EPA - New England

Clean Water Act NPDES Permitting Determinations for Thermal Discharge and Cooling Water Intake from Mirant Kendall Station in Cambridge, MA

NPDES Permit No. MA 0004898

Date: June 8, 2004

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1.0 Determination Document

1.1 Introduction

This document presents EPA-New England's (EPA) determinations regarding thermal discharges and cooling water intake requirements for the new Draft National Pollutant Discharge Elimination System (Draft NPDES) permit (No. MA0004898) being developed under the Clean Water Act, 33 U.S.C. §§ 1251 et seq. (CWA), for the Mirant Kendall Station (MKS) power plant in Cambridge, Massachusetts. MKS is currently owned and operated by the Mirant Corporation and is referred to herein as either MKS, Kendall Station, the Station, the Facility, the permittee, the applicant, or the company, unless otherwise noted.

This document constitutes an important part of the administrative record supporting the new Draft NPDES permit for MKS and it is incorporated by reference in the permit's Fact Sheet. Furthermore, its key determinations are described in the Fact Sheet. Other necessary determinations to support the new Draft NPDES permit for MKS (i.e., issues not related to thermal discharge and cooling water intake) are discussed in the Fact Sheet and other supporting materials in the administrative record but not in this document. Because the determinations presented in this document are being developed to support a draft permit, EPA and the Massachusetts Department of Environmental Protection (DEP) will be soliciting public comment on the draft permit. Therefore, these determinations are subject to potential revision based on the comments received if the permitting agencies conclude that changes are warranted.

Thermal discharge limitations may be governed either by technology-based, water quality-based or CWA § 316(a) variance-based requirements, whereas cooling water intake requirements are governed by CWA § 316(b), 33 U.S.C. § 1326(b). Each of these potential sources of permit requirements is addressed in a separate determination section herein. In some cases, this document incorporates by reference analyses from other documents. For example, fish spawning and thermal tolerance levels analyses for certain species of fish, conducted by the Commonwealth of Massachusetts, are incorporated by reference. All such documents are referenced at the end of each section of this document, where applicable, or are found in the administrative record.

EPA and DEP are developing this permit to meet the requirements of the Clean Water Act and other pertinent statutes. Viewed in larger context, however, EPA and DEP see development of this permit to minimize Mirant Kendall Station's impact on the lower Charles River Basin as an important component of broader public and private efforts to restore the basin's health. These efforts include projects to develop a Total Maximum Daily Load (TMDL) for the lower Charles River Basin, to improve recreational and public access areas, to abate combined sewer overflows into the river, to upgrade operations at the Watertown Dam and the New Charles

River Dam and Locks, and to possibly remediate the polluted sediments of the river. Since MKS is the largest industrial discharger impacting the habitat and fishery of the lower Charles River Basin, placing appropriate controls on the power plant's operations can make a critical contribution to this larger effort and this can be done while allowing the plant to become a significant source of electrical power for the greater Boston area.

In addition, the renewal of this permit takes into consideration the power upgrade of Mirant Kendall Station and the intention of the permittee to change the operation of the station from a “peaking unit”, or station used sporadically as power needs dictate, to a “base load unit”, operating near full power on a more or less continuous basis. A significant increase of waste heat to the lower basin will result from this shift in station operation when compared with past heated discharge effects.

While EPA has independently drawn the conclusions presented in this document, EPA consulted closely with a number of agencies from the Commonwealth of Massachusetts and the Federal Government in carrying out the analyses discussed herein. Such consultation was essential because, along with EPA, these other agencies also have relevant substantive expertise and regulatory responsibilities related to development and issuance of this permit, as well as public responsibility for ensuring protection of the natural resources of the lower Charles River ecosystem.

Specifically, EPA consulted with DEP because this state agency co-issues the NPDES permit with EPA, has substantive expertise in a number of relevant areas (e.g., water quality, engineering, fisheries), and must determine which permit requirements are needed to satisfy the Commonwealth’s Water Quality Standards and any other requirements of state law. See 33 U.S.C. § 1341(a)(1) and (d). EPA also consulted with the Massachusetts Division of Fisheries and Wildlife (MA DFW), which has responsibilities and expertise related to Massachusetts fisheries, and the Massachusetts Office of Coastal Zone Management (CZM) which has substantive expertise and must certify that the permitted discharge will be consistent with the Commonwealth’s coastal zone management plan. See 40 C.F.R. § 122.49(d). EPA also consulted with the Massachusetts Department of Urban Parks and Recreation (DUPR), formerly the MDC, which has jurisdiction over any activities affecting the use of the Charles River in this vicinity and which also operates the New Charles River Dam and Locks.

