
Blueback Herring	12,714	12,714	1,719	351	31,118	31,118	4,058	828	18,512	18,512	2,399	489
Cunner	3,977	3,345	3,345	82	6,384	5,364	5,364	132	3,979	3,341	3,341	82
Fourbeard Rockling	22	22	22	0	25	25	25	0	17	17	17	0
Grubby	1,083	650	650	7	1,364	818	818	9	946	568	568	7
Northern Searobin	24	24	24	1	25	25	25	2	18	18	18	1
Sand Lance	27	14	14	0	32	17	17	0	24	14	14	0
Searobins	17	17	17	1	49	49	49	3	27	27	27	2
Silver Hake	332	332	177	43	775	775	413	100	473	473	252	61
Spotted Hake	30	30	30	7	52	52	52	12	32	32	32	7
Tautog	217	98	19	36	396	181	37	70	248	117	23	43
White Hake	115	100	100	23	129	112	112	26	87	76	76	18
Windowpane	143	86	31	8	163	99	32	8	119	73	30	8
Winter Flounder	575	211	37	37	782	275	47	47	509	183	31	31
Total Fish	74,242	72,119	14,555	2,303	163,499	160,309	27,707	4,635	97,878	95,813	16,856	2,789
Lobster	845		591	658	1,197		838	934	755		528	588

Table 5. Estimated latent impingement survival at Mirant Canal.

Species	Latent Survival (%)
Alewife	0
Atlantic Cod	9
Atlantic Herring	0
Atlantic Menhaden	0
Atlantic Silverside	0
Blueback Herring	0
Cunner	16
Fourbeard Rockling	0
Grubby	40
Sand Lance	50
Searobins	0
Silver Hake	0
Spotted Hake	0
Tautog	55
White Hake	13
Windowpane	40
Winter Flounder	65

Latent survival based on 48-hour holding periods.

Survival rates were adjusted for a 1999 chlorine event. See text for details.

Table 6. Age at which fish were assumed to mature for the Mirant Canal equivalent adult analysis.

Common Name	Equivalent Adult Age
Alewife	3
American Plaice	3
Atlantic Cod	2
Atlantic Herring	3
Atlantic Mackerel	3
Atlantic Menhaden	3
Atlantic Silverside	1
Blueback Herring	3
Cunner	1
Fourbeard Rockling	1
Grubby	2
Hakes (Red and White)	1
Sand Lance	2
Searobins	1
Silver Hake	2
Tautog	6
Windowpane	3
Winter Flounder	3
American Lobster	82 mm

Table 7. Estimated number of fish eggs and larvae passing through the Cape Cod Canal compared with the corresponding number entrained under three plant flow regimes.

Priority Taxa	Estimated Number Passing in the Cape Cod Canal	Actual Flow 1999 - 2000	Maximum Plant Flow	2006-2007 Flow
River Herring Larvae =	8,520,023	22,288 0.26%	25,494 0.30%	18,262 0.21%
Atlantic Menhaden Eggs =	520,242,530	2,761,158 0.53%	3,163,620 0.61%	2,120,663 0.41%
Atlantic Menhaden Larvae =	257,962,504	740,561 0.29%	1,095,581 0.42%	686,947 0.27%
Atlantic Herring Larvae =	1,944,780,968	975,579 0.05%	1,624,877 0.08%	1,043,520 0.05%
Rockling Eggs =	5,633,026,269	33,784,338 0.60%	43,775,959 0.78%	28,095,951 0.50%
Rockling Larvae =	2,515,024,387	8,115,074 0.32%	9,848,308 0.39%	6,654,402 0.26%
Atlantic Cod Eggs =	253,028,421	1,118,967 0.44%	1,597,157 0.63%	1,021,503 0.40%
Atlantic Cod Larvae =	240,718,750	1,105,005 0.46%	1,357,940 0.56%	951,029 0.40%
Silver Hake Eggs =	1,710,414,599	3,476,071 0.20%	4,380,541 0.26%	2,906,820 0.17%
Silver Hake larvae =	1,602,320,974	6,418,642 0.40%	9,980,770 0.62%	6,240,371 0.39%
Hake Eggs =	17,373,491,602	60,271,070 0.35%	77,900,563 0.45%	52,173,826 0.30%
Hake Larvae =	1,791,824,356	9,675,631 0.54%	11,963,458 0.67%	8,025,435 0.45%
Silverside Larvae =	12,552,067	688,514 5.49%	765,366 6.10%	528,351 4.21%
Searobin Eggs =	269,860,794	5,019,471 1.86%	6,111,503 2.26%	4,169,753 1.55%
Searobin Larvae =	22,015,012	134,225 0.61%	152,914 0.69%	107,296 0.49%
Grubby Larvae =	528,232,478	2,297,385 0.43%	4,546,754 0.86%	2,774,918 0.53%
Cunner Eggs =	48,461,391,220	1,958,253,694 4.04%	2,189,321,006 4.52%	1,515,565,234 3.13%
Cunner Larvae =	15,074,409,932	56,306,380 0.37%	64,923,636 0.43%	45,517,033 0.30%
Tautog Eggs =	2,623,000,722	105,969,058 4.04%	118,466,497 4.52%	82,009,700 3.13%

Table 7. Continued.

Priority Taxa	Estimated Number Passing in the Cape Cod Canal	Actual Flow 1999 - 2000	Maximum Plant Flow	2006-2007 Flow
Tautog Larvae =	815,911,123	5,068,342 **0.62%**	5,662,312 **0.69%**	3,942,433 **0.48%**
Sand Lance Larvae =	17,070,622,990	33,259,172 **0.19%**	57,699,883 **0.34%**	38,676,152 **0.23%**
Atlantic Mackerel Eggs =	78,856,563,332	186,119,583 **0.24%**	281,290,293 **0.36%**	183,936,409 **0.23%**
Atlantic Mackerel Larvae =	87,957,504	9,458,078 **10.75%**	10,713,066 **12.18%**	7,477,925 **8.50%**
Windowpane Eggs =	8,217,873,961	45,056,160 **0.55%**	57,304,807 **0.70%**	38,213,544 **0.47%**
Windowpane Larvae =	1,271,503,026	2,093,238 **0.16%**	3,153,391 **0.25%**	1,945,035 **0.15%**
American Plaice Eggs =	110,379,360	1,433,222 **1.30%**	2,040,221 **1.85%**	423,565 **0.38%**
American Plaice Larvae =	209,387,623	1,198,909 **0.57%**	660,647 **0.32%**	401,410 **0.19%**
Winter Flounder Larvae =	942,324,347	6,530,552 **0.69%**	10,368,117 **1.10%**	6,541,899 **0.69%**
American Lobster Larvae =	331,636,361	259,030 **0.08%**	271,193 **0.08%**	189,842 **0.06%**

Table 8. Entrainment percent survival and mortality for fish egg and larvae life stages.

Species	Life Stage	% Survival[1]	% Mortality	Change in Temperature °C (ΔT)[2]	Temperature (°C)	Source of Data
River Herring	Egg	0.0	100.0			
	Larvae	0.0	100.0			
Atlantic Menhaden	Egg	60.0	40.0	7 - 18		Collings et al. 1981
	Larvae	26.3	73.7		25 - > 35	Ecological Analysts, Inc. 1978 (EPRI 2000)
Atlantic Herring	Egg	na				
	Larvae	0.0	100.0			
Fourbeard Rockling	Egg	38.8	61.2	7 - 18		Collings et al. 1981
	Larvae	0.0	100.0		> 25	
Atlantic Cod	Egg	0.0	100.0		> 12	Lough 2004, Hardy 1978a
	Larvae	0.0	100.0		> 12	Lough 2004
Silver Hake	Egg	17.6	82.4	7 - 18		Collings et al. 1981
	Larvae	0.0	100.0		> 25	
Hake	Egg	38.8	61.2	7 - 18		Collings et al. 1981
	Larvae	0.0	100.0		> 25	
Silverside	Egg	na				
	Larvae	49.3	50.7		25 - > 35	Ecological Analysts, Inc. 1978 (EPRI 2000)
Searobin	Egg	23.1	76.9	7 - 18		Collings et al. 1981
	Larvae	0.0	100.0		> 25	
Grubby	Egg	na				
	Larvae	35.0	65.0	7 - 18		Collings et al. 1981
Tautog	Egg	31.7	68.3	7 - 18		Collings et al. 1981
	Larvae	0.0	100.0		> 25	
Cunner	Egg	31.7	68.3	7 - 18		Collings et al. 1981
	Larvae	49.3	50.7		25 - > 35	Ecological Analysts, Inc. 1978 (EPRI 2000)
Sand Lance	Egg	54.2	45.8	7 - 18		Collings et al. 1981
	Larvae	8.6	91.4	7 - 18		Collings et al. 1981
Atlantic Mackerel	Egg	36.9	63.1	7 - 18		Collings et al. 1981
	Larvae	0.0	100.0		> 25	
Windowpane	Egg	16.7	83.3	7 - 18		Collings et al. 1981
	Larvae	0.0	100.0		> 25	
American Plaice	Egg	0.0	100.0		> 14	Howell & Caldwell 1984
	Larvae	0.0	100.0		> 14	Howell & Caldwell 1984
Winter Flounder	Egg	0.0 [3]	100.0		> 18	Pereira et al. 1999
	Stage 1 Larvae	0.0	100.0			PG&E National Energy Group 2001
	Stage 2 Larvae	0.0	100.0			PG&E National Energy Group 2001
	Stage 3 Larvae	48.9	51.1			PG&E National Energy Group 2001
	Stage 4 Larvae	49.4	50.6			PG&E National Energy Group 2001
American Lobster	Egg	na				
	Larvae	50.0	50.0	5 - 17		Collings et al. 1981

[1]Larval survival was assumed to be 0% at water temperatures greater than 25°C for species with no documented entrainment survival rates.

[2]Change in temperature in °C (ΔT) range is based on the Canal Station Ichthyoplankton Entrainment Survival Study 1977-1979 (Collings et al. 1981).

[3] Entergy Nuclear reported some entrainment survival of winter flounder eggs at the Pilgrim Nuclear Power Station, however sample size was very small, therefore a 0% survival rate was used (MRI 1986).

Table 9. Estimated numbers entrained and equivalent adults adjusted for survival for eggs and larvae of priority species collected at Mirant Canal for a representative year[1] based on three flow scenarios; actual recorded 1999-2001, maximum rated flow, and average recorded 2006-2007 flows. Weights are also shown.

	Actual Recorded Flow 1999 - 2001				Maximum Rated Flow (518 MGD)				Average Recorded Flow 2006 - 2007			
Species	**Eggs**	**Larvae**	**EA Lost**	**Weight (lbs)**	**Eggs**	**Larvae**	**EA Lost**	**Weight (lbs)**	**Eggs**	**Larvae**	**EA Lost**	**Weight (lbs)**
River Herring	56,923	22,288	3	1	61,694	25,494	4	1	43,352	18,262	3	1
Atlantic Menhaden	1,104,463	545,793	5	2	1,265,448	807,443	6	3	848,265	506,280	4	2
Atlantic Herring	0	975,579	1,060	320	0	1,624,877	1,766	533	0	1,043,520	1,134	342
Fourbeard Rockling	20,676,015	8,115,074	252	4	26,790,887	9,848,308	313	4	17,194,722	6,654,402	208	3
Atlantic Cod	1,135,277	1,105,005	1,750	429	1,597,157	1,357,940	2,153	527	1,021,503	951,029	1,507	369
Silver Hake	2,864,283	6,418,642	128	31	3,609,566	9,980,770	196	47	2,395,220	6,240,371	123	30
Hake	36,885,895	9,675,631	355	82	47,675,145	11,963,458	449	104	31,930,382	8,025,435	301	69
Silverside	0	349,077	150	3	0	388,041	167	3	0	267,874	115	2
Searobin	3,859,973	134,225	755	45	4,699,746	152,914	911	55	3,206,540	107,296	624	38
Grubby[2]	0	1,166,322	946	11	0	2,964,452	2,405	28	0	1,809,548	1,468	17
Tautog	72,381,865	5,068,342	8	15	80,912,618	5,662,312	9	17	56,012,625	3,942,433	6	12
Cunner	1,337,579,610	28,547,335	403,563	9,928	1,495,306,247	32,916,284	456,905	11,240	1,035,131,055	23,077,136	317,963	7,822
Sand Lance[2]	20,890	30,895,231	25,069	183	30,889	53,285,704	43,235	316	16,477	35,706,288	28,971	211
Atlantic Mackerel	117,441,457	9,458,078	307	196	177,494,175	10,713,066	407	260	116,063,874	7,477,925	274	175
Windowpane	37,531,781	2,093,238	382	101	47,734,904	3,153,391	506	134	31,831,882	1,945,035	331	88
American Plaice	1,433,222	423,565	58	11	2,040,221	660,647	89	17	1,198,909	401,410	54	10
Winter Flounder	16,636,274	4,591,122	2,950	2,941	23,434,479	7,335,997	4,263	4,250	14,643,576	4,615,734	2,755	2,747
American Lobster	na	129,515	3	3	na	135,597	3	3	na	94,921	2	2
Total	1,649,607,927	109,714,061			1,912,653,176	152,976,696			1,311,538,381	102,884,898		

[1]Representative year denotes that the data provided are the average of two annual estimates based on data collected from March 1999 through February 2000 and March 2000 - February 2001.

[2] Grubby and sand lance spawn in winter, therefore to obtain two complete year classes entrainment numbers were based on December 1999 - June 2000, and December 2000 - June 2001.

APPENDIX A

Life history summaries and parameters for priority species.

PRIORITY SPECIES LIFE HISTORIES

The Adverse Environmental Impact Assessment for Mirant Canal Station focused on 18 taxa of fish and one invertebrate, the American lobster. These 19 taxa were selected based on susceptibility to entrainment and/or impingement, ecological importance, and commercial and/or recreational value to fisheries. Brief life history summaries follow.

A.1 River Herring (Alewife and Blueback Herring; *Alosa pseudoharengus and Alosa aestivalis*)

The alewife is an anadromous species ranging from the St. Lawrence River, Canada to North Carolina (Neves 1981). Landlocked freshwater populations exist in places such as the Great Lakes and the New York Finger Lakes (Bigelow and Schroeder 1953). Adult alewives are typically 10 to 11 inches in length and 8 to 9 ounces in weight but may reach 15 inches (Bigelow and Schroeder 1953). Movements consist of springtime, upstream spawning migrations from the ocean in a chronological south-to-north progression. Homing to natal rivers for spawning appears to be strong (Havey 1961; Thunberg 1971). Adults spawn in ponds, lakes, or slow-flowing riverine areas, then return to sea while young-of-the-year remain in fresh water for several months before gradually descending to the ocean by their first autumn (Bigelow and Schroeder 1953; Neves 1981).

Larval, juvenile, and adult alewives feed on copepods, amphipods, and shrimp (Stone and Daborn 1987). Adults also feed on small fish such as herring, eels, sand lance, cunner, and other alewives (Bigelow and Schroeder 1953). In fresh water, alewives have been reported to feed on copepods, cladocerans, and insect larvae (Vigerstad and Cobb 1978). Janssen (1976) showed that alewives can feed selectively by feeding on individual prey, or non-selectively, by filtering water through their gill rakers.

Alewives spawning in the Parker River, Massachusetts, mature at ages 3, 4, and 5 with all individuals being mature at age 6 (Rideout 1974). Fecundity estimates for a coastal population in Connecticut ranged from 48,000 to 360,000 eggs depending on size (Kissil 1974). In northern Massachusetts spawning migrations begin in mid-April and end late in May (Rideout 1974; Mayo 1974). Eggs are about 1 mm in diameter, adhesive, and require 3 to 6 days to hatch over a temperature range of 16 to 22 C. Larvae are 3 to 5 mm in total length at hatching (Cianci 1969) and about 20 mm when they become juveniles (Jones et al. 1978).

Alewives have considerable commercial value and are frequently combined with blueback herring. According to NOAA fisheries statistics, U.S. landings (Great Lakes excluded) average 4,800 tons with an average value of 848,000 dollars from 1980-1988. The 1993 landings total for Massachusetts was 18,900 pounds with a value of 2,300 dollars. No commercial alewife landings were reported in Massachusetts from the 1998-2003. Due to stock declines harvest moratoria were established in Massachusetts, Rhode Island, Connecticut, and North Carolina beginning in 2006 and extending through at least 2011.

The blueback herring and the alewife are morphological very similar and thus difficult to distinguish from one another. The blueback herring attains about the same size as the alewife and, like the alewife, grows in salt water but migrates to fresh water to spawn (Bigelow and Schroeder 1953). Its breeding habits do not differ from the alewife except that it "runs" later in the season, does not run up as far above tidewater, and does not spawn until the water is much warmer (70-75 F instead of 55-60 F). The blueback has the same diet as the alewife but has a greater geographical range, occurring as far south as Florida (Bigelow and Schroeder 1953). No distinction is made commercially between the blueback and the alewife; it is equally useful for bait and for food.

A.2 Atlantic Menhaden (*Brevoortia tyrannus*)

The Atlantic menhaden is a migratory, eurohaline species found in coastal waters from New Brunswick to Florida (Peppar 1974; Vaughan and Smith 1988). Menhaden form surface schools off Florida, Georgia, and the Carolinas in the spring, and move slowly northward as coastal waters warm, reaching southern New England by April. They stratify by age and size during the summer with older and larger fish generally found further north. A southern migration of adults followed by the young-of-year begins in early fall, and surface schools disappear entirely in early winter off the Carolinas (Dryfoos et al. 1973; Ahrenholz et al. 1987; Vaughan and Smith 1988). They apparently do not range beyond the continental shelf (Reintjes 1969). Adult menhaden are typically 12 to 15 inches in length with a weight of 10 ounces to one pound (Bigelow and Schroeder 1953).

Adult menhaden are planktivorous, filtering both large phytoplankton and zooplanton from the water column (Durbin and Durbin 1975). June and Carlson (1971) reported that larval menhaden usually feed on large copepods. Filter feeding does not begin until after metamorphosis when the gill rakers are highly developed. Menhaden are sexually mature at three years, but some mature at younger ages (Hingham and Nicholson 1964). Fecundity estimates range from and 38,000 to 631,000 (Hingham and Nicholson 1964; Dietrich 1979). Spawning occurs in coastal oceanic waters (Reintjes 1969) or in large bays, such as Narragansett Bay (Herman 1963; Bourne and Govoni 1988). In Southern New England spawning may occur from mid-April to November with a peak generally occurring in May or June. Temperatures at which spawning has been observed throughout the species' range may extend from 4.4 to 23.6 C (Jones et al. 1978). Ferraro (1980) reported that spawning occurred primarily between 13 and 22 hours after sunrise. Eggs are buoyant and approximately 1 to 2 mm in diameter (Colton and Marak 1969).

Incubation of eggs requires 42 to 54 hours at 15 to 20 C (Reintjes 1969). Larvae are 2.4 to 4.5 mm in total length at hatching (Kuntz and Radcliffe 1917; Wheatland 1956). The larvae enter estuarine systems where they metamorphose into juveniles and remain until fall (Wilkens and Lewis 1971; Lewis et al. 1972). Metamorphosis occurs at 30 to 38 mm (Lewis et al. 1972). Kendall and Reintjes (1975) reported no significant difference in larval catch in shallow (0-15m) and deep (18-33m) tows or during day or night along the Atlantic coast.

Menhaden contribute a large portion of the fishmeal produced in the United States (Huppert 1980).

A.3 Atlantic Herring (*Clupea harengus*)

The Atlantic herring lives in open waters, traveling in schools of hundreds or thousands (Bigelow and Schroeder 1953). This species ranges north to the edge of the polar ice in Greenland and as far south as Cape Hatteras (Anthony 1982).

Atlantic herring are plankton feeders. Larvae eat larval snails, crustaceans, diatoms, peridinians, and copepods. The adult diet consists chiefly of copepods and pelagic euphausid shrimp (Bigelow and Schroeder 1953). On Georges Bank, Maurer (1975) found that herring prefer chaetognaths, euphausiids, and pteropods.

Herring is the preferred food for predaceous fish such as cod, pollock, haddock, silver hake, striped bass, mackerel, tuna, salmon, and dogfish (Bigelow and Schroeder 1953). Silver hake may drive schools of herring out of the water onto beaches where both predator and prey strand on the sand.

Individual Atlantic herring populations spawn within the same 4-6 week period every year but, as a species, they spawn throughout the year (Chadwick and Claytor 1989; Sinclair and Tremblay 1984). Spawning occurs from August through October over rocky or gravel bottoms, and a female may deposit from 20,000 to 40,000 eggs (Bigelow and Schroeder 1953). The eggs are demersal and stick to sand, rocks, or seaweed. From Georges Bank to the middle-Atlantic herring grow to six inches by the end of their first year and may reach up to 14 inches at their maximum life span of 14-15 years (Anthony 1972).

Initially herring were used as bait for the cod fisheries, but in the 1960's intensive fishing of this species began by other nations (i.e., the Soviet Union and Poland). In 1967, spawning stock on Georges Bank reached a peak of 1.4 million metric tons (Anthony 1982), decreasing in 1973 to about 140,000 metric tons because of overfishing and only average or poor recruitment to the stock. By 1977 the stock collapsed. Three decades ago Atlantic herring exceeded 300,000 metric tons annually (Friedland 1998), falling to an average of 94,500 metric tons from 1992 to 1996. In Georges Bank, fishery landings peaked in 1968 at 373,600 metric tons, declining to 43,500 metric tons in 1976. The directed herring fishery ceased on Georges Bank from 1979 to 1994. In 1994, both the United States and Canada herring fleets began mid-water trawling; landings peaked in 2001 at 35,000 mt with an average of 13,000 mt from 1994-2005 (Overholtz et al. 2004, Overholtz 2006).

A.4 Fourbeard Rockling (*Enchelyopus cimbrius*)

The fourbeard rockling is a small fish in the cod family found primarily over soft mud or sand bottoms along the continental margins of the North Atlantic Ocean (Bigelow and Schroeder 1953). This rockling has been described as growing to a length of 16.5 inches in Scandinavian waters, but 12 inches is the largest recorded from the Gulf of Maine, where they average 6 to 10 inches (Bigelow and Schroeder 1953). They are year-round residents wherever they are found although there may be local inshore-offshore seasonal movements in some areas (Bigelow and Schroeder 1953).

Food habits of the fourbeard rockling vary with location. In the Gulf of Maine the diet consists primarily of bivalves, copepods, and decapods (Deree 1999). However prey composition in the diet can change with age. One-year old fish preyed primarily on copepods, whereas 2-7 year-old fish preferred bivalves (Deree 1999). In Newfoundland, adult rockling diets consist mainly of polychaetes, with younger fish eating decapod crustaceans and fish larvae (Keats and Steele 1990)

In the Gulf of Maine, fourbeard spawn from spring to early autumn (Bigelow and Schroeder 1953). The buoyant eggs are 0.66 to 0.98 in diameter and newly hatched larvae are around 2 mm long (Bigelow and Schroeder 1953). Rockling are neither large enough nor plentiful enough to be of importance commercially.

A.5 Atlantic Cod (*Gadus morhua*)

The Atlantic cod range on both sides of the North Atlantic from Greenland to Cape Hatteras. Their offshore boundary is the continental slope and they are abundant from Labrador to Nantucket Shoals and from New York to New Jersey in winter (Bigelow and Schroeder 1953). Cod live near the surface down to 250 fathoms (Bigelow and Schroeder 1953) and may attain a length of 130 cm and a weight up to 77 pounds (Mayo and O'Brien 1998). Adult cod can live in waters ranging from 32-55 F (Bigelow and Schroeder 1953).

Larval and postlarval cod feed on copepods and other zooplankton. Juvenile cod feed on copepods, amphipods, barnacles, and small worms. As adults they feed on a variety of invertebrates and fish such as mollusks, tunicates, ctenophores, squid, crabs, silver hake, shad, mackerel, silversides, and herring (Bigelow and Schroeder 1953).

Some cod are mature by age 3 and all are mature by Age 9 (Bigelow and Schroeder 1953). Mayo and O'Brien (1998) stated that sexual maturity is attained between the ages 2-4. Cod spawn mostly in winter on shoal areas (Heyerdahl and Livingstone 1982). However, in American and European waters, the breeding season lasts from late October to April (Bigelow and Schroeder 1953; Mayo and O'Brien 1998). Total egg production in cod ranges anywhere from 3 million to 9 million eggs a year (Bigelow and Schroeder 1953; Wise 1962). Cod eggs are buoyant, transparent, without oil, and 1.1 to 1.82 mm in diameter. The time of hatching is dependent on water temperature. Eggs hatch in 10 or

11 days at 47 F, 14 or 15 days at 43 F , 20 to 23 days at 38 to 39 F, and more than 40 days at 32 F (Bigelow and Schroeder 1953). Larvae are about 4 mm long at hatching (Bigelow and Schroeder 1953) and move to the bottom when they are about 4-6 cm mm in length (Lough 2004).

Cod have been one of the most important food fishes in the Gulf of Maine since colonial times.

A.6 Silver Hake (*Merluccius bilinearis*)

Silver hake range along the continental shelf of eastern North America from Newfoundland to South Carolina being most abundant between Cape Sable and New York (Bigelow and Schroeder 1953; Leim and Scott 1966). There are two silver hake stocks in US waters: a northern stock in the Gulf of Maine and a southern stock in the mid-Atlantic region (Almeida and Anderson 1978). They are a bentho-pelagic schooling species living in depths of up to 40 fathoms (see review in Hardy 1978). They over-winter in relatively deep water and move closer to shore during warmer months. Adults average about 14 inches in length but may reach upwards of 30 inches and 5 pounds in weight (Bigelow and Schroeder 1953).

Bowman (1984) reported that small silver hake (<20 cm TL) feed mostly on amphipods, decapod shrimp, and euphasiids. As they increase in size, fish and squid become of greater importance in their diet. Dominant fish prey recorded by Bowman (1984) include smaller silver hake, Atlantic mackerel, butterfish, herring, sand lance, scup, Atlantic saury, and longfin hake. Most feeding occurs at night and has been described as voracious.

Silver hake begin to mature at age 2 (Almeida and Anderson 1978). Fecundity estimates range from 60,000 eggs for 20 cm fish to 650,000 for 50 cm fish from the Scotian Shelf (Mari and Ramos 1979). Other estimates include 230,000 to 1.6 million eggs for fish 30-54 cm in length (W. Morse, NMFS, personal communication). Bigelow and Schroeder (1953) report that the Gulf of Maine is the principal nursery area for silver hake, with eggs being collected from June through October north of Cape Cod. Spawning occurs in both inshore and offshore water (Bigelow and Schroeder 1953) in the upper 10 meters of the water column (Kendall and Naplin 1981). The pelagic eggs are positively bouyant, and range from 0.8 to 1 mm in diamter (Colton and Marak 1969). The eggs require about 39 hours to hatch at 22-23 C (Kendall and Naplin 1981) and larvae are approximately 4 mm long at hatching. Complete transformation to the juvenile stage is completed by about 40 mm (Fahay 1983). Kendall and Naplin (1981) reported that numbers of larvae increased with added depth, although they apparently moved upward at night.

The silver hake has considerable commercial value.

A.7 Hake (Red Hake, *Urophycis chuss* and White Hake, *Urophycis tenuis*)

These two fish agree so closely in habits and distribution that what is said of one applies equally to the other. Both the white hake and the red hake are exclusively American, occurring in continental waters from the Gulf of St. Lawrence southward to the Mid-Atlantic states. The red hake has not been reported farther south than Virginia, but the white hake is known off North Carolina (Bigelow and Schroeder 1953). Historically hakes were found in the south channel (gulf) and on the northwestern slope of Georges Bank with heaviest concentrations from the southwestern area of Georges Bank to Hudson Shelf Valley (Anderson1982). They spend their first months drifting at or near the surface, but at the size of 2-4 inches they take to the bottom and become ground fish for the remainder of their lives (Bigelow and Schroeder 1953). Inshore small hakes (2 to 6 inches) are closely associated with eelgrass (*Zostera marina*), but offshore in deeper waters young fish frequently hide in the living shells of the giant scallop (*Pecten magellanicus*). Adults prefer mud bottom, only rising to the upper layers in pursuit of food. Temperature preference for adults ranges between 5 to 12 C (Musick 1969); hakes move inshore or offshore with seasonal temperature changes.

Hakes forage on shrimp, amphipods, and other small crustaceans, which they find on the bottom. They are also known to capture small fish such as alewives, butterfish, cunner, and many other species (Bigelow and Schroeder 1953).

Hakes reach sexual maturity in about two years at a length of around 11 inches (Musick 1969). Peak spawning activity for red hake occurs off Long Island from the end of June through July (Perlmutter 1939) and in mid-July on Georges Bank (Domanevsky and Nozdrin 1963). White hake spawn from late winter to late summer (Bigelow and Schroeder 1956). The New York Bight appears to be an important spawning and nursery area for red hake (Anderson 1982). Eggs are pelagic and average 0.74 mm in diameter (Hildebrand and Cable 1938). At hatching, larvae measure an average of 2.04 mm (Miller and Marak 1959) and become demersal when they are between 35 and 40 mm long (Anderson 1982).

The maximum length of the white hake is 4 feet, and the maximum weight about 40 pounds, but most of the white hake caught weigh between 1 and 20 pounds. (Bigelow and Schroeder 1953). The red hake is smaller; normally they grow to a maximum of 22 inches in length and weigh up to 5 pounds. Hakes older than 6 years are not common in commercial catches although their maximum age may be as high as 12 years (Rikhter 1974). Red hake females are both longer and heavier than males of the same age (Bigelow and Schroeder 1953).

The hakes are not very important commercially although they are sold in fish markets, if large enough, and smaller fish have been used for poultry feed. They are usually sold in the form of fresh and frozen fillets and are commonly used in fish cakes. Hake landings have been relatively low since 1985, and have been able to maintain stock biomass at high levels. Therefore, hake stocks are currently under-exploited (Sosebee 1998).

A.8 Atlantic Silverside (*Menidia menidia*)

Atlantic silversides are distributed along the coast of North America from New Brunswick to northern Florida (Gosline 1948; Leim and Scott 1966). They are chiefly associated with the shore zone, particularly over sand or gravel bottoms in estuaries. They may extend considerable distances upstream in large rivers but become rare as fresh water is approached (Hildebrand and Schroeder 1928). In many areas they are often cited as the most numerous fish species encountered (see for example Mulkana 1966; Richards and Castagna 1970; Briggs 1975; Dominion Energy Brayton Point 2008). Adults reach an average total length of approximately 4.5 to 5 inches (Collette and Klein-MacPhee 2002).

Conover and Murawski (1982) reported that Atlantic silverside populations north of Cape Hatteras migrate in winter from inland to inner continental shelf waters. However, some do over-winter in deep inland waters. During the winter months, mortality may reach 99% (Conover 1979) and many of those remaining die during the spawning season (Bayliff 1950; Conover and Ross 1982). Bayliff (1950) occasionally noted a two-year-old individual, but generally the Atlantic silverside is believed to complete its life cycle in one year.

Stomach contents were found to consist primarily of copepods in spring, followed by a more varied diet in the summer; e.g. diatoms and other algae, annelids, squid, amphipods, crabs, cladocerans, terrestrial insects, small fish, and silverside eggs have been found (Kendall 1902, summarized in Bayliff 1950). In Connecticut, Cadigan and Fell (1985) found their diet dominated by copepods, shrimp, and plant material with eggs and fish also being important.

Atlantic silversides mature and spawn at age 1 from late April though June in northern Massachusetts (Conover and Kynard 1984). These authors reported that spawning was highly periodic occurring on a two-week cycle during daytime high tides (see also Middaugh et al. 1984). Fecundity estimates range from 500-1000 eggs (Bayliff 1950) to 4,500-5,000 (45 eggs per mm body length, Conover 1979). Fertilized eggs are 1 to 1.5 mm in diameter, demersal (see review in Martin and Drewry 1978), and attached by sticky filaments to marsh grasses, intertidal algae and debris (Middaugh 1981; Conover and Kynard 1984). Incubation requires 4 days at 30 C to 27 days at 15 C (Austin et al. 1975). Larvae are 3.8 to 5.0 mm in total length at hatching and become juveniles at about 20 mm (Wang 1974).

Silversides have little commercial value although some are used for bait. They are an important forage species for striped bass, Atlantic mackerel, and bluefish (Bigelow and Schroeder 1953; Bayliff 1950; Schaefer 1971). Because of their rapid growth and abundance in estuarine systems coupled with winter movement offshore, they are considered to be an important pathway of energy flow from and within estuaries (Conover and Murawski 1982; Conover and Ross 1982; Cadigan and Fell 1985).

A.9 Northern Searobin (*Prionotus carolinus*) and Striped Searobin (*Prionotus evolans*)

Two searobin species are common in the temperate, western North Atlantic. They range from Canada to northern Florida (Collette and Klein-MacPhee 2002; Gilmore 1977; Scott and Scott 1988) but are most common year-round on the continental shelf from Cape Cod to Cape Hatteras, preferring sandy bottoms (Hildebrand and Schroeder 1928; Edwards et al. 1962). In a study done by McBride et al. (1998) they found that geographic distributions of both species overlapped year-round but, on average, northern searobins were found in colder, deeper water than were striped searobins. They also found that northern searobins began their inshore spring migration and offshore fall migration earlier than the striped searobin.

The northern searobin has been found to grow up to 16 inches, but few grow to be over 12 inches. In contrast, the striped searobin grows to be larger than the northern searobin with a maximum length reported to be 18 inches (Bigelow and Schroeder 1953; McBride et al. 1998).

Searobins are omnivores and usually eat whatever food is available to them. They feed on shrimps, polychaetes, crabs, amphipods, squids, mollusks, worms and smaller fish (Collette and Klein-MacPhee 2002; Richards et al. 1979)

The northern searobin and the striped searobin both spawn from June to September (Bigelow and Schroeder 1953; Richards et al. 1979). They reach sexual maturity at 2 to 3 years (Roberts-Goodwin 1981) and produce buoyant eggs 0.94 to 1.15 mm in diameter. Newly hatched larvae are between 2.5 to 2.8 mm long (Bigelow and Schroeder 1953; Collette and Klein-MacPhee 2002).

Searobins are commonly taken by pound-net and bottom trawl fisheries along the United States eastern coast, but are only occasionally sold as foodfish, lobster bait, or livestock feed. As a result they are of little commercial importance. However, because fishery landings, value, and catch rates for mid-Atlantic states have all declined over the past several decades, underused species such as searobins may have potential to counter these trends. The recommendations of many who have tasted searobin and efforts to expand the marketability of this fish may encourage the utilization of this underexploited resource (McBride et al. 1998).

A.10 Grubby (*Myoxocephalus aenaeus*)

Grubbies are small sculpins found in coastal waters of North America from New Jersey to Newfoundland (Collette and Klein-MacPhee 2002). In the New England area they are commonly found year-round in eelgrass habitat, whereas in Newfoundland they are found in shallow protected areas on mud, sand and gravel bottoms (Ennis 1969). Grubbies are the smallest of the common sculpins. Juveniles grow to about 60-65 mm standard length during their first year, whereas adults ranged from 66-98 mm SL (Lazzari et al. 1989).

Grubbies are omnivores, but fish of all sizes have been found to feed primarily on crustaceans (i.e. *Crangon* sp.). Amphipods and isopods are more important in juvenile diets, and other fish are a minor component found only in adult stomachs (Lazzari et al. 1989). Bigelow and Schroeder (1953) report that grubbies have been found to feed on a diversity of organisms including worms, shrimps, crabs, copepods, snails, mollusks, and small fishes.

Grubbies exhibit sexual dimorphism in color and adult size (females larger than males). The spawning season lasts throughout the winter in New England and until June in Newfoundland, with some females reaching sexual maturity during their first year (Lazzari et al. 1989). Eggs are 1 mm in diameter, and can be green or rose-colored depending on the type of seaweed or algae to which they have attached (Lazzari et al. 1989; Bigelow and Schroeder 1953).

The grubby is small and therefore is of little commercial or recreational value; however it does serves as a source of food for larger commercially important fishes.

A.11 Cunner (*Tautogolabrus adspersus*)

The cunner occurs farther north than any other member of the family labridae in the western Atlantic. Cunner occur north to the Strait of Belle Isle along the north coast of Newfoundland (Pottle and Green 1979) and south to the mouth of Chesapeake Bay (Leim and Scott 1966). They are year-round, coastal residents and live near cover such as rocks, pilings, and macrophytes (Collette and Klein-MacPhee 2002; Olla et al. 1979). They are sedentary and occupy home ranges of only a few hundred to a few thousand square meters (Green 1975, Olla et al. 1978). Adult cunner are typically 6-10 inches in length weighing under one-half pound but have been reported to reach 16 inches in length and a weight over two pounds (Johansen 1925; Bigelow and Schroeder 1953).

T. adspersus are active only during the day, remaining essentially asleep during darkness, and hibernate when water temperature falls below 5-6 EC (Green and Farwell 1971). They forage on a large variety of organisms, particularily invertebrates such as mussels and amphipods (Johansen 1925; Richards 1963; Chao 1973; Olla et al. 1975). They are also known, however, to occasionally capture small fish, eat fish eggs, and feed on dead animal matter. Foraging generally takes place within a few meters of subtidal home shelters, but some cunner utilize intertidal areas around high water to feed (Whorisky 1983).

Cunner can reach maturity as early as the end of their first summer. All age 1 fish were mature in a study done in Connecticut by Dew (1976), but two years may be required for populations found further north (Johansen 1925). Fecundity has been estimated to be approximately 100,000 eggs (Williams et al. 1973) and from 1,192 eggs for a 76 mm TL fish to 84,403 eggs for a 171 mm TL fish (Nitschke 1998). Spawning occurs in late afternoon and evening (Ferraro 1980) from May to August depending on latitude (Johansen 1925). Eggs are buoyant, about 0.75 to 1.0 mm in diameter, and hatch in 2-6 days depending on the water temperature (Johansen 1925; Bigelow and Schroeder 1953). At hatching, larvae are 2 to 3.4 mm in length (Colton and Marak 1969) and they attain juvenile characteristics at about 25 mm (Bigelow and Schroeder 1953). Larvae were found to be most abundant at mid-depths in Block Island Sound (MRI 1976).

Cunner are of little commercial value, but they do provide some recreation enjoyment because of their affinity for piers and wharves and their susceptibility to hook and line.

A.12 Tautog (*Tautoga onitis*)

The tautog is a coastal species ranging from Nova Scotia to South Carolina, and is most abundant between Cape Cod and the Chesapeake Bay (Bigelow and Schroeder 1953; Collette and Klein-MacPhee 2002; Cooper 1966). Its distribution is limited primarily to inshore regions in close association with rocks, wrecks, pilings, jetties, or uneven bottom (Olla et al. 1974). Tautog occasionally enter brackish water, but not fresh water (Bigelow and Schroeder 1953).

Tautog migrate onshore in the spring and move to deeper waters offshore in the autumn. These migrations are in response to water temperature (Stolgitis 1970; Cooper 1966). Olla et al. (1974) reported that only older tautog moved offshore for the winter, while the younger fish remained inshore in a torpid state.

Based on a diet study of tautog in New York, the blue mussel (*Mytilus edulis*) was the principal item ingested (Olla et al. 1974). They are also known to eat barnacles, crabs, sand dollars, scallops, amphipods, shrimp, isopods, lobsters, and small fishes (Bigelow and Schroeder 1953; Collette and Klein-MacPhee 2002).

Tautog mature at about three years old (Chenoweth 1963) and may live as long as 34 years (Cooper 1965). Fecundity ranges from about 16,000 eggs at Age 3 to 500,000 among older fish (Chenoweth 1963). Spawning occurs primarily between May and August (Wheatland 1956). Ferraro (1980) calculated that spawning occurred primarily between 15 and 21 hours after sunrise in New York waters.

The tautog is an important sport fish in Massachusetts from the time it moves inshore in the spring through September (Clayton et al. 1978). Briggs (1969) reported that tautog contributed 10% of the seasonal sport catch in the inshore waters of eastern Long Island and, in September and October, it represented 50% of the game fish caught. Maximum size for a tautog is about three feet (Bigelow and Schroeder 1953).

A.13 Sand Lance (*Ammodytes americanus*)

The taxonomy of these fishes has not been satisfactorily established at this time (Richards et al. 1963; Richards 1965; Richards and Kendall 1973) so that we have chosen not to assign a specific name to the specimens collected in Mount Hope Bay, RI. Since they are most probably *Ammodytes hexapterus* (*A. americanus*), life history information for this species was selected whenever possible.

On the North American coast, the sand lance ranges from Greenland to Cape Hatteras, North Carolina (Reay 1970; Collette and Klein-MacPhee 2002). They are found over sandy bottom, frequently in large schools, and commonly burrow into the sand where they may rest with snouts exposed (Meyer et al. 1979; Leim and Scott 1966). According to Bigelow and Welsh (1925), sand lance move to deeper water in summer and return in early autumn as the water cools. Adults range in size from 4 to 6 inches (Collette and Klein-MacPhee 2002). Meyer et al. (1979) found that sand lance on Stellwagen Bank eat primarily copepods. Similar results were found by Richards (1963) in Long Island Sound. Other reported food items include amphipods, mysids, euphasiids, chaetognaths, salps, animal eggs, barnacle cyprids, fish eggs, dinoflagellages, diatoms and larval sand lance (Richards 1963; Meyer et al. 1979).

Sand lance spawn in winter and early spring. Their larvae have been taken from late December to early June in Mount Hope Bay, RI. No data on maturity or fecundity for *A. americanus* are available from the North American Coast south of Nova Scotia. Information provided by Scott (1968) for *A. dubius* indicated that fish mature in their second year. Fecundity estimates calculated from *A. dubius* collected in the Merrimac River, range from 21,271 at Age 1 to 31,640 at Age 5 (Westin et al. 1979).

Sand lance are utilized as both food for predators and as a bait fishery (Jerome et al. 1965). They are of considerable value as a link in the food chain between zooplankton and such commercial species as Atlantic cod, haddock, silver hake and yellowtail flounder (Bowman and Langton 1978; Langton and Bowman 1980; Scott 1968). Certain valuable sport fish such as striped bass and bluefish also utilize sand lance as food, as do certain species of whales (Bigelow and Schroeder 1953; Overholtz and Nicholas 1979).

A.14 Atlantic Mackerel (*Scomber scombrus*)

Atlantic mackerel are swift-moving fish that gather in dense schools of many thousands. Young-of-the-year almost always form schools separately from the older fish. Although schooling is not a necessity, it is their usual habit (Collette and Klein-MacPhee 2002). This species is found in the western North Atlantic from Labrador to North Carolina. According to Sette (1950) there appear to be separate northern and southern contingents, both of which overwinter in deep water near the edge of the continental shelf from Sable Island Bank to the Chesapeake Bay region. In the spring an inshore and northwestward migration occurs and in the autumn the pattern is reversed (Berrien 1982). The depth range of Atlantic mackerel is from the surface down to perhaps 90 fathoms, and the usual temperature range is 7-20 C (Collette and Klein-MacPhee 2002).

Small mackerel often enter estuaries and harbors in search of food whereas adults are fish of the open sea and are not dependent on the coastline or the bottom at any stage of their lives (Bigelow and Schroeder 1953). Mackerel feed on copepod eggs and larvae, euphausiid shrimp, squid, and small fish larvae obtained by active pursuit of individual animals or by passive filtering (Bigelow and Schroeder 1953). Practically all floating animals of a certain size regularly serve as food items for mackerel.

S. scombrus spawns in spring and early summer when the water has warmed to 8 C, starting in mid-April off Chesapeake Bay and progressively moving north in June and July to the southern side of the Gulf of St. Lawrence. The mackerel is a prolific fish with a fecundity of 285,000 to 1.98 million eggs (Collette and Klein-MacPhee 2002). Rate of development is temperature-dependent, normally limited to a range between 11 and 21 C. Fish grow to a length of 2 inches during the first one to two months after hatching, and in eight years they will attain a length of about 17 inches.

Mackerel are an important food source for humans as well as other marine organisms. Predators of mackerel include whales, porpoises, mackerel and thresher sharks, dogfish, tunas, bonito, bluefish, striped bass, cod, squid, and seabirds. Mackerel is a delicious fish although oily and historically was one of the four most valuable fishes in the Gulf of Maine surpassed only by haddock, cod, and rosefish (Bigelow and Schroeder 1953). Practically the entire commercial catch of mackerel has been made with purse seines, pound nets, weirs, floating traps, and gill nets. Anglers troll or bait-fish for mackerel along the coast as well.

A.15 Windowpane (*Scophthalmus aquosus*)

The windowpane, is a left-sided, benthic flatfish ranging along the Atlantic coast of North America from the Gulf of St. Lawrence to Florida (Gutherz 1967). They are generally found year-round on sandy bottoms to about 45 meters deep off southern New England, and to depths of 45 to 75 meters on Georges Bank (Bigelow and Schroeder 1953). They appear to be most numerous from southern New England to Chesapeake Bay (Smith et al. 1975) and to be sedentary as far as movements or migrations are concerned (Moore 1947). However, some movement to deeper water does occur in the colder months of the year (Lange and Lux 1978). Maximum reported size is 18 inches total length, but generally adults range from 10 to 12 inches and weigh less than one pound (Moore 1947).

Windowpane have been reported to feed on mysid shrimp, sand shrimp, crabs, squid, worms, and fish such as hake, anchovies, sand lance, and silversides (Moore 1947; Collette and Klein-MacPhee 2002).

Windowpane mature in their third and fourth years (Moore 1947). Spawning takes place during most of the year but generally from May through October in New England (Smith et al. 1975). Two peaks of egg production are noted in New England: one in May-June and the other in September-November (MRI 1992; Morse and Able 1995). The optimal spawning temperature is anywhere between 13-19 C (Morse and Able 1995). Eggs are pelagic, 1 to 1.4 mm in diameter (Colton and Marak 1969), and require 8 days to hatch at 12 C (Martin and Drewry 1978). Colton and Marak (1969) reported that windowpane are 2 mm in length at hatching and 13 mm at metamorphosis. There is no information on the fecundity of this species. During the pelagic larval period, eyes are on opposite sides of the head, migration to the left side beginning at about 6.5 mm. A study of vertical distribution in Block Island Sound (MRI 1976) found windowpane larvae to be most abundant in deeper water (30-45 feet).

The windowpane is of limited commercial value because it is very thin-bodied and does not grow particularly large.

A.16 American Plaice *(Hippoglossoides platessoides)*

American plaice are right eyed flounders with a large mouths. They range from southern Labrador to Rhode Island along the Northwest Atlantic continental shelf in deep waters (O'Brien 1998). They are bottom fish and prefer sand and mud substrates. They can be found from the tide line down to 700 m (Bigelow and Schroeder 1953). Plaice live in temperatures from 29 to 45 F (Bigelow and Schroeder 1953).

Adult plaice range in size from 12 to 24 inches (Collette and Klein-MacPhee 2002). They average about 0.5 pounds at 12 inches and 6 pounds at 24 inches (Bigelow and Schroeder 1953).

All plaice are not sexually mature until four years of age, although some may mature earlier. They spawn in the spring, March through May (O'Brien 1998). Females produce between 100,000 at 38 cm to 2,200,000 at 70 cm buoyant eggs (Pitt 1964). Eggs hatch from 11 to 14 days. When plaice first metamorphosis into bottom fish, approximately 1.5 to 1.75 inches long, they eat small invertebrates. As they grow, they eat larger invertebrates such as sea urchins, brittle stars, sand dollars, crabs, shrimp, and mollusks (Collette and Klein_MacPhee 2002).

American plaice is a species of commercial importance in the Gulf of Maine. Plaice are principally caught with otter trawls. American plaice have little recreational value.

A.17 Winter Flounder (*Pleuronectes americanus*)

The winter flounder is a right-sided benthic flatfish ranging from northern Labrador to Georgia (Leim and Scott 1966), being most abundant from the Gulf of St. Lawrence to Chesapeake Bay (Collette and Klein-MacPhee 2002). In New England it occurs from inshore estuaries to the offshore fishing banks. According to Bigelow and Schroeder (1953), fish caught inshore are commonly 12 to 15 inches in length and weigh 1.5 to 2 pounds; however, they have been known to reach nearly 23 inches in length. Flounder caught on Georges Bank, known as lemon sole, are generally larger in size, reaching 7 to 8 pounds.

Movements of winter flounder are in response to changes in water temperature (McCracken 1963). They consist of migrating to deeper, cooler water in summer and returning to shallow, nearshore areas in the fall. Based on a ten-year tagging study, Howe and Coates (1975) showed that flounder north of Cape Cod displayed relatively localized movements confined to inshore waters. Fish south of Cape Cod dispersed in spring and summer in a southeasterly direction generally beyond the territorial limit; little mixing occurred between Georges Bank and inshore areas.

Juvenile winter flounder have been found to eat a wide variety of invertebrate food items. Pearcy (1962) identified 77 organisms representing seven phyla in juvenile stomachs. Adults eat primarily polychaete worms, amphipods and isopods, pelecypods, and plant material but, in a series of studies, 14 phyla and 260 species were identified in the stomachs of winter flounder (MacPhee 1978).

Winter flounder mature at age 2 to 3 (Perlmutter 1947), but in the northern areas of its range it may not mature until age 6 or 7 (Kennedy and Steele 1971). Fecundity estimates range from 93,000 (Saila 1962) to 2,604,000 eggs (Kennedy and Steele 1971) depending on size. Spawning occurs at night (Breder 1922) in inshore waters once a year from November to June depending on geographic location. For example in Massachusetts Bay flounder spawn from February through May. The demersal eggs are adhesive, about 0.7 to 0.9 mm in diameter, and require 5 to 33 days to hatch over a temperature range of 2 to 12 C (Scott 1929; Rogers 1976; MRI 1986).

Winter flounder larvae are pelagic and about 2.3 to 3.5 mm in total length at hatching (Sullivan 1915; Pearcy 1962). Pearcy (1962) found that larvae were generally more abundant near bottom except for the smallest sizes which were more abundant nearer the surface. Studies at the mouth of Plymouth Harbor-Kingston, Duxbury Bay found flounder larvae to be more abundant nearer bottom although a reversal of this pattern occurred on one date (Scherer 1984). At the mouth of the Taunton River larvae were found to be significantly more abundant in the lower half of the water column early in the season, in the upper half in the middle of the season, and again in the lower half late in the spawning season (MRI 1979). No clear day-night variation in catch was apparent. Metamorphosis, during which the left eye migrates to the right side and juveniles assume a benthic habit, begins at about 6 mm and is generally complete by 6.6 to 10 mm TL (Chambers and Leggett 1987).

The winter flounder is a species of considerable economic importance to both commercial and recreational fisheries in New England.

A.18 American Lobster (*Homarus americanus*)

The American lobster, a benthic decapod, ranges from Labrador to North Carolina from intertidal areas to the edge of the continental shelf. They are most abundant along the Maine coastline northward to Newfoundland (McLeese and Wilder 1958). Inshore lobsters are most commonly found on rocky bottom with a sand base where the rocks provide cover. They are also common on mud substrates where they excavate burrows or occupy those formed by fish such as hake (Cooper and Uzmann 1971). Tagging studies conducted in North Atlantic coastal waters have generally indicated that lobster movements are localized (Cooper 1970) in the 6 to 10 km range (Fogarty et al. 1980). Long-distance movements from 50 to 250 km, however, have been recorded (Morrissey 1971; Dow 1974). Lobsters tagged on the outer continental shelf have shown more consistent long-range movements apparently shoalward in spring and summer and returning to the shelf margin in fall (Uzmann et al. 1977).

Since they have a hard exoskeleton, lobsters must molt to grow. With increasing age, the frequency of molting declines. For example, American lobsters may molt ten times during their first year, dropping to once per year after four years. There is apparently no terminal molt and therefore no maximum size. Lobsters over two feet long weighing over 42 pounds have been reported (Phillips et al. 1980).

The American lobster is omnivorous and predacious. Foods include such invertebrates as crabs, polychaetes, mussels, periwinkles, sea urchins, clams, and starfish as well as fish, both alive and dead (see review in Cooper and Uzmann 1971).

Lobsters reach maturity at a different size and age depending on location, with those further north where average temperatures are lower requiring more time. For example, they mature at 55-59 mm carapace length (CL) in Long Island Sound compared with 90 mm CL in the Bay of Fundy (Krouse 1973; Phillips et al. 1980). Maturity can require 7 to 12 years to attain. Mating occurs generally during summer and within 48 hours of a female molt. After mating, sperm is stored by the female for about nine months at which time eggs are extruded, fertilized, and glued to the abdominal appendages called pleopods. There they incubate for 9 to 13 months depending on water temperature so that approximately two years elapse between mating and egg hatching (Herrick 1911; Hughes and Matthiessen 1962; Phillips et al. 1980). Fecundity estimates range from 3045-115,000 eggs (Herrick 1911; Saila et al. 1969; Perkins 1971; Estrella and Cadrin 1995) depending on female size. Eggs hatch and larvae are released into the water column most frequently at night, usually shortly after darkness, but larvae are released throughout the day as well (Ennis et al. 1975). Hatching occurs primarily during late-May early-June in New England (Hughes and Matthiessen 1962), larvae being found in Cape Cod Bay from mid-May though September (Matthiessen and Scherer 1983). Lobster larvae pass through four free-swimming planktonic larval stages over a period of 25 to 35 days depending on temperature (Templeman 1936) before settling to the bottom and molting into juveniles (MacKenzie and Moring 1985, Charmantier et al. 1991). Larvae are generally considered to be neustonic (see review in Fogarty 1983) however stage 1 lobster larvae show significant vertical migration occurring between 15 and 30 m deep during daylight and at less than 10 m deep at night. Stage 2 and 3 larvae occur throughout the upper 30 m of the water column. Stage 4 lobster larvae occur primarily at the surface (Harding et al. 1987).

The American lobster is one of the most valuable fishery resources along the east coast of the United States (Fogarty 1983). From 1980 through 1988, according to NOAA statistics, total New England landings averaged 40.6 million pounds with an average value over 102 million dollars. Corresponding numbers for Massachusetts were 13 million pounds and 34 million dollars. The 1990 landings of lobster in Massachusetts totaled 15.8 million pounds valued at 44 million dollars. The Massachusetts commercial lobster landings in 1998 were 13,236,091 pounds and were valued at 47,914,649 dollars. The total recreational lobster landings in Massachusetts in 1998 were 329,444 pounds (Pava et al. 1998).

Appendix A Table 1a. Life history parameters used for alewife

Life Stage	M[a]	F[b]	Fraction vulnerable to fishing[c] (v)	Z_i[d]	S_i[e]	Adjusted[f] S_i ($2Se^{-Ln(1+S)}$)	Weight (lbs)[g]
Egg	0.54	0.00	0.00	0.54	0.5804	0.7345	0.00000128
Larvae	5.50	0.00	0.00	5.50	0.0041	0.0081	0.00000141
YOY	2.57	0.00	0.00	2.57	0.0765	0.1422[h]	0.00478
Age 1+	0.94	0.10	0.00	1.04	0.3535	0.5223	0.0443
Age 2+	0.94	0.10	0.00	1.04	0.3535	0.5223	0.139
Age 3+	0.94	0.10	0.00	1.04	0.3535	0.5223	0.264
Age 4+	0.94	0.10	0.45	1.04	0.3535	0.5223	0.386
Age 5+	0.94	0.10	0.90	1.04	0.3535	0.5223	0.489
Age 6+	0.94	0.10	1.00	1.04	0.3535	0.5223	0.568
Age 7+	0.94	0.10	1.00	1.04	0.3535	0.5223	0.626
Age 8+	0.94	0.10	1.00	1.04	0.3535	0.5223	0.667
Age 9+	0.94	0.10	1.00	1.04	0.3535	0.5223	0.696
Forage yield per recruit value = 0.1109 pounds[i]							

YOY = young of the year

[a] Instantaneous natural mortality from EPA (2004) and ASMFC (2007).

[b] Alewife were considered a forage species due the current moratoriums in Massachusetts, Rhode Island, Connecticut, and North Carolina.

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight based on EPA (2004).

[h] For impingement calculations the YOY stage mortality was adjusted by dividing the stage mortality by the number of days for that stage producing a daily mortality rate. The daily mortality rates were multiplied by the number of days until the next stage and this adjusted mortality rate was converted to produce an adjusted survivability rate. The adjusted survival for the alewife YOY stage was based on an assumed April 1 birthday, a daily mortality rate of 0.008140, and a stage duration of 316 days (EPA 2004).

[i] Forage yield per recruit or forage species forgone production is a measure of the amount of fish not available to higher trophic levels since the fish are lost to entrainment and impingement. The forage yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Conservative value for age at sexual maturity for alewife is 3 years (Collette and Klein-MacPhee 2002).

Appendix A Table 1b. Life history parameters used for blueback herring

Life Stage	M[a]	F[b]	Fraction vulnerable to fishing[c] (v)	Z_i[d]	S_i[e]	Adjusted[f] S_i ($2Se^{-Ln(1+S)}$)	Weight (lbs)[g]
Egg	0.558	0.00	0.00	0.558	0.5724	0.7280	0.00000115
Larvae	3.57	0.00	0.00	3.57	0.0282	0.0548	0.004805
YOY	6.26	0.00	0.00	6.26	0.0019	0.0038[h]	0.011195
Age 1+	0.30	0.00	0.00	0.30	0.7408	0.8511	0.0160
Age 2+	0.30	0.00	0.00	0.30	0.7408	0.8511	0.0905
Age 3+	0.30	0.00	0.00	0.30	0.7408	0.8511	0.204
Age 4+	0.90	0.00	0.00	0.90	0.4066	0.5781	0.318
Age 5+	1.50	0.00	0.00	1.50	0.2231	0.3649	0.414
Age 6+	1.50	0.00	0.00	1.50	0.2231	0.3649	0.488
Age 7+	1.50	0.00	0.00	1.50	0.2231	0.3649	0.540
Age 8+	1.50	0.00	0.00	1.50	0.2231	0.3649	0.576
Forage yield per recruit value = 0.1109 pounds[i]							

YOY = young of the year

[a] Instantaneous natural mortality is from EPA (2004).

[b] Blueback herring were considered a forage species due the current moratoriums in Massachusetts, Rhode Island, Connecticut, and North Carolina.

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight based on EPA (2004).

[h] For impingement calculations the YOY stage mortality was adjusted see text for details.

[i] Forage yield per recruit or forage species forgone production is a measure of the amount of fish not available to higher trophic levels since the fish are lost to entrainment and impingement. The forage yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Conservative value for age at sexual maturity for blueback herring is 3 years (Collette and Klein-MacPhee 2002).

Appendix A Table 1c. Life history parameters used for Atlantic menhaden

Life Stage	M[a]	F[b]	Fraction vulnerable to fishing[c] (v)	Z_i[d]	S_i[e]	Adjusted[f] S_i ($2Se^{-Ln(1+S)}$)	Weight (lbs)[g]
Egg	1.20	0.00	0.00	1.20	0.3012	0.4630	0.00000482
Larvae	4.47	0.00	0.00	4.47	0.0114	0.0226	0.00000530
YOY	6.19	0.00	0.00	6.19	0.0020	0.0041[h]	0.000684
Age 1+	0.54	0.00	0.10	0.54	0.5827	0.7364	0.0251
Age 2+	0.45	1.10	1.00	1.55	0.2122	0.3502	0.235
Age 3+	0.45	1.10	1.00	1.55	0.2122	0.3502	0.402
Age 4+	0.45	1.10	1.00	1.55	0.2122	0.3502	0.586
Age 5+	0.45	1.10	1.00	1.55	0.2122	0.3502	0.863
Age 6+	0.45	1.10	1.00	1.55	0.2122	0.3502	1.08
Age 7+	0.45	1.10	1.00	1.55	0.2122	0.3502	1.27
Age 8+	0.45	1.10	1.00	1.55	0.2122	0.3502	1.43
Harvest yield per recruit value = 0.1166 pounds[i]							

YOY = young of the year

[a] Instantaneous natural mortality is from EPA (2004).

[b] Stage-specific instantaneous fishery mortality (commercial and recreational combined) is from EPA (2004).

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight based on EPA (2004).

[h] For impingement calculations the YOY stage mortality was adjusted by dividing the stage mortality by the number of days for that stage producing a daily mortality rate. The daily mortality rates were multiplied by the number of days until the next stage and this adjusted mortality rate was converted to produce an adjusted survivability rate. The adjusted survival for the Atlantic menhaden YOY stage was based on an assumed June 1 birthday, a daily mortality rate of 0.019102, and a stage duration of 324 days (EPA 2004).

[i] Harvest yield per recruit or foregone fishery yield is a measure of the amount of fish not harvested since the fish are lost to entrainment and impingement (EPA 2004). The harvest yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Conservative value for age at sexual maturity for Atlantic menhaden is 3 years (Collette and Klein-MacPhee 2002).

Appendix A Table 1d. Life history parameters used for Atlantic herring

Life Stage	M[a]	F[b]	Fraction vulnerable to fishing[c] (v)	Z_i[d]	S_i[e]	Adjusted[f] S_i ($2Se^{-Ln(1+S)}$)	Weight (lbs)[g]
Egg	3.36	0.00	0.00	3.36	0.0347	0.0671	0.00000473
Larvae	3.26	0.00	0.00	3.26	0.0384	0.0739	0.00000531
YOY	3.26	0.00	0.00	3.26	0.0384	0.0739[h]	0.00126
Age 1+	0.20	0.28	0.50	0.48	0.6188	0.7645	0.0314
Age 2+	0.20	0.28	1.00	0.48	0.6188	0.7645	0.173
Age 3+	0.20	0.28	1.00	0.48	0.6188	0.7645	0.302
Age 4+	0.20	0.28	1.00	0.48	0.6188	0.7645	0.420
Age 5+	0.20	0.28	1.00	0.48	0.6188	0.7645	0.463
Age 6+	0.20	0.28	1.00	0.48	0.6188	0.7645	0.525
Age 7+	0.20	0.28	1.00	0.48	0.6188	0.7645	0.588
Age 8+	0.20	0.28	1.00	0.48	0.6188	0.7645	0.642
Age 9+	0.20	0.28	1.00	0.48	0.6188	0.7645	0.699
Age 10+	0.20	0.28	1.00	0.48	0.6188	0.7645	0.732
Age 11+	0.20	0.28	1.00	0.48	0.6188	0.7645	0.766
Age 12+	0.20	0.28	1.00	0.48	0.6188	0.7645	0.848
Age 13+	0.20	0.28	1.00	0.48	0.6188	0.7645	0.855
Age 14+	0.20	0.28	1.00	0.48	0.6188	0.7645	0.862
Age 15+	0.20	0.28	1.00	0.48	0.6188	0.7645	0.869
Age 16+	0.20	0.28	1.00	0.48	0.6188	0.7645	0.877
Harvest yield per recruit value = 0.1402 pounds[i]							

YOY = young of the year

[a] Instantaneous natural mortality is from Overholtz et al. (2004) and EPA (2004).

[b] Stage-specific instantaneous fishery mortality (commercial and recreational combined) is from EPA (2004).

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight based on EPA (2004).

[h] For impingement calculations the YOY stage mortality was adjusted see text for details.

[i] Harvest yield per recruit or foregone fishery yield is a measure of the amount of fish not harvested since the fish are lost to entrainment and impingement (EPA 2004). The harvest yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Conservative value for age at sexual maturity for Atlantic herring is 3 years (Collette and Klein-MacPhee 2002).

Appendix A Table 1e. Life history parameters used for fourbeard rockling

Life Stage	M[a]	F[b]	Fraction vulnerable to fishing[c] (v)	Z_i[d]	S_i[e]	Adjusted[f] S_i ($2Se^{-Ln(1+S)}$)	Weight (lbs)[g]
Egg	2.30	0.00	0.00	2.30	0.1003	0.1822	0.000000637
Larvae	4.25	0.00	0.00	4.25	0.0143	0.0281	0.0000007
YOY	0.92	0.00	0.00	0.92	0.4001	0.5715	0.00187
Age 1+	0.49	0.00	0.00	0.49	0.6126	0.7598	0.0142
Age 2+	0.49	0.00	0.00	0.49	0.6126	0.7598	0.0209
Age 3+	0.49	0.00	0.00	0.49	0.6126	0.7598	0.0402
Age 4+	0.49	0.00	0.00	0.49	0.6126	0.7598	0.0617
Age 5+	0.49	0.00	0.00	0.49	0.6126	0.7598	0.0906
Age 6+	0.49	0.00	0.00	0.49	0.6126	0.7598	0.151
Age 7+	0.49	0.00	0.00	0.49	0.6126	0.7598	0.188
Age 8+	0.49	0.00	0.00	0.49	0.6126	0.7598	0.251
Age 9+	0.49	0.00	0.00	0.49	0.6126	0.7598	0.323
Forgae yield per recruit value = 0.0413 pounds[h]							

YOY = young of the year

[a] Instantaneous natural mortality is from EPA (2004).

[b] Fourbeard rockling are a forage species, there is no commercial or recreational harvest for this species.

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight based on EPA (2004).

[h] Forage yield per recruit or forage species forgone production is a measure of the amount of fish not available to higher trophic levels since the fish are lost to entrainment and impingement. The forage yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Age at sexual maturity for fourbeard rockling was assumed to be 1 year.

Appendix A Table 1f. Life history parameters used for Atlantic cod

Life Stage	**M**[a]	**F**[b]	**Fraction vulnerable to fishing**[c] **(v)**	$\mathbf{Z_i}$[d]	$\mathbf{S_i}$[e]	**Adjusted**[f] $\mathbf{S_i}$ $(2Se^{-Ln(1+S)})$	**Weight (lbs)**[g]
Egg	4.87	0.000	0.00	4.870	0.0077	0.0152	0.00000567
Larvae	5.83	0.000	0.00	5.830	0.0029	0.0059	0.00000624
YOY	0.92	0.000	0.00	0.916	0.4001	0.5715[h]	0.000337
Age 1+	0.40	0.000	0.00	0.400	0.6703	0.8026	0.0225
Age 2+	0.20	0.290	0.50	0.490	0.6703	0.8026	0.245
Age 3+	0.20	0.290	1.00	0.490	0.6703	0.8026	0.628
Age 4+	0.20	0.290	1.00	0.490	0.6703	0.8026	1.29
Age 5+	0.20	0.290	1.00	0.490	0.6703	0.8026	2.45
Age 6+	0.20	0.290	1.00	0.490	0.6703	0.8026	3.33
Harvest yield per recruit value = 0.3566 pounds[i]							

YOY = young of the year

[a] Instantaneous natural mortality is from EPA (2004).

[b] Stage-specific instantaneous fishery mortality (commercial and recreational combined) is from EPA (2004).

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight based on EPA (2004).

[h] For impingement calculations the YOY stage mortality was adjusted see text for details.

[i] Harvest yield per recruit or foregone fishery yield is a measure of the amount of fish not harvested since the fish are lost to entrainment and impingement (EPA 2004). The harvest yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Conservative value for age at sexual maturity for Atlantic cod is 2 years (Collette and Klein-MacPhee 2002).

Appendix A Table 1g. Life history parameters used for silver hake

Life Stage	**M[a]**	**F[b]**	**Fraction vulnerable to fishing[c] (v)**	**Z_i[d]**	**S_i[e]**	**Adjusted[f] S_i ($2Se^{-Ln(1+S)}$)**	**Weight (lbs)[g]**
Egg	1.43	0.00	0.00	1.43	0.2393	0.3862	0.0000203
Larvae	6.62	0.00	0.00	6.62	0.0013	0.0027	0.0000223
YOY	4.58	0.00	0.00	4.58	0.0103	0.0203[h]	0.00516
Age 1+	0.40	0.00	0.00	0.40	0.6703	0.8026	0.0729
Age 2+	0.40	0.00	0.00	0.40	0.6703	0.8026	0.242
Age 3+	0.40	0.40	1.00	0.80	0.4493	0.6201	0.456
Age 4+	0.40	0.40	1.00	0.80	0.4493	0.6201	0.646
Age 5+	0.40	0.40	1.00	0.80	0.4493	0.6201	0.788
Age 6+	0.40	0.40	1.00	0.80	0.4493	0.6201	0.889
Age 7+	0.40	0.40	1.00	0.80	0.4493	0.6201	0.958
Age 8+	0.40	0.40	1.00	0.80	0.4493	0.6201	1.00
Age 9+	0.40	0.40	1.00	0.80	0.4493	0.6201	1.03
Age 10+	0.40	0.40	1.00	0.80	0.4493	0.6201	1.05
Age 11+	0.40	0.40	1.00	0.80	0.4493	0.6201	1.06
Age 12+	0.40	0.40	1.00	0.80	0.4493	0.6201	1.06
Harvest yield per recruit value = 0.1309 pounds[i]							

YOY = young of the year

[a] Instantaneous natural mortality is from EPA (2004).

[b] Stage-specific instantaneous fishery mortality (commercial and recreational combined) is from EPA (2004).

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight based on EPA (2004).

[h] For impingement calculations the YOY stage mortality was adjusted see text for details.

[i] Harvest yield per recruit or foregone fishery yield is a measure of the amount of fish not harvested since the fish are lost to entrainment and impingement (EPA 2004). The harvest yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Conservative value for age at sexual maturity for silver hake is 2 years (Collette and Klein-MacPhee 2002).

Appendix A Table 1h. Life history parameters used for hakes

Life Stage	**M**[a]	**F**[b]	**Fraction vulnerable to fishing**[c] **(v)**	Z_i[d]	S_i[e]	**Adjusted**[f] S_i ($2Se^{-Ln(1+S)}$)	**Weight (lbs)**[g]
Egg	1.22	0.00	0.00	1.22	0.2952	0.4559	0.000000487
Larvae	6.70	0.00	0.00	6.70	0.0010	0.0025	0.0000048
YOY	4.83	0.00	0.00	4.83	0.0080	0.0158	0.00345
Age 1+	0.40	0.39	0.50	0.79	0.4538	0.6243	0.231
Age 2+	0.40	0.39	1.00	0.79	0.4538	0.6243	0.805
Age 3+	0.40	0.39	1.00	0.79	0.4538	0.6243	0.991
Age 4+	0.40	0.39	1.00	0.79	0.4538	0.6243	1.22
Age 5+	0.40	0.39	1.00	0.79	0.4538	0.6243	1.55
Age 6+	0.40	0.39	1.00	0.79	0.4538	0.6243	1.93
Age 7+	0.40	0.39	1.00	0.79	0.4538	0.6243	2.36
Age 8+	0.40	0.39	1.00	0.79	0.4538	0.6243	2.86
Age 9+	0.40	0.39	1.00	0.79	0.4538	0.6243	3.42
Age 10+	0.40	0.39	1.00	0.79	0.4538	0.6243	3.66
Harvest yield per recruit value = 0.3023 pounds[h]							

YOY = young of the year

[a] Instantaneous natural mortality is from EPA (2004).

[b] Stage-specific instantaneous fishery mortality (commercial and recreational combined) is from EPA (2004).

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight based on EPA (2004).

[h] Harvest yield per recruit or foregone fishery yield is a measure of the amount of fish not harvested since the fish are lost to entrainment and impingement (EPA 2004). The harvest yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Conservative value for age at sexual maturity for hake is 1 years (Collette and Klein-MacPhee 2002).

Appendix A Table 1i. Life history parameters used for the searobin species

Life Stage	M[a]	F[b]	Fraction vulnerable to fishing[c] (v)	Z_i[d]	S_i[e]	Adjusted[f] S_i ($2Se^{-Ln(1+S)}$)	Weight (lbs)[g]
Egg	2.30	0.00	0.00	2.30	0.1003	0.1822	0.00000132
Larvae	3.66	0.00	0.00	3.66	0.0257	0.0502	0.00000145
YOY	0.916	0.00	0.00	0.92	0.4001	0.5715	0.000341
Age 1+	0.420	0.10	0.50	0.52	0.5945	0.7457	0.0602
Age 2+	0.420	0.10	1.00	0.52	0.5945	0.7457	0.176
Age 3+	0.420	0.10	1.00	0.52	0.5945	0.7457	0.267
Age 4+	0.420	0.10	1.00	0.52	0.5945	0.7457	0.386
Age 5+	0.420	0.10	1.00	0.52	0.5945	0.7457	0.537
Age 6+	0.420	0.10	1.00	0.52	0.5945	0.7457	0.721
Age 7+	0.420	0.10	1.00	0.52	0.5945	0.7457	0.944
Age 8+	0.420	0.10	1.00	0.52	0.5945	0.7457	1.21
Harvest yield per recruit value = 0.0412 pounds[h]							

YOY = young of the year

[a] Instantaneous natural mortality is from EPA (2004).

[b] Stage-specific instantaneous fishery mortality (commercial and recreational combined) is from EPA (2004).

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight based on EPA (2004).

[h] Harvest yield per recruit or foregone fishery yield is a measure of the amount of fish not harvested since the fish are lost to entrainment and impingement (EPA 2004). The harvest yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Conservative value for age at sexual maturity for northern searobin and striped searobin is 2 years (Collette and Klein-MacPhee 2002).

Appendix A Table 1j. Life history parameters used for grubby

Life Stage	M[a]	F[b]	Fraction vulnerable to fishing[c] (v)	Z_i[d]	S_i[e]	Adjusted[f] S_i ($2Se^{-Ln(1+S)}$)	Weight (lbs)[g]
Egg	2.30	0.00	0.00	2.30	0.1003	0.1822	0.00000473
Larvae	3.79	0.00	0.00	3.79	0.0226	0.0442	0.0000052
YOY	0.92	0.00	0.00	0.92	0.4001	0.5715	0.0000197
Age 1+	0.46	0.00	0.00	0.46	0.6313	0.7740	0.0063
Age 2+	0.46	0.00	0.00	0.460	0.6313	0.7740	0.0115
Age 3+	0.46	0.00	0.00	0.460	0.6313	0.7740	0.019
Age 4+	0.46	0.00	0.00	0.460	0.6313	0.7740	0.0292
Age 5+	0.46	0.00	0.00	0.460	0.6313	0.7740	0.0424
Age 6+	0.46	0.00	0.00	0.460	0.6313	0.7740	0.0592
Age 7+	0.460	0.00	0.00	0.460	0.6313	0.7740	0.0799
Age 8+	0.460	0.00	0.00	0.460	0.6313	0.7740	0.105
Age 9+	0.460	0.00	0.00	0.460	0.6313	0.7740	0.135
Forage yield per recruit value = 0.0198 pounds[h]							

YOY = young of the year

[a] Instantaneous natural mortality is from EPA (2004).

[b] Grubby are a forage species, there is no commercial or recreational harvest for this species.

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight based on EPA (2004).

[h] Forage yield per recruit or forage species forgone production is a measure of the amount of fish not available to higher trophic levels since the fish are lost to entrainment and impingement. The forage yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Age at sexual maturity for grubby was assumed to be 1 year.

Appendix A Table 1k. Life history parameters used for tautog

Life Stage	M[a]	F[b]	Fraction vulnerable to fishing[c] (v)	Z_i[d]	S_i[e]	Adjusted[f] S_i ($2Se^{-Ln(1+S)}$)	Weight (lbs)[g]
Egg	1.40	0.00	0.00	1.40	0.2466	0.3956	0.00000123
Larvae	5.86	0.00	0.00	5.86	0.0029	0.0057	0.0221
YOY	8.18	0.00	0.00	8.18	0.0003	0.0006[h]	0.0637
Age 1+	0.175	0.00	0.00	0.175	0.8395	0.9127	0.217
Age 2+	0.175	0.00	0.00	0.175	0.8395	0.9127	0.440
Age 3+	0.175	0.00	0.00	0.175	0.8395	0.9127	0.734
Age 4+	0.175	0.24	1.00	0.415	0.6603	0.7954	1.08
Age 5+	0.175	0.24	1.00	0.415	0.6603	0.7954	1.48
Age 6+	0.175	0.24	1.00	0.415	0.6603	0.7954	1.89
Age 7+	0.175	0.24	1.00	0.415	0.6603	0.7954	2.32
Age 8+	0.175	0.24	1.00	0.415	0.6603	0.7954	2.76
Age 9+	0.175	0.24	1.00	0.415	0.6603	0.7954	3.18
Age 10+	0.175	0.24	1.00	0.415	0.6603	0.7954	3.60
Age 11+	0.175	0.24	1.00	0.415	0.6603	0.7954	4.00
Age 12+	0.175	0.24	1.00	0.415	0.6603	0.7954	4.38
Age 13+	0.175	0.24	1.00	0.415	0.6603	0.7954	4.73
Age 14+	0.175	0.24	1.00	0.415	0.6603	0.7954	5.07
Age 15+	0.175	0.24	1.00	0.415	0.6603	0.7954	5.38
Harvest yield per recruit value = 0.6413 pounds[i]							

YOY = young of the year

[a] Instantaneous natural mortality is from EPA (2004).

[b] Stage-specific instantaneous fishery mortality (commercial and recreational combined) is from EPA (2004).

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight based on EPA (2004).

[h] For impingement calculations the YOY stage mortality was adjusted see text for details.

[i] Harvest yield per recruit or foregone fishery yield is a measure of the amount of fish not harvested since the fish are lost to entrainment and impingement (EPA 2004). The harvest yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Conservative value for age at sexual maturity for tatuog is 6 years (Collette and Klein-MacPhee 2002).