EPA also consulted with the National Marine Fisheries Service (NOAA Fisheries) because this agency has obvious expertise on fisheries issues. In addition, EPA is directed by 40 C.F.R. § 125.72(d) to consult with this agency when considering an application for a variance under CWA § 316(a). NOAA Fisheries also has regulatory responsibility for applying the Essential Fish Habitat requirements of the Sustainable Fisheries Act and NOAA Fisheries and the F&WS share responsibility for applying the requirements of the Endangered Species Act. See 40 C.F.R. §§ 124.59(b) and (c) and 122.49(d); 16 U.S.C. §§ 1801 et seq.

EPA and the state and federal agencies listed above, referred to as “the agencies” in this document, have also consulted extensively with the permittee on the issues addressed in this permit, and have carefully considered the data and analyses presented by the permittee both in writing and at numerous meetings. The company has brought information to bear on a variety of subjects relevant to this draft permit. In addition, the permittee continued to submit new information to the regulatory agencies up to the time of the completion of the draft permit, fact sheet and this document. As a result of the late date of the submission of this information, EPA did not in all cases give full consideration to all of the recently submitted studies prior to issuance of the draft permit. EPA does, however, look forward to giving this information careful evaluation during the public comment period, along with any other public comments and/or new information that may be submitted. See December 21, 2001, Letter from Michael Hill (EPA) to Norm Cowden (Mirant). On January 16, 2002, Mirant Kendall submitted a response to EPA’s December 21, 2001, letter.

EPA greatly appreciates the time, effort and expertise that each organization mentioned above, along with the permittee, have contributed to assist in the development of this draft permit.

1.2 References

Hill, M. 2002. 12/21/01 Letter to Norm Cowden, Mirant. EPA Comments on Submissions for NPDES Permit Renewal.

Cowden, N. 1/16/02 Letter to Michael Hill, EPA. Mirant Response to the EPA 12/21/01 Comment Letter.

2.0 Ecological Setting

2.1 Introduction

The Kendall Square Electric Generating Station is located in Cambridge, Massachusetts, along the shore of the Charles River, approximately one mile upstream from the mouth of the river. The cooling water intake structure (CWIS) of the station is located in the Broad Canal, approximately 200 feet from where the canal joins the Charles River. The station heats this water in a once through, non-contact design configuration and discharges the heated water to the Charles River. The discharge water passes through two pipes and enters the river at a seawall fronting the Cambridge side of the Charles River, just downstream of the station. The water is discharged from this sidewall location near the surface of the river. An additional cooling water discharge point has been proposed as part of the NPDES Permit Application. This discharge would travel through a piping system into the river and be ultimately discharged from diffuser ports placed in a deep area of the lower Charles River Basin, about 750 feet from the shore. As described in Attachment A of the Fact Sheet, this proposed bottom diffuser has not been included as a permitted discharge location in the draft Permit.

The entire Charles River is approximately 80 miles long and flows through eastern Massachusetts. Kendall Station's operation is thought to have an impact on the water quality and indigenous aquatic populations that exist in the Charles River from the mouth of the river upstream to where the river passes Watertown, Massachusetts. This section is identified as the Charles River basin or the "basin". The portion of the river that is the focus of this document when discussing environmental impacts of water intake and heated water discharge from Kendall Station is that which is bracketed by the New Charles River Dam at the mouth and the Boston University bridge upstream, and is identified as the lower Charles River Basin, or the "lower basin". A brief overview of the ecological setting of this section of the river is provided below.

2.2 Physical Characteristics of the Lower Basin

The Charles River basin encompasses a 9.8 mile section of the river, from the Watertown Dam at the upstream boundary of the basin, to the New Charles River Dam near the mouth of the river. Before construction of the first (Old) Charles River Dam in 1908, the river in this area was a tidal estuary, with exposed mudflats at low tide. The dam, built approximately one mile upstream from the natural mouth of the river, created a freshwater basin in the Charles River with stable water levels. Waters upstream of the dam were removed from the influence of the Boston Harbor marine tidal cycle of fluctuating water levels and saltwater mixing. In 1978, the New Charles River Dam replaced the original dam. The original dam was not removed from the river. Instead, the navigational lock was modified into a passage canal, with both ends open at all times. While the old dam, now know as Science Park, no longer impedes the passage of water, the structure does constrict the passage of boat traffic and the movement of aquatic species past the site.