Appendix A Table 1l. Life history parameters used for cunner

Life Stage	M[a]	F[b]	Fraction vulnerable to fishing[c] (v)	Z_i[d]	S_i[e]	Adjusted[f] S_i ($2Se^{-Ln(1+S)}$)	Weight (lbs)[g]
Egg	3.49	0.00	0.00	3.49	0.0305	0.0592	0.000000787
Larvae	2.90	0.00	0.00	2.90	0.0550	0.1043	0.00000236
YOY	2.90	0.00	0.00	2.90	0.0550	0.1043[h]	0.0000814
Age 1+	0.831	0.00	0.00	0.831	0.4356	0.6069	0.00311
Age 2+	0.831	0.10	0.50	0.931	0.3942	0.5654	0.0246
Age 3+	0.286	0.10	1.00	0.386	0.6798	0.8094	0.0749
Age 4+	0.342	0.10	1.00	0.442	0.6427	0.7825	0.145
Age 5+	0.645	0.10	1.00	0.745	0.4747	0.6438	0.229
Age 6+	1.260	0.10	1.00	1.360	0.2567	0.4085	0.624
Harvest yield per recruit value = 0.0055 pounds[i]							

YOY = young of the year

[a] Instantaneous natural mortality is from EPA (2004).

[b] Stage-specific instantaneous fishery mortality (commercial and recreational combined) is from EPA (2004).

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight based on EPA (2004).

[h] For impingement calculations the YOY stage mortality was adjusted by dividing the stage mortality by the number of days for that stage producing a daily mortality rate. The daily mortality rates were multiplied by the number of days until the next stage and this adjusted mortality rate was converted to produce an adjusted survivability rate. The adjusted survival for the cunner YOY stage was based on an assumed May 1 birthday, a daily mortality rate of 0.009508, and a stage duration of 305 days (EPA 2004).

[i] Harvest yield per recruit or foregone fishery yield is a measure of the amount of fish not harvested since the fish are lost to entrainment and impingement (EPA 2004). The harvest yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Conservative value for age at sexual maturity for cunner is 1 years (Nitschke et al. 2001).

Appendix A Table 1m. Life history parameters used for Atlantic silverside

Life Stage	**M**[a]	**F**[b]	**Fraction vulnerable to fishing**[c] **(v)**	$\mathbf{Z_i}$[d]	$\mathbf{S_i}$[e]	**Adjusted**[f] $\mathbf{S_i}$ **(**$\mathbf{2Se^{-Ln(1+S)}}$**)**	**Weight (lbs)**[g]
Egg	1.41	0.00	0.00	1.41	0.2441	0.3925	0.00000473
Larvae	5.81	0.00	0.00	5.81	0.0030	0.0060	0.0000052
YOY	2.63	0.00	0.00	2.63	0.0721	0.1345[h]	0.0049
Age 1+	3.00	0.00	0.00	3.00	0.0498	0.0949	0.0205
Age 2+	6.91	0.00	0.00	6.91	0.0010	0.0020	0.0349
Forage yield per recruit value = 0.2555 pounds[i]							

YOY = young of the year

[a] Instantaneous natural mortality is from EPA (2004).

[b] Atlantic silversides are a forage species, there is no commercial or recreational harvest for this species.

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight based on EPA (2004).

[h] For impingement calculations the YOY stage mortality was adjusted by dividing the stage mortality by the number of days for that stage producing a daily mortality rate. The daily mortality rates were multiplied by the number of days until the next stage and this adjusted mortality rate was converted to produce an adjusted survivability rate. The adjusted survival for the Atlantic silverside YOY stage was based on an assumed June 1 birthday, a daily mortality rate of 0.008207, and a stage duration of 320 days (EPA 2004).

[i] Forage yield per recruit or forage species forgone production is a measure of the amount of fish not available to higher trophic levels since the fish are lost to entrainment and impingement. The forage yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Conservative value for age at sexual maturity for Atlantic silversides is 1 years (Conover and Ross 1982).

Appendix A Table 1n. Life history parameters used for sand lance

Life Stage	M[a]	F[b]	Fraction vulnerable to fishing[c] (v)	Z_i[d]	S_i[e]	Adjusted[f] S_i ($2Se^{-Ln(1+S)}$)	Weight (lbs)[g]
Egg	1.41	0.00	0.00	1.41	0.2441	0.3925	0.00000126
Larvae	2.97	0.00	0.00	2.97	0.0513	0.0976	0.00000139
YOY	2.90	0.00	0.00	2.90	0.0550	0.1043[h]	0.00119
Age 1+	1.89	0.00	0.00	1.89	0.1511	0.2625	0.00384
Age 2+	0.364	0.00	0.00	0.364	0.6949	0.8200	0.0073
Age 3+	0.364	0.00	0.00	0.364	0.6949	0.8200	0.0113
Age 4+	0.364	0.00	0.00	0.364	0.6949	0.8200	0.0153
Age 5+	0.364	0.00	0.00	0.364	0.6949	0.8200	0.0191
Age 6+	0.364	0.00	0.00	0.364	0.6949	0.8200	0.0225
Age 7+	0.720	0.00	0.00	0.720	0.4868	0.6548	0.0255
Age 8+	0.720	0.00	0.00	0.720	0.4868	0.6548	0.0280
Age 9+	0.720	0.00	0.00	0.720	0.4868	0.6548	0.0301
Age 10+	0.720	0.00	0.00	0.720	0.4868	0.6548	0.0319
Forage yield per recruit value = 0.0061 pounds[i]							

YOY = young of the year

[a] Instantaneous natural mortality is from EPA (2004).

[b] Sand lance are a forage species, there is no commercial or recreational harvest for this species.

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight based on EPA (2004).

[h] For impingement calculations the YOY stage mortality was adjusted see text for details.

[i] Forage yield per recruit or forage species forgone production is a measure of the amount of fish not available to higher trophic levels since the fish are lost to entrainment and impingement. The forage yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Conservative value for age at sexual maturity for sand lance is 2 years (Collette and Klein-MacPhee 2002).

Appendix A Table 1o. Life history parameters used for Atlantic mackerel

Life Stage	M^a	F^b	Fraction vulnerable to fishing[c] (v)	Z_i^d	S_i^e	Adjusted[f] S_i ($2Se^{-Ln(1+S)}$)	Weight (lbs)[g]
Egg	2.39	0.00	0.00	2.39	0.0916	0.1679	0.000000176
Larvae	5.30	0.00	0.00	5.30	0.0050	0.0099	0.00000193
YOY	5.30	0.00	0.00	5.30	0.0050	0.0099	0.000833
Age 1+	0.52	0.00	0.00	0.52	0.5945	0.7457	0.309
Age 2+	0.37	0.25	0.50	0.62	0.5379	0.6996	0.51
Age 3+	0.37	0.25	1.00	0.62	0.5379	0.6996	0.639
Age 4+	0.37	0.25	1.00	0.62	0.5379	0.6996	0.752
Age 5+	0.37	0.25	1.00	0.62	0.5379	0.6996	0.825
Age 6+	0.37	0.25	1.00	0.62	0.5379	0.6996	0.918
Age 7+	0.37	0.25	1.00	0.62	0.5379	0.6996	1.02
Age 8+	0.37	0.25	1.00	0.62	0.5379	0.6996	1.10
Age 9+	0.37	0.25	1.00	0.62	0.5379	0.6996	1.13
Harvest yield per recruit value = 0.1376 pounds[h]							

YOY = young of the year

[a] Instantaneous natural mortality is from EPA (2004).

[b] Stage-specific instantaneous fishery mortality (commercial and recreational combined) is from EPA (2004).

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight based on EPA (2004).

[h] Harvest yield per recruit or foregone fishery yield is a measure of the amount of fish not harvested since the fish are lost to entrainment and impingement (EPA 2004). The harvest yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Age at sexual maturity for Atlantic mackerel was assumed to be 3 years.

Appendix A Table 1p. Life history parameters used for windowpane

Life Stage	M[a]	F[b]	Fraction vulnerable to fishing[c] (v)	Z_i[d]	S_i[e]	Adjusted[f] S_i ($2Se^{-Ln(1+S)}$)	Weight (lbs)[g]
Egg	1.41	0.00	0.00	1.41	0.2441	0.3925	0.00000154
Larvae	6.99	0.00	0.00	6.99	0.0009	0.0018	0.00165
YOY	2.98	0.00	0.00	2.98	0.0508	0.0967[h]	0.00223
Age 1+	0.42	0.00	0.00	0.42	0.6570	0.7930	0.0325
Age 2+	0.42	0.00	0.00	0.42	0.6570	0.7930	0.122
Age 3+	0.42	0.00	0.00	0.42	0.6570	0.7930	0.265
Age 4+	0.42	0.00	0.00	0.42	0.6570	0.7930	0.433
Age 5+	0.42	0.00	0.00	0.42	0.6570	0.7930	0.603
Age 6+	0.42	0.10	1.00	0.52	0.5945	0.7457	0.761
Age 7+	0.42	0.10	1.00	0.52	0.5945	0.7457	0.899
Age 8+	0.42	0.10	1.00	0.52	0.5945	0.7457	1.01
Age 9+	0.42	0.10	1.00	0.52	0.5945	0.7457	1.11
Age 10+	0.42	0.10	1.00	0.52	0.5945	0.7457	1.19
Harvest yield per recruit value = 0.0194 pounds[i]							

YOY = young of the year

[a] Instantaneous natural mortality is from EPA (2004).

[b] Stage-specific instantaneous fishery mortality (commercial and recreational combined) is from EPA (2004).

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight based on EPA (2004).

[h] For impingement calculations the YOY stage mortality was adjusted see text for details.

[i] Harvest yield per recruit or foregone fishery yield is a measure of the amount of fish not harvested since the fish are lost to entrainment and impingement (EPA 2004). The harvest yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Conservative value for age at sexual maturity for windowpane is 3 years (Collette and Klein-MacPhee 2002).

Appendix A Table 1q. Life history parameters used for American plaice

Life Stage	M[a]	F[b]	Fraction vulnerable to fishing[c] (v)	Z_i[d]	S_i[e]	Adjusted[f] S_i ($2Se^{-Ln(1+S)}$)	Weight (lbs)[g]
Egg	2.30	0.00	0.00	2.30	0.1003	0.1822	0.0000115
Larvae	8.22	0.00	0.00	8.22	0.0003	0.0005	0.0000126
YOY	0.92	0.00	0.00	0.92	0.4001	0.5715[h]	0.00011
Age 1+	0.20	0.00	0.00	0.20	0.8187	0.9003	0.00903
Age 2+	0.20	0.32	0.50	0.52	0.5945	0.7457	0.0871
Age 3+	0.20	0.32	1.00	0.52	0.5945	0.7457	0.190
Age 4+	0.20	0.32	1.00	0.52	0.5945	0.7457	0.328
Age 5+	0.20	0.32	1.00	0.52	0.5945	0.7457	0.494
Age 6+	0.20	0.32	1.00	0.52	0.5945	0.7457	0.711
Age 7+	0.20	0.32	1.00	0.52	0.5945	0.7457	0.986
Age 8+	0.20	0.32	1.00	0.52	0.5945	0.7457	1.24
Age 9+	0.20	0.32	1.00	0.52	0.5945	0.7457	1.53
Age 10+	0.20	0.32	1.00	0.52	0.5945	0.7457	1.86
Age 11+	0.20	0.32	1.00	0.52	0.5945	0.7457	2.24
Age 12+	0.20	0.32	1.00	0.52	0.5945	0.7457	2.68
Age 13+	0.20	0.32	1.00	0.52	0.5945	0.7457	3.17
Age 14+	0.20	0.32	1.00	0.52	0.5945	0.7457	3.52
Age 15+	0.20	0.32	1.00	0.52	0.5945	0.7457	3.91
Age 16+	0.20	0.32	1.00	0.52	0.5945	0.7457	4.32
Age 17+	0.20	0.32	1.00	0.52	0.5945	0.7457	4.77
Age 18+	0.20	0.32	1.00	0.52	0.5945	0.7457	5.24
Age 19+	0.20	0.32	1.00	0.52	0.5945	0.7457	5.75
Age 20+	0.20	0.32	1.00	0.52	0.5945	0.7457	6.28
Age 21+	0.20	0.32	1.00	0.52	0.5945	0.7457	6.86
Age 22+	0.20	0.32	1.00	0.52	0.5945	0.7457	7.46
Age 23+	0.20	0.32	1.00	0.52	0.5945	0.7457	8.11
Age 24+	0.20	0.32	1.00	0.52	0.5945	0.7457	8.44
Age 25+	0.20	0.32	1.00	0.52	0.5945	0.7457	8.55
Harvest yield per recruit value = 0.1730 pounds[i]							

YOY = young of the year

[a] Instantaneous natural mortality is from EPA (2004).

[b] Stage-specific instantaneous fishery mortality (commercial and recreational combined) is from EPA (2004).

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight based on EPA (2004).

[h] For impingement calculations the YOY stage mortality was adjusted see text for details.

[i] Harvest yield per recruit or foregone fishery yield is a measure of the amount of fish not harvested since the fish are lost to entrainment and impingement (EPA 2004). The harvest yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Conservative value for age at sexual maturity for American plaice is 3 years (Collette and Klein-MacPhee 2002).

Appendix A Table 1r. Life history parameters used for winter flounder

Life Stage	M[a]	F[b]	Fraction vulnerable to fishing[c] (v)	Z_i[d]	S_i[e]	Adjusted[f] S_i ($2Se^{-Ln(1+S)}$)	Weight (lbs)[g]
Egg	0.288	0.00	0.00	0.288	0.7498	0.8570	0.00000115
Larvae 1	2.050	0.00	0.00	2.050	0.1287	0.2281	0.00441
Larvae 2	3.420	0.00	0.00	3.420	0.0327	0.0634	0.0110
Larvae 3	3.520	0.00	0.00	3.520	0.0296	0.0575	0.0176
Larvae 4	0.177	0.00	0.00	0.177	0.8378	0.9117	0.0221
YOY	2.380	0.00	0.00	2.380	0.0926	0.1694[h]	0.033
Age 1+	1.100	0.0066	1.00	1.107	0.3307	0.4970	0.208
Age 2+	0.924	0.082	1.00	1.006	0.3657	0.5355	0.562
Age 3+	0.200	0.20	1.00	0.400	0.6703	0.8026	0.997
Age 4+	0.200	0.33	1.00	0.530	0.5886	0.7410	1.42
Age 5+	0.200	0.33	1.00	0.530	0.5886	0.7410	1.78
Age 6+	0.200	0.33	1.00	0.530	0.5886	0.7410	2.07
Age 7+	0.200	0.33	1.00	0.530	0.5886	0.7410	2.29
Age 8+	0.200	0.33	1.00	0.530	0.5886	0.7410	2.45
Age 9+	0.200	0.33	1.00	0.530	0.5886	0.7410	2.57
Age 10+	0.200	0.33	1.00	0.530	0.5886	0.7410	2.65
Age 11+	0.200	0.33	1.00	0.530	0.5886	0.7410	2.71
Age 12+	0.200	0.33	1.00	0.530	0.5886	0.7410	2.75
Age 13+	0.200	0.33	1.00	0.530	0.5886	0.7410	2.78
Age14+	0.200	0.33	1.00	0.530	0.5886	0.7410	2.80
Age 15+	0.200	0.33	1.00	0.530	0.5886	0.7410	2.82
Age 16+	0.200	0.33	1.00	0.530	0.5886	0.7410	2.83
Harvest yield per recruit value = 0.4179 pounds[i]							

YOY = young of the year

[a] Instantaneous natural mortality is from EPA (2004).

[b] Stage-specific instantaneous fishery mortality (commercial and recreational combined) is from EPA (2004).

[c] Proportion vulnerable to fishing gear is from EPA (2004).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage i to the next stage = e^{-Z}

[f] Since all fish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Stage-specific weight is from EPA (2004).

[h] For impingement calculations the YOY stage mortality was adjusted by dividing the stage mortality by the number of days for that stage producing a daily mortality rate. The daily mortality rates were multiplied by the number of days until the next stage and this adjusted mortality rate was converted to produce an adjusted survivability rate. The adjusted survival for the winter flounder YOY stage was 0.2969 based on an assumed April 1 birthday, a daily mortality rate of 0.008345, and a stage duration of 285 days (EPA 2004).

[i] Harvest yield per recruit or foregone fishery yield is a measure of the amount of fish not harvested since the fish are lost to entrainment and impingement (EPA 2004). The harvest yield per recruit value is based on EPA (2004) and EPRI (2005).

* - shaded box denotes age at sexual maturity. Conservative value for age at sexual maturity for winter flounder is 3 years (Collette and Klein-MacPhee 2002).

Appendix A Table 1s. Life history parameters used for American lobster

Life Stage	M[a]	F[b]	Fraction vulnerable to fishing[c] (v)	Z_i[d]	S_i[e]	Adjusted[f] S_i ($2Se^{-Ln(1+S)}$)	Weight (lbs)[g]
Egg	0.450	0.00	0.00	0.450	0.6376	0.7787	-
Larvae I	0.441	0.00	0.00	0.441	0.6434	0.7830	-
Larvae II	0.588	0.00	0.00	0.588	0.5554	0.7142	-
Larvae III	0.882	0.00	0.00	0.882	0.4140	0.5855	-
Larvae IV	2.205	0.00	0.00	2.205	0.1103	0.1986	-
Settlement to 7 mm CL	1.33	0.00	0.00	1.33	0.2645	0.4183	-
Juvenile (7 - 82 mm CL)	5.60	0.00	0.00	5.60	0.0037	0.0074	-
82 - 87 mm CL	0.10	0.69	1.00	0.79	0.4538	0.6243	1.11
88 - 92 mm CL	0.10	0.69	1.00	0.79	0.4538	0.6243	1.32
93 - 97 mm CL	0.10	0.69	1.00	0.79	0.4538	0.6243	1.55
98 - 102 mm CL	0.10	0.69	1.00	0.79	0.4538	0.6243	1.80
103 - 107 mm CL	0.10	0.69	1.00	0.79	0.4538	0.6243	2.09
108 - 112 mm CL	0.10	0.69	1.00	0.79	0.4538	0.6243	2.39
113 - 117 mm CL	0.10	0.69	1.00	0.79	0.4538	0.6243	2.73
118 - 122 mm CL	0.10	0.69	1.00	0.79	0.4538	0.6243	3.10
123 - 127 mm CL	0.10	0.69	1.00	0.79	0.4538	0.6243	3.53
Harvest yield per recruit value = 1.1346 pounds[h]							

[a] Instantaneous natural mortality is from French McCay et al. (2003). The daily larval morality rate was 0.147 (French McCay et al. 2003). Larval stage durations were based on MacKenzie and Moring (1985) and a 28 day larval period (French McCay et al. 2003).

[b] Stage-specific instantaneous fishery mortality (commercial and recreational combined) is from Dean et al. (2004, 2005) and Dean et al. (2006).

[c] Proportion vulnerable to fishing is based on the current Massachusetts legal size of 82 mm CL (Dean et al. 2004, 2005 and Dean et al. 2006).

[d] Total instantaneous mortality Z = M + F

[e] S_i = Probability of survival of stage *i* to the next stage = e^{-Z}

[f] All shellfish life stages are not entrained or impinged at the same point in a given life stage, it is assumed that the further along in development the greater their probability in reaching the next stage. To account for this, survival rates were adjusted based on EPRI (2004).

[g] Weights for egg through the juvenile life stages are currently unavailable. Stage-specific weights for lobsters 82 mm CL and larger were calculated by weight (g) = aCL_t^b where a = 0.001143 and b = 2.9337 (French McCay et al. 2003).

[h] Harvest yield per recruit or foregone fishery yield is a measure of the amount of shellfish that is not harvested since the shellfish are lost to entrainment and impingement. The harvest yield per recruit value is based on EPA (2004), EPRI (2005), and French McCay et al. (2003).

* - shaded boxes denotes size that American lobster enter the fishery. Size at maturity varies with summer water temperatures, high water temperatures enhance maturity at small sizes (ASMFC 2006c).

Exhibit 11

January 26, 2009

Mirant Canal Generating Station
Alternative Technology Considerations
Fine-mesh Screen Proposal

On December 10, 2008, the United States Environmental Protection Agency (EPA) Region 1, withdrew certain provisions of Mirant Canal's final National Pollutant Discharge Elimination System (NPDES) Permit (MA0004928) and re-issued these provisions as draft conditions for public review and comment. The re-issued draft provisions require, in part, that:

> *"…The design, location, construction and capacity of the Permittee's CWIS shall reflect the best technology available (BTA) for minimizing the adverse environmental impacts of entrainment due to the CWIS. In order to satisfy this BTA standard, the Permittee shall reduce current levels of entrainment of marine organisms through the facility's CWISs to an extent comparable to what would be achieved by the use of closed-cycle cooling for all electrical generating units, with the closed-cycle cooling system optimized to maximize cooling water intake flow reductions to the extent practicable in light of site-specific constraints..."*

Closed-cycle cooling has a number of unresolved issues relative to aesthetics, navigation and other impacts that make its availability for retrofit at Canal questionable. Additional, due to a significant change in facility operations the economic feasibility of a retrofit is uncertain. Mirant addresses these issues in a separate document. Cylindrical wedgewire screens, if installed at Canal, would have reductions in entrainment equivalent to or greater than closed-cycle cooling; however, there are still unanswered questions relative to navigation, cleaning, and durability that make it uncertain if wedgewire screens are feasible. Therefore, Mirant may wish to consider fine-mesh (0.5 to 2.0 mm) traveling water screens with fish protection features to reduce entrainment and impingement mortality at Canal. Fine-mesh traveling water screens have the following advantages compared to wedgewire screens and closed-cycle cooling:

- Would not impact navigation
- Demonstrated maintenance and operational experience from other sites
- Would not require extensive civil/structural modifications
- Would not alter site aesthetics
- Would not change plant foot print
- Would not have associated energy penalties

The fine-mesh screens would be installed in the existing screenbays of Unit 1 and Unit 2. A new fish/debris return trough would be installed to safely return impinged organisms back to the

Canal. Alden has assumed that this fish/debris return trough would be capable of discharging both east and west of the existing screen houses depending on which direction the Canal is flowing. The existing fish/debris return system could be modified to reduce re-impingement. However, this would need to be investigated further.

The following sections provide descriptions of the technology, site-specific biology, projected biological efficacy, a proposed conceptual design and operation of the screens, cost estimates, and recommended pilot studies at Canal.

Description of Technology

Modified traveling water screens with fish protection features are very similar to conventional traveling water screens, such as those currently installed at Canal, but have been altered to incorporate modifications that improve survival of fish collected. Such state-of-the-art modifications minimize fish mortality associated with screen collection and spraywash removal. Screens modified in this manner are commonly called "Ristroph screens." These screens are compatible with standard coarse meshes (9.5 mm) or can be designed with finer mesh to collect smaller organisms and life stages. Each screen basket is equipped with a water-filled lifting bucket that safely contains collected organisms as they are carried upward with the rotation of the screen. The screens typically operate continuously to minimize screen interaction time. As each bucket passes over the top of the screen, fish are rinsed into a collection trough by a low-pressure spraywash system. Once collected, the fish are transported back to a safe release location. Such features are also available for through-flow, dual-flow, and center-flow screens. New traveling water screens such as rotary-disc screens can be equipped with similar fish protection features. The recently introduced W Intake Protection (WIP) screen uses fish pumps instead of a spraywashes to reduce the stresses of air-exposure and spraywash associated with more conventional traveling water screens. Based on the potential environmental benefits of this screen it has also been included in this evaluation.

Ristroph screens have been shown to improve fish survival and have been installed and evaluated at a number of power plants. Improvements have recently been made to the design that has resulted in increased fish survival. The most important advancement was developed through extensive laboratory and field experimentation. A series of studies conducted by Fletcher (1990) indicated that substantial injury associated with these traveling screens was due to repeated buffeting of fish inside the lifting buckets as a result of undesirable hydraulic conditions. To eliminate these conditions, a number of alternative bucket configurations were developed to create a sheltered, hydraulically calm area in which fish could safely reside during screen rotation. After several attempts, a bucket configuration was developed that achieved the desired conditions (Envirex 1996). In 1995, Public Service Electric and Gas (PSE&G) performed a biological evaluation of the improved screening system installed at the Salem Generating Station in the Delaware River (PSE&G 1999; Ronafalvy 1999). The reported survival rates for this installation are among the highest for any traveling screen system (PSE&G 1999). These types of modified screens, with fine-mesh screening (0.5 mm), are being evaluated in the laboratory by the Electric Power Research Institute for protection of early lifestages of fish (EPRI 2008).

Site-specific Biology

A report by Normandeau Associates provides data from sampling conducted at Mirant Canal Station by Marine Research from February 1999 to June 2001. Biological efficacy estimates were developed for the numerically dominant and/or commercially or recreationally important species (Table 1).

Table 1 Common name, family, and scientific names of the numerically dominant or commercially or recreationally important species impinged or entrained at Canal

Common Name	Family	Scientific Name
American sand lance	Ammodytidae	*Ammodytes americanus*
Silverside	Atherinopsidae	*Menidia sp.*
river herring	Clupeidae	*Alosa sp.*
Atlantic menhaden		*Brevoortia tyrannus*
Atlantic herring		*Clupea harengus*
Grubby	Cottidae	*Myoxocephalus aenaeus*
Atlantic cod	Gadidae	*Gadus morhua*
Haddock		*Melanogrammus aeglefinus*
cunner	Labridae	*Tautogolabrus adspersus*
Tautog		*Tautoga onitis*
hakes (red, white, and spotted)	Merlucciidae	
silver hake		*Merluccius bilinearis*
fourbeard rockling	Phycidae	*Enchelyopus cimbrius*
winter flounder	Pleuronectidae	*Pseudopleuronectes americanus*
American plaice		*Hippoglossoides platessoides*
Atlantic mackerel	Scombridae	*Scomber scombrus*
Windowpane	Scophthalmidae	*Scophthalmus aquosus*
Searobin	Triglidae	*Prionotus sp.*
American lobster	Nephropidae	*Homarus americanus*

Biological Efficacy of Modified Traveling Screens

Biological performance of fine-mesh screens is species-, lifestage-, and site-specific. Therefore the estimates of performance provided herein are based on best professional judgment and may not match what could ultimately be achieved at Canal. Pilot-scale studies and screen optimization would be needed to better estimate the performance that could be achieved with the species/lifestages impinged and entrained at Canal.

Fine-mesh screens at Canal would decrease the entrainment of larval fish through the circulating water system (CWS). The effectiveness of a fine-mesh screening system is measured in two ways: retention and survival. Fine-mesh screens will exclude most organisms from being entrained by collecting them from the cooling water and returning them to the source waterbody. However, the number of organisms a fine-mesh screen will prevent from entraining is dependent upon the size of the organisms and the opening size of the mesh. The second measurement of effectiveness is the survival of the eggs, larvae, and early juveniles that are currently entrained into the CWS, but would be now collected on fine-mesh screens. The survival of collected organisms is dependent upon their biology (lifestage, relative hardiness, etc.) and the screen operating characteristics (approach velocity, rotation speed, cleaning mechanism, etc.). The performance of fine-mesh screens, therefore, is species-, lifestage-, and site-specific.

Because of the site-specificity in screening performance, it can be difficult to extrapolate the results from one field installation to another. Retention is best estimated using data collected in the field under similar operating conditions as would be expected at Canal. However, there are very limited data from fine-mesh screen studies in northeast coastal waters with similar species compositions.

In the absence of empirical data, retention of fine-mesh can be estimated using the head capsule depths (HCD), the widest non-compressible portion of the larval body) of the entrained larvae. When head capsules are larger than the nominal opening size of the screening material, a larva will not be entrained. With larvae, the orientation of the organism at the time of contact with the screen will influence the likelihood of being entrained. As mesh sizes increase, the accuracy of the HCD method decreases. That is, as mesh size increases, other factors not included in the HCD model (such as fish behavior, hydraulics, and swimming ability), play a greater role in exclusion and the HCD method tends to under estimate performance.

In addition, since retention increases with fish length (albeit with the above caveats), it is important to know the sizes of organisms currently entrained at Canal. At present, length frequency data of entrained organisms are not available for Canal. Instead, entrainment was classified by lifestage (eggs, yolk-sac larvae, and post yolk-sac larvae). Estimates of larval lengths by lifestage and egg diameters were obtained from available taxonomic keys (e.g., Wang and Kernehan 1979, Martin and Drewry 1978, Fritzcsche 1978, Hardy 1978, Jones 1978), journal articles (e.g., Ditty et al. 2005, Lund and Marcy 1975), books (e.g., Bigelow and Schroeder 1953), and on-line resources (e.g., www.fishbase.org). It was further assumed that the larval lengths of entrained organisms within each lifestage were equally distributed. These assumptions impart considerable uncertainty in the estimates of retention. For illustrative purposes, exclusion estimates for a 0.5 mm mesh options are presented herein (Table 2).

Estimates of retention were calculated from scale drawings or actual morphometric measurements of selected species. For each species a regression equation was developed to calculate head capsule depths for larvae at any given length. Predicted retention assumed a normal distribution with standard deviation calculated from the specimens or scale drawings. Actual retention may be higher depending upon the orientation of the organism at the time of impingement. A similar method was used for eggs. To determine the exclusion of eggs, it was assumed that eggs could be compressed to 90% of their average diameter; otherwise the method for estimating egg exclusion was the same as that used for larvae. Estimates of exclusion are presented in Figure 1.

Survival estimates were derived from available data from other sites with modified traveling screens or other evaluations (e.g., laboratory and pilot-scale studies). Alden maintains a database of post-collection survival from power plants throughout North America. Data were gleaned from published papers in peer-reviewed journals and corporate-sponsored efficacy reports (gray literature). Data to estimate larval survival were limited to lifestages identified in the literature as “larvae.” The data were too sparse to distinguish between yolk-sac and post yolk-sac larvae. Only one post-collection survival study has been conducted with eggs, which found that survival clustered in two distinct groups (Brueggemeyer et al. 1988). The more fragile species, such as bay anchovy and scaled sardine had egg survival near 26%. The members of the family Sciaenidae had survival around 74%. For estimates at Canal, the species considered “fragile” were assigned survival estimates of 26% and the remaining species were assigned survival estimates of 74%.

Included in the database are over 1,300 survival estimates representing over 160 species of fish. In some cases, limited data were available for a given species. In such cases, the data were expanded to include other members of the same genus or family. The underlying assumption is that fish in the same genus have similar morphology and hardiness. In some cases, no data were available in the same family and a surrogate taxa was selected based on perceived heartiness.

For estimates of juvenile fish survival, the data were expanded to include other modified traveling water screens with larger mesh sizes. The assumption being that survival of a 40 mm juvenile will not differ when collected on a 9.5 mm screen compared to a 0.5 mm screen. The data were limited to studies that: 1) were conducted at facilities with modified Ristroph or other screen designs with fish-friendly modifications and 2) were conducted at facilities with the more sophisticated bucket designs developed in the 1980s. The estimated survival of each fish species is provided in Table 3. Estimates were generated using a weighted mean. Confidence intervals (95% CI) were estimated using a normal approximation of the binomial distribution.

Biological performance of fine-mesh screens is species-, lifestage-, and site-specific. Pilot-scale studies and screen optimization would be needed to better estimate the performance that could be achieved with the species/lifestages impinged and entrained at Canal.

Table 2 BPJ estimates of retention, survival, and the total efficiency of fine-mesh modified traveling screens for protecting the early lifestages at Canal

		0.5 mm Fine-mesh Traveling Screens			
Species	Lifestage	Retention (%)	Survival (%)	Total Efficacy (%)	Surrogate Species
River Herring	egg	100.0	26.0	26.0	
	LRV	75.5	1.5	1.1	Clupeidae (not lab)
Atlantic Menhaden	egg	100.0	26.0	26.0	
	LRV	100.0	1.5	1.5	Clupeidae (not lab)
Atlantic Herring	egg	100.0	26.0	26.0	
	LRV	86.6	1.5	1.3	Clupeidae (not lab)
Fourbeard Rockling	egg	100.0	74.0	74.0	
	LRV	97.7	14.0	13.7	Cynoscion sp.
Atlantic Cod	egg	100.0	74.0	74.0	
	LRV	99.0	14.0	13.9	Cynoscion sp.
Haddock	egg	100.0	74.0	74.0	
	LRV	93.5	14.0	13.1	Cynoscion sp.
Silver Hake	egg	99.0	74.0	73.3	
	LRV	80.9	14.0	11.3	Cynoscion sp.
Hake	egg	99.0	74.0	73.3	
	LRV	80.9	14.0	11.3	Cynoscion sp.
Silverside	egg	100.0	26.0	26.0	
	LRV	85.9	43.2	37.1	Cyprinidae sp.
Searobin	egg	100.0	74.0	74.0	
	LRV	98.9	14.0	13.8	Cynoscion sp.
Grubby	egg	100.0	74.0	74.0	
	LRV	100.0	14.0	14.0	Cynoscion sp.
Tautog	egg	100.0	74.0	74.0	
	LRV	79.7	14.0	11.2	Cynoscion sp.
Cunner	egg	100.0	74.0	74.0	
	LRV	77.3	14.0	10.8	Cynoscion sp.
American Sand Lance	egg	100.0	74.0	74.0	
	LRV	87.6	14.0	10.8	Cynoscion sp.
Atlantic Mackerel	egg	100.0	26.0	26.0	
	LRV	100.0	1.5	1.5	Clupeidae (not lab)
Windowpane	egg	100.0	74.0	74.0	
	LRV	98.6	9.1	9.0	winter flounder (not lab)
American Plaice	egg	100.0	74.0	74.0	
	LRV	90.7	9.1	8.3	winter flounder (not lab)
Winter Flounder	egg	100.0	74.0	74.0	
	LRV	86.4	9.1	7.9	winter flounder (not lab)
Lobster	LRV	100.0	9.1	9.1	winter flounder (not lab)

Table 3 Estimated post-impingement survival (weighted mean) of juvenile and adult fish, number of organisms (N) used to estimate post-impingement survival, the range in reported survival, and the 95% confidence interval surrounding the weighted mean.

Common Name	Surrogate	*N*	Range	Weighted Mean	Normal Approximation (±95% CI)	
					Lower	Upper
Silverside	Atlantic silverside	963	97.7 - 99.1	97.9	97.0	98.9
Atlantic herring	Atlantic menhaden	123	0.0 - 75.5	50.4	41.1	59.6
Atlantic mackerel	Atlantic menhaden	123	0.0 - 75.5	50.4	41.1	59.6
Grubby	Cottidae	190	82.1 - 86.9	86.2	81.2	91.5
Fourbeard rockling	*Cynoscion* sp.	12,582	18.0 - 96.8	47.8	46.9	48.7
Searobin	*Cynoscion* sp.	12,582	18.0 - 96.8	47.8	46.9	48.7
Atlantic Cod	Gadidae	141	20.3 - 100.0	40.4	32.0	48.9
Haddock	Gadidae	141	20.3 - 100.0	40.4	32.0	48.9
American Sand Lance	Labridae	353	96.3 - 100.0	96.6	94.6	98.6
Cunner	Labridae	353	96.3 - 100.0	96.6	94.6	98.6
Tautog	Labridae	353	96.3 - 100.0	96.6	94.6	98.6
Hake	Merlucciidae	37	81.8 - 100.0	89.2	77.8	100.5
Silver Hake	Merlucciidae	37	81.8 - 100.0	89.2	77.8	100.5
Atlantic menhaden	Not used	123	0.0 - 75.5	50.4	41.1	59.6
river herring	blueback herring	39,651	0.2 - 95.7	6.5	6.2	6.7
American Plaice	winter flounder	383	0.0-97.2	96.7	95.0	98.7
Windowpane	winter flounder	383	0.0-97.2	96.7	95.0	98.7
Winter Flounder	not used	383	0.0-97.2	96.7	95.0	98.7
American Lobster	blue crab	337	91.6 - 97.7	95.9	93.5	98.1

American Sand Lance		Length (mm)																								
	Eggs			3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Predicted Exclusion	100			0	8	39	75	93	99	100																
Lifestage				YSL					PYSL																	

Cunner		Length (mm)																								
	Eggs		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Predicted Exclusion	100		0	20	98	100																				
Lifestage			YSL			PYSL					Juvenile															

Atlantic Mackerel		Length (mm)																								
	Eggs			3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Predicted Exclusion	100			100																						
Lifestage				YSL				PYSL																		

Hakes		Length (mm)																								
	Eggs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Predicted Exclusion	99	0	3	87	100																					
Lifestage		YSL			PYSL								Juvenile													

Winter Flounder		Length (mm)																								
	Eggs		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Predicted Exclusion	100		7	84	100																					
Lifestage			YSL					PYSL			Juvenile															

Fourbeard Rockling		Length (mm)																								
	Eggs		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Predicted Exclusion	100		68	99	100																					
Lifestage			YSL		PYSL																	Juvenile				

Grubby		Length (mm)																								
	Eggs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Predicted Exclusion	100				100																					
Lifestage					YSL			PYSL			Juvenile															

Figure 1 Predicted percent exclusion that could be achieved with 0.5 mm modified traveling screens with the commonly involved species at Canal based on head capsule depth.

Figure 1 Continued

Tautog		Length (mm)																								
	Eggs		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Predicted Exclusion	100		0	22	95	100																				
Lifestage			YSL		PYSL						Juvenile															

Windopane		Length (mm)																								
	Eggs		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Predicted Exclusion	100		83	100																						
Lifestage			YSL					PYSL							Juvenile											

River Herring		Length (mm)																								
	Eggs		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Predicted Exclusion	100		0				56	65	72	92	100															
Lifestage			YSL						PYSL															Juvenile		

Atlantic Menhaden		Length (mm)																								
	Eggs		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Predicted Exclusion	100		100																							
Lifestage			YSL				PYSL																			

Atlantic Silverside		Length (mm)																								
	Eggs			3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Predicted Exclusion	100			0	25	91	100																			
Lifestage				YSL		PYSL											Juvenile									

Atlantic Cod																										
	Eggs			3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Predicted Exclusion	100			79	99	100																				
Lifestage				YSL			PYSL																			Juv

Haddock		Length (mm)																								
	Eggs		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Predicted Exclusion	100		3	87	100																					
Lifestage			YSL			PYSL														Juvenile						

Figure 1 Continued

American Plaice		Length (mm)																								
	Eggs		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Predicted Exclusion	100		0	3	75	99	100																			
Lifestage			YSL						PYSL																	

Searobin		Length (mm)																								
	Eggs			3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Predicted Exclusion	100			74	100																					
Lifestage				YSL	PYSL																					

Atlantic herring		Length (mm)																								
	Eggs					5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Predicted Exclusion	100					1	12	42	74	92	98	100														
Lifestage						YSL				PYSL																

Conceptual Design

Fine-mesh (0.5 to 2.0 mm mesh) traveling screens with fish protection features could be installed in the existing CWISs. Most modified traveling water screens with fish protection features are very similar to conventional traveling water screens with the exception that they have fish buckets, both high- and low-pressure spraywashes, and are rotated continuously. Currently, there are several variations of traveling screens available. Each of these technologies has comparable impingement survival while offering unique operational considerations. Modified Ristroph screens have been successfully used at a number of facilities for many years (Figure 2). Dual-flow and center-flow screens are also a proven technology and offer the additional benefit of eliminating debris carry-over (Figure 3). Rotary-disc screens are another screening technology that also provides the benefit of eliminating debris carryover. These screens would be similar to those currently installed at the Mirant Mid-Atlantic's Potomac Generating Station (Figure 4). Polymer belt screens are through-flow screens that use lightweight polymer material for the sprockets and screening material which results in a lighter weight screen compared to standard traveling water screens (Figure 5). The lighter weight screen reduces the power required to rotate the screens. In addition, these screens are less costly to repair and replace when compared to other screen types. This type of screen designed for impingement mortality reduction has been tested at Keyspan's Barrett facility on Long Island, NY and the results indicate high survival of impingeable organisms. To date, these screens have not been evaluated for entrainment reduction.

A newly developed screen, the WIP screen, uses a fish-pump to clean the screens eliminating potential stresses related to air exposure and spraywashes. This screen uses a series of stacked discs each rotating around a fixed center point as shown in Figure 6. Each disc is divided into twelve screen wedges. As the disc rotates each wedge passes under a suction head which removes fish and debris from the surface of the screen. The fish-friendly pump used to create the suction is a "mature technology" and is expected to have little effect on the survival of collected organisms. This screen has only had one test installation but is based on the Beaudrey W-filter, which has been used successfully for many years. The one test installation was at power plant in Nebraska where the screen was tested with impingeable-sized organism, where observed survival was high. However, without full-scale operating data and further biological studies with additional species, this technology is not considered ready for full-scale operation at a marine facility. For these reasons, a pilot study of the WIP screen would be needed before a full-scale installation were considered for use at Canal.

The velocity approaching the existing traveling water screens is approximately 0.7 ft/sec at the Unit 1 screens and 0.8 ft/sec at the Unit 2 screens. Post-collection survival should be high with most of the commonly impinged species (juvenile and adult) at Canal based on the consistently high survival observed in recent laboratory evaluations (EPRI 2006, Black 2007) and field evaluations (e.g., Beak 2000a, 2000b) using the latest screen designs. In addition, the laboratory findings indicate that approach velocity was not a significant predictor of mortality over the range tested (1 to 3 ft/sec). Therefore, no velocity reduction would be necessary to protect juvenile and adult fish at Canal and the new screens could be installed in the existing screen bays.

The new screens would have a mesh size in the range of 0.5 mm to 2.0 mm. The final mesh size selected would be determined after a series of pilot and/or laboratory studies. Although these meshes would be more prone to debris loading than a coarse-mesh screen, because they retain finer debris, the smoothness of the mesh material tends to increase the cleaning efficiency of the spraywash system by reducing the potential for stapling of filamentous debris. Continuous rotation of the screens would limit the period of debris accumulation; mitigating any increase in headloss as a result of debris retention and improve post-collection survival. During a pilot study of a 0.5 mm fine-mesh screen at Tampa Electric's Big Bend Station, the prototype fine-mesh screen operated successfully during periods of heavy jellyfish and detritus concentrations (Mussalli 1978). This study also found that horseshoe crabs, which would entangle on 3/8 in. mesh, did not get stuck on the fine-mesh. Since completion of the pilot study, fine-mesh screens have been installed and operated successfully at Big Bend.

The new fish protection screens would be fitted with 10.0 ft wide baskets for fish collection. Each screen basket would have a fish bucket that would hold collected organisms in about 2 inches of water while they were lifted to the fish return system. A low-pressure spray would be used to gently remove the fish from the fish holding buckets into a fish and debris trough. A conventional high-pressure wash would be used to remove the debris. The fish and debris trough would be located on the descending side of the screens.

The return troughs from each CWIS would flow into a single combined return pipe. To reduce the potential for re-impingement, the return pipe would discharge to either the east or west depending on the direction of the tide. The discharge locations for these pipes would be approximately 100 ft to either the east or west of the CWISs, depending on the tide. A plan showing the new fish return trough is provided on Figure 7. Mirant may be able to modify the existing fish/debris discharge location to reduce the costs and permitting associated with new return locations. Using the existing return location would require a hydraulic model (physical or numeric) of the fish/debris return and intakes to ensure that fish and debris are not re-impinged on the screens.

Removal of the existing traveling water screens, installation of the new screens, and completion of mechanical and electrical work would require about 2 weeks per screen and would require a truck-mounted crane. Alden has assumed that all the screens would be installed at the same time requiring each Unit to be shutdown for 2 weeks including de-watering. The new fish/debris return line would be constructed prior to the installation of the new screens. Leaving the CWIS would be an 18 inch diameter fish/debris pipe. The (2) two 18 inch diameter fish/debris pipes would combine into (1) one 30 inch diameter pipe, designed to handle the return flow of both CWISs. The new fish/debris pipes would be predominately located below grade once the pipes have exited the CWIS structures, requiring crossing penetrations through the existing sheet pile intake flumes. Alternatively, pipes could be routed over the flumes, but this would limit access to existing lay down areas near the existing screen houses. Installation of new fish/debris pipes would limit or prohibit access to Freezer Road for approximately 2 weeks. As the return locations are outside of the existing right of ways, Mirant would need to seek an easement to access the Canal. Construction of this alternative should not impact navigation in the canal.

Maintenance of the new, modified traveling screens would be similar to that for the existing screens. To reduce impingement duration and improve survival, the screens would be rotated and cleaned continuously. Total power requirements to clean and operate the screens year-round would be about 460 MWh per year. Approximately 1,175 man-hours per year would be needed to maintain the screens. Screen wear could be reduced by reducing the screen rotation speed during periods when impingement and entrainment are low. To develop costs, Alden estimated that the screens would be overhauled every 5 years.

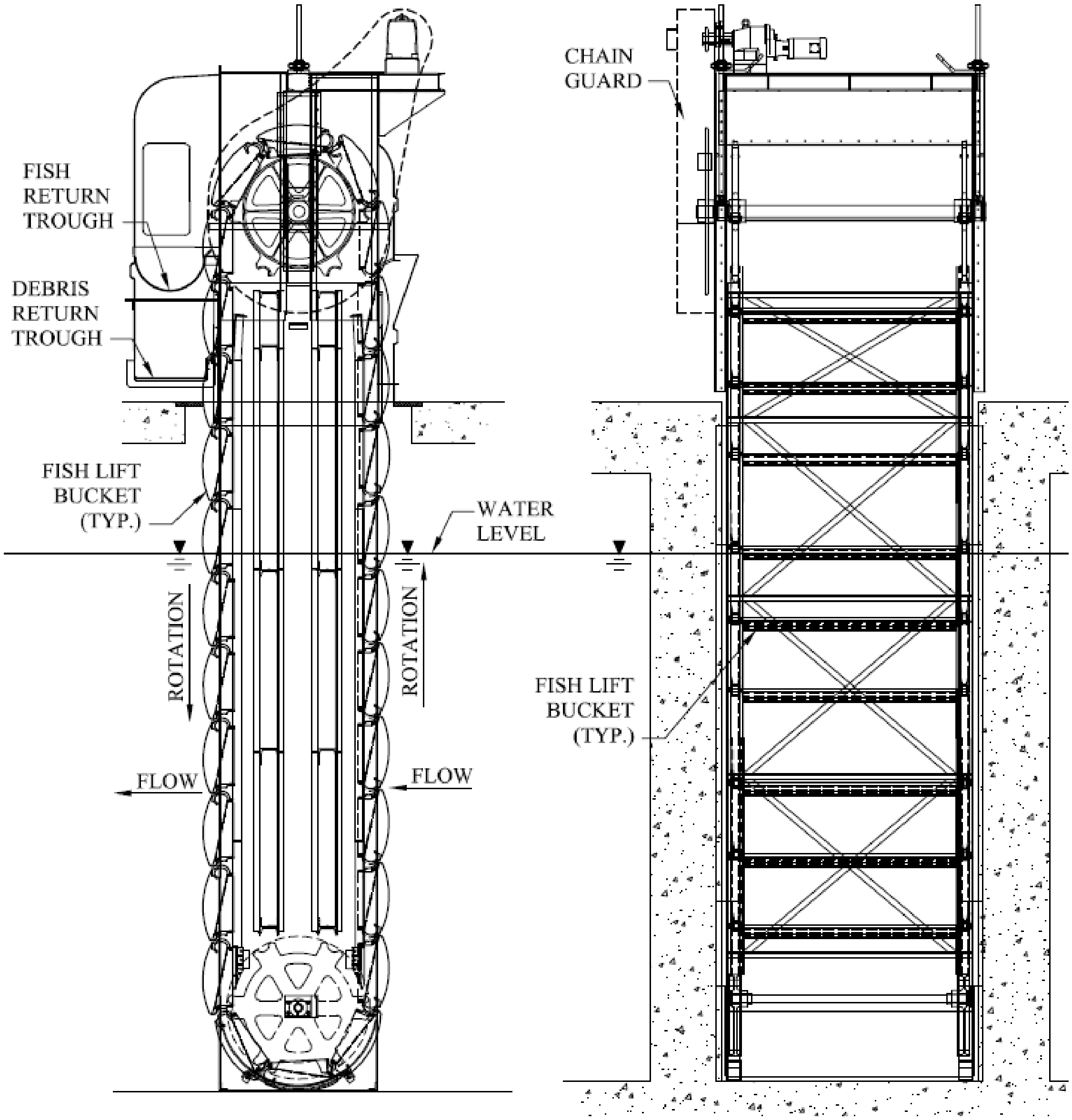


Figure 2 Typical Modified Ristroph Screen – Section and Elevation

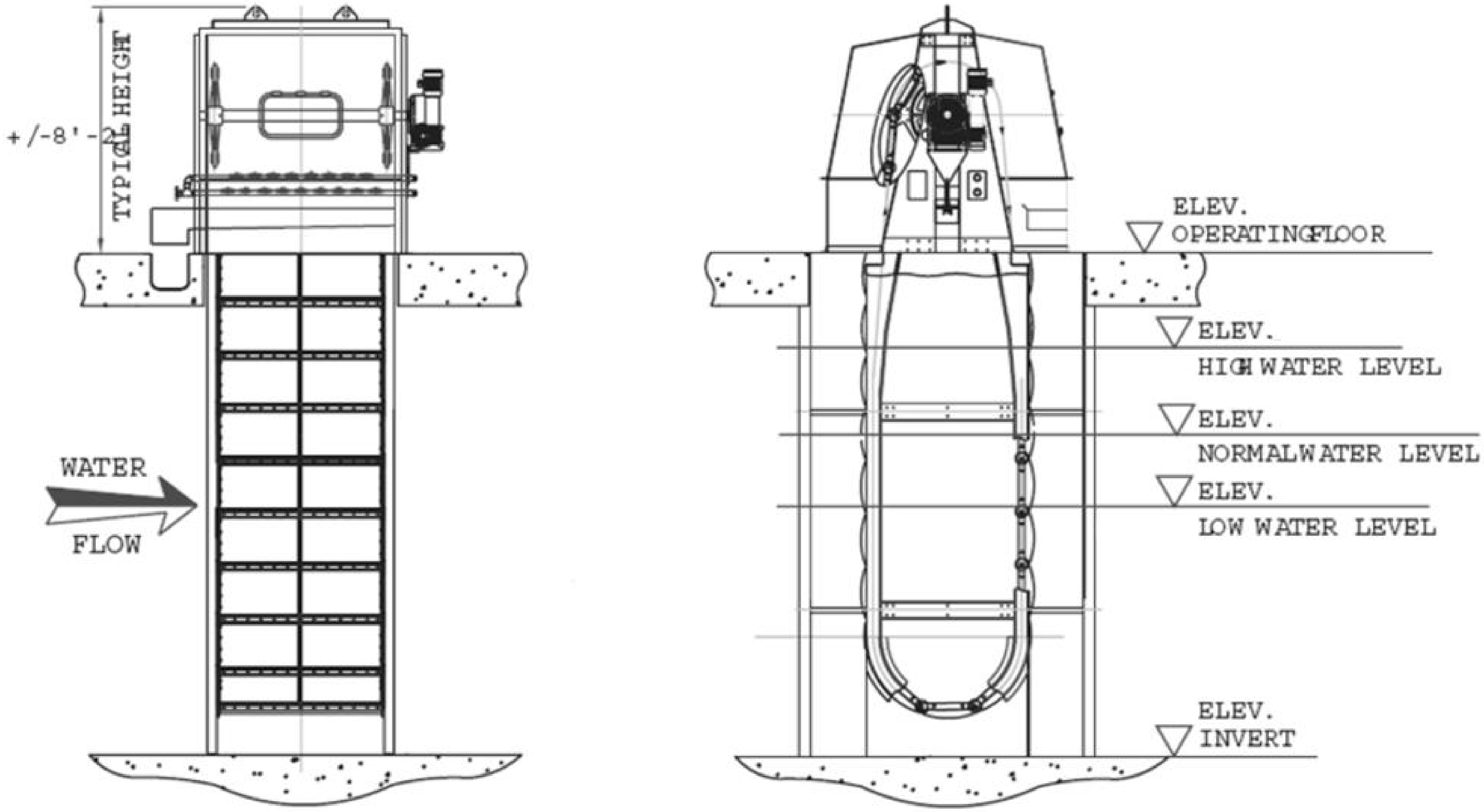


Figure 3 Typical Dual-flow Screen – Section and Elevation (Bracket Green 2007)

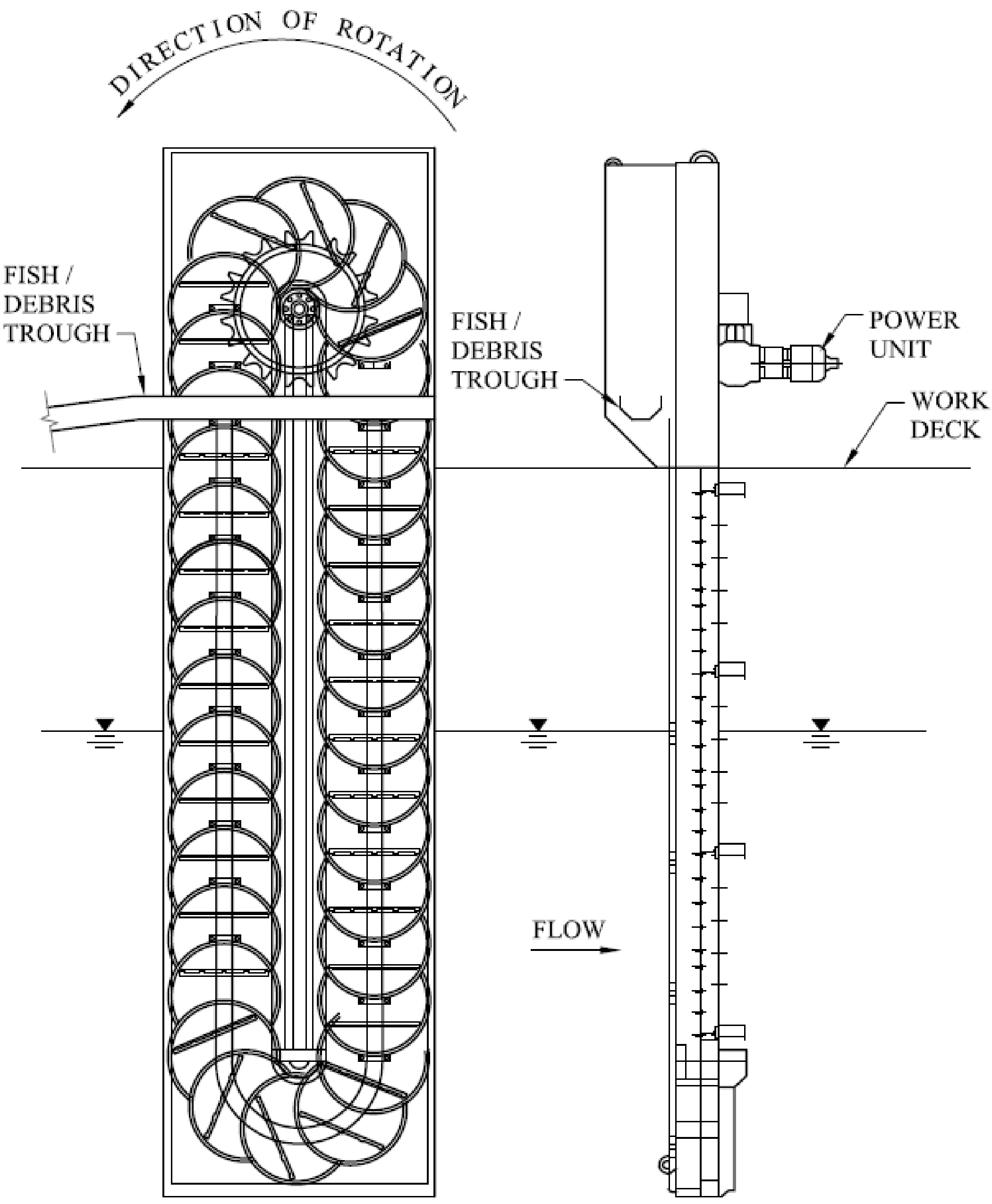


Figure 4 Typical Rotary-disc Screen – Section and Elevation (adapted from Geiger 2005)

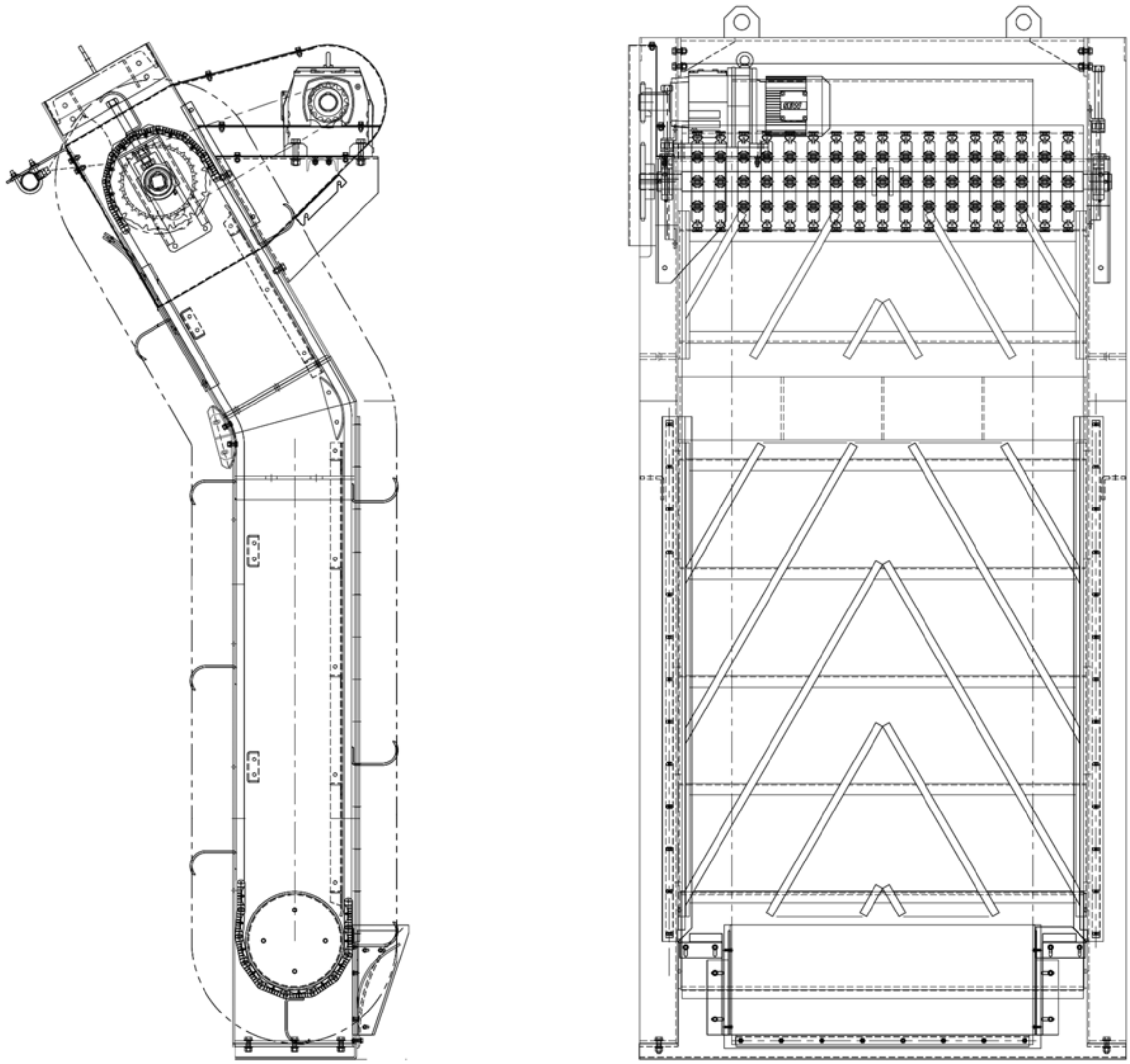


Figure 5 Typical Polymer Belt Screens (adapted from Intralox 2004)

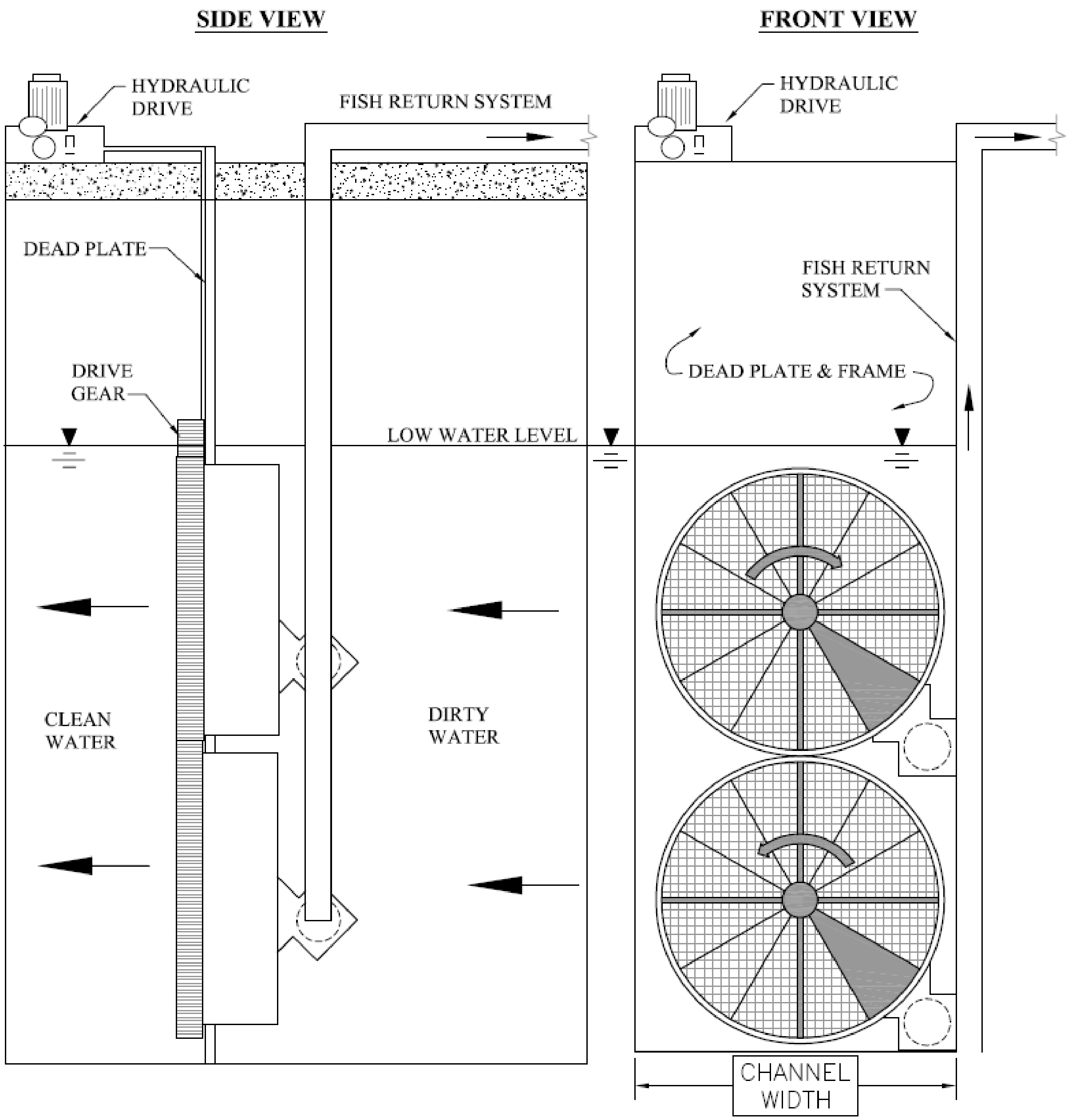


Figure 6 Typical WIP Screen (adapted from Beaudrey 2004)

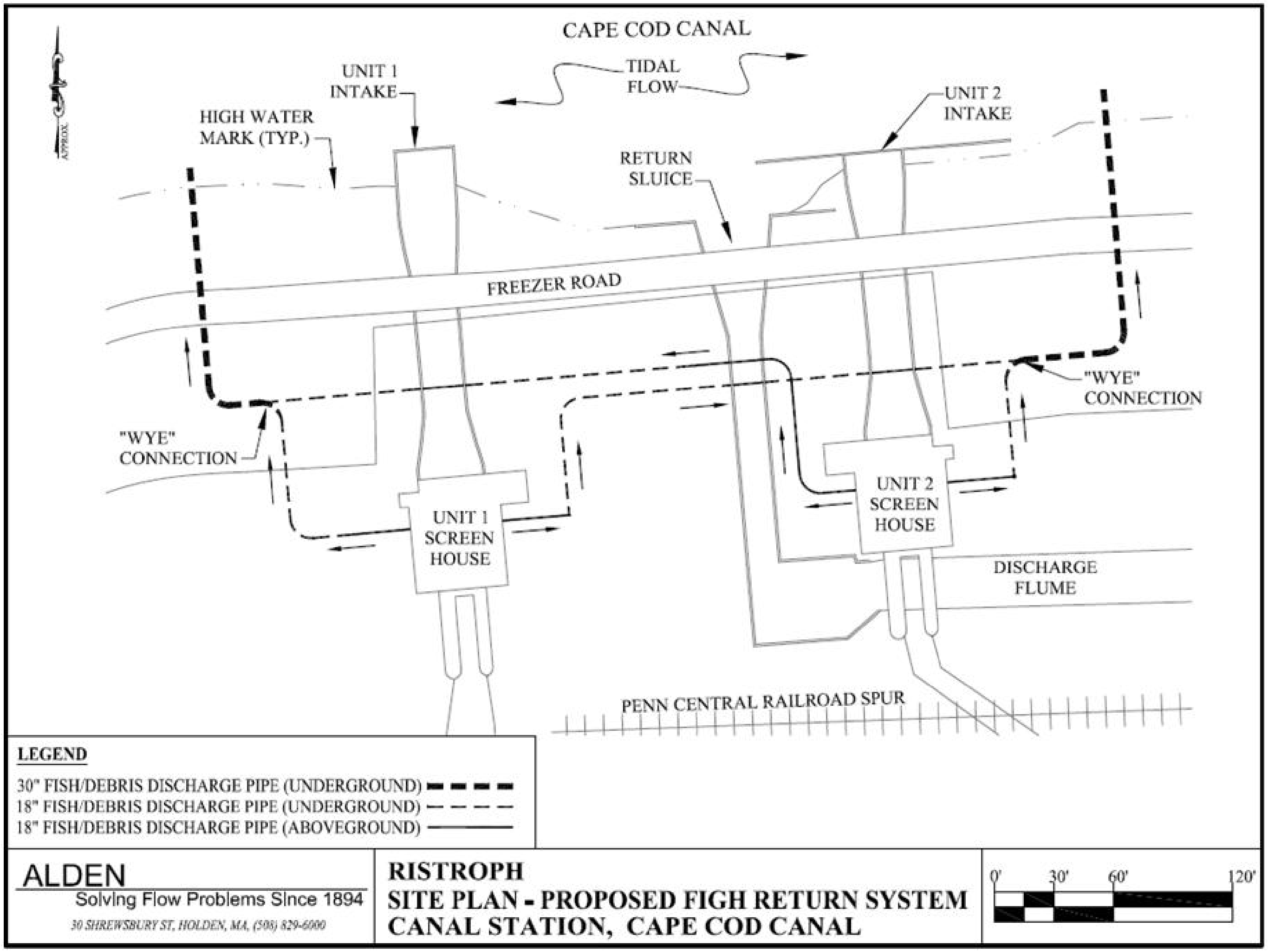


Figure 7 Fine-mesh Traveling Water Screens with Fish Protection Features in the Existing Screenbays

Pilot Studies

Pilot tests of a fine-mesh traveling water screen system would be warranted at Canal for several reasons. The performance of fine-mesh traveling water screens is highly species, lifestage, and site-specific. There have been few installations of fine-mesh screens in the North Atlantic. As such there are very limited post-collection survival data available for most of the early lifestages currently entrained at Canal. In addition, improvement in screen designs and monitoring methods have led to improvements in juvenile and adult survival with coarse-mesh (e.g., 9.5 mm mesh) modified traveling screens. Unfortunately, there have been no new fine-mesh installations evaluated using these newer screen designs, so it is unknown whether the observed improvements in juvenile and adult post-impingement survivals would also be observed for earlier lifestages (eggs and larvae). Finally, there are several other promising screen designs (e.g., WIP screen) that have not been tested with any eggs and larvae.

For this study, a fine-mesh screen would be installed in one of the existing screenbays. The test screen would be designed to operate continuously with components suitable for a long-term deployment; allowing the screen to be placed into full-time service if the study proves successful. The installation would include new spraywash supply piping, debris/fish trough, fish collection device, and a temporary laboratory to process collected samples. Organisms collected from the pilot screen would be washed into a fish trough. The new trough would be capable of discharging to a fish collection area during testing or the existing fish/debris return during normal operation.

A second pilot study could be conducted to determine if the existing fish/debris return location is sufficient to prevent the re-impingement of fish and debris may be warranted. Using the existing location would reduce the construction and permitting costs associated with updating the screens. There are several methods available to conduct this study. The first method would be an in-situ study using a physical tracer or die dilution testing to determine potential for re-impingement. This type of study would be relatively low cost but would not allow for modifications to the return configuration. A second potential method would be to conduct a hydraulic or computational fluid dynamics (CFD) model study. This type of study would require a greater effort in the preliminary stages to build and verify the model, but would be relatively easy to modify and test alternative configurations.

A timeline showing the estimated durations needed to conduct a pilot study and install fine-mesh traveling water screens is provided in Table 4.

Table 4 Pilot Study and Installation Schedule

Task	Duration
Pilot Study	
Pilot study plan	2 months
Fabrication and installation of the test screen	10 months
In situ tests	6 months (March 1st to August 31st)
Full Scale Installation	
Final Design	2 months
Permitting	2 months
Fabrication and installation of the screens	10 months
Installation	3 months

Estimated Costs

The costs associated with the evaluated technology are provided to inform Best Professional Judgment (BPJ) compliance decision making. Order-of-magnitude installation, O&M and power costs associated with the fish protection alternative are presented in this section. The costs were estimated using quantities developed from the conceptual design and cost data from other projects that were adjusted for identifiable differences in project sizes and operations. The estimated costs are based on the following:

- Present-day prices and fully contracted labor rates as of December 2008[1].
- Forty-hour work-week with single-shift operation for construction activities that do not impact plant operations and fifty-hour workweek with double-shift operation for construction activities that impact plant operations.
- Direct costs for material and labor required for construction of all project features. The direct costs also include distributable costs for site non-manual supervision, temporary facilities, equipment rental, and support services incurred during construction. These costs have been taken as 85% of the labor portion of the direct costs.
- Indirect costs for labor and related expenses for engineering services to prepare drawings, specifications, and design documents. The indirect costs have been taken as 10% of the direct costs.
- Allowance for indeterminates to cover uncertainties in design and construction at this preliminary stage of study. An allowance for indeterminates is a judgment factor that is added to estimated figures to complete the final cost estimate, while still allowing for other uncertainties in the data used in developing these estimates. The allowance for indeterminates has been taken as 10% of the direct, distributable, and indirect costs.
- Contingency factor to account for possible additional costs that might develop but cannot be predetermined (e.g., labor difficulties, delivery delays, weather). The contingency factor has been taken as 15% of the direct, distributable, indirect, and allowance for indeterminate costs.

The project costs do not include the following items that should be included to obtain total capital cost estimates:

- Costs to perform additional laboratory or field studies that may be required, such as hydraulic model studies, biological evaluations of prototype fish protection systems, soil sampling, and wetlands delineation and mitigation.
- Accurate costs to dispose of any hazardous or non-hazardous materials that may be encountered during excavation and dredging activities.

[1] Costs have been updated based on the cost indexes in the December 15, 2008 Engineering News-Record (ENR 2008)

- Mirant costs for administration of project contracts and for engineering and construction management.
- Price escalation
- Permitting costs
- Replacement power costs

Alden has only calculated the costs for a generic screen as at this level of detail the cost differences between different mesh sizes and screen manufacturers is assumed to be negligible.

The installation and annual operation and maintenance requirements are presented in Table 5. The annualized costs are presented in Table 6. To annualize the costs, the following assumptions were made:

- the capital costs were annualized over 20 years;
- a 7% discount rate was used; and,
- the cost assumed per MWh is $70.00.

Table 5 Installation and Operation and Maintenance Costs for 0.5 mm to 2.0 mm Traveling Water Screens with Fish Protection Features

Item	Estimated Cost ($ x 10^3)
Direct Costs	
Mobilization and Demobilization	288
Fine-mesh Screen	2,354
Fish Troughs, Collection Facility and Return Piping	242
Spray Wash System	225
Barges, Cranes, Divers and Equipment	59
Direct Costs (December 2008 $)	$3,168
Indirect Costs	317
Subtotal	$3,485
Allowance for Indeterminates/Contingencies	871
Total Estimated Project Costs (December 2008 $)	$4,356
Impacts on Plant Operation	
Item	**Impact**
Construction	
Duration	3 months
Unit 1 Outage	2 weeks
Unit 2 Outage	2 weeks
Incremental Annual Operation and Maintenance	
Labor, (hrs)	1,175
Component Replacement	$483,000
Energy (kwh)	460,000
Peak Power (kw)	53

Table 6 Annualized Costs

Description	Capital Costs			Annualized O&M			
	Total Project Construction Costs (2008 $)	Replacement Power during Construction (MWh)[1]	Total Capital Costs (2008 $)[2]	Annual Energy (MWh)	Energy (2008 $)[3]	Labor (2008 $)	Component Replacement (2008 $)
Traveling Screens with Fish Protection Features	$4,356,000	81,800	$5,174,000	460	$32,000	$44,000	$483,00

Description	Annualized Costs			Capital Costs
	Total Annual O&M	Annualized Capital Costs	Total Annualized Costs	Pilot Study Test Facility
Traveling Screens with Fish Protection Features	$559,000	$488,000	$1,047,000	$650,000

1. Determined by using 1,120 MW for units 1 &2 and a plant capacity factor of 20%
2. Assumed cost of $10 /MWh
3. Assumed $70 per MWh for consumptive power.

Summary

- Fine-mesh (0.5 mm to 2.0 mm) traveling water screens with fish protection features could be installed in the existing screenbays to increase survival of collected organisms.
- A new fish/debris trough may be needed to safely return impinged organisms back to the Canal. This trough would need to be designed to prevent re-impingement.
- Performance of modified traveling screens is species- lifestage- and site-specific.
- New screens on the market have to potential to increase collection survival by eliminating any air and spraywash exposure.
- Information on the sizes of organisms currently entrained is currently lacking making estimates of exclusion highly uncertain.
- Pilot-scale evaluation would be necessary to better estimate the biological effectiveness of fine-mesh modified traveling screens.
- The relative ease of retrofit and proven engineering performance in saline environments makes fine-mesh traveling screens an attractive alternative to reduce entrainment and impingement losses at Canal.

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Economic Issues Regarding BTA for Canal Generating Station

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1. Introduction

Cooling water intake structures (CWIS) are regulated under Section 316(b) of the Clean Water Act (CWA). This statute directs the United States Environmental Protection Agency (EPA) to ensure that the location, design, construction, and capacity of CWIS reflect the "best technology available" (BTA) for minimizing adverse environmental impacts (AEI). EPA developed national technology standards for CWIS in three phases. The 316(b) Phase II Rule, promulgated in 2004, requires that existing electric generating plants designed to use more than 50 million gallons of cooling water per day reduce impingement mortality and entrainment (IM&E) of aquatic organisms according to the EPA's national performance standards.

In January 2007 the U.S. Second Circuit Court of Appeals issued a decision that remanded most of the Phase II Rule back to the EPA. The court's decision requires that EPA redefine BTA with consideration of closed-cycle cooling in a remanded rulemaking process. The reasons provided for this instruction were that EPA's determinations were not clear and that comparing the benefits with the costs of the management options could not be used as a basis to reject closed-cycle cooling. Following the court's decision, the EPA suspended the rule (Grumbles 2007).

Under the suspension, EPA has directed that all permits for Phase II facilities be considered by the permitting agencies on a Best Professional Judgment (BPJ) basis. Specifically, EPA stated that it "…is not suspending 40 *CFR* 125.90(b). This retains the requirement that permitting authorities develop BPJ controls for existing facility cooling water intake structures that reflect the best technology available for minimizing adverse environmental impact" (72 *Fed. Reg.* 130, pp. 37107–37109, July 9, 2007).

In July 2008, EPA Region 1 (Region 1) notified Mirant Canal, LLC that closed-cycle cooling (or a technology with comparable effectiveness) was determined to be BTA for the CWIS at its Canal Electric Generating Station (Canal Plant) in Sandwich, Massachusetts. In December 2008, Region 1 re-opened the comment period for its BTA determination. This report, prepared by Veritas Economic Consulting (Veritas) at the request of Mirant Canal, LLC, addresses the economic issues related to Region 1's determination of BTA for the Canal Plant. Our primary conclusions are:

- Absent a cost-recovery mechanism, the Canal Plant will shut down if a retrofit is required.
- The shutdown will cause serious reliability impacts.