The new dam is located approximately one half mile downstream from the original dam. This dam is presently the physical demarcation between the fresh waters of the Charles River and the coastal marine waters of Boston Harbor. The dam has three navigational locks and was designed with an anadromous fish passage structure, which has never been fully operational.

The Charles River Basin travels in a generally easterly direction before discharging into Boston Harbor. For the majority of the distance from the Watertown Dam downstream, the river is generally in the range of 500 feet wide. The river in this section of the basin meanders and has a measurable flow; generally displaying characteristics that are more closely associated with a riverine habitat. Approximately three miles upstream from the mouth of the river, the basin widens significantly, deepens, and has a greatly reduced flow, assuming impoundment-like characteristics. This pronounced change in the characteristics of the basin takes place just downstream of the Boston University Bridge.

The mean depth of the basin, from the Watertown Dam to the New Charles River Dam, is approximately 12.5 feet (3.8 meters), with the deepest point being approximately 40 feet deep (12 meters). The bottom configuration of the wide, impoundment-like portion of the basin varies greatly, having many deep depressions. These deep bathythermic depressions have been reported to collect dense, cold water, during certain times of the year. The water is low in dissolved oxygen and sometimes high in salinity. The poor water quality in these deep areas has been shown to be difficult to flush out or mix with upper layers of the water column, even under high flow conditions (Mirant Kendall NPDES Permit Application, February 2001).

The shoreline of the basin is highly developed, with rock walls, concrete retaining walls, docks, marinas, and roadways constructed along the banks. There are eight bridges that cross the river in the lower basin. Several smaller tributaries empty into the lower basin, including Laundry Brook, Hyde Brook, Faneuil Brook, Shepard Brook, Salt Creek, Muddy River, and Stony Brook; all from the southern drainage area of the watershed. Most of the stream channels in these tributaries have been enclosed in conduits (Zarriello and Barlow , 2002).

On the Cambridge side (northern drainage) of the lower basin, the Broad Canal is located just upstream of the station. The canal is a man-made inlet originally constructed to encourage business development along the Charles River. The Broad Canal now extends approximately 700 feet perpendicular to the Charles River and is about 15 feet deep. The canal is used as a source of cooling water for Kendall Station (Mirant Kendall NPDES Permit Application, Volume I, February 2001).

2.3 Watershed Description

The drainage area to the Charles River basin, excluding areas above the Watertown Dam, is estimated to be 36.6 square miles, but drainage divides are complicated by man-made drainage systems that are common in the major metropolitan area which encompasses the majority of the watershed. The basin watershed is one of the oldest urban areas in the United States, including the municipalities of Cambridge, Boston, Brookline, Newton and Watertown (Zarriello and Barlow , 2002). The basin watershed is extremely urbanized, with intense commercial, residential, industrial and recreational land uses along both sides of the river (Fiorentino, 2000). Through pavement and other urban development, a large percentage of the land in this watershed has been made impervious to rainfall. Sheet runoff from storm events is carried through a complex infrastructure of pipes and diversionary canals. This characteristic of the extensively modified landscape causes streamflow in the lower Charles River Watershed to be unsettled and subject to rapidly increased flows in response to rain events (Breault *et al*., 2002).

2.4 Hydrology

The average monthly lower basin river flows for the months of May, July and September for the period of record (1931 - 1990), in the vicinity of Kendall Station, were calculated to be 449 cubic feet per second (cfs) in May, 160 cfs in July and 140 cfs in September (United States

Geological Survey [USGS] Historic Record). These flows were derived by adding 24% to the Charles River flows recorded upstream at the USGS gauging station at Waltham, Massachusetts (Gauging Station 01104500), to account for the tributary flows (USGS, 2002).