- The shutdown will negatively affect the local community.
- The economic benefits of the cooling tower retrofit do not justify its costs.
- Cost-effectiveness analysis is likely to eliminate cooling towers from consideration.

Our basis for reaching these conclusions is described below. Models containing supporting details are available to Region 1 by request.

2. Absent a Cost-Recovery Mechanism, the Canal Plant Will Shut Down If a Retrofit Is Required

In its January 2007 decision, the Second Circuit Court identified whether the costs of a cooling tower retrofit can be "reasonably borne" as a factor for consideration in 316(b) BTA determination. An important consideration is whether such a test should be applied at the industry, corporate, or plant level.

A key result of this investigation is that the affordability of plant-specific regulatory requirements should reflect the individual plant's ability to bear costs and its viability rather than the corporate parent's ability to do so. This position is supported by regulatory guidance and the realities of corporate finance. In its guidance document for evaluating water quality variances associated with other sections of the CWA, EPA explicitly notes that the financial impacts analysis of compliance costs is to be conducted at the plant level (EPA 1995). EPA also considers plant-specific financial conditions when evaluating affordability for Section 316(b) of the CWA. EPA has applied the affordability criterion at the plant level and, as reported in *Response to Comments, Mirant Kendall Station* (Page 2-54), said that it "…usually will not require a facility to install a technology if the facility cannot reasonably bear the costs."[1]

With respect to the financial decisions of regulated corporations, the ability to bear the costs of a regulation is only a threshold. If the new capital and higher operating costs of the retrofit requirement result in a facility becoming unprofitable, profit-maximizing behavior dictates it will be shut down rather than bear the costs of the retrofit.[2] Thus, the only salient financial feature of the corporation is its cost of capital. The following subsections provide greater detail on why the affordability criterion should be considered at the plant rather than corporate level and demonstrate the Canal Plant's inability to bear the costs of the requirement.

2.1 The Corporate Parent Makes Prudent Financial Decisions

The Canal Plant, owned by Mirant Canal, LLC is one of several power generation facilities in the United States that is owned by a subsidiary of Mirant Corporation. Like many companies with generation assets, Mirant Corporation is the parent corporation of a set of wholly owned subsidiaries that are themselves corporations or limited liability companies. When

[1] At the plant-specific level, Region 1 indicates that "availability" is the facility-specific analog of "ability to bear" (Kendall Response to Comments 2.18.1).

[2] An extension of the "reasonably borne" criterion can be applied to the concept of electricity reliability. The local electricity industry (composed of generation, transmission, and distribution) cannot succeed at its primary task—the reliable delivery of electricity—if the retrofit causes the plant to close. Thus, from a reliability standpoint, the industry is "unable to bear the cost" if it results in shutdowns that impact reliability. See a more detailed discussion of reliability impacts in Section 3.

the company is structured as a holding company, as is Mirant Corporation, Region 1 has argued that it may consider the finances of the parent corporation when applying the affordability criterion (see *Response to Comments, Mirant Kendall Station* page 2-44).

In 2007, Mirant Corporation generated income of almost $2 billion. As of September 30, 2008, it had cash and cash equivalents of $2.3 billion. The financial flows of a company that owns generation assets, such as Mirant Corporation, are depicted diagrammatically in Figure 1. In this representation, payments are drawn from the "Net Cash" box. To pay for the costs of a cooling tower, Mirant Corporation has the following broad options:

- Issue new equity
- Issue new debt and letters of credit
- Reduce future dividend payments
- Draw down cash reserves.

Mirant Corporation, as does any corporation, obtains funds from these sources in a manner that minimizes the cost of securing capital.[3]

[3] The marginal source of investment funds for non-financial firms is typically retained earnings (Auerbach and Hassett 2000).

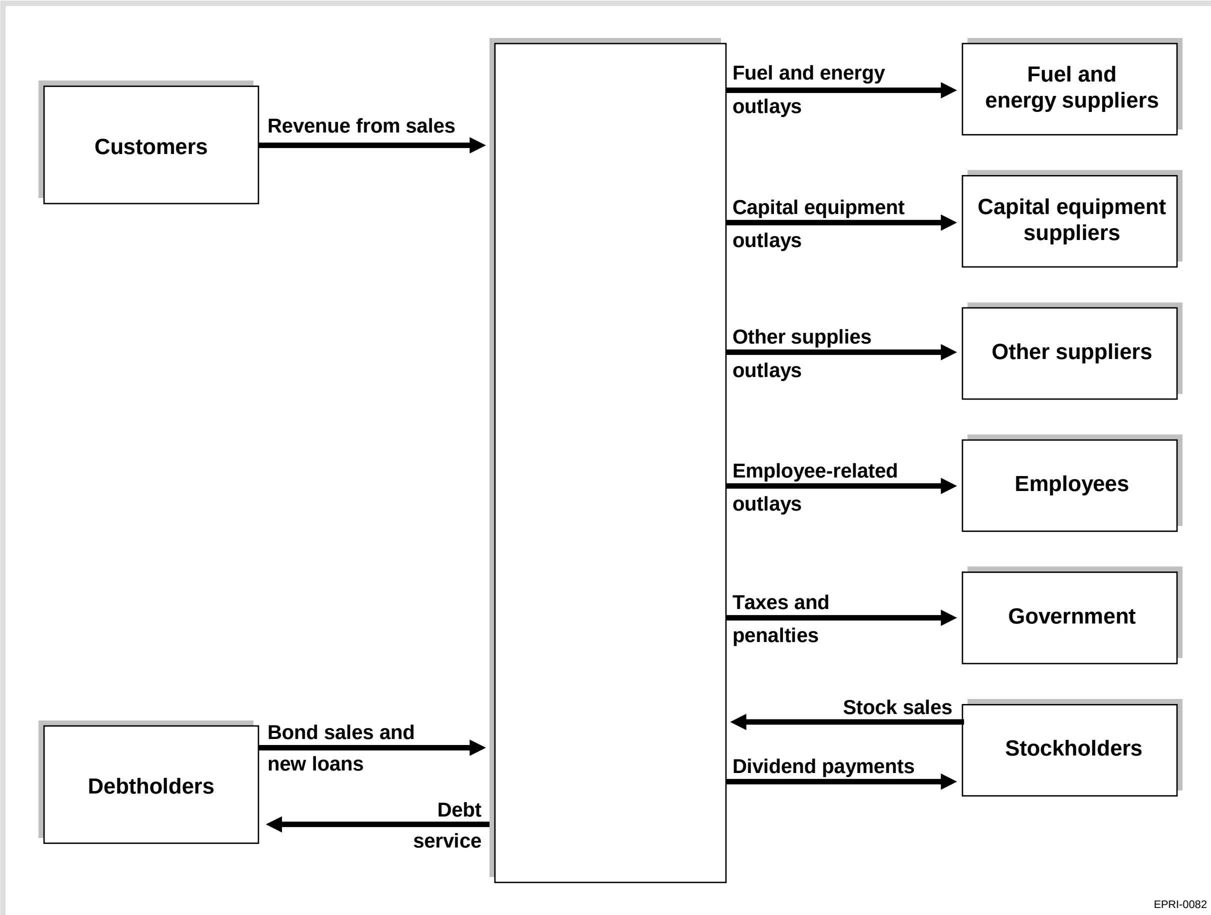

Figure 1: Corporate Level Cash Flows

Clearly a limited financial evaluation ignores the fiduciary responsibility that corporate officers bear for stockholders. Without regard to Mirant Corporation's cash position or creditworthiness, corporate decision makers are obliged to consider the impact of large financial decisions on share values. Regardless of the financing approach, stock prices are impacted. Stockholders pay for new equity issues in the form of lower wealth due to share dilution. They pay for new debt issues through an increased risk of default. Financing compliance capital from cash on hand reduces the expected return on equities. Moreover, each of these approaches carries opportunity costs in the form of forgone profits as the funds available for investments that increase firm profitability are reduced.

With this overarching consideration of share value, identifying cost impacts of a closed-cycle cooling requirement at the Canal Plant demands consideration not of whether the parent company could bear the retrofit costs, but of whether it *would* bear these costs. Maximizing shareholder return requires consideration of asset value with a closed-cycle cooling retrofit and with premature closure. Closure cuts off a profit stream, but is preferable to retrofitting when retrofitting leads to financial losses. This situation is fundamentally different from that considered by Region 1 in its Mirant Kendall, LLC Response Comments, where the presumptive outcome of an unaffordable fine is bankruptcy rather than facility closure.

These principles of corporate financing and fiduciary responsibility demonstrate that the corporate financial situation bears little on the disposition of an individual asset subject to an expensive compliance requirement. Certainly the overall financial picture relates to creditworthiness and the corporate cost of capital. However the corporate cost of capital is only an input to a facility-specific decision. Speaking generally, the stream of future profits from the facility must be expected to exceed the stream of conversion-related costs. If not, closure is the responsible alternative. Mirant Corporation's annual report (2007) contains a discussion of the impact of environmental regulations on plant operation decisions: "To comply with these legal requirements and the terms of our operating permits, we must spend significant sums … We may be required to shutdown facilities if we are unable to comply with the requirements, or if we determine the expenditures required to comply are uneconomic" (p. 25). This consideration of profitability at the plant level is consistent with profit-maximizing corporate behavior in which responsibility to shareholders dictates that investments with negative expected returns not be undertaken.

2.2 The Canal Plant Will Become Uneconomic If a Retrofit Is Required

The Canal Plant is a 1,112-megawatt power plant, located on the Cape Cod Canal in Sandwich, Massachusetts. It is about 40 years old and has two generating units. Unit 1 generates electricity utilizing residual fuel oil, and Unit 2 generates electricity utilizing residual fuel oil and, on occasion, natural gas. Prior to installation of nearly 10,000 MW of more flexible, combined-cycle generation in the New England control area, the Canal Plant competed effectively in the market. With the installation of nearly 10,000 MW of more flexible, combined-cycle generation in the New England control area, the Canal Plant runs substantially less than it has in the past. This relative change in costs pushed it from a baseload plant to one that infrequently operates in merit order. The Canal Plant's net capacity factor was 23 percent in 2007,[4] a value substantially lower than in previous years.

The Canal Plant generates revenue from the sale of electricity and from the provision of ancillary services that provide security of electricity supply. The output of the Canal Plant is

[4] This factor is calculated as the average production as a share of potential net dependable capacity used over the year.

sold, primarily, into the wholesale markets operated by the Independent System Operator-New England (ISO-NE). To generate electricity and provide ancillary services, the Canal Plant incurs costs for the inputs to production, including outlays for fuel (e.g., oil or gas); payments to suppliers of other materials and services; and employee-related payments (e.g., wages and salaries, pensions, and health care), as illustrated in Figure 2.

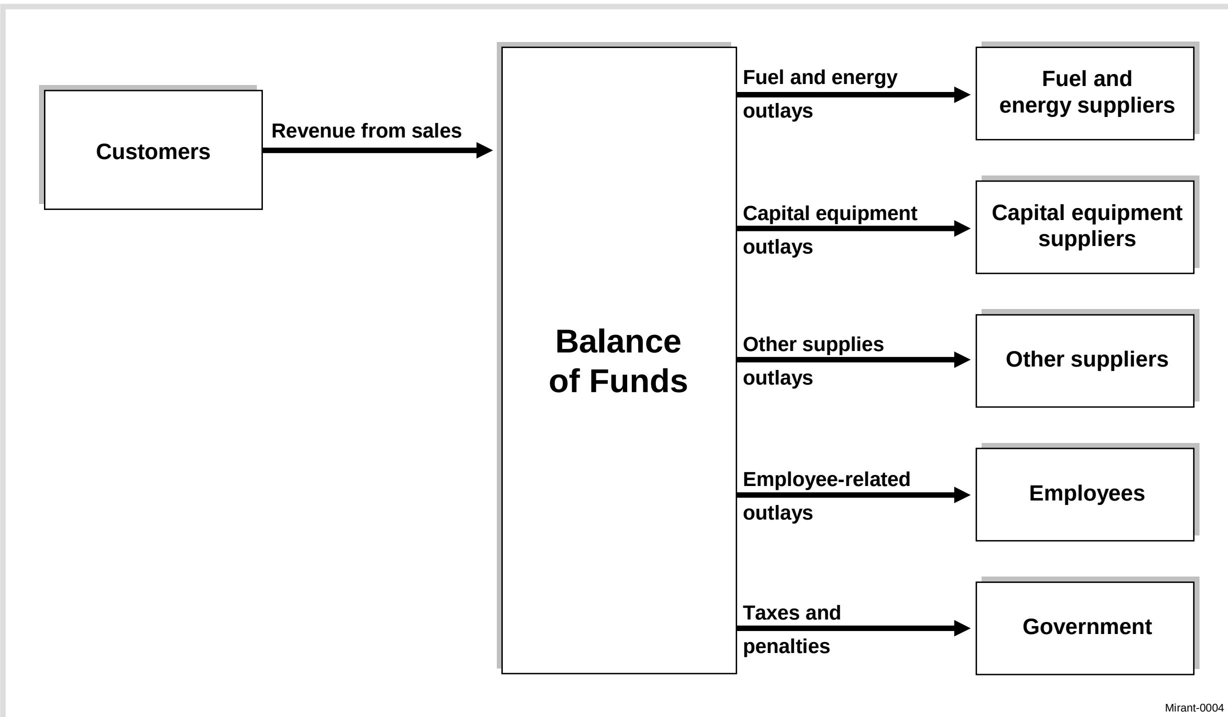

Figure 2: Plant-Level Finances

The costs of retrofitting the Canal Plant with cooling towers are substantial. These costs include the design and installation of the cooling towers, which would require removal of some existing equipment and structures, and the on-going costs of operating this closed-cycle cooling system. The Shaw analysis (2009) reports that the capital costs would be between $182 and $225 million. Cooling towers also increase variable costs. The total increase in variable costs is the sum of increased operations and maintenance cost, decreased efficiency, and increased parasitic load. These costs would be incurred over the remaining lifetime of the plant.

The Canal Plant has three potential sources of funds to cover these costs:

- Increase the price of electricity or ancillary services to generate more revenue.
- Reduce the prices paid for fuel, capital, labor, and materials.

- Use the surplus of revenues over costs of owning and operating the plant.

The first and second of these are unlikely sources. The Canal Plant operates in the New England control area. Power markets in this region employ bid-based market clearing to encourage the use of lower-cost and more flexible energy resources. As evidenced by its low capacity factor, the Canal Plant energy bids rarely clear the market. Cooling tower retrofit costs might induce higher bids from the Canal Plant. However, the Canal Plant bids rarely set the price of electricity. With respect to input prices, the rigorous review required of facility expenditures indicates that the Canal Plant pays market prices for fuel, labor, and materials.

As a price taker, the Canal Plant's remaining option is to pay for the costs of the cooling towers out of surplus revenues. Doing so requires that the present value of future net cash flows from the facility exceeds the costs of the cooling tower at the corporate cost of capital. To assess whether the Canal Plant would shut down if a retrofit were required, we applied an engineering-economic model that simulates the effect of water regulations on the electric industry. This Water Policy Simulation Model (WPSM) incorporates electricity production and cost relationships for existing and new generation facilities to mathematically simulate outcomes for electric power markets in the New England control area. This model employs engineering data that are largely from the public domain.[5] The WPSM simulates current and future electricity market conditions (load, generation, prices, dispatch, unit and plant economics). To evaluate the retrofit requirement, conversion to closed-cycle cooling for the Canal Plant is introduced in the year 2013.

Evaluating affordability at the facility level requires revenue and cost projections that are typically considered confidential business information. Mirant Corporation has provided revenue and cost projections sufficient to support analysis of the financial viability of cooling towers for the Canal Plant (see appendix). Comparisons with cost experiences of similar facilities and simulations from the WPSM are used to validate facility-specific data provided for the Canal Plant. This evaluation considered whether all relevant cost and revenue streams are represented and whether these streams are internally consistent.[6]

ISO-NE uses markets and market signals (prices and quantities) to manage the generation and distribution of electricity. It is possible, however, for a facility to obtain revenue outside these markets. Revenue projections for the Canal Plant include compensation (uplift) reflecting payment for out-of-merit operations to ensure reliability. Uplift revenue is expected to

[5] The model employs a heat rate of 9,726 BTU/kWh for Unit 1 and 10,515 BTU/kWh for Unit 2.
[6] For example, there is typically a strong correlation between energy revenue and fuel expenditures.

be approximately $2.16 million per year, ending prior to 2014. This reflects operating Unit 1 at its minimum operating level of 200 MW for 50 days (24 hours a day) with a payment of $9 per MWh. This level of operation is consistent with NSTAR Electric Company's plan to construct new transmission equipment in southeastern Massachusetts (MDPU 2008). The Canal Plant is projected by ISO-NE to provide reliability services for less than 50 days per year once these transmission upgrades are complete in the fall of 2009 (Kowalski 2008). After 2013, a 345 kV transmission line is expected to be complete, eliminating the need for these services entirely. Based on this background, the level and duration of the projected uplift payments are appropriate.

Simulations in the WPSM predict energy revenues of $44.54 million in 2013. These energy sales reflect a capacity factor of 4.1 percent for Unit 1 and 2.1 percent for Unit 2. The $44.54 million in energy revenue is from in-merit order energy sales that occur during peak periods. The Canal Plant's projected market revenues total $73 million in 2013. With consideration of revenue from energy and capacity payments this is a reasonable expectation for revenue in 2013.

Both the WPSM and Mirant models reflect aging steam electric fossil plants that were constructed as baseload facilities but have gradually transitioned to load following, peaking, and reliability support roles (California Energy Commission 2004). Because of this, both models project a gradual decline in the units' capacity factors over time. WPSM projects flat revenues over time. Mirant does project a slight increase in revenues over the long term, but the rate of increase is less than inflation resulting in a decline in real economic value over time. Pending CO2 regulations tend to put Unit 1 at more economic risk than Unit 2 which can run partially on gas. Although the two models show slightly different rates of real economic decline, the Mirant projections are plausible and consistent with the Canal Plant's position in the marketplace.

Cost provided for the Canal Plant include total operating costs of $42.49 million in 2013 and total production costs of $29.48 million in 2013. The generic scalars for fixed operating and maintenance costs listed in the National Electric Energy Data System (NEEDS) database calculate Unit 1 as having fixed costs of $21,180 per MW and a capacity of 559 MW, and Unit 2 having fixed costs of $26,570 per MW and a capacity of 553 MW.[7] Thus, the NEEDS scalars applied to the Canal Plant yield fixed annual cost estimates of $36.47 million. The difference between estimates likely reflects cost differences from the NEEDS base year of 2004 and 2013 (first year of the Canal Plant projections). Accordingly, the projected fixed annual costs

[7] NEEDS is a publicly available dataset containing information about economic features of existing plants.

provided by Mirant are consistent with national average cost experiences. With respect to production costs, dispatch simulations in the WPSM predict $40.4 million in production costs. The Mirant production cost estimate is slightly lower at $29.48 million for 2013. Overall, these production costs are reasonable and consistent with increasing costs generally and emissions costs that increase at a rate greater than inflation.

To evaluate the retrofit requirement, conversion to closed-cycle cooling for the Canal Plant is introduced in the year 2013. WPSM represents the retrofit requirement by adding cooling tower capital costs, cooling tower operational and maintenance costs, and cooling tower efficiency/consumption impacts to the Canal Plant's supply characterization. Within the context of a simulation model, costs specified in this manner become part of the objective function for the Canal Plant. It will maximize profits by installing cooling towers or by prematurely shutting down either or both of its generating units. Also, because the model simulates market outcomes, the ability of the Canal Plant to pass costs along to electricity consumers is explicitly evaluated. With the addition of a closed-cycle cooling retrofit requirement to the Canal Plant, WPSM simulations project that the Canal Plant's net present value is negative $180 million, similar to Mirant projections of negative $200 million. Absent a cost-recovery mechanism, the Canal Plant will shut down rather than incur the cost of a closed-cycle cooling retrofit.

The finding that some facilities, especially the less efficient ones, will close when faced with a requirement to retrofit the plant with cooling towers is supported by other studies. In 2008, the Department of Energy (DOE) conducted an analysis that evaluated the impact of U.S. generation facilities subject to the 316(b) regulation. DOE identified the financially marginal plants by using capacity factor as a proxy. DOE determined that the U.S. would lose between 38,000 and 75,000 MW of generation capacity as a result of the retrofit requirement. DOE concluded that "older units may not have sufficient useful operating life remaining to recover the retrofit investment. Also, less efficient generation facilities may not be operated enough hours of the year to justify the retrofit investment" (p. iv). DOE's study identifies New England as a region where the cost impacts are likely to be more severe, with potentially as much as an 18-percent reduction in capacity (p. 28).

When the issue of economic affordability is considered at the plant, rather than at the corporate level, the weight of the evidence strongly suggests that a cooling tower retrofit (or any BTA measure with a comparable cost), is not economically sensible (affordable) for the Canal Plant. This determination is based on plant-specific information (provided by Mirant

Corporation) and market simulations that validate Mirant's projections and indicate the Canal Plant will not be able to pass costs along to consumers in the energy markets.

Thus, given the inability of the Canal Plant to pass the costs associated with the retrofit to closed-cycle cooling along to customers, or to recover them through lower operating costs, it is likely that Mirant Corporation's stockholders would be required to fund these costs. However, as the plant is not expected to recover these costs from future surplus revenue, absent a cost-recovery mechanism, the response of a prudent enterprise to this requirement will be to prematurely close the Canal Plant rather than impose a loss on the company's stockholders.

3. The Shutdown of the Canal Plant Will Cause Electricity Reliability Impacts

Another factor that the Second Circuit Court indicated the EPA should consider in its determination of BTA is the impact of a retrofit requirement on energy production and efficiency. One important aspect of energy production relates to the reliability of the bulk power system. Reliability is the ability of the electric system to supply electricity, taking account of planned and forced outages, and its ability to withstand sudden disturbances, such as unanticipated loss of system facilities. The North American Electric Reliability Corporation's (NERC's) mission is to ensure that the bulk power system in North America is reliable. To achieve this objective, NERC develops and enforces reliability standards. As of June 18, 2007, the U.S. Federal Energy Regulatory Commission (FERC) granted NERC the legal authority to enforce reliability standards with all U.S. owners, operators, and users of the bulk power system, and made compliance with those standards mandatory, as opposed to voluntary.

When New England's wholesale market does not satisfy NERC's reliability requirements, ISO-NE takes additional steps to ensure that the electrical system is reliable. ISO-NE has issued reliability agreements and supplemental commitments to generators to ensure reliability. Both the agreements and the commitments keep uneconomic units in service. Owners receive payments that are recovered from market participants (Patton and LeeVanSchaick 2008). Thus, in order to meet NERC's reliability requirements, some uneconomic units will be kept on line.

Since 2006, the Canal Plant has provided supplemental commitment to ISO-NE as a part of the contingency plan for reliable service (Patton and LeeVanSchaick 2008; Sullivan 2007). The Canal Plant has a total generation capacity of 1,112 MW. With higher oil prices, the Canal Plant is rarely able to compete in the market at the competitive price. However, because there are no other large power plants within the region, the ISO-NE has historically operated the Canal Plant out of merit order to meet reliability needs in the region, and nearly all of the electricity consumed on Cape Cod, Martha's Vineyard, and Nantucket is supplied by the Canal Plant during summer peak. Thus, the location of the Canal Plant relative to the existing transmission system for the Southeastern Massachusetts (SEMA) load zone makes the facility uniquely able to fulfill ISO-NE's reliability requirements, despite its relative inefficiency (Sullivan 2007; Patrick 2008). A recent FERC ruling (2008) confirms the Canal Plant's important role in ensuring reliability for SEMA.

Furthermore, the Canal Plant is also important during other times of the year in the case of certain transmission outages. The loss of the two transmission lines currently serving the area would require generation from the Canal Plant to re-establish electrical service during almost all time periods. During many time periods, the loss of a single line would require generation from the Canal Plant to maintain reliability. For example, during 2002, a fire at the Canal Plant occurred when an existing transmission line was out-of-service. As a result of this combination, 300,000 electricity customers in southeastern Massachusetts lost service. Given this important role, even a temporary shutdown of the Canal Plant to retrofit with closed-cycle cooling has the potential to negatively impact reliability in SEMA.[8]

To more completely understand the reliability impacts associated with the closure of the Canal Plant, Mirant engaged PwrSolutions, Inc. (PwrSolutions) to execute an independent analysis. The evaluation considers the reliability of the electric transmission grid in SEMA and ISO-NE first with the Canal Plant operating. Then the analysis is re-run with the Canal Plant closed. The difference between these two cases informs the reliability assessment. The full details of this assessment are presented in Exhibit 15. The primary assumptions of the assessment are:

- The FERC 715 ISO-NE 2012 Summer Peak case, developed in 2007, provides the "with Canal Plant" scenario. The "without Canal Plant" scenario simulates the generation, transmission, and grid impacts by taking the Canal Plant off-line.
- Loads were modeled to represent the forecasts of the individual utilities in the region.
- A list of approximately 1,450 ISO-NE certified planning contingencies was utilized for the N-1 analysis. The primary analysis criterion is incremental voltage and thermal overload violations following the execution of full AC power flow analysis under normal operating and N-1 contingency conditions.
- All branches with nominal voltage of 69 kV and above in the New England Power Pool (NEPOOL) area (FERC area #701) were monitored for over loading conditions.
- Transmission lines were listed as overloaded when their operating MVA were in excess of 100 percent of their thermal rating.
- Bus Voltage range of 0.95–1.05 per unit was deemed within acceptable limits under normal operating conditions while a range of 0.9–1.1 per unit was deemed within acceptable limits under N-1 contingency conditions.

When simulating the "without Canal Plant" scenario under the N-1 contingency conditions, the results indicate that the closure of the Canal Plant poses serious threats to the

[8] The installation of a new 345 kV transmission facility or the installation of new, quick-start peaking capacity will eliminate this reliability need. Either of these options is years away. Shutting down the Canal Plant prior to the completion of these options will present reliability problems for the region.

reliability of the lower SEMA transmission system. Under the identified contingency/outage configurations, the absence of the Canal Plant could lead to a blackout in lower SEMA region, due to either load shedding or voltage collapse. Moreover, the resulting requirement to import electricity from various ISO-NE load zones into lower SEMA places considerable stress on the remaining SEMA transmission system beyond SEMA.

Specifically, the analysis identifies 11 incremental transmission system overloads in SEMA. Seven of these are at the 345 kV level and result in the system not being able to meet the load in the lower SEMA region. All of these contingencies involve the opening of certain sections of the 345 kV lines connecting the Cape Cod region in lower SEMA to the remaining SEMA region. Five incremental voltage violations are experienced in SEMA under N-1 contingency conditions, indicating a shortage of reactive power support in the lower SEMA region. The five incremental voltage violations occur at the 115kV and below level. Numerous incremental voltage violations occur under N-1 contingency conditions across the Maine, New Hampshire and Connecticut zones.

4. The Canal Plant's Shutdown Will Negatively Affect the Local Community

If the Canal Plant closes because it cannot afford the cooling tower retrofit, Region 1's BTA determination will negatively affect the local community. The plant's closure will result in negative impacts to the local economy in the form of job losses, reduced local spending, decreased tax revenues, and potentially tax increases for some residents. Thus, Region 1's BTA determination is adverse for the local community.

About 80 people work at the Canal Plant (Mirant 2008a). With plant closure, most, if not all, would lose their jobs. The additional impacts in the local community occur as the unemployed no longer have income to spend on local goods and services. Local economic impacts are commonly evaluated using input/output models of the regional economy under consideration. Kotval and Mullin (1997) conducted an economic impact study of the 1992 closure of the Yankee Plant in Rowe, Massachusetts. The authors determined that for every 1.8 jobs lost at the plant, another job was lost in the local economy. In that community, the decreased local spending resulted in the closure of the town's only grocery store, and other retail stores suffered as well. A local economic impact study has not been conducted for the Canal Plant closure. However, the closure of the Canal Plant could have similar effects on the local community in the vicinity of Sandwich, Massachusetts.

Sandwich, like many small towns in Massachusetts, relies on property tax revenues to provide local funding for schools, public safety, and other public services. The Canal Plant's continuing presence provides an important source of tax revenue for the community, currently in excess of $2 million (Dunham 2008). A shutdown of the Canal Plant would allow Mirant to apply for an abatement of its property taxes. The town may be able to maintain its tax revenue by shifting the tax burden to other property owners in the town. In this case, the average homeowner would pay $230 more in annual property taxes (Dunham 2008). The closure of the Canal Plant would result in tax repercussions for the town. Region 1 should have given careful consideration to the potential negative impacts that the local community will bear if Region 1 requires a cooling tower retrofit for the Canal Plant.

5. The Economic Benefits of the Cooling Tower Retrofit Do Not Justify the Costs

In its determination of BTA for the Canal Plant, Region 1 indicated that the Second Circuit Court's decision invalidates the use of benefit-cost analysis in regulatory decision making related to Section 316(b) of the CWA. On December 2, 2008, the U.S. Supreme Court heard arguments related to the legality of benefit-cost analysis as part of the 316(b) Rule. The Court's decision is anticipated to be announced between March and July of 2009. Region 1 further concedes that if the Supreme Court determines that benefit-cost analysis has an appropriate role in determining compliance with Section 316(b), then Region 1 may reconsider BTA for the Canal Plant in the future. Given the uncertainty surrounding both the timing and the result of the Supreme Court's future ruling on the role of benefit-cost analysis, as well as Region 1's potential reconsideration of BTA for the Canal Plant, it is appropriate to understand how the benefits of the cooling tower retrofit at the Canal Plant compare to the costs of the retrofit.

5.1 Population Dynamics Models Simulate Catch Changes

Economic benefits analysis in the 316(b) decision-making context dates to the original enforcement of the enabling regulation. These economic assessments involve developing a link between measured impingement and entrainment rates and changes in the value of commercial and recreational fisheries. An early example, Stanford et al. (1982) address "the economic implications of a biological phenomenon, and also show the suitability of combining methodologies from two different scientific disciplines to evaluate a broader scope of impacts associated with impingement and entrainment."[9] In a more recent application, Newbold and Iovanna (2007) statistically identify impacts to populations of 15 harvested stocks.

Following the work of Leslie (1945), we developed preliminary bio-economic impact estimates based on dynamic population simulations for selected species in the Canal Plant's entrainment data.[10] Age-structured population models are the most sophisticated models typically employed to evaluate changes in recreational and commercial catch. Leslie's (1945)

[9] Stanford et al. (1982) evaluate the bio-economic impacts of impingement and entrainment of yellow perch at the J.R. Whiting Generating Plant.

[10] In contrast, the EPA did not use dynamic population models when developing the Phase II 316(b) Rule. For example, the North Atlantic Regional Study (EPA 2004) reflects a static approach to modeling fish population changes. This static approach computes Age-1 equivalents for all species of fish, regardless of their maturity level at that age. This same increase in fish numbers occurs year after year in the EPA method. The use of dynamic fish-population models in our bio-economics assessment is a considerable improvement over the EPA approach used in the North Atlantic Regional Study.

model is frequently used in fisheries management[11] and has long been an important component of professional judgment in 316(b) assessments under 1977 draft guidance (Akçakaya, Burgman, and Ginzburg 2002; Public Service Electric and Gas Company [PSEG] 1999; EPA 2002).[12]

The identification of catch impacts via simulation over specified survival parameters provides an approach for extrapolating measured entrainment impacts on recreational and commercial species. However, many species that are prevalent in IM&E samples are not harvested recreationally or commercially. Thus, the economic valuation of these forage species must be accomplished outside of a single-species survival simulation. In the 316(b) context, those fish have been considered to have either nonuse or indirect economic benefits. Indirect-use benefits arise from the role forage species play in supporting game fish and commercially harvested populations. Indirect-use benefits can be calculated by evaluating the degree of energy transfer that occurs through the consumption of forage fish by harvested species.

The evaluated species in Table 1 represent the numerically dominant species entrained based on the data provided by Normandeau (2009). Table 1 provides the classification of the entrained species and shows whether the species is a harvested species or a forage species. For the harvested species, Table 1 indicates whether it is harvested recreationally, commercially, or both. The dynamic population models use available information on life stages, natural and fishing mortality rates, and fecundity to simulate catch changes for the affected species.[13]

[11] Fishery managers use the Leslie matrix in various applications. For example, the Shark Population Assessment Group of the National Oceanic and Atmospheric Administration (NOAA) (2006) uses the Leslie matrix to represent the population dynamics of sharks through demographic methods and to assess the status of shark stocks through stock assessment methodology. Sabaton et al. (1997) use a mathematical model to represent long-term change in a trout population under different river management scenarios. Their model describes the structure of a population divided into age classes based on the Leslie matrix. Hein et al. (2006) use an age-structured Leslie matrix model to determine which removal method most effectively reduced the population of invasive rusty crayfish in an isolated lake in Wisconsin. Carlson, Cortés, and Bethea (2003) simulated Leslie matrices to study the life history and population dynamics of the finetooth shark in the northeastern Gulf of Mexico.

[12] This mathematical structure is employed by Stanford et al. (1982) and Newbold and Iovanna (2007).

[13] For a list of data sources used in the dynamic population models, see Able and Fahay (1998); Atlantic States Marine Fisheries Commission (2001); Bigelow and Schroeder (1953a; 1953b); Clayton et al. (1978); Deree (1999); Entergy Nuclear Generation Company (2000); Fay, Neves, and Pardue (1983); Froese and Pauly (2001, 2003, 2008, 2009a, 2009b, 2009c); Gulf of Maine Aquarium (2008); Johnson (2004); Kocik (2000); Mayo and O'Brien (2000); Morse and Able (1995); Nitschke, Mather, and Juanes (2001); NMFS (2003, 2009); NOAA (1993, 2001, 2007); O'Brien (2000); Overholtz (2002a, 2002b); Overholtz et al. (1991); PG&E National Energy Group (2001); PSE&G (1999); Richards (1982); Roseman et al. (2005); Saila et al. (1997); Schultz (2000); Scott and Scott (1988); Serchuk and Cole (1974); Steimle and Shaheen (1999); Stone & Webster Engineering Corporation (1977); Studholme et al. (1999); Virginia Tech (1998); Wang and Kernehan (1979); and Yuschak (1985).

Table 1
Classification of Selected Species Entrained at the Canal Plant

Species	Recreational	Commercial	Forage
Cunner			X
Atlantic herring		X	
Atlantic cod	X	X	
Tautog	X	X	
Atlantic mackerel	X	X	
Windowpane		X	
American plaice		X	
Fourbeard rockling			X
Silver hake		X	
Hake (red or white)		X	
Grubby			X
Sand lance			X
Searobin	X		
Winter flounder	X	X	
Atlantic menhaden		X	
River herring			X
Atlantic silverside			X

As indicated by Table 1 above, several forage species are among the entrained species. This assessment reflects forage species value in the contribution they make as a food source for harvested species.[14] Table 2 identifies the key predators for the forage species in this assessment. The last column in Table 2 reveals that our forage-to-harvested species includes bluefish, Atlantic cod, striped bass, and pollock. Most of these species are harvested both recreationally and commercially. Pollock is harvested commercially. The conversion of biomass of forage species listed in Table 2 into harvested species employs a 10-percent trophic transfer (Pauly and Christensen 1995).

[14]In some cases, increases in forage fish will not lead to increases in harvests. In instances where the predators have an adequate food supply, increasing the forage base may not result in additional recreational and commercial harvests. See Bingham et al. (2007) for an example. For purposes of this assessment, we have not evaluated whether the predators of the affected forage fish have sufficient food supply but have assumed that the forage biomass will be transferred into harvested species.

Table 2
Predators of the Selected Species

Species	Predators of the Species	Harvested Species Selected for Assessment
Fourbeard rockling (Enchelyopus cimbrius)	Goosefish (Lophius americanus), bluefish (Pomatomus saltatrix)	Bluefish
Grubby (Myoxocephalus aenaeus)	Atlantic cod (gadus morhua), skate (raja erinacea), sea raven (Hemitripterus americanus), longhorn sculpin (Myoxocephalus octodecemspinosus)	Atlantic cod
Sand lance (Ammodytes americanus)	Striped seabass (Morone saxatilis), humpback whale (Megaptera novaengliae), fin whale (Balaenoptera physalus)	Striped bass
Alewife (river herring) (Alosa pseudoharengus)	Goosefish (Lophius americanus), common eel (Anguilla anguilla), burbot (Lota lota), Coho salmon (Oncorhynchus kisutch), rainbow trout (Oncorhynchus mykiss), gray trout (Cynoscion regalis), piked dogfish (Squalus acanthias), striped seabass (Morone saxatilis)	Striped bass
Atlantic silverside (Menidia menidia)	Striped seabass (Morone saxatilis), bluefish (Pomatomus saltatrix), gray trout (Cynoscion regalis), dusky smooth-hound (Mustelus canis)	Striped bass and bluefish
Blueback herring (river herring) (Alosa chrysochloris)	Bluefish (Pomatomus saltatrix), weakfish (Cynoscion regalis), striped seabass (Morone saxatilis)	Striped bass and bluefish
Cunner (Tautogolabrus adspersus)	Pollock (Pollachius virens)	Pollock

Source: Froese and Pauly (2008); Levid (1996)

Measuring the benefits associated with a cooling tower retrofit requires distinguishing the current level of entrainment for the Canal Plant from the level of entrainment that would occur with the retrofit. For purposes of this assessment, we evaluate the entrainment impacts based on the full design flow for the Canal Plant. Although the Canal Plant is not currently operating at full design flow, using design flow as the basis of benefits results in a larger benefits estimate. If the Canal Plant operates at a level less than design flow, the resulting benefits will be smaller, potentially much smaller, than those reported here. For the retrofit scenario, we assume that entrainment is reduced by 92.8 percent from the current level (Shaw 2009). This difference in entrainment impacts corresponds to the benefits of the retrofit.

For the species identified in Tables 1 and 2 above, we develop estimates of changes in recreational and commercial harvests associated with the retrofit. Because these changes are derived from age-structured dynamic population models, the changes vary from year to year.

For species that are harvested both commercially and recreationally, we allocate catch across the two categories in the same proportion reflected in the 2007 National Marine Fisheries Service (NMFS) data (NMFS 2008).

5.2 The Recreational Benefits of the Retrofit Are Less than $600,000

The economics assessment proceeds by developing the estimated benefits, in dollars, associated with the changes in catch that result from the population dynamic models. Estimating recreational benefits requires a simulation of angler behavior and changes in social welfare resulting from reductions in entrainment and the associated increases in expected catch. Important factors that should be accounted for include the number and quality of substitute fishing sites, the popularity of the impacted species, and the number of trips with improved catch rates.

Random utility analysis is the accepted method for valuing IM&E reductions on recreational fishing.[15] The environmental economics literature contains numerous examples of random utility models (RUMs) for assessing recreational fishing values (Berman, Haley, and Kim 1997; Bockstael, McConnell, and Strand 1989; Breffle and Morey 2000; Chen and Cosslet 1998; Feather, Hellerstein, and Tomasi 1995; Greene, Moss, and Spreen 1997; Hauber and Parsons 2000; Jakus, Dadakas, and Fly 1998; Jakus et al. 1997; Kaoru 1995; Kaoru, Smith, and Liu 1995; Milon 1988; Morey and Waldman 1998; Parsons and Kealy 1992; Parsons and Needelman 1992; Schuhmann 1998; Train 1998; Whitehead and Haab 2000).

The RUM is based on welfare theory and posits that individuals make choices that maximize their satisfaction, subject to constraints. It uses recreators' actual choices to model the factors that influence the site a recreator chooses to visit. To the extent that the recreator trades off factors—such as distance to the site—against the quality of the recreation opportunity, the model reflects relative influence of these factors as revealed by recreators' decisions. Incorporating relevant recreation sites, the RUM can then evaluate the importance of site characteristics at each of these sites to determine the change in recreator satisfaction associated with a change in the site's features. The characteristics of each fishing site, such as fish catch rate, presence of facilities like a boat ramp, and distance to the site from the angler's home, distinguish one site from another. Anglers choose the "best" site and fish at the site with

[15] RUMs are recognized in the Department of the Interior (DOI) regulations (43 *CFR* §11.83) as an appropriate method for quantifying recreation service losses in natural resource damage claims. Currently, the RUM is the most widely used model for quantifying and valuing natural resource services. RUMs are also widely accepted in other areas of the economics profession. RUMs have been used in transportation (Beggs, Cardell, and Hausman 1981; Hensher 1991), housing (McFadden 1977), and electricity demand estimation (Cameron 1985), as well as more recently in environmental and resource economics.

the combination of characteristics that gives them the most satisfaction. The “best” site may differ for each angler, depending on the distance to the site and individual preferences for other site features. The decision to travel to a site is also affected by time and angler income.

The distance traveled to a site is one of the most important site characteristics in a RUM. It acts as a proxy for the cost to the angler of visiting the site. Using standard transportation routing software, we can calculate the distance that anglers travel not only to their chosen sites, but also to other sites that are available to anglers. In some RUMs, distance is actually converted to a cost in a two-step process. First, the same routing software can calculate the travel time associated with any route in the program. Using information on wage rates, we convert travel time to an individualized cost that varies by angler income. In some RUMs, out-of-pocket costs, such as gasoline costs and boat launch fees, are added to the travel time cost.

The focus on site characteristics, such as catch rates, allows estimating the increase in angler satisfaction that results from changes in the site’s features when all other site characteristics are held constant. The better the characteristics of a site are, the higher is the probability that an angler will choose that site, which is reflected in a higher value for the site. RUMs can be used to estimate both the distribution of trips among various sites and the total satisfaction received from a given set of fishing opportunities.

The statistical model used in estimating a RUM is the conditional logit. The conditional logit evaluates a specific outcome conditional on the available alternatives. In fishing models, the conditional logit evaluates the selection of a particular fishing site based on the characteristics of that site and the characteristics of other fishing sites. The output from the conditional logit is a set of coefficients for each site characteristic. Each coefficient reflects the importance of that site characteristic in the site-choice decision. These coefficients play a key role in the site-calibrated model used in this assessment.

Developing an original RUM requires extensive primary data. A site-calibrated transfer of an existing RUM can capture important compensating behavioral responses without requiring survey data collection and original model development. The calibrated-RUM transfer applies the entire model, including preferences and trade-offs for all of the site characteristics, to the transfer context. The accuracy of the site-calibrated RUM depends on the analyst’s ability to calibrate a previously estimated preference function to a different geographic area and angler population (Smith, van Houtven, and Pattanayak 2002).

Figure 3 contains the four-step process used in the site-calibrated RUM. The first step in our site-calibrated RUM involves identifying the best available RUM study. In this analysis, a transfer study should include a similar recreation experience to that offered by the Cape Cod area and be a high quality study.

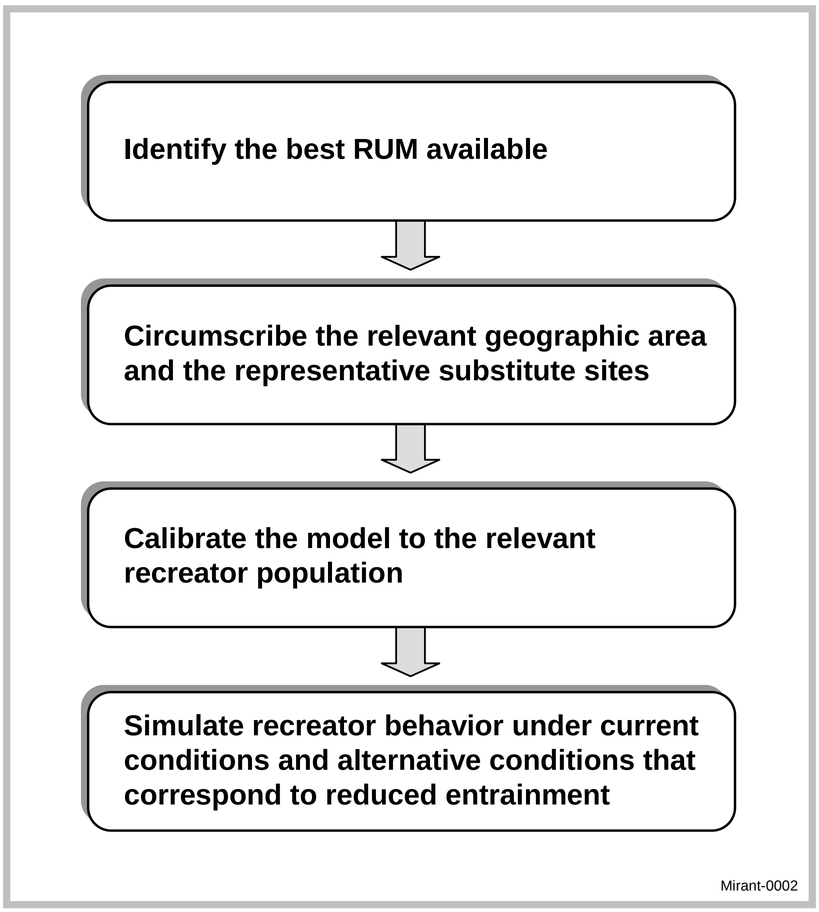

Figure 3: Steps in the Site-Calibrated RUM

The consideration of quality encompasses all aspects of a study, such as the data, the methodology, the survey protocols, and the analysis technique. The quality criterion asks whether the original study is sufficiently sound to pass scientific muster. For example, if the results were not based on reliable data, rigorous protocols, and valid analyses, then the study is not sound and should not be used.

For this assessment, we have selected a recreational fishing study conducted by Hicks et al. (1999) that meets both the similarity and quality criteria. This study covers marine recreational fishing in the northeastern United States, using data from the 1994 Marine Recreational Fisheries Statistics Survey (National Marine Fisheries Service). These data were collected on-site by interviewing anglers at the conclusion of their fishing trips, and via telephone. The EPA uses this study as the basis for its North Atlantic regional case study (2004). In terms of similarity, the marine fisheries in the Hicks et al. study contain similar species of fish that are prevalent in coastal Massachusetts waters, such as winter flounder, tautog, and Atlantic cod.

The Hicks et al. study also satisfies the quality criterion. The underlying data reflect more than 8,000 trips in the marine waters of the northeast U.S. The data are collected using established protocols consistent with survey research guidelines. The recreational fishing model developed by Hicks et al. is consistent with the RUM framework described above. The model is rigorous, performs well, and reflects results that are consistent with expectations.

The Hicks et al. (1999) model aggregates catch across groups of similar species. The recreational fish species included in this assessment are represented in the model by three variables:

- Small game fish (striped bass and bluefish through trophic transfer, Atlantic mackerel)
- Flat fish (winter flounder)
- Bottom fish (tautog, Atlantic cod, searobin).

Table 3 presents the coefficients from the Hicks et al. (1999) study.

Table 3
Coefficients in the Hicks Model

Variable	Coefficient
Travel Cost	–0.036
Big Game Catch	0.974
Small Game Catch	0.579
Bottomfish Catch	0.572
Flatfish Catch	0.665
Non-Targeted Catch	0.324

The next step in the site-calibrated RUM involves identifying the appropriate geographic scope for substitute sites and selecting a representative sample of substitute sites. We use available information on recreation in the area and typical travel distances to develop an appropriate radius for substitute sites, generally within 100 miles of the affected site (see Figure

4). Although the actual number of substitute sites can be in the hundreds, most RUMs based on original data do not include nearly that many sites. For this assessment, the selected substitute sites are Massachusetts Bay, Salem Harbor, Mount Hope Bay, Plymouth Bay, and Narragansett Bay (in Rhode Island).

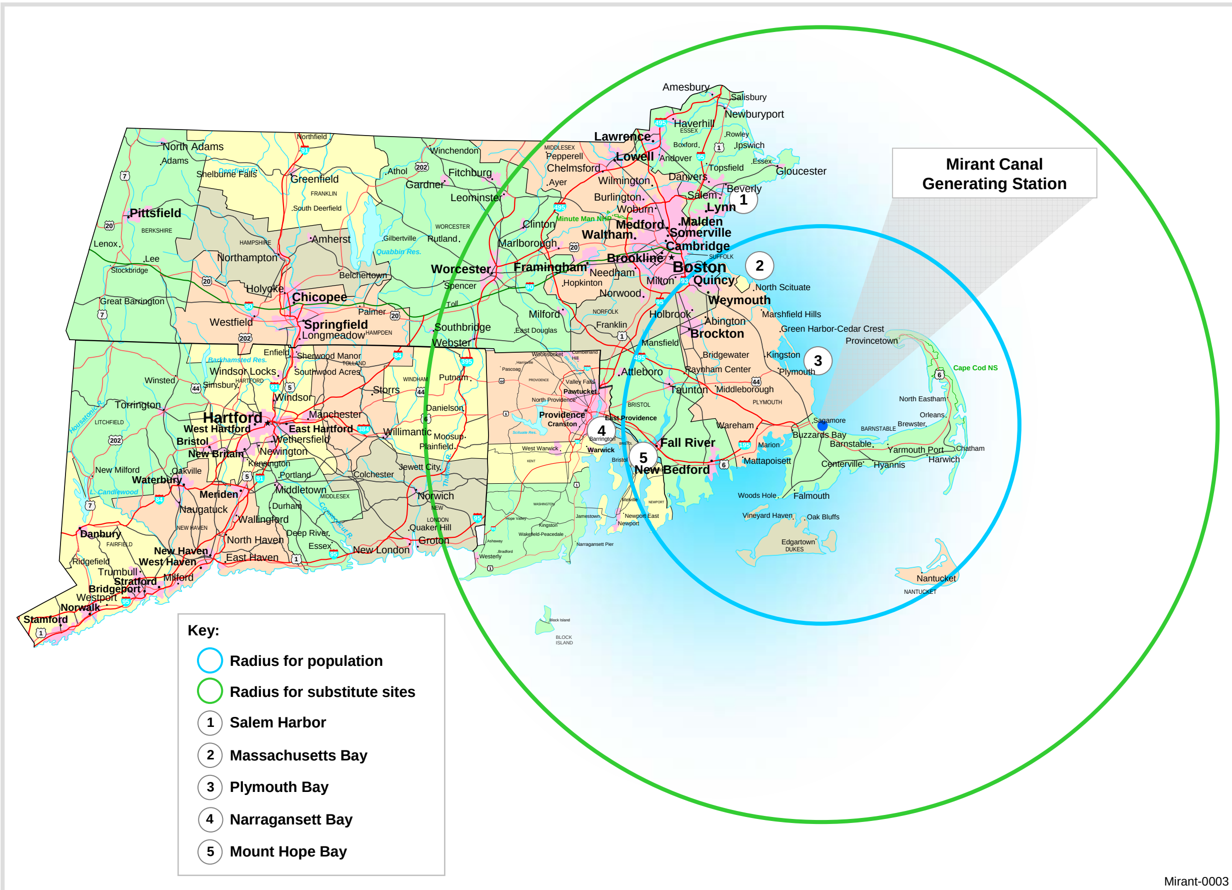

Figure 4: Affected Population and Substitute Sites
This figure shows the 50-mile radius where potentially affected anglers live, the 100-mile radius for potential substitute sites, and the substitute sites for this study.

The third step in the site-calibrated RUM is calibration to the affected population of anglers. Based on publicly available information about typical travel distances, we identify the likely users of the affected site within a 50-mile radius from the affected site. For the affected site, we fix the number of trips to correspond to the best available visitation information for the Cape Cod area. Within these constraints, the remaining trips are distributed among the substitute sites in an appropriate manner, also based on available visitation information. Trips to Cod Cape and the selected substitute sites are based on a customized compilation of the NMFS data, performed by the NMFS staff in the Fisheries Statistics Division (NMFS 2006). Our calibration reflects distances from all angler origins (zip codes) to the sites within the calibrated model.

In the fourth step, we simulate changes in trip patterns that anglers make in response to changes in catch rates for the Cape Cod area. We develop the travel cost calibration, using income information for the affected population of anglers, from the travel cost function in the original model. The RUM coefficients provide both the importance weights of the various site characteristics in determining angler site selection, as well as confidence intervals for the model. The simulation first includes the current site features and the current pattern of trips. Then, we alter the catch rate for the Cape Cod area to reflect likely changes associated with the retrofit requirement. The difference in angler welfare with and without the increased catch rates is the benefits uniquely associated with reduced entrainment at the Canal Plant.

The calibrated model evaluates whether a different pattern of trips than the current pattern maximizes angler satisfaction. Subtracting the angler satisfaction under current conditions from the higher angler satisfaction under alternative conditions provides the change in value associated with higher catch rates for anglers using Cape Cod Bay. Moreover, we calculate changes in values within an explicit Monte Carlo framework. This analysis reveals that the discounted present value over 20 years of reducing entrainment is $583,600. This estimate is based on a 3 percent discount rate, consistent with EPA guidance (2000).

5.3 The Commercial Benefits of the Retrofit Are Less than $400,000

Commercial benefits from entrainment reductions accrue primarily to commercial fishermen as increased profit attributable to the higher catch per unit effort (CPUE) associated with increases in fish populations. The ability of commercial fishermen to realize sustained increased profits depends on the responsiveness of market prices to higher CPUE. Market extremes determine the upper and lower bounds on commercial benefits. In competitive markets, prices adjust instantly and there are no benefits. In restricted markets, prices do not change and direct commercial benefits are maximized at price times quantity (P * Q). Estimating the commercial benefits of entrainment reductions involves consideration of the fishery's market conditions as well as related markets.

For purposes of this assessment, we assume that all increases in commercial catch are caught by commercial fishermen who dock in Massachusetts, without any additional fuel or labor expenses. We assume that these additional catch increases have no effect on 2007 dockside prices (NMFS 2008). Calculated in this manner, over 20 years, the discounted present value of commercial fishing benefits associated with a retrofit is $358,000.

5.4 The Costs of the Retrofit Are Wholly Disproportionate

The total benefits of reducing entrainment are estimated at less than $1.0 million.[16] According to Shaw, the capital costs of a cooling tower at the Canal Plant range from $182 million to $225 million (2009). If a retrofit were economically feasible, Mirant Corporation would likely finance the capital costs of the cooling towers. To accurately reflect the cost to Mirant Corporation of borrowing funds, we construct a company-specific weighted cost of capital. This cost of capital assumes a 50/50 debt-equity structure. The debt portion comprises a weighted average of the debts and interest rates reported in Mirant Corporation's most recent 10-Q (Mirant 2008b). The equity portion is based on the capital asset pricing model (Sharpe 1998). Sources that provide the data inputs for this model include Standard & Poors (2008), Bankrate, Inc. (2008), Nasdaq (2008), and Bloomberg (2008). The resulting cost of capital is adjusted to reflect the federal corporate tax rate (A/N Group, Inc. 2008). The capital cost is amortized over 20 years, reflecting an annual cost of $20.1 to $24.7 million. We add the annual operating and maintenance cost estimated by Shaw to the annual loan amount and discount the total at 7 percent, consistent with OMB recommendations (1992). Over 20 years, the discounted present value of the costs is $225–264 million. The ratio of costs to benefits exceeds 200-to-1.[17]

Sherman (1998) provides a summary of the judicial and regulatory decisions where a wholly disproportionate standard has been applied to compare costs with monetized benefits. His research reveals that the EPA has not defined a bright line that signifies wholly disproportionate. In addition, the EPA has a long history of both finding specific proposals wholly disproportionate as well as finding them acceptable. In the recently issued Phase III Rule, EPA promulgated national standards only for new offshore oil and gas extraction facilities, but also prepared a benefit-cost analysis of regulating additional Phase III facilities (i.e., existing

[16] Uncaught recreational fish and forage fish do not have a traditional use value and are therefore categorized as having potential nonuse value. Nonuse values are the values that people may hold for a resource independent of their use of the resource. That is, some people may gain benefit simply from knowing the resource exists—either because they want it to be available for people to use in the future or because they believe the resource has some inherent right to exist. Currently, the only methods available for estimating nonuse values are survey-based techniques that ask respondents to value, choose, rate, or rank natural resource services in a hypothetical context. In light of the limitations of current methods to accurately measure potential nonuse values, EPA (2004) recommends that nonuse values related to IM&E reductions only need to be quantified and monetized when endangered or threatened species are affected. A review of the entrainment data provided by Normandeau (2009) reveals that none of the species entrained at the Canal Plant is endangered or threatened. Accordingly, we do not quantify or monetize nonuse values in this assessment.

[17] In the absence of financing and amortization, the costs-to-benefits ratio exceeds 150-to-1, assuming that the capital costs of the retrofit are incurred in the first 2 years.

manufacturing facilities that use cooling water). In this analysis, EPA found a ratio of costs to benefits that ranged from 17-to-1 to 22-to-1 and found this to be "wholly disproportionate" (71 *Fed. Reg.* 35017).

Although a specific ratio-based standard does not exist, by any reasonable standard, the ratio of cost to benefits for retrofitting with cooling towers at the Canal Plant is dramatic. Thus, the benefits of reducing entrainment at the Canal Plant do not justify the costs of the retrofit. This conclusion, combined with the uncertainty of both the timing and outcome of the Supreme Court's decision regarding the role of benefit-cost analysis, reveals that Region 1's BTA determination is premature. A retrofit for closed-cycle cooling is an extremely expensive and lengthy undertaking. As Region 1 points out, it may reconsider BTA for the Canal Plant if the Supreme Court decides that benefit-cost analysis is permissible as part of a 316(b) determination. Despite this statement, Region 1 would have the Canal Plant commit now to an expensive and lengthy retrofit process while simultaneously admitting that the Supreme Court's future ruling may result in that commitment being unnecessary. Once funds are spent and construction is complete, the Canal Plant cannot undo the retrofit and recoup its financial loss. A more reasonable strategy is to wait for the Supreme Court's decision before requiring the Canal Plant to incur the costs associated with a cooling tower retrofit.

6. Cost-Effectiveness Analysis Is Likely to Eliminate Cooling Towers from Consideration

In its January 2007 decision, the Second Circuit Court of Appeals provides the option of using cost-effectiveness analysis to identify BTA for minimizing AEI. The role of cost-effectiveness analysis depends on whether or not a standard is in place. When a standard is in place, cost-effectiveness analysis is cost minimization, with some allowance for uncertainty. This is the type of analysis discussed in the following excerpts from *Riverkeeper II*:

> For example, assuming the EPA has determined that power plants governed by the Phase II Rule can reasonably bear the price of technology that saves between 100–105 fish, the EPA, given a choice between a technology that costs $100 to save 99–101 fish and one that costs $150 to save 100–103 fish (with all other considerations, like energy production or efficiency, being equal), could appropriately choose the cheaper technology on cost-effectiveness grounds…
>
> We … acknowledge that the comparable technologies considered by the Agency need not be identically effective for the Agency to engage in cost-effectiveness analysis. Were that the case, all that would be required would be the simple determination of which among competing technologies that achieved the same degree of reduction of adverse environmental impacts is the cheapest. Instead, the specified level of benefit is more properly understood as a narrowly bounded range, within which the EPA may permissibly choose between two (or more) technologies that produce essentially the same benefits but have markedly different costs.

As these statements indicate, consideration of technologies with lower costs and higher or lower effectiveness is warranted.

Applying cost-effectiveness analysis in this manner presumes a standard. When there is not a standard, incremental cost-effectiveness analysis is the appropriate methodology. *Riverkeeper I* describes an incremental cost-effectiveness comparison when the Court notes that "dry cooling costs more than ten times as much per year as closed-cycle wet cooling … it is estimated to reduce water intake by only an additional 5 percent relative to once-through cooling" (358 F.3d at 194-5). This decision goes on to say "it is undeniably relevant that that difference represents a relatively small improvement over closed-cycle cooling at a very significant cost" (p. 194). This is an example of using incremental cost-effectiveness analysis to choose the appropriate level of environmental protection.

Incremental cost-effectiveness analysis has an extensive history in regulation making. Its value in the current state of the 316(b) rule is that it can help analysts choose among various goals (stringency levels). Incremental cost-effectiveness analysis provides a ratio of costs to incremental reductions in pollution. The Office of Management and Budget confirms this important distinction for incremental cost-effectiveness analysis (OMB 2003).

Figure 5 provides an overview of the steps for conducting cost-effectiveness and wholly disproportionate analyses. As the figure shows, there are three main components to the evaluation, which are implemented in three successive steps. The first entails conducting a cost-effectiveness analysis of the potential IM&E reduction options available for a generating plant. Conducting the cost-effectiveness analysis involves determining the lowest-cost IM&E reduction option for each level of effectiveness. As Figure 5 shows, the results from the cost-effectiveness analysis separate the set of potential options into cost-effective and inferior options. The cost-effective options are those that produce the greatest IM&E reduction for a given cost, and the inferior options are those for which there is an alternative option that produces the same or greater IM&E reduction for lower or equal cost.

Once the cost-effectiveness analysis is complete, the second component of the evaluation entails evaluating the incremental cost effectiveness of the set of cost-effective options identified in Step 1. The incremental cost-effectiveness analysis identifies how much is gained in IM&E reduction for each additional cost increase from a previous cost-effective option. By evaluating the relationship between the incremental gains in IM&E reduction for the corresponding incremental increases in cost, the incremental cost analysis provides context for each of the cost-effective options. Once these first two steps are complete, the final component of the analysis is to evaluate the point at which the costs of an individual option are wholly disproportionate to its corresponding environmental effects.[18] This entails comparing the results of the incremental cost effectiveness across the set of cost-effective options.

[18] As used in this context, environmental effect refers to the change in biological conditions, as measured in alternative biological or non-monetized, bio-economic metrics associated with an IM&E reduction option. An example of an alternative biological metric is the increase in the steady-state population.

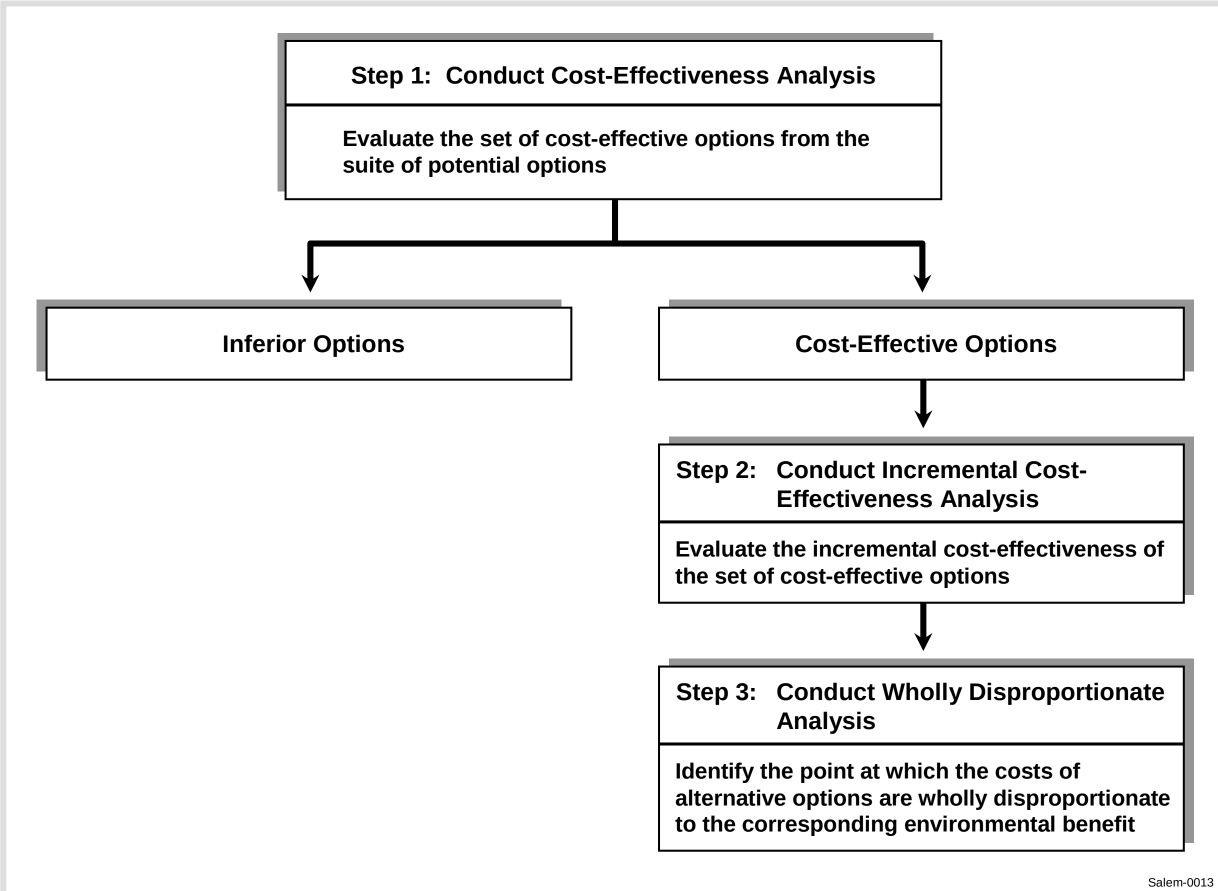

Figure 5: Overview of Cost-Effectiveness and Wholly Disproportionate Analyses

For the Canal Plant, we conducted a preliminary cost-effectiveness analysis, using available information for two technologies: 0.5mm traveling screens and closed-cycle cooling. Alden (2009) provides the costs and effectiveness for the traveling screens, and Shaw (2009) provides the costs and effectiveness for closed-cycle cooling. For purposes of this preliminary analysis, we focus on a single-year increase in the steady-state numbers of fish as the biological metric. Using this metric to evaluate effectiveness is consistent with the dynamic population models introduced in Section 5.1. Moreover, this analysis evaluates reducing entrainment at the Canal Plant based on full-flow design.

Table 4 contains the results of this preliminary cost-effectiveness analysis. The results in Table 4 show that the traveling screens would result in 201,900 additional fish. Closed-cycle cooling would result in 573,300 additional fish. Considering costs provides context for the effectiveness evaluation.

Table 4
Preliminary Cost-Effectiveness Analysis for the Canal Plant

	0.5mm Traveling Screens	Closed Cycle Cooling
Increase in the steady-state estimates of fish	201,900	573,300
Installed cost[a]	$4.4 million	$202 million
Cost per fish	$21	$355
Incremental cost per fish	N/A	$534

[a]Does not include annual operating costs

For the Canal Plant, installation of a closed-cycle cooling system is estimated to cost about $200 million more than the installation of the traveling screens would. Although the more expensive technology would result in additional fish, it costs more per fish (by well more than an order of magnitude). Now consider the incremental cost of the gains associated with closed-cycle cooling. To make this calculation, we compare the difference in the gains and the difference in the costs. This incremental gain in fish costs almost $200 million more, for an incremental cost per fish of $534. Thus, the incremental cost per fish associated with closed-cycle cooling is $534 per fish.

Due to the limited nature of this cost-effectiveness analysis, there are several caveats associated with this preliminary analysis. First, the analysis above does not include uncertainty. In particular, the estimates of effectiveness are not based on actual site conditions present at the Canal Plant, but on professional judgments from observations at other sites. Alden notes that the estimates of biological performance of the traveling screens "may not match what could ultimately be achieved at [the] Canal Plant" (2009, p. 3). Suppose that the site-specific conditions result in a higher effectiveness for the traveling screens than that predicted here. Depending on the size of the improvement, an alternative technology, such as traveling screens, may produce increases in the fish that are comparable to that of closed-cycle cooling.

In particular, this result is likely if entrainment survival for a once-through cooling system were included in the analysis. In commenting on the "Notice of Data Availability (NODA) Regarding the Proposed 316(b) Rule for Existing (Phase II) Facilities," several companies pointed out that the U.S. EPA should allow the use of data showing entrainment survival, where such data exist. For example, Electric Power Research Institute (EPRI 2003) noted that scientific data demonstrate with certainty that entrainment survival can be significant for many species, exceeding 50 percent in some cases. "Stations that have good entrainment survival data should be permitted to incorporate those data into their plan for compliance with entrainment criteria" (EPRI 2003).

Studies conducted at power plants demonstrate that organisms can survive entrainment. For example:

- During a study of entrainment at the Port Jefferson Generating Station, Long Island, New York, Ecological Analysts (1978) found that 27 percent of sand lance (post-yolk-sac larvae) and 100 percent of American eel (juveniles), fourbeard rockling (eggs), sculpin (post-yolk-sac larvae), and winter flounder (post-yolk-sac larvae) survived through-plant entrainment (Marlow pump).
- Ecological Analysts (1980) studied entrainment during 1979 at the Cayuga Generating Plant on the Wabash River, Indiana. Survival ranged from 23 to 100 percent.
- Ecological Analysts (1982) studied entrainment during 1980 at the Indian Point Generating Station on the Hudson River, New York. Survival ranged from 5 to 97 percent.
- Lawler, Matusky & Skelly (1985) studied entrainment during 1984 at the Quad Cities Station near Cordova, Illinois. Survival ranged from 0 to 100 percent.
- Mayhew et al. (2000) compared entrainment survival studies for several power plants in estuarine environments: Bowline Point, Calvert Cliffs, Danskammer Point, Indian Point, Lovett, Pittsburg, and Roseton. Survival ranged from 3 to 100 percent.

Most relevant for this analysis is the Lawler, Matusky & Skelly (1999) study of entrainment during 1997–1998 at the Brayton Point Power Plant in Somerset, Massachusetts. Table 5 summarizes the study's estimates of entrainment survival for the dominant organisms collected at Brayton Point. For several of the species, survival estimates exceed 50 percent.

Table 5
Estimates of Entrainment Survival at the Brayton Point Power Plant, 1997–1998

Species (All Post-Yolk-Sac Larvae)	Percent Survival at Intake	Percent Survival at Discharge
American sand lance	0.13 to 0.15	0.41 to 7.69
Atlantic cod	—	50.0 to 56.25
Atlantic herring	—	0
Atlantic silverside	52.57 to 59.19	49.45 to 56.88
Bay anchovy	0	0.03 to 0.04
Butterfish	—	23.08
Clupeid	0 to 3.33	0 to 3.33
Cunner	—	0
Fourbeard rockling	—	6.25
Northern pipefish	—	35.71 to 42.86
Rainbow smelt	0	0 to 6.54
Rock gunnel	—	24.56 to 38.60
Sculpins	24.52 to 33.97	42.64 to 58.29
Seaboard goby	4.61 to 5.14	1.02 to 1.44
Tautog	4.35	4.24 to 4.38
Windowpane flounder	43.86 to 45.61	28.57 to 30.36
Winter flounder	31.56 to 32.08	23.81 to 38.16
Unidentified	72.82 to 83.67	51.64 to 70.18

In terms of the site-specific conditions at the Canal Plant, Normandeau (2009) estimates entrainment survival of some fish eggs and larvae that are entrained at the Canal Plant. For example, nearly half of the cunner larvae and more than one-third of the cunner eggs are predicted to survive entrainment in a once-through cooling system. However, such survival is not applicable to a closed-cycle system. Given the numerical dominance of the cunner eggs and larvae, including survival entrainment in the analysis of effectiveness will increase the steady-state estimates of gains for the traveling screens without a corresponding increase in the gains associated with closed-cycle cooling. Preliminary estimates indicate that recognizing the entrainment survival of cunner could increase effectiveness by more than an additional 100,000 fish.

This and similar changes could cause the effectiveness of the traveling screens to be essentially the same as the effectiveness of closed-cycle cooling. In this case, the difference in the effectiveness of the two technologies may be *de minimis*. The potential outcome shows how, in contrast to Region 1's hypothetical thought experiment (p. 2-51 of the Kendall Response to Comments), the results of an appropriate cost-effectiveness analysis may well affect the permit conditions. For this reason, a thorough cost-effectiveness analysis should be conducted for the Canal Plant.

A second caveat to this analysis is that the preliminary analysis only considers two technologies. There may be other technologies that should be considered at the Canal Plant. Suppose that there is an additional technology that provides essentially the same level of effectiveness as does closed-cycle cooling. Indeed, Region 1 suggests this possibility in its draft permit by not requiring closed-cycle cooling *per se*, but allowing a technology that provides the same level of effectiveness. If this alternative technology costs less than closed-cycle cooling does, then closed-cycle cooling would not be cost effective.

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Appendix

Canal - Cooling Tower

Valuation

Period Ending			31-Dec-12	31-Dec-13	31-Dec-14	31-Dec-15	31-Dec-16	31-Dec-17	31-Dec-18	31-Dec-19	31-Dec-20	31-Dec-21	31-Dec-22	31-Dec-23	31-Dec-24	31-Dec-25
Year			2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

Valuation

	NPV															
Revenue																
Energy Revenue **[Redacted]**	523,207	[$000s]														
Capacity Revenue **[Redacted]**	399,676	[$000s]														
Total Revenue	922,883	[$000s]	-	73,051	76,226	84,353	70,615	74,965	88,399	96,759	105,320	107,542	109,812	112,131	114,501	116,922
Costs of Production																
Fuel Cost **[Redacted]**	315,294	[$000s]														
Start-Up Costs **[Redacted]**	15,187	[$000s]														
Net Emissions Cost **[Redacted]**	46,999	[$000s]														
Total Costs of Production	377,479	[$000s]	-	29,475	29,022	32,553	24,017	25,443	35,619	38,858	45,862	46,774	47,704	48,652	49,619	50,605
Gross Margin	545,404	[$000s]	-	43,577	47,204	51,800	46,598	49,522	52,780	57,902	59,458	60,768	62,108	63,479	64,882	66,317
Total Operating Costs	486,390	[$000s]	-	42,489	43,551	44,640	45,756	46,900	48,072	49,274	50,506	51,769	53,063	54,390	55,749	57,143
Operating Cash Flow	59,014	[$000s]	-	1,088	3,652	7,160	842	2,623	4,708	8,627	8,951	8,999	9,045	9,090	9,133	9,174
Capital Costs																
Construction Capital	220,763	[$000s]	220,763	-	-	-	-	-	-	-	-	-	-	-	-	-
Ongoing Capital	38,855	[$000s]	-	3,394	3,479	3,566	3,655	3,747	3,840	3,936	4,035	4,136	4,239	4,345	4,454	4,565
Total Capital Costs	259,618	[$000s]	220,763	3,394	3,479	3,566	3,655	3,747	3,840	3,936	4,035	4,136	4,239	4,345	4,454	4,565
Pre Tax Cash Flow	(200,604)	[$000s]	(220,763)	(2,307)	173	3,594	(2,813)	(1,124)	868	4,691	4,917	4,864	4,806	4,745	4,679	4,609
Tax Paid	3,671	[$000s]	3,671	-	-	-	-	-	-	-	-	-	-	-	-	-
After Tax Cash Flow	(204,276)	[$000s]	(224,434)	(2,307)	173	3,594	(2,813)	(1,124)	868	4,691	4,917	4,864	4,806	4,745	4,679	4,609

31-Dec-26 2026	31-Dec-27 2027	31-Dec-28 2028	31-Dec-29 2029	31-Dec-30 2030	31-Dec-31 2031	31-Dec-32 2032	31-Dec-33 2033	31-Dec-34 2034	31-Dec-35 2035	31-Dec-36 2036	31-Dec-37 2037	31-Dec-38 2038	31-Dec-39 2039	31-Dec-40 2040	31-Dec-41 2041	31-Dec-42 2042	31-Dec-43 2043	31-Dec-44 2044	31-Dec-45 2045
																	-	-	-
																	-	-	-
119,395	121,923	124,506	127,145	129,841	132,596	135,411	138,288	141,227	144,231	147,301	148,851	150,446	152,087	153,775	155,512	157,298	-	-	-
																	-	-	-
																	-	-	-
																	-	-	-
51,611	52,636	53,683	54,750	55,838	56,947	58,079	59,234	60,411	61,612	62,836	62,522	62,209	61,898	61,589	61,281	60,974	-	-	-
67,785	69,287	70,823	72,395	74,003	75,649	77,332	79,054	80,817	82,620	84,465	86,329	88,237	90,189	92,187	94,231	96,323	-	-	-
58,572	60,036	61,537	63,075	64,652	66,268	67,925	69,623	71,364	73,148	74,977	76,851	78,772	80,742	82,760	84,829	86,950	-	-	-
9,213	9,251	9,286	9,320	9,351	9,380	9,407	9,431	9,453	9,472	9,488	9,478	9,464	9,447	9,427	9,402	9,373	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4,679	4,796	4,916	5,039	5,165	5,294	5,426	5,562	5,701	5,843	5,989	6,139	6,293	6,450	6,611	6,777	6,946	-	-	-
4,679	4,796	4,916	5,039	5,165	5,294	5,426	5,562	5,701	5,843	5,989	6,139	6,293	6,450	6,611	6,777	6,946	-	-	-
4,534	4,455	4,370	4,281	4,186	4,086	3,981	3,869	3,752	3,628	3,499	3,339	3,172	2,997	2,815	2,625	2,427	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4,534	4,455	4,370	4,281	4,186	4,086	3,981	3,869	3,752	3,628	3,499	3,339	3,172	2,997	2,815	2,625	2,427	-	-	-

Exhibit 13

January 6, 2009

Mirant Canal Generating Station
Closed-cycle Cooling and the Alden 2003 Report

There is some discussion as to the appropriateness of the United States Environmental Protection Agency Region 1 (EPA) use of the 2003 Alden Report as the basis for requiring closed-cycle cooling at the Mirant Canal Station. Alden would like to clarify our position on the cost estimates provided for this option.