Daily average values for Charles River discharge, measured in cubic feet per second (cfs), as recorded by the USGS Gauging Station at Waltham, Massachusetts, from January 1994 through November 2002, have been plotted continuously in Figure 2.4-1. This figure is included to provide a visual representation of more recent fluctuations in magnitude and seasonal component to the discharge of the river. In order to more easily compare river discharge during the warmer months, Figure 2.4-2 was included. This figure displays Charles River discharge information for June through September of each year from 1994 through 2002 (USGS provisional data). As previously discussed, to account for the additional watershed drainage between the USGS Waltham Station and the starting point of the lower Charles River Basin at the Watertown Dam, 24% must be added to any flow recorded at Waltham (USGS, 2002). Once this 24% additional flow factor has been applied, the maximum and minimum daily river flows estimated in the vicinity of Kendall Station from January 1994 through November 2002 were 3249 cfs and 14 cfs, respectively. Highest daily flows were generally seen in the late winter and spring, with low flows generally recorded in the summer and early fall (Figure 2.4-1).

An examination of the more recent USGS data, adjusted for the increased lower basin flow, reveals an average flow of 113 cfs in the vicinity of Kendall Station for the month of August from the years 1994 through 2002. The 7Q10 flow (the average of the lowest flows for seven continuous days over a ten year period) near the station is estimated to be approximately 22 cfs. To put this into perspective with regard to the water use of the station, the maximum withdrawal capacity of the intake pumps at Kendall Station is 123 cfs (80 million gallons per day [MGD]), and the average withdrawal is projected to be approximately 108 cfs (70 MGD). Based on a comparison with Charles River flows, future Kendall Station heated discharge may generally equal the flow of the entire lower Charles River Basin in August, and could be almost five times the flow of the river under low flow conditions.

Retention time in the basin, from the Watertown Dam to the New Charles River Dam, at the annual mean flow rate is calculated to be almost 17 days. Under low flow conditions of 22 cfs (7Q10 flow), retention time in the basin can be as high as 295 days.

The volume of the portion of the lower basin from the Boston University Bridge to the New Charles River Dam is 10.4 million cubic meters of water (367.3 million cubic feet). It would take Kendall Station approximately 36 days at the station’s maximum water withdrawal capacity of 119 cfs to pass the entire volume of the basin from the BU Bridge to the New Charles River Dam through the cooling water system.

The New Charles River Dam highly regulates the flow and water level of the basin to control flooding of the surrounding shoreline during storm conditions and to prevent dewatering of a large percentage of basin sediment under low flow conditions and low tides in the harbor. The Metropolitan District Commission (MDC) operates the dam and generally holds the lower Charles River Basin water surface elevation level steady at 108 feet, Metropolitan District Commission Datum (MDCD). The mean tidal fluctuations on the Boston Harbor side of the dam range between 101.1 and 110.6 feet MDCD, with a mean spring tide range of 11.0 feet (US Army Corps of Engineers, New England Division,1992).

Operation of the navigational locks and sluice gates at the New Charles River Dam, especially during high tide in the harbor, when the harbor water level is higher than the Charles River water level, has been known to result in the movement of a dense, saline wedge of water from the harbor into the freshwater basin (Mirant Kendall NPDES Permit Application, Volume I, February 2001).

2.5 Water Quality

Approximately 73% of the drainage area of the entire Charles River system is above the Watertown Dam (USGS, 2002). Therefore, the water quality of the lower Charles River Basin is initially influenced by the watersheds and river conditions upstream of the basin. One example of this influence is the brownish color of the water in the lower basin, which is in part a result of the tannins contributed by upstream wetlands that drain into the river.

Once the water passes the Watertown Dam and enters the lower Charles River Basin, watershed conditions and processes unique to the lower basin substantially influence the water quality of the basin. This is especially true when the water enters the wide, slow flowing, impoundment-like area of the lower basin, at the furthest downstream location.

Under the state water use classification system, DEP has designated the lower Charles River Basin as Class B waters (314 CMR 4.00). Class B waters are designated as a habitat for fish, other aquatic life, and wildlife and for primary and secondary contact recreation. These waters are to be suitable for public water supply following appropriate treatment, irrigation and other agricultural uses, and compatible industrial cooling and process uses. As a warm water fishery, temperatures shall not exceed 28.3 ºC (83 ºF), and the rise in temperature due to a discharge shall not exceed 2.8 ºC (5 ºF), based on the minimum expected flow for the month. The waters shall have consistently good aesthetic value. The basin does not always meet the water quality standards prescribed for Class B waters, especially after wet weather. Following rainstorms, the water quality of the river may become impaired. This impairment has been documented as described in Attachment A of the accompanying Fact Sheet. This is because storm water quality in the lower Charles River Watershed, similar to that of other urban areas, is poor. The poor quality of the storm water and its relatively large quantity, delivered to the river over a short period of time due to the impervious nature of the landscape (see Section 2.3), together with untreated sewage from combined sewer overflow (CSO) discharges, result in large contaminant loads that appear to exceed the river’s assimilative capacity, primarily with respect to fecal coliform bacteria (Breault *et al*., June 2001 Draft). Sediment contaminants, from years of unregulated municipal and industrial discharges to the basin, may also be re-entrained into the water column under certain hydrological conditions, further impairing water quality. Because of these factors, DEP has designated the waters of the lower basin as impaired due to organic enrichment/low dissolved oxygen (DO), noxious aquatic plants, and taste, odor and color problems, along with, contaminated sediments, harmful bacteria, and increased turbidity.