In 2003, Mirant Canal, L.L.C. (Mirant Canal) requested that Alden Research Laboratory, Inc. (Alden) provide services necessary to respond to the EPA's Request for Supplemental Information, dated April 30, 2003, relative to the Section 316(b) permitting of the Mirant Canal Station. Alden was to identify advances in fish protection technologies that may provide effective fish protection at the cooling water intake structures (CWIS) and select alternatives that were applicable to the Mirant Canal Station. To put alternative technology costs in perspective, Alden included flow reduction options that included closed-cycle cooling, which is technically not an intake technology, per se.

The Alden 2003 report provided only a conceptual analysis of closed–cycle cooling based on a generic EPRI cost model. As stated in the Alden 2003 report:

> *…An evaluation of cooling tower costs for retrofitting existing power stations was provided in EPRI's report entitled "Cooling System Retrofit Costs Analysis" prepared in July of 2002. This report was prepared in response to the proposed EPA Rulemaking. This study was conducted to provide generalized methods and supporting data for estimating the cost of retrofitting existing plants with re-circulating systems (EPRI 2002).*
>
> *The EPRI 2002 report developed the likely costs for "all cooling towers." To develop these costs, three assumptions were made:*
>
> 1. *The addition of a cooling tower would connect to the existing condenser so circulating water rates would not change.*
> 2. *Portions of the existing condenser conduit systems can be used, even though some modifications may be required.*
> 3. *The cost methodology is based on new facilities and must be adjusted using multiplying factors to determine the cost of retrofitting an existing facility.*
>
> *Using these assumptions, the costs were broken down into easy, average, and difficult retrofitting costs. These three cost levels are based mainly on site-specific factors (EPRI 2002).*

There are a number of site-specific factors that the EPRI 2002 generalized cost methodology cannot accurately estimate for the unique conditions at Canal, such as:

- Geotechnical site conditions (this impacts the foundation design)
- Salt drift
- Plume abatement
- Noise abatement
- Existing condenser design and limitations or modifications required for retrofit
- Waste water treatment
- Navigation impacts
- Traffic impacts
- Permitting

These site-specific factors will impact ability for retrofit and the overall retrofit costs. These issues need to be studied in greater detail to determine an accurate site-specific cost for closed-cycle cooling retrofit at Canal Station. In addition, the EPRI 2002 closed-cycle cooling cost model is outdated and is currently being updated by EPRI.

The Alden 2003 report estimated costs for several alternatives that were deemed to be commercially available, practicable "from an engineering stand-point," and potentially biologically effective. Alden did not perform an analysis of Canal Station's ability to afford closed-cycle cooling; therefore, we did not and could not determine if closed-cycle cooling was economically practicable.

In addition to the preliminary nature of the closed-cycle cooling option evaluated in the Alden (2003) report, there have been several changes to the status of other intake technologies that have occurred since that report was written. As such, the Alden (2003) report is outdated and does not reflect the current operating conditions of Canal Station, current installation costs, or current energy costs. These costs have increased substantially since 2003.

In summary, the Alden Report was a response to requests for information on advances in fish protection technologies and did not include a site-specific detailed cost estimate of closed-cycle cooling. Although detailed conceptual designs and costs were developed for intake technologies that would be potentially applicable at Mirant Canal Station, the same was not true for the closed-cycle cooling design or costs.

Exhibit 14

Using Benefit-Cost, Cost-Effectiveness, and Wholly Disproportionate Analyses to Evaluate and Compare Alternative IM&E Reduction Options:

Technical Overview

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1. Introduction

In addition to benefit-cost analysis, cost-effectiveness and wholly disproportionate analyses provide a means of reviewing and comparing the implications of implementing alternative impingement mortality and entrainment (IM&E) reduction options. Given the current regulatory uncertainty associated with estimating the economic benefits of alternative IM&E reduction options, cost-effectiveness and wholly disproportionate analyses provide the ability to compare the costs of IM&E reduction options to the predicted environmental effect of such reductions.[1] This technical overview describes how estimating and comparing the costs, benefits, and environmental effects of alternative IM&E reduction options within the context of benefit-cost, cost-effectiveness, and wholly disproportionate analyses can be used to inform and support a best professional judgment (BPJ) evaluation of the best technology available (BTA) for minimizing adverse environmental impact (AEI) associated with a generating station's IM&E.

This document presents the methods for conducting cost-effectiveness and wholly disproportionate analyses and provides illustrative examples of their implementation. The document begins with a brief description of cost-effectiveness and wholly disproportionate analyses and their use and relevance in the current and historic implementation and development of Section 316(b) of the Clean Water Act. It then presents an overview and illustrative example of the methods and corresponding results of evaluating cost effectiveness and wholly disproportionate costs. The document concludes by illustrating how the results of benefit-cost analysis can be used in conjunction with cost-effectiveness analysis to illustrate the relative results and implications of each analysis.

1.1 Relevant Regulatory Background

In its January 2007 decision, the Second Circuit Court of Appeals provides the option of using cost-effectiveness analysis to identify the BTA for minimizing AEI. The role of cost-effectiveness analysis depends on whether or not a standard is in place. When a standard is in place, cost-effectiveness analysis is cost minimization with some allowance for uncertainty. This type of analysis is discussed in the following excerpts from Riverkeeper II:

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[1] By environmental effect, we mean the change in biological conditions, as measured in alternative biological or non-monetized, bio-economic metrics that are associated with, and provide context for, evaluating the relative impact of the varying IM&E reductions associated with each IM&E reduction option. Examples of alternative biological metrics include number of impinged and entrained organisms, biomass, equivalent adults, equivalent adult biomass, and increase in the number of fish (age-1 and older) projected to occur under steady state conditions. Examples of non-monetized, bio-economic metrics include increases in recreational and commercial catch. As used here, the term "environmental effect" does not encompass the change in other environmental conditions (e.g., increases in air emissions, noise, habitat displacement, fogging and icing, etc.) that are associated with some IM&E control technologies.

> For example, assuming the EPA has determined that power plants governed by the Phase II Rule can reasonably bear the price of technology that saves between 100–105 fish, the EPA, given a choice between a technology that costs $100 to save 99–101 fish and one that costs $150 to save 100–103 fish (with all other considerations, like energy production or efficiency, being equal), could appropriately choose the cheaper technology on cost-effectiveness grounds…
>
> We…acknowledge that the comparable technologies considered by the Agency need not be identically effective for the Agency to engage in cost-effectiveness analysis. Were that the case, all that would be required would be the simple determination of which among competing technologies that achieved the same degree of reduction of adverse environmental impacts is the cheapest. Instead, the specified level of benefit is more properly understood as a narrowly bounded range, within which the EPA may permissibly choose between two (or more) technologies that produce essentially the same benefits but have markedly different costs.

Applying cost-effectiveness analysis in this manner presumes the existence of a standard. When there is not a standard, incremental cost-effectiveness analysis is the appropriate methodology. Riverkeeper I describes an incremental cost-effectiveness comparison when the Court notes that while “dry cooling costs more than ten times as much per year as closed-cycle wet cooling…it is estimated to reduce water intake by only an additional 5 percent relative to once-through cooling” (358 F.3d at 194-5). This decision goes on to say “it is undeniably relevant that that difference represents a relatively small improvement over closed-cycle cooling at a very significant cost” (p. 194). This is an example of using incremental cost-effectiveness analysis to choose the appropriate level of environmental protection.

Incremental cost-effectiveness analysis has an extensive history in regulation making. Its value in the current state of the 316(b) rule is that it can help analysts choose among various goals (stringency levels). Incremental cost-effectiveness analysis provides a ratio of costs to incremental reductions in pollution. The Office of Management and Budget confirms this important distinction for incremental cost effectiveness (OMB 2003). The next section provides an overview of incremental cost-effectiveness analysis and how it can be used to conduct a wholly disproportionate test across alternative IM&E reduction options.

1.2 Analysis Overview

Figure 1.1 provides an overview of the steps for conducting cost-effectiveness and wholly disproportionate analyses. As the figure shows, there are three main components to the evaluation, which are implemented in three successive steps. The first entails conducting a cost-effectiveness analysis of all the potential IM&E reduction options available for a generating station. Conducting the cost-effectiveness analysis involves determining the lowest-cost IM&E reduction option for each level of effectiveness. As Figure 1.1 shows, the results from the cost-effectiveness analysis separate the set of potential options into cost-effective and inferior options. The cost-effective options are those that produce the greatest IM&E reduction for a given cost, and the inferior options are those for which there is an alternative option that produces the same or greater IM&E reduction for lower or equal cost.

Once the cost-effectiveness analysis is complete, the second component of the evaluation entails evaluating the incremental cost effectiveness of the set of cost-effective options identified in Step 1. The incremental cost-effectiveness analysis identifies how much is gained in IM&E reduction for each additional, incremental cost increase from a previous cost-effective option. By evaluating the relationship between the incremental gains in IM&E reduction for the corresponding incremental increases in cost, the incremental cost analysis provides context for each of the cost-effective options. Once these first two steps are complete, the final component of the analysis is to evaluate the point at which the costs of an individual option are wholly disproportionate to their corresponding environmental effects. This entails comparing the results of the incremental cost effectiveness across the set of cost-effective options.

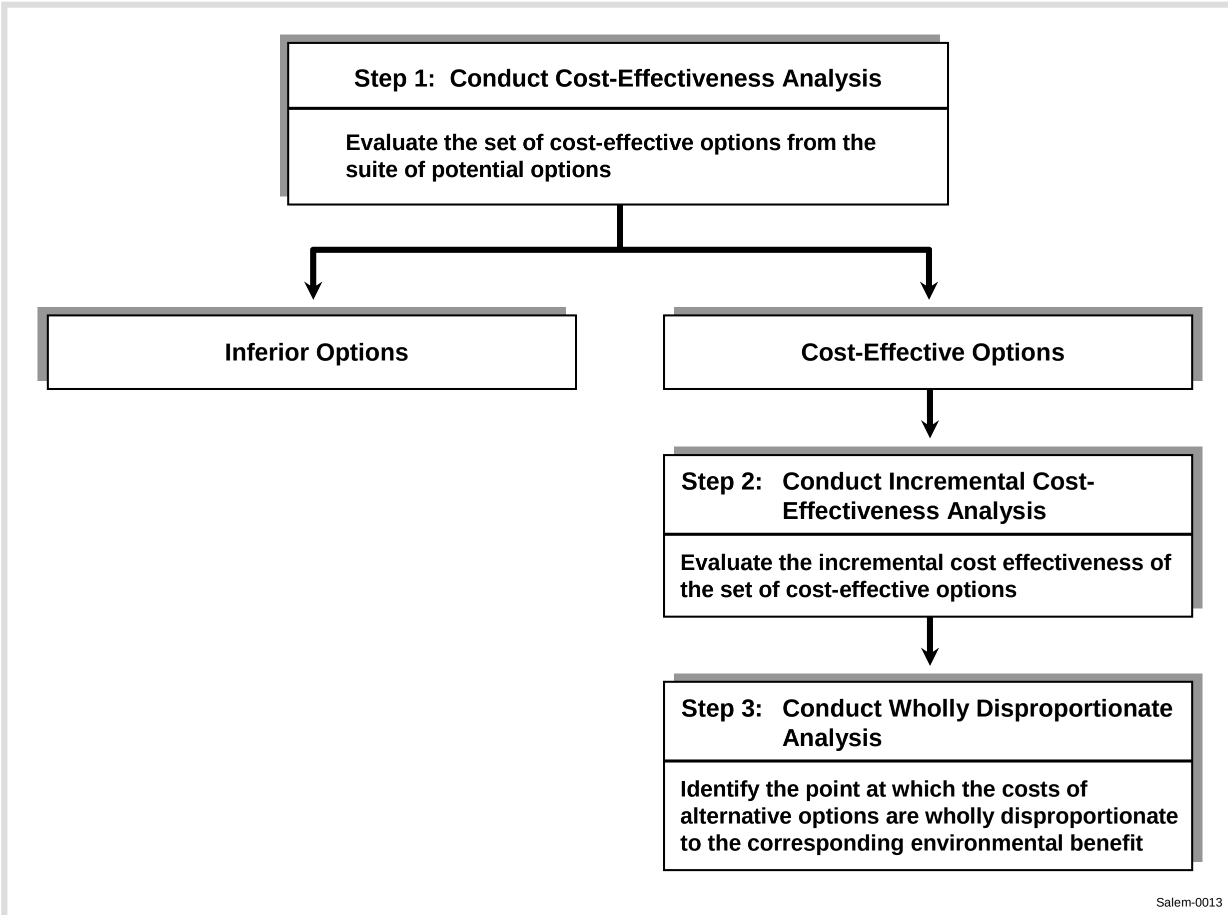

Figure 1.1: Overview of Cost-Effectiveness and Wholly Disproportionate Analyses

Figure 1.2 provides an illustrative example of the cost-effectiveness and wholly disproportionate components summarized in Figure 1.1. All of the economic and biological estimates presented herein were selected by Veritas solely for purposes of illustration and do not represent estimates of actual cost or performance at any specific facility. Specifically, the figure presents an illustrative example of the results of a cost-effectiveness and wholly disproportionate analysis of nine alternative IM&E reductions at a hypothetical plant. These nine options, which vary in their design, costs, and effectiveness, include the following:

1. Barrier Net
2. Fish Return
3. Variable Frequency Drives (VFDs)
4. Fine Mesh Screens with Ristroph and a Fish Return
5. Aquatic Filter Barrier
6. Wedgewire Screens (2mm)
7. Wedgewire Screens (0.5mm)
8. Cooling Tower: Natural Draft
9. Cooling Tower: Mechanical Draft

The top panel of Figure 1.2 illustrates the results of a cost-effectiveness analysis that determines which of an illustrative plant's potential IM&E reduction options are cost-effective and which are inferior options. The horizontal axis measures the effectiveness of each option, here measured by the change in the steady state estimate, and the vertical axis measures the corresponding cost of each option.[2]

[2] One point to note is that while the example presents the metric of increase in the number of fish (age-1 and older) projected to occur under steady state conditions (which we will refer to as the "steady state estimate"),as a means of quantifying the environmental effect of each IM&E reduction option, the analysis provides the ability to evaluate the environmental effects across varying metrics. Evaluating alternative metrics allows for examining the consistency of the cost-effectiveness results and the implications of using varying levels of rigor and sophistication. As previously noted, various metrics include both biological and non-monetized, bio-economic metrics. Biological metrics include examples such as biomass, equivalent adults (EA), and increase in the steady state estimate. Increases in biomass are the simplest of the metrics, which estimates the biomass of the organisms that would remain in the source waterbody as a result of the IM&E reductions associated with each technology. Increase in equivalent adults (EA) is a more complex metric, estimating how many equivalent adults would result from the IM&E reductions associated with each technology. Measuring the increase in the number of fish under steady state conditions is the most complex of these metrics because it estimates how the population changes dynamically as a result of IM&E reductions associated with each technology. In addition, biomass and EA represent static estimates associated with a one-year reduction in IM&E, yet the costs and life cycle of the potential IM&E reduction options are long-lived. To account for this, the population metric typically evaluates the results of IM&E reduction holding all else constant, such as the fecundity of equivalent adult females and the natural, commercial, and recreational mortality of each species. As a result, this estimate can also inform the additional bio-economic metrics of increases in recreational and commercial catch.

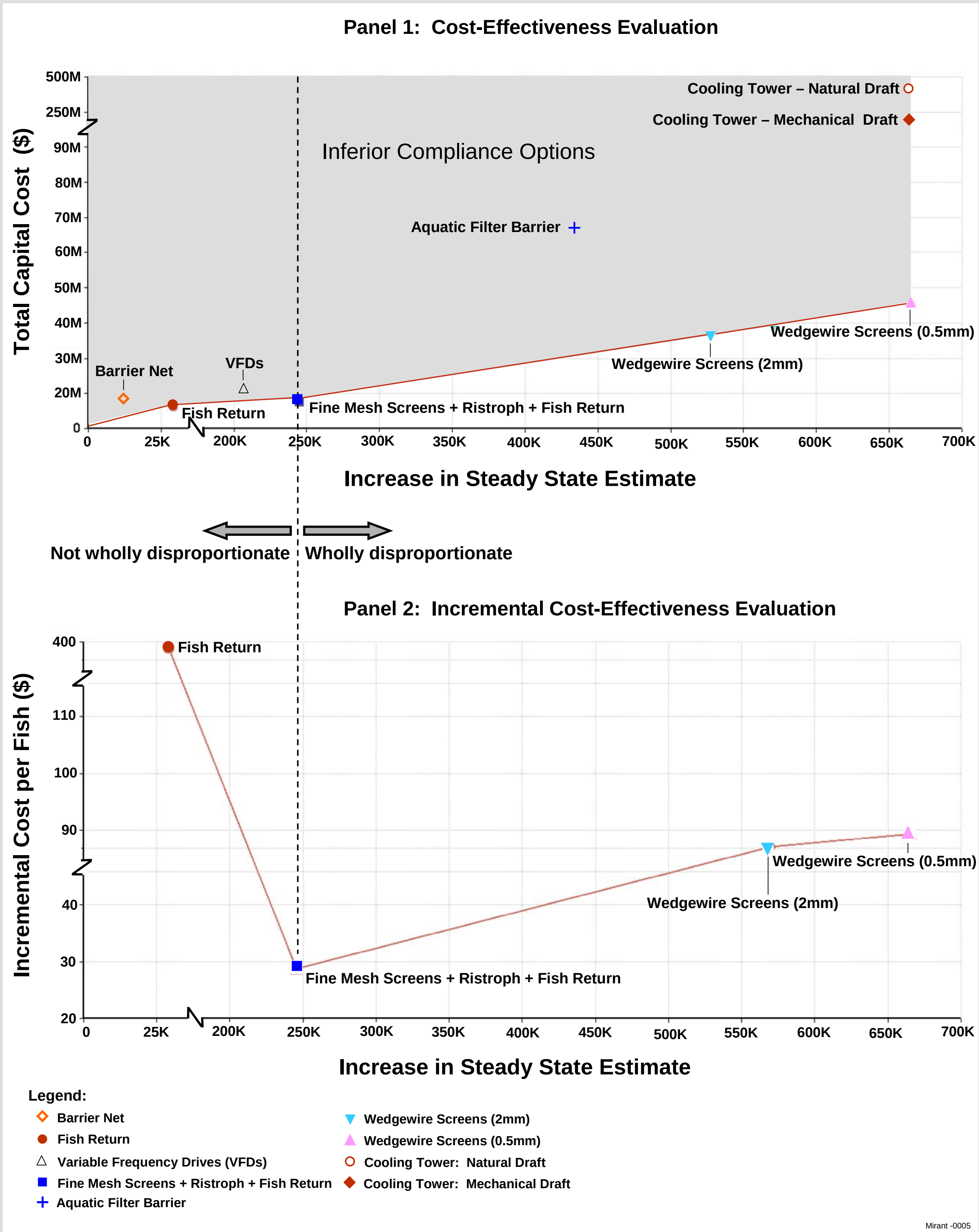

Figure 1.2: Illustrative Example of the Results of Cost-Effectiveness and Wholly Disproportionate Analyses of Alternative IM&E Reduction Options

The curve in Panel 1 creates the envelope of cost-effective options and also identifies the space of inferior solutions, the shaded area above and to the left of the cost-effectiveness curve. Any IM&E reduction option lying within the shaded area represents an inferior option, relative to the options lying along the curve. Specifically, for each of the IM&E reduction options lying within the shaded area, there is an equal or lower-cost option that produces a greater or equal environmental effect. For example, installing the aquatic filter barrier option, which is located within the shaded area, will increase the steady state estimate by about 430,000 fish for a capital cost of $65 million. In contrast, the 2mm wedgewire screens option, located along the curve, will provide an estimated increase of about 525,000 fish at a capital cost of $37 million.

While Panel 1 illustrates relative cost effectiveness across alternative options, the individual options must be compared incrementally to evaluate whether their costs are wholly disproportionate to their corresponding environmental effect. This is because the cost-effectiveness portion of the evaluation determines only those options that reduce IM&E at a particular level for the lowest cost. It does not provide any insight into whether reductions at that level justify the incremental increase in cost. This is the role of the wholly disproportionate analysis, which is implemented through the use of incremental cost-effectiveness analysis (Steps 2 and 3 of Figure 1.1).

The second panel in Figure 1.2 contains the results of the wholly disproportionate analysis, which plots the incremental increase in cost against the incremental increase in the steady state estimate. As Panel 2 shows, the wholly disproportionate analysis is only performed on the set of cost-effective options in Panel 1 because the inferior options can be replaced with equal or lower-cost options that generate equal or greater environmental effects. In Panel 2, the wholly disproportionate analysis compares the incremental increase in the steady state estimate (labeled on the horizontal axis) to the corresponding incremental increase in cost (labeled on the vertical axis). For example, comparing the fish return option to fine mesh screens with Ristroph and a fish return option shows that for the additional $6 million spent on adding fine mesh screens and a Ristroph system to the fish return, the corresponding incremental increase in the environmental effect is approximately 213,000 fish. This results in a decrease from approximately $370 per fish for the fish return to approximately $28 per fish for the combination of fine mesh screens with Ristroph and a fish return.

As the graph shows, the incremental cost per fish decreases from the fish return option to the fine mesh screens with Ristroph and a fish return option and then begins to increase for each corresponding option. It is at the bottom point of the incremental cost-effectiveness curve that the costs become wholly disproportionate to the corresponding environmental benefit. The results of this illustrative analysis show that while a fish return, fine mesh screens with Ristroph and a fish return, 2mm wedgewire screens, and 0.5mm wedgewire screens are more cost-effective than other means of achieving IM/E reductions, the costs of the two wedgewire screen options are wholly disproportionate to their environmental effects.

Specifically, Panel 2 shows that the incremental cost per fish is $370 for installing a fish return, decreases to $28 per fish for the combination of fine mesh screens with Ristroph and a fish return, and then rises to $74 per fish for 2mm wedgewire screens, and $81 per fish for 0.5mm wedgewire screens. Table 1.1 summarizes these results. It is the point at which the incremental cost curve starts to rise that costs are wholly disproportionate to the corresponding environmental benefits, indicated by the dotted line in Figure 1.2 and the red line in Table 1.1.

Table 1.1
Summary of Incremental Cost per Fish for Increases in the Steady State Estimate

Technology	Total Cost	Incremental Cost	Maximum Change in Steady State Estimate	Incremental Change in Steady State Estimate	Incremental Cost per Fish
Fish return	$10,000,000	$10,000,000	27,000	27,000	$370
Fine mesh screens with Ristroph and a fish return	$16,000,000	$6,000,000	240,000	213,000	$28
Wedgewire screens (2mm)	$37,000,000	$21,000,000	525,000	285,000	$74
Wedgewire screens (0.5mm)	$48,000,000	$11,000,000	660,000	135,000	$81

One additional point to note with this example is that it does not describe the implications of evaluating the range of IM&E reductions by technology nor how those reduction ranges vary by species across technologies. For example, results of technology effectiveness evaluations have shown that effectiveness estimates not only vary within and across technologies but also vary by species for a specific technology (Alden 2009). Examining the intersection of performance variation and alternative evaluation metrics may alter the set of inferior, cost-effective, and wholly disproportionate options.

1.3 Integrating Benefit-Cost and Cost-Effectiveness Comparisons

Although cost-effectiveness and wholly disproportionate analyses provide a means of evaluating and comparing alternatives, they also lead to the identification of an individual option whose costs are not wholly disproportionate to the corresponding environmental effects. This does not mean that the corresponding economic benefits of this option exceed the costs. Benefit-cost analysis gives context to the results of cost-effectiveness and wholly disproportionate analyses.

Figures 1.3 and 1.4 provide an illustrative example of estimating and comparing the benefits and costs associated with each of the options illustrated in Figure 1.2. In addition, to provide context for the results of the cost-effectiveness analysis presented in Figure 1.2, Figures 1.3 and 1.4 present and compare the costs of each option to its corresponding environmental effect. The vertical axis on the left side of Figure 1.3 depicts the annual costs and benefits of each option, measured in dollars, and the vertical axis on the right side illustrates the corresponding environmental effect, measured in annual increase in the steady state estimate. The annual cost of the IM&E reduction option is represented by the red bars on the left of each option. The annual economic benefits are represented by the black bars in the middle of each option, and the increase in the steady state estimate is represented by the blue bars on the right of each option. Comparing the height of the red bars in Figure 1.3 to the height of the black bars reveals that costs exceed economic benefits many times over for every IM&E reduction option.

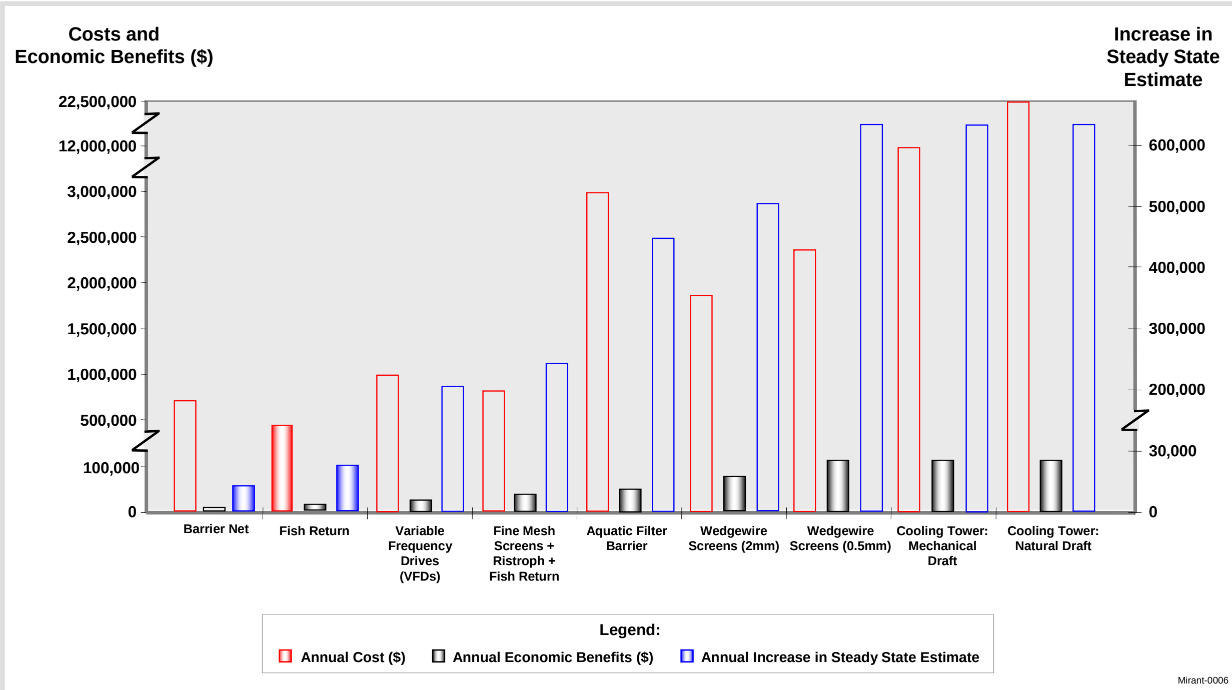

Figure 1.3 Costs, Benefits, and Increase in Steady State Estimate

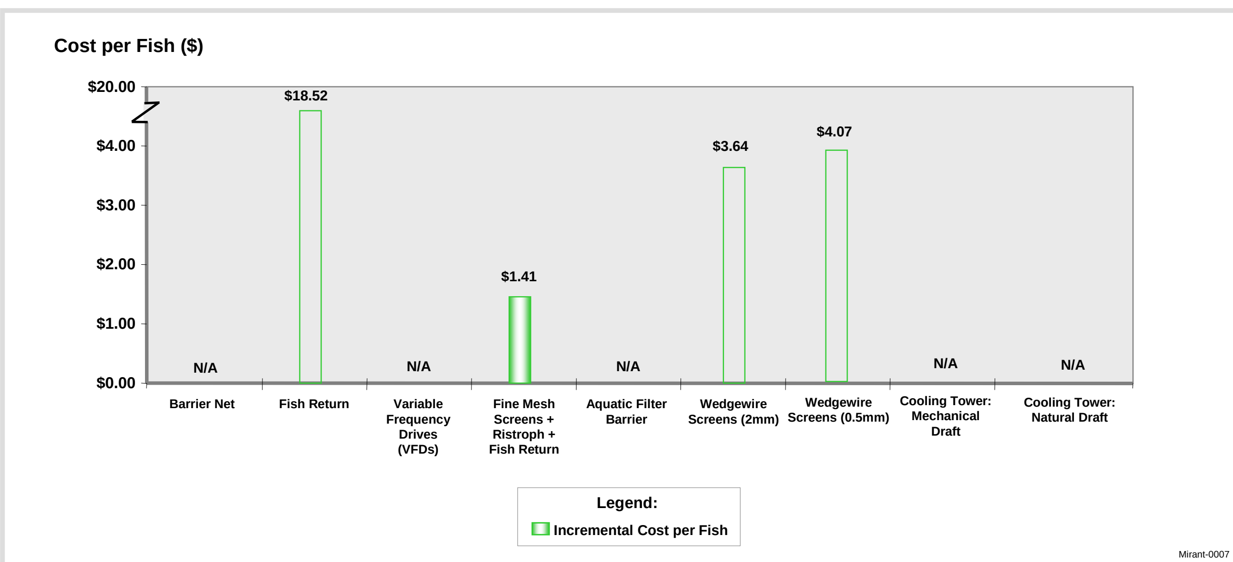

Figure 1.4 Incremental Cost per Fish

To compare the corresponding environmental effect for each option, Figure 1.3 displays the IM&E reduction options in order of increase in the steady state estimate. Barrier Net is on the left in Figure 1.3 because it provides the smallest increase in the steady state estimate for the IM&E reductions shown in this example. Installing 0.5mm wedgewire screens or cooling towers are on the right in Figure 1.3 because each has the highest increase in the steady state estimate, compared to all of the other options. Specifically, the IM&E reductions associated with 0.5mm wedgewire screens and both types of cooling towers are estimated to yield more than 650,000 fish per year. The natural draft cooling tower is at the far right of this figure because it is the most expensive.

Ordering the options in this manner illustrates the variation in both the costs and effectiveness across options. For example, the costs of installing an aquatic filter barrier are over $3 million per year versus approximately $2 million per year for 2mm wedgewire screens. However, the 2mm wedgewire screens option results in nearly 525,000 fish per year while the aquatic filter barrier option results in approximately 440,000 fish per year.

Ordering the options in this manner also illustrates the relationship between the incremental costs of the various IM&E reduction options and the corresponding incremental environmental effect of each option. For example, comparing the 0.5mm wedgewire screens to the next option in Figure 1.3, a mechanical draft cooling tower, shows that while the cooling tower has an incremental cost of nearly $10 million annually over the wedgewire screens, it does not produce more fish than the wedgewire screens: both produce approximately 660,000 fish. This incremental comparison of costs and corresponding increase in the steady state estimate illustrates the relative effect of each option.

To quantitatively compare each option, the analysis includes an incremental cost comparison, which evaluates the relationship between the incremental costs of the various IM&E reduction options and the corresponding incremental environmental effect of each option. The incremental cost analysis takes place in two parts. The information in Figure 1.3 contains sufficient information to illustrate the first part by comparing the annual costs, depicted by the red bars, to the annual increase in the steady state estimate, depicted by the blue bars. Starting at the left side of Figure 1.3 and progressing right, we identify the first IM&E reduction option that generates the largest increase in the steady state estimate at the least cost, which is the fish return. The barrier net option to the left of the fish return produces a lower increase in the steady state estimate, but at a higher cost. Therefore, it is not relevant for calculating incremental cost per fish because the fish return is a lower-cost option that produces a greater increase in the steady state estimate.

The analysis proceeds by comparing the options in Figure 1.3 and identifying those options that produce an increase in the steady state estimate for an equal or lower cost than either a previous or subsequent option. Through this sequential comparison process, three additional options are identified as relevant for calculating the incremental cost per fish: the fine mesh traveling screens with a Ristroph system and a fish return, 2mm wedgewire screens, and 0.5mm wedgewire screens. These four options offer successively larger increases in the steady state estimate for a lower cost than a previous or subsequent alternative. (Although 0.5mm wedgewire screens are more expensive than 2mm wedgewire screens, they produce a greater increase in the steady state estimate. In addition, the two subsequent cooling tower options produced the same increase in the steady state estimate, but at higher cost).

Figure 1.4 summarizes the result of this comparison and the corresponding calculation of the incremental cost per fish. The horizontal axis contains the same set and ordering of IM&E reduction options as illustrated in Figure 1.3, but the vertical axis in Figure 1.4 reports the corresponding incremental cost per fish for each relevant option. For each option that has an "N/A," estimating the incremental cost per fish is not applicable for that particular option because the comparison illustrated in Figure 1.3 identified an equal or lower-cost option that produces a greater increase in the steady state estimate. For example, the aquatic filter barrier is designated as not applicable (N/A) because the 0.5mm wedgewire screens option is both less expensive and produces a greater number of fish.

As Figure 1.4 shows, the fine mesh traveling screens with Ristroph and a fish return has the lowest incremental cost per fish at $1.41. In addition, the figure also shows that the results have the same pattern as the incremental cost-effectiveness and wholly disproportionate analyses illustrated in Figure 1.2. The incremental cost per fish decreases as we move from the fish return option to the option of fine mesh traveling screen with Ristroph and fish return. From that point, the incremental cost per fish then increases for the 2mm and 0.5mm wedgewire screen options.[3]

[3] The estimated incremental cost per fish is different between Figures 1.2 and 1.4 because Figure 1.2 uses the total capital cost of each IM&E reduction option and Figure 1.4 uses the annual cost of each option.

2. References

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ASSESSMENT OF IMPACT OF CLOSURE OF THE CANAL PLANT ON THE RELIABILITY OF TRANSMISSION SYSTEM IN THE SOUTH-EASTERN MASSACHUSETTS (SEMA) LOAD ZONE AND NEW ENGLAND CONTROL AREA

DATE: 01/29/2009

TO: MIRANT CANAL, LLC

FROM: PWRSOLUTIONS INC

INTRODUCTION

Mirant Canal, LLC (Mirant Canal), an independent power producer, owns and operates the Canal Plant located in Sandwich Massachusetts, on the banks of Cape Cod Canal within the New England control area. While the Canal Plant has been in operation since 1968, Mirant Canal acquired the same in 1999. The plant consists of 2 generating units comprising a total generation capacity of 1,112 MW with the fuel comprising mostly of No. 6 residual fuel oil. The Canal Plant is located in the Southeastern Massachusetts (SEMA) load zone.

With high oil prices, the Canal Plant is rarely in merit order. However, it operates to provide reliability service when demand in lower SEMA exceeds 720 MW. Because there are no other large power plants within the region, at times nearly all of the electricity consumed on Cape Cod, Martha's Vineyard, and Nantucket is supplied by the Canal Plant. This occurs when there is not enough active and/or reactive generation (i.e., summer peak). Furthermore, the Canal Plant is also important during other times of the year in the case of certain transmission outages. The loss of the two transmission lines serving the area at any time would require generation from the Canal Plant to re-establish electrical service during almost all time periods. During many time periods, the loss of a single line would require generation from the Canal Plant to maintain reliability. Empirical evidence of this is that during 2002, the combination of an out-of-service transmission line and a fire at the Canal Plant caused outages resulting in 300,000 electricity customers losing service on Cape Cod and in wide areas of southeastern Massachusetts.

Mirant Canal is interested in understanding the impacts associated with the closure of the Canal Plant on the reliability of the electric transmission system in SEMA and the New England control area as a whole. To this effect, Mirant engaged Veritas Economic Consulting (Veritas) and PwrSolutions Inc (PwrSolutions) to execute an independent analysis to assess the impact of the closure of the Canal Plant on the reliability of the electric transmission grid in SEMA and the New England control area. The ensuing sections of the report provide discussions associated with the assumptions, methodology, results and inferences characterizing the analysis.

ANALYSIS CRITERIA

The analysis of the aforementioned transmission system reliability assessment study was based on the FERC 715 ISO-NE 2012 Summer Peak base case developed in 2007. No incremental changes were made to the transmission system modeled in the base case. A change case was formulated wherein the 2 generation units comprising the Canal Plant were taken off-line. Figure 1 provides the one-line diagram depicting the 2 generation units comprising the Canal Plant. Appropriate generation adjustments to the ISO-NE system were made following the removal of the Canal Plant. Table 1 depicts the generation & load levels in all the 8 load zones within ISO-NE. As is evident from Table 1, the loss of generation at Canal Plant in the change case was accounted for by increase in generation primarily in Maine and Western Massachusetts load zones. Local (SEMA) and over-all ISO-NE system reliability, in terms of incremental voltage and thermal overload violations following the execution of full AC power flow analysis under normal operating and N-1 contingency conditions (Category A/B/C/D assessment), was utilized as the primary analysis criterion.

STUDY ASSUMPTIONS:

The following were assumed while carrying out the transmission system reliability assessment study for the base and change case associated with the Canal Plant closure:

1. The change case reasonably identifies network stresses for other levels of power transfers from the plant site.
2. Loads modeled in the base case reasonably represent the forecasts of the individual utilities in the region.
3. Transmission line ratings in the base case (Rating B) represent appropriate limits for evaluating the effects of the contingencies simulated.
4. Transmission lines were listed as overloaded when their operating MVA were in excess of 100% of their thermal rating. Note that some utilities and reliability councils have more stringent overload criteria.
5. For the analysis all branches with nominal voltage of 69 kV and above in the NEPOOL area (FERC area #701) were monitored for over loading conditions.
6. Bus Voltage range of 0.95-1.05 per unit was deemed within acceptable limits under normal operating conditions while a range of 0.9-1.1 per unit was deemed within acceptable limits under N-1 contingency conditions.
7. A list of approximately 1450 ISO-NE certified planning contingencies (Category A/B/C/D assessment) were utilized for the N-1 analysis.

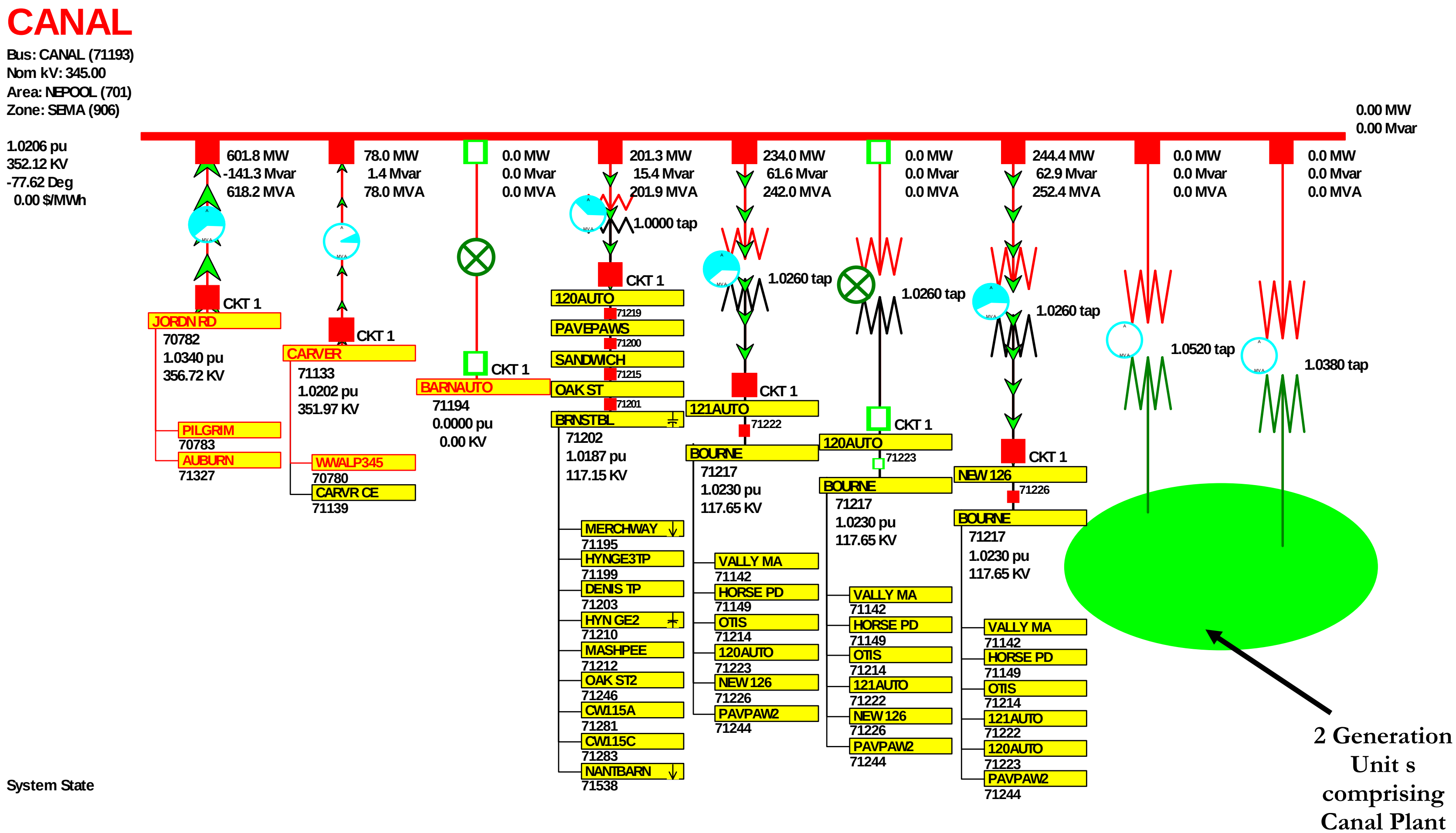

Figure 1: One-line Schematic Depicting the 2 Generation Units Comprising Canal Plant

Zone Num	Zone Name	Load MW		Gen MW	
		Base Case	Change Case	Base Case	Change Case
901	Maine	2385.67	2385.67	2640.86	3043.76
902	NH	2969.87	2969.87	4186.2	4232.5
903	VT	1157.18	1157.18	778.76	852.98
904	NEMA	6868.95	6868.95	3443.29	3563.9
905	CMA	1330.59	1330.59	456.73	460.25
906	SEMA	4504.31	4504.31	6078.32	5131.33
907	WMA	1695.68	1695.68	3193.81	3433.14
908	RI	2116.73	2116.73	1673.3	1746.2
909	CT	8582.25	8582.25	8135.05	8176.95
		31611.23			

Table 1: Generation & Load Details on a Load-zone basis – Base & Change Cases

PROCESS METHODOLOGY:

The following methodology was adopted to assess the impact of the closure of the Canal Plant on the reliability of the transmission system within SEMA and ISO-NE:

- **Transmission Model**: The FERC Form 715 ISO-NE 2012 Summer Peak power flow base case was utilized as the base transmission model for the reliability assessment. No incremental transmission and/or generation changes were made to the base model.
- **Assessment Duration:** The reliability impact assessment has been carried out for the 2012 Summer Peak condition (instant snap-shot of time) which is consistent with long-term planning & reliability assessment procedures.
- **Scenarios:** A base and change case with the following definitions were prepared in order to assess the incremental impact of the closure of the Canal Plant on the reliability of the transmission system within SEMA and ISO-NE:
  - **Base Case:** The base case represents as is conditions of generation and transmission as obtained in the 2012 summer peak model. No incremental generation and/or transmission changes were made to the case
  - **Change Case:** The change case represents the incorporation of the Canal Plant closure by means of opening the 2 generating units comprising the plant. As mentioned earlier, the loss of generation was made up by generation rich load zones of Maine and WMA primarily apart from other zones in ISO-NE.
- **Complete AC Power Flow Analysis:** Complete AC power flow analysis under normal operating and N-1 contingency conditions has been performed for both the base case and change case conditions.
- **Transmission System Monitoring:** All transmission system elements 69kV and above in all load zones comprising the ISO-NE footprint have been monitored under normal operating and N-1 contingency conditions. The following transmission system parameters have been utilized in assessing the impact of the closure of the Canal Plant on the reliability of the transmission system within SEMA and ISO-NE.
  - **Transmission Line Overloads:** Any transmission system element loaded to or beyond 100% of its thermal rating is deemed overloaded and hence a threat to the system reliability. Normal (A) rating has been utilized under normal operating conditions while Emergency (B) ratings utilized while assessing Category B/C/D contingencies.
  - **Voltage Violations:** Apart from transmission system overload, voltage collapse issues present a major reliability threat to the system. All buses in the ISO-NE footprint, 69kV and above have been monitored for voltage violations. The limit of 0.95–1.05 per unit is utilized as threshold to assess voltage violations under normal operating conditions. The limit of 0.90–1.10 per unit is utilized as threshold to assess voltage violations under category B/C/D conditions.

RESULTS AND ANALYSIS

As mentioned in the previous sub-section, the voltage and transmission system violations under normal operating and Category B/C/D conditions have been utilized as metrics to assess the impact of the closure of the Canal Plant on the reliability of the transmission system within SEMA and ISO-NE. Given the size and complexity of the ISO-NE system and the fact that close to 1450 contingencies were executed for the base and change case, the incremental reliability impacts associated with the reliability impact assessment have been categorized based on the following:

- **Control Area/Utility associated with violation/overload**: It would be important to assess if certain load zones within ISO-NE would be specifically impacted in terms of reliability following the closure of the Canal Plant. Of specific interest would be the impact of the closure of the Canal Plant on the reliability of the transmission system in and within vicinity of SEMA. In such a situation, it would be important to align the nature and severity of the reliability issues associated with the loss of Canal generation with respect to various load zones.
- **Severity of Violation/Overload**: Based on various categories assigned to the violations/overloads, the severity of the reliability issues posed has been classified.
- **Nominal kV associated with Violation/Overload:** The severity of voltage violations depends upon the voltage of the affected transmission element. For example, Extra-High Voltage (EHV) violations (345 kV levels, for instance) are a more serious cause of concern than violations at lower voltage levels.

The classification of results in the aforementioned three categories when viewed in unison allows the assessment of specific regions wherein the incremental impact of the closure of the Canal Plant maybe thoroughly analyzed, if any. Furthermore, the generation capacity and demand statistics associated with the base and change case when viewed in conjunction with the incremental reliability impacts organized as mentioned above provide a comprehensive picture of the impact of closure of Canal Plant on various load zones within ISO-NE.

i. Transmission System Overloads—Normal Operating Conditions (Category A Assessment)

Table 2 presents the results associated with the incremental transmission system overloads following the incorporation of the Canal Plant closure to the base case under normal operating conditions. The results associated with the incremental transmission system violations have been organized in the categories described above. The following observations can be made from the incremental transmission system violations owing to the closure of the Canal Plant as depicted in Table 2:

- **SEMA Region**: The SEMA load zone witnesses a lone incremental transmission system violation following the closure of the Canal Plant. The lone incremental transmission system violation occurs at the 115 kV Somerset-Sykes Rd transmission line. The results seem to be in line with the historical trend in the region given that there is sufficient transmission system capacity to account for the loss of the Canal Plant under normal operating conditions.

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Transmission System Overloads – Summary – Normal Operation							
Area Num	**Area Name**	**345kV**	**230 – 115kV**	**115kV & below**	**100-125%**	**125-150%**	**150% & above**
901	Maine	0	0	10	7	2	1
902	NH	0	0	0	0	0	0
903	VT	0	0	0	0	0	0
904	NEMA	0	0	1	1	0	0
905	CMA	0	0	0	0	0	0
906	SEMA	0	0	1	1	0	0
907	WMA	0	0	0	0	0	0
908	RI	0	0	0	0	0	0
909	CT	0	0	0	0	0	0

Table 2: Incremental Transmission System Overloads following Canal Plant Closure under Normal Operating Conditions

Bus Voltage Violations – Summary – Normal Operation								
Area Num	**Area Name**	**345kV**	**230 – 115kV**	**115kV & below**	**<0.95**	**>1.05**	**0.95**	**1.05**
901	Maine	0	0	2	2	0	0	0
902	NH	0	0	0	0	0	0	0
903	VT	0	0	0	0	0	0	0
904	NEMA	0	0	0	0	0	0	0
905	CMA	0	0	0	0	0	0	0
906	SEMA	0	0	0	0	0	0	0
907	WMA	0	0	1	1	0	0	0
908	RI	0	0	0	0	0	0	0
909	CT	0	0	0	0	0	0	0

Table 3: Incremental Bus Voltage Violations following Canal Plant Closure under Normal Operating Conditions

The 2 major 345 kV transmission lines feeding the Lower SEMA when functional provide ample import capacity under normal operating conditions. However, the key aspect to be assessed when evaluating the reliability impact of the Canal Plant closure is the system performance under contingency conditions.

- **ISO-NE System**: The other load zone to witness any major incremental stress on the transmission system following the closure of the Canal Plant is the Maine region. As mentioned earlier, the generation rich Maine region is the load zone that makes up for a major part of the generation lost due to the Canal Plant closure. Increased generation dispatch in certain regions of Maine seems to stress the transmission system capacity at the lower voltage transmission system levels. All the incremental transmission system violations occurring at the 115kV and below voltage level is indicative of the same. No major 345kV transmission system in any load zone seems to be incrementally stressed following the closure of the Canal Plant under normal operating conditions

ii. Voltage Violations—Normal Operating Conditions (Category A Assessment)

Table 3 presents the results associated with the incremental voltage violations following the incorporation of the Canal Plant closure to the base case under normal operating conditions. The results associated with the incremental voltage violations have been organized in the categories described above. The following observations can be made from the incremental voltage violations owing to the closure of the Canal Plant as depicted in Table 3:

- **SEMA Region**: No major voltage issues seem to present themselves in the SEMA region following the closure of the Canal Plant under normal operating conditions. In other words, unless a transmission system outage occurs, there do seem to be sufficient reactive power resources in the vicinity of lower SEMA to maintain the voltage within acceptable limits under normal operating conditions.
- **ISO-NE System:** 2 incremental low-voltage issues are witnessed in Maine load zone following the closure of the Canal Plant. However both these low voltage violations are at the 115kV and below level and seem to be generation dispatch related issues thereby presenting a localized reactive power issue which in all probability could be resolved by generation re-dispatch. Further investigation maybe required to confirm the same. However, no major voltage issues or reliability threat seems to present itself in ISO-NE system following the closure of the Canal Plant under normal operating conditions

iii. Transmission System Overloads—N-1 Contingency Conditions (Category B/C/D Assessment)

Table 4 presents the results associated with the incremental transmission system overloads following the incorporation of the Canal Plant closure to the base case under N-1 contingency conditions. The results associated with the incremental transmission system overloads have been organized in the categories described above. The following observations can be made from the incremental transmission system overloads owing to the closure of the Canal Plant as depicted in Table 4:

- **SEMA Region**: Some major reliability issues are witnessed within the SEMA region under N-1 contingency conditions following the closure of the Canal Plant. There are 7 Category B/C/D contingencies for which the system is not able to meet the load in the lower SEMA region following the closure of the Canal Plant. All of these contingencies involve the opening of certain sections of either one or both of the 345 kV lines connecting the Cape Cod region in lower SEMA to the remaining SEMA region. Table 6 provides a list and description of all the contingencies for which the system is not able to supply load or faces voltage collapse issues. In other words, the closure of the Canal Plant poses major threats to the reliability of the lower SEMA region in the event of any of these contingencies occurring.

  That apart, the N-1 contingency analysis results in 11 incremental transmission system overloads in SEMA, 7 of which happen to be at the 345 kV level. Figure 2 depicts the regions within SEMA that are subjected to incremental transmission system stress under N-1 contingency conditions following the closure of the Canal Plant. Details associated with incremental contingency-overload pairs resulting from the Canal Plant closure have been provided in the comprehensive results file attached at the conclusion of this report.

- **ISO-NE System:** Apart from SEMA, there are certain contingencies in NH and Maine load zones that present potential voltage collapse and load shedding problems. This is so since the generation making up for the loss of the Canal Plant is primarily obtained from Maine and the outage of certain combinations of transmission system elements connecting Maine and NH to SEMA could result in such issues. That apart, 5 incremental transmission system violations are witnessed in Maine load zone under N-1 contingency conditions following the Canal Plant closure. Overall there is considerable stress on the ISO-NE transmission under N-1 contingency conditions following the closure of the Canal Plant. Details associated with the same have been provided in the comprehensive results file attached at the conclusion of this report.

iv. Voltage Violations—N-1 Contingency Conditions (Category B/C/D Assessment)

Table 5 presents the results associated with the incremental voltage violations following the incorporation of the Canal Plant closure to the base case under N-1 contingency conditions. The results associated with the incremental voltage violations have been organized in the categories described above. The following observations can be made from the incremental voltage violations owing to the closure of the Canal Plant as depicted in Table 5:

- **SEMA Region**: 5 incremental voltage violations are experienced in SEMA under N-1 contingency conditions following the closure of the Canal Plant, all of them being low voltage issues. The results do seem to be indicative of shortage of reactive power support in the lower SEMA region following the closure of the Canal Plant under certain outage combinations. However all the 5 incremental voltage violations occur at the 115kV and below level within SEMA. Further investigations maybe needed to assess the exact cause and potential remedy associated with these voltage violations.

Transmission System Overloads – Summary – N-1 Contingency Conditions							
Area Num	Area Name	345kV	230 – 115kV	115kV & below	100-125%	125-150%	150% & above
901	Maine	0	0	5	5	0	0
902	NH	0	0	0	0	0	0
903	VT	0	0	2	2	0	0
904	NEMA	0	1	2	3	0	0
905	CMA	0	0	1	1	0	0
906	SEMA	7	0	4	10	1	0
907	WMA	0	0	2	2	0	0
908	RI	0	0	1	1	0	0
909	CT	0	0	1	1	0	0

Table 4: Incremental Transmission System Overloads following Canal Plant Closure under N-1 Contingency Conditions

Bus Voltage Violations – Summary – N-1 Contingency Conditions								
Area Num	Area Name	345kV	230 – 115kV	115kV & below	<0.9	>1.1	0.9	1.1
901	Maine	0	0	8	8	0	0	0
902	NH	0	0	7	6	0	1	0
903	VT	0	0	0	0	0	0	0
904	NEMA	0	0	0	0	0	0	0
905	CMA	0	0	0	0	0	0	0
906	SEMA	0	0	5	2	0	3	0
907	WMA	0	0	2	2	0	0	0
908	RI	0	0	0	0	0	0	0
909	CT	0	0	6	5	0	1	0

Table 5: Incremental Bus Voltage Violations following Canal Plant Closure under N-1 Contingency Conditions

Contingency Label	Contingency Definition	From Nominal kV	To Nominal kV	Circuit ID	Associated Load Zone
107BOUFAL50	OPEN Branch OTIS_115.0 (71214) TO BOURNE_115.0 (71217) CKT 1	115	115	CKT 1	SEMA
	OPEN Branch FLMTH TP_115.0 (71206) TO OTIS_115.0 (71214) CKT 1	115	115	CKT 1	SEMA
342+355 DCT	OPEN Branch JORDN RD_345.0 (70782) TO AUBURN_345.0 (71327) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO CANAL_345.0 (71193) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO PILGRIM_345.0 (70783) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch PILGRIM_345.0 (70783) TO BRIDGWTR_345.0 (71326) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch PLGRM G1_ 22.8 (71094) TO PILGRIM_345.0 (70783) CKT 1	22.8	345	CKT 1	SEMA
	OPEN Gen PLGRM G1_ 22.8 (71094) #1	22.8			SEMA
342355DCT32	OPEN Branch JORDN RD_345.0 (70782) TO PILGRIM_345.0 (70783) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO CANAL_345.0 (71193) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO AUBURN_345.0 (71327) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch PILGRIM_345.0 (70783) TO BRIDGWTR_345.0 (71326) CKT 1	345	345	CKT 1	SEMA
342LINE2	OPEN Branch JORDN RD_345.0 (70782) TO CANAL_345.0 (71193) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO AUBURN_345.0 (71327) CKT 1	345	345	CKT 1	SEMA
AUBURN-2130	OPEN Branch HOLBROOK_345.0 (70781) TO AUBURN_345.0 (71327) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch AUBURN_345.0 (71327) TO AUBURN B_115.0 (71349) CKT 1	345	115	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO AUBURN_345.0 (71327) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO PILGRIM_345.0 (70783) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO CANAL_345.0 (71193) CKT 1	345	345	CKT 1	SEMA
CANAL412	OPEN Branch JORDN RD_345.0 (70782) TO AUBURN_345.0 (71327) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO CANAL_345.0 (71193) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO PILGRIM_345.0 (70783) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch CANAL_345.0 (71193) TO CANAL G2_ 18.0 (71252) CKT 1	345	18	CKT 1	SEMA
L342	OPEN Branch JORDN RD_345.0 (70782) TO AUBURN_345.0 (71327) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO CANAL_345.0 (71193) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO PILGRIM_345.0 (70783) CKT 1	345	345	CKT 1	SEMA

Table 6: Category B/C/D Contingencies Resulting in Load Shedding and/or Voltage Collapse following Canal Plant Closure

- **ISO-NE System:** Numerous incremental voltage violations do seem to occur under N-1 contingency conditions across various load zones in ISO-NE following the closure of the Canal Plant. Of note are the incremental voltage violations in Maine, NH and CT zones. Although these zones do present a relatively large number of incremental voltage violations following the closure of the Canal Plant, all the low-voltage issues are at the 115kV and below level. Further investigation may be needed to identify the exact nature of these voltage issues and whether local reactive power support could resolve the problem. The same is beyond the purview of this report. Details associated with the same can be obtained from the comprehensive results file attached at the conclusion of this document.

CONCLUSION:

Study assumptions withstanding, the following inferences can be drawn from the results and analysis presented in this report:

- The closure of the Canal Plant poses some serious threats to the reliability of the lower SEMA transmission system under specific contingency/outage configurations. Details associated with those contingencies/outages have been presented in the report. Under the aforementioned outage configurations, the absence of the Canal Plant could lead to a blackout in lower SEMA region due to either load shedding or potential voltage collapse

- Apart from lower SEMA, the closure of the Canal Plant places considerable stress on the remaining SEMA transmission system owing to the excess generation to be imported from various ISO-NE load zones into lower SEMA via upper SEMA given the topology of SEMA load zone. The increased stress on the transmission system poses a threat to the reliability of the system

- In terms of voltage and reactive power support, certain low-voltage pockets in SEMA, Maine and CT do form under N-2 contingency conditions following the closure of the Canal Plant. However a more detailed analysis would be required to evaluate the exact nature of these issues and whether local voltage support solutions could adequately address the same

- The presence of the 2 major 345 kV lines connecting lower SEMA region to the remaining SEMA region allows the system to operate without any major issues under normal operating conditions. However, given NERC and ISO-NE reliability and planning criteria, not much should be read into adequacy under normal operating conditions.

Comprehensive Results

Bus Voltage Violations: NO

				PU Volt	
Number	Name	Zone Name	Volt (kV)	Base Case	Without Canal units
70015	ENFIELD	Maine	115		0.94569
70016	UP5 115	Maine	115		0.94564
72427	WILBRAHM	WMA	69		0.94847

Thermal Overloads: NO

								% of Limit Used	
From Number	From Name	From Zone Name	To Number	To Name	To Zone Name	Circuit	Limit Used	Base Case	Without Canal Units
70101	RUMFRDGN	Maine	70168	WOODSTK	Maine	1	185.1		113.7
70101	RUMFRDGN	Maine	70211	MEADPAPR	Maine	1	155.4		125
70114	WINSLOW	Maine	70150	S83C TAP	Maine	1	135.3		103.6
70117	LIVERMOR	Maine	70153	S200A TP	Maine	1	185.1		113.7
70118	GULF ISL	Maine	70153	S200A TP	Maine	1	185.1		134.4
70150	S83C TAP	Maine	70173	SDW SOMS	Maine	1	93.9		105.8
70152	RILEY	Maine	70184	AEC 115	Maine	1	185.1		102.1
70152	RILEY	Maine	70183	JAY IP	Maine	1	88.4		139
70347	WARREN 2	Maine	70173	SDW SOMS	Maine	1	46		122.5
70434	J/MILL F	Maine	70183	JAY IP	Maine	2	25		216.3
70833	KINGBNTB	NEMA	70834	HIGHST A	NEMA	1	154		102.2
71377	SOMERSET	SEMA	71390	SYKES RD	SEMA	1	163		111.6

Thermal Overloads: N-1

		Change Case			
Element	**Limit MVA**	**Contingency**	**Percent**	**From Zone Name**	**To Zone Name**
ANP 336 (70785) -> NEA 336 (70773) CKT 1 at ANP 336	1400	3520+BELL G1	101.15	SEMA	SEMA
BARBR HL (73219) -> ENFIELD (73220) CKT 1 at BARBR HL	202	1200LINE	108.74	CT	CT
BELLNGHM (71802) -> W MEDWAY (70772) CKT 1 at BELLNGHM	1412	336-A	101.67	SEMA	SEMA
BLCHX176 (72984) -> THRNDIKE (72402) CKT 1 at BLCHX176	268	CARPNHLSTA	100.58	WMA	WMA
BUCKSPOR (70210) -> BETTSRD (70034) CKT 1 at BUCKSPOR	228.3	BKSPT6586	111.66	Maine	Maine
E WINCHS (72107) -> ASHBR135 (72116) CKT 1 at E WINCHS	119	354	104.59	CMA	CMA
EVRTT1BM (71917) -> EVERETT (71914) CKT 1 at EVRTT1BM	50	F-158N&S	100.4	NEMA	NEMA
FARNUM T (71408) -> RIVERSID (71402) CKT 1 at FARNUM T	245	V-148	103.67	RI	RI
FRENCH K (72939) -> WENDEL27 (72404) CKT 1 at FRENCH K	119	MILLBSTA	102.52	WMA	WMA
GORBELL (70123) -> HARTLAND (70112) CKT 1 at GORBELL	162.4	L83	103.79	Maine	Maine
HARTLAND (70112) -> DETROIT (70108) CKT 1 at DETROIT	162.4	L83	101.19	Maine	Maine
IDC BELL (70784) -> W MEDWAY (70772) CKT 1 at IDC BELL	1647	3520+BELL G1	104.47	SEMA	SEMA
KINGBNTB (70833) -> HIGHST A (70834) CKT 1 at KINGBNTB	241	KST17	111.94	NEMA	NEMA
LIVERMOR (70117) -> S200A TP (70153) CKT 1 at LIVERMOR	226.1	L66	111.59	Maine	Maine
MWRA (72289) -> NBOROTP2 (72290) CKT 1 at NBOROTP2	99	MILLBSTD	105.86	SEMA	SEMA
N.LITCH1 (71827) -> TEWKSBRY (71961) CKT 1 at N.LITCH1	382	N-214	103.37	NH	NEMA
NEA 336 (70773) -> IDC BELL (70784) CKT 1 at NEA 336	1647	3520+BELL G1	104.55	SEMA	SEMA
SOMERSET (71377) -> SYKES 13 (71397) CKT 1 at SOMERSET	192	N-12	103.69	SEMA	SEMA
ST.ALBAN (70510) -> NASON ST (70611) CKT 1 at ST.ALBAN	29	F-206	100.85	VT	VT
ST.ALBAN (70510) -> NASON ST (70611) CKT 2 at ST.ALBAN	29	F-206	100.68	VT	VT

Thermal Overloads: N-1, continued

		Change Case			
Element	**Limit MVA**	**Contingency**	**Percent**	**From Zone Name**	**To Zone Name**
TEWKSBRY (71961) -> TWKS4MID (72045) CKT 1 at TEWKSBRY	568	TEWKSSTB	100.08	NEMA	NEMA
W MEDWAY (70772) -> WWALP345 (70780) CKT 1 at W MEDWAY	1130	WMEDWAY-111	124.4	SEMA	SEMA
W MEDWAY (70772) -> WWALP345 (70780) CKT 1 at WWALP345	1130	389	114.62	SEMA	SEMA
W MEDWAY (70772) -> WWALP345 (70780) CKT 2 at W MEDWAY	1410	325+344 DCT	127.41	SEMA	SEMA
W WALPOL (70895) -> WALP-508 (70896) CKT 1 at W WALPOL	205	HOLBRKST8	108.81	SEMA	SEMA
WEST ST2 (72291) -> WEST ST (72327) CKT 2 at WEST ST2	19	READ ST T1	101.5	SEMA	SEMA
WYMAN (70113) -> GORBELL (70123) CKT 1 at WYMAN	162.4	L83	106.86	Maine	Maine

Bus Voltage Violations: N-1

		Without Canal units		
Element	pu Volt Limit	Contingency	Value	Zone
ANHUS BH (72710)	0.9	HDFB5	0.87	NH
CANTONT3 (70912)	0.9	LINE 447-508	0.89	SEMA
CHESTER (72716)	0.9	SCOB_SB_721	0.69	NH
GTBAY115 (72775)	0.9	SCOB_SB_721	0.84	NH
HINGHAM8 (71712)	0.9	478-508-A	0.84	SEMA
IND.WELL (73705)	0.9	1545-1570DCT	0.88	CT
KIBBE14 (72441)	0.9	X-176	0.89	WMA
LACONIA2 (72708)	0.9	MERRMK_SB_2	0.9	CT
LEW LWR (70104)	0.9	SURWIC1661	0.88	Maine
LONG HL (72730)	0.9	HDFB5	0.84	NH
MARSHFLD (71147)	0.9	116CVRBRK45	0.9	SEMA
MIS G3 1 (70032)	0.9	L392 W/MIS	0.84	Maine
PRIDESCR (70135)	0.9	L167	0.33	Maine
RDS FERY (72740)	0.9	HDFB5	0.89	NH
ROCKVILL (73340)	0.9	1310LINE	0.86	CT
RPA 115 (70186)	0.9	SURWIC1661	0.89	Maine
RUMFD IP (70182)	0.9	SURWIC1661	0.89	Maine
S167A TP (70176)	0.9	L167	0.33	Maine
S200A TP (70153)	0.9	SURWIC1661	0.87	Maine
S61A TAP (70131)	0.9	SURWIC1661	0.87	Maine
SACO VLY (72761)	0.9	SURWIC1661	0.81	NH
SACO_PAR (72706)	0.9	SURWIC1661	0.85	CT
STONY HL (73165)	0.9	1770-1887DCT	0.83	CT
SWANZEY (72747)	0.9	N186/K186	0.9	NH
WENDELL (72403)	0.9	A-127E	0.75	WMA
WEST ST2 (72291)	0.9	F-184	0.9	SEMA
WNDSRLN2 (73462)	0.9	1310LINE	0.86	CT
WPOND117 (71145)	0.9	116CVRBRK45	0.9	SEMA

Critical Contingency List

Contingency Label	Contingency Definition	From Nominal kV	To Nominal kV	Circuit ID	Associated Load Zone
107BOUFAL50	OPEN Branch OTIS_115.0 (71214) TO BOURNE_115.0 (71217) CKT 1	115	115	CKT 1	SEMA
	OPEN Branch FLMTH TP_115.0 (71206) TO OTIS_115.0 (71214) CKT 1	115	115	CKT 1	SEMA
342+355 DCT	OPEN Branch JORDN RD_345.0 (70782) TO AUBURN_345.0 (71327) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO CANAL_345.0 (71193) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO PILGRIM_345.0 (70783) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch PILGRIM_345.0 (70783) TO BRIDGWTR_345.0 (71326) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch PLGRM G1_ 22.8 (71094) TO PILGRIM_345.0 (70783) CKT 1	22.8	345	CKT 1	SEMA
	OPEN Gen PLGRM G1_ 22.8 (71094) #1	22.8			
342355DCT32	OPEN Branch JORDN RD_345.0 (70782) TO PILGRIM_345.0 (70783) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO CANAL_345.0 (71193) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO AUBURN_345.0 (71327) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch PILGRIM_345.0 (70783) TO BRIDGWTR_345.0 (71326) CKT 1	345	345	CKT 1	SEMA
342LINE2	OPEN Branch JORDN RD_345.0 (70782) TO CANAL_345.0 (71193) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO AUBURN_345.0 (71327) CKT 1	345	345	CKT 1	SEMA

Critical Contingency List, continued

Contingency Label	Contingency Definition	From Nominal kV	To Nominal kV	Circuit ID	Associated Load Zone
AUBURN-2130	OPEN Branch HOLBROOK_345.0 (70781) TO AUBURN_345.0 (71327) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch AUBURN_345.0 (71327) TO AUBURN B_115.0 (71349) CKT 1	345	115	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO AUBURN_345.0 (71327) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO PILGRIM_345.0 (70783) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO CANAL_345.0 (71193) CKT 1	345	345	CKT 1	SEMA
BCKSPT203205	OPEN Branch DETROIT_115.0 (70108) TO BUCKSPOR_115.0 (70210) CKT 1	115	115	CKT 1	Maine
	OPEN Branch ORRINGTN_115.0 (70027) TO BETTSRD_115.0 (70034) CKT 1	115	115	CKT 1	Maine
	OPEN Branch BOGGY 11_115.0 (70033) TO BETTSRD_115.0 (70034) CKT 1	115	115	CKT 1	Maine
	OPEN Branch BETTSRD_115.0 (70034) TO BUCKSPOR_115.0 (70210) CKT 1	115	115	CKT 1	Maine
CANAL412	OPEN Branch JORDN RD_345.0 (70782) TO AUBURN_345.0 (71327) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO CANAL_345.0 (71193) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO PILGRIM_345.0 (70783) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch CANAL_345.0 (71193) TO CANAL G2_ 18.0 (71252) CKT 1	345	18	CKT 1	SEMA

Critical Contingency List, continued

Contingency Label	Contingency Definition	From Nominal kV	To Nominal kV	Circuit ID	Associated Load Zone
GREGGS_SB	OPEN Branch GREGGS_115.0 (72722) TO MERRMACK_115.0 (72734) CKT 1	115	115	CKT 1	NH
	OPEN Branch GREGGS_115.0 (72722) TO MERRMACK_115.0 (72734) CKT 2	115	115	CKT 2	NH
	OPEN Branch GREGGS_115.0 (72722) TO RDS FERY_115.0 (72740) CKT 1	115	115	CKT 1	NH
	OPEN Branch GREGGS_115.0 (72722) TO RIMMON_115.0 (72755) CKT 1	115	115	CKT 1	NH
	OPEN Branch GREGGS_115.0 (72722) TO PINE HIL_115.0 (72769) CKT 1	115	115	CKT 1	NH
	OPEN Branch GREGGS_115.0 (72722) TO GREGG RX_115.0 (72771) CKT 1	115	115	CKT 1	NH
	OPEN Branch GREGGS_115.0 (72722) TO GREGG RX_115.0 (72771) CKT 2	115	115	CKT 2	NH
	OPEN Branch GREGGS_115.0 (72722) TO N.MK 115_ 1.0 (72782) CKT 1	115	1	CKT 1	NH
	OPEN Branch GREGG PH_ 34.5 (72805) TO GREGGS_115.0 (72722) CKT 1	34.5	115	CKT 1	NH
L200	OPEN Branch GULF ISL_115.0 (70118) TO S200A TP_115.0 (70153) CKT 1	115	115	CKT 1	Maine
	OPEN Branch LIVERMOR_115.0 (70117) TO S200A TP_115.0 (70153) CKT 1	115	115	CKT 1	Maine
	OPEN Branch S200A TP_115.0 (70153) TO AEI HSB_115.0 (70154) CKT 1	115	115	CKT 1	Maine
	OPEN Branch AEI HSB_115.0 (70154) TO AEI GEN_ 13.8 (70370) CKT 1	115	13.8	CKT 1	Maine

Critical Contingency List, continued

Contingency Label	Contingency Definition	From Nominal kV	To Nominal kV	Circuit ID	Associated Load Zone
L210211	OPEN Branch KIMBL RD_115.0 (70103) TO WOODSTK_115.0 (70168) CKT 1	115	115	CKT 1	Maine
	OPEN Branch RUMFRDGN_115.0 (70101) TO WOODSTK_115.0 (70168) CKT 1	115	115	CKT 1	Maine
L217	OPEN Branch KIMBL RD_115.0 (70103) TO RUMFD IP_115.0 (70182) CKT 1	115	115	CKT 1	Maine
L228	OPEN Branch RUMFRDGN_115.0 (70101) TO RUMFD IP_115.0 (70182) CKT 1	115	115	CKT 1	Maine
L342	OPEN Branch JORDN RD_345.0 (70782) TO AUBURN_345.0 (71327) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO CANAL_345.0 (71193) CKT 1	345	345	CKT 1	SEMA
	OPEN Branch JORDN RD_345.0 (70782) TO PILGRIM_345.0 (70783) CKT 1	345	345	CKT 1	SEMA
SCOB_SB_7287	OPEN Branch CHESTER_115.0 (72716) TO SCOBIE2_115.0 (72746) CKT 1	115	115	CKT 1	NH
	OPEN Branch MAIN ST._ 34.5 (72798) TO CHESTER_115.0 (72716) CKT 1	34.5	115	CKT 1	NH
	OPEN Branch MAMTH RD_115.0 (72733) TO SCOBIE2_115.0 (72746) CKT 1	115	115	CKT 1	NH
	OPEN Branch MAMTH RD_115.0 (72733) TO WATTSBRK_115.0 (72773) CKT 1	115	115	CKT 1	NH
	OPEN Branch MAMMOTH_ 34.5 (72796) TO MAMTH RD_115.0 (72733) CKT 1	34.5	115	CKT 1	NH

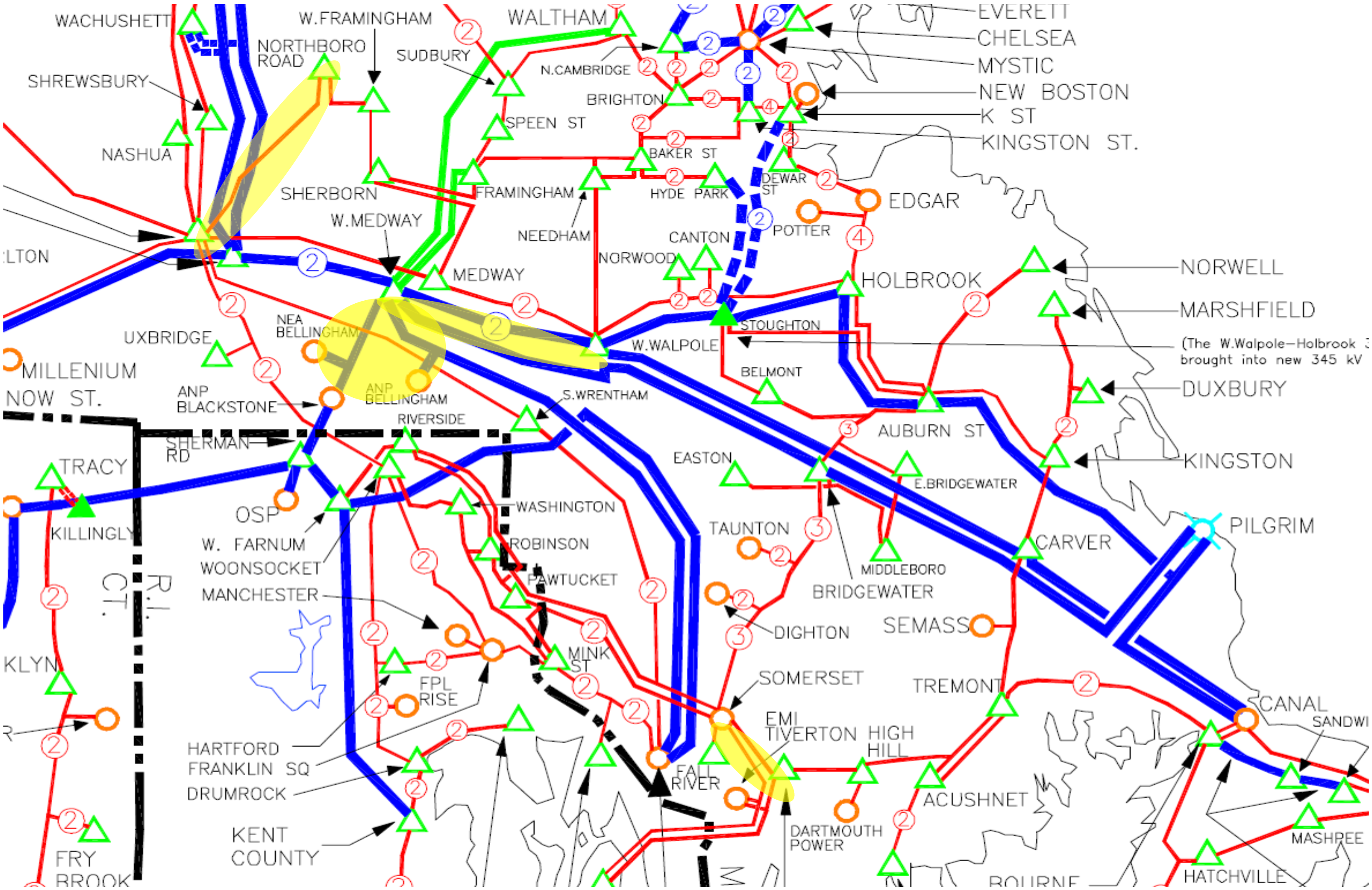

Figure 2: Regions Suffering from Transmission System Stress under N-1 Contingency Conditions following Canal Plant Closure