The low current velocity and relatively deep, impoundment-like nature of the basin below the Boston University Bridge promotes the development of seasonal thermal stratification and a hypolimnion below approximately 15 feet. This hypolimnion, where cooler, dense water is cut off from upper level mixing, becomes naturally depleted of oxygen as the summer progresses. This isolated water layer has the potential to be a cool water refuge for fish species, when not pursuing prey in the upper warm waters of the basin. The surface water is heated both from solar input and warm summer air temperatures, as well as the waste heat discharged to the basin from Kendall Station and other man-made sources. Respiration from organisms and other chemical and biological processes that use oxygen, deplete oxygen levels in the hypolimnion to the point where long term residence of fish species is diminished. As the summer season progresses, the hypolimnion becomes so devoid of oxygen, it does not meet water quality standards for dissolved oxygen and fish species are excluded from this habitat.

A potentially beneficial aspect of the Kendall Station's NPDES Permit proposal may be the impact of a deep water diffuser designed to discharge up to 50% of the station's heated discharge water. The permittee has submitted information contending that this discharge water, because of its higher temperature and comparatively lower density, is expected to break up the summertime basin stratification, prevent the development of an oxygen depleted, seasonal hypolimnion and allow oxygenated water to circulate to all depths of the basin in the late summer. If this possible by-product of the deep water discharge were realized, it may improve a significant portion of the deep water habitat for fish species, by increasing oxygen levels in deeper, stratified waters in the summer and early fall. Some of the potential impacts of the operation of the deep water diffuser are briefly outlined below and in Attachment A of the Fact Sheet.

There are, however, other potential water quality impacts associated with the proposed operation of the diffuser that may negatively affect the basin. Among these impacts is an overall warming of the deeper waters of the basin. Deep water that still contains sufficient oxygen is sometimes 9 ºC (~16.2 ºF) cooler than surface waters in the early summer (example: July 5, 2000; Museum Station). This deeper, cooler water is available as a cool water refuge for fish when surface temperatures rise. Once the basin undergoes the mixing proposed by diffuser operation (Mirant Kendall NPDES Permit Application, Volume I and II, 2001), the difference in temperature between surface and deeper waters may become much less. This mixing effect may substantially reduce the cool water refuge currently available to fish when surface temperatures rise and deeper water has not yet been depleted of oxygen.

Also, mixing of the basin and introduction of oxygenated water to the substrate may have adverse effects. This process may make available potentially harmful contaminants, such as the inorganic elements cadmium, chromium, copper, lead, mercury, nickel, silver and zinc. These elements, which are among the US EPA's priority pollutants (US EPA Water Quality Standards Handbook,1994) have been found in the basin sediment at concentrations characterized as "probable adverse biological effects levels" (USGS, 2000). Some organic contaminants present in the sediment, including polychlorinated biphenyls, exceeded the direct-contact, exposure based soils standards for protection of human health (USEPA, 1997). These constituents, for the most part, remain locked in the sediment of the lower basin under present physical and chemical conditions. Increased mixing may make them available to balanced indigenous populations, resulting in bioaccumulation, which may cause serious adverse effects to fish populations and higher levels of the food chain that feed on the contaminated fish. Resuspension of organic contaminants into the water column may also pose a health threat to human activities in the basin. Since the basin is classified as a primary and secondary contact recreational resource, this resuspension may degrade a designated use of the basin.

Nutrients also tend to accumulate in the hypolimnion of an impoundment. Excessive nutrient loading has already been identified as a problem in the lower basin. The high levels of nutrients have contributed to large algal blooms in the basin. It is possible that the addition of more nutrients from a previously isolated hypolimnion that would now be mixed by a deep water diffuser may cause further impairment to the water quality of the lower basin.

Water quality in the lower Charles River Basin is also complicated by the operation of the New Charles River Dam. Under certain conditions, the use of the navigational locks and sluice gates allows a seasonal lens of cool, dense water to migrate from Boston Harbor and travel "upstream" into the basin. This water is generally low in dissolved oxygen and high in salinity, rendering it very poor habitat for the resident freshwater or anadromous fish populations that exist in the basin. This saline intrusion collects in deep depressions of the basin and the volume of the basin it occupies in the summer varies from year to year. These pockets of dense water have been seen to persist in the basin, at least in the deepest areas, even when storm events have resulted in an overall flushing of the basin. Anoxic saline water overlying organic sediment has been documented to produce hydrogen sulfide in the bottom layer of the basin. Hydrogen sulfide, released to the upper layers of the basin during upwelling from wind and wave action, has been implicated in fish kill events in the basin (USGS, 2002). The operation of the proposed deep water diffuser, discussed previously as a way to destratify the basin, may also generate an upwelling effect that may introduce levels of hydrogen sulfide to the water column that could be potentially lethal to fish populations. It has also been proposed that vertical mixing caused by the diffuser could break up this salt water wedge and improve the overall quality of the habitat of the lower basin with only short lived negative impacts.

2.6 Aquatic Habitat

The lower Charles River Basin has a degraded benthic habitat, primarily due to high concentrations of inorganic and organic contaminants that have been deposited in the basin over many years (USGS, 2000). Low instream velocities and soft substrates are characteristic of the lower basin. Macroinvertebrate populations show low numbers and the dominance of pollution-tolerant taxa such as Tubificid worms. Density studies have revealed that an average of one macroinvertebrate per eight square meters was measured in the lower Charles River Basin. This value is much less than the average of eight macroinvertebrate per eight square meters for other urban rivers (Fiorentino, 2000).

Submerged aquatic vegetation is present in shallow portions of the lower basin, but alteration of the shoreline by human activity has likely degraded the amount and type of vegetation available as structure and food source for various stages of fish species in the basin.

Phytoplankton and zooplankton communities have been documented in the lower basin. In some cases, nuisance algal blooms and high levels of chlorophyl a have been reported in the lower basin. A full discussion of phytoplankton communities in the lower basin is included in Attachment A of the Fact Sheet.

There are 20 species of fish found in the Charles River, including resident freshwater species such as yellow perch, largemouth bass, chain pickerel and sunfish (CRWA publication). Anadromous species, such as blueback herring and alewife have also been documented in the basin. Since coastal assessments conducted by NOAA Fisheries and the Atlantic States Marine Fisheries Commission (ASMFC) have indicated a measurable decline of anadromous species over the past decades, any populations occurring in the Charles River take on added importance to the health of the overall coastal assemblage of the species. A listing of finfish priority species compiled by the permittee is found in Table 2.6-1 (Table 5-1 of Mirant Kendall Permit Application). Sufficient biological information has not yet been compiled to reliably estimate the population of fish species in the basin.

Anadromous species must navigate past the New Charles River Dam to enter the basin to spawn. The fish passage structure designed as part of the dam has never been fully operational. An operational protocol for one navigational lock at the dam has been developed to promote anadromous fish passage during spawning. Since the primary objective of dam operation is flood control and river level stabilization, the manual application of the fish passage protocol is at best a poor substitute for a continuous, well designed fish passage system.

Efforts were initiated by the MA DFW in 1980's and 1990's to reestablish American shad in large numbers in the Charles River. These efforts did not achieve their desired goals. The reason or reasons for the poor results of the restoration programs have not been documented with certainty. While no restocking activity is currently underway, the MA DFW is still interested in promoting this restoration effort and may resume a program in the future.

Preliminary information from environmental sampling conducted by the permittee in 2002 reveals that gizzard shad have been collected in the lower basin (Cowden Mirant Letter, November 5, 2002). This anadromous fish has not been routinely seen in sizable numbers in the basin in past years' sampling efforts. It is unclear if the documentation of these fish is an indication that their numbers are growing in the basin, perhaps indicating an improving aquatic habitat. It could also be possible that increased or improved sampling efforts are now capturing gizzard shad that have always been part of the anadromous fish populations in the basin.

The thermal discharge from Kendall Station is limited to an average flow of 70 MGD, which is equivalent to 108 cfs. Under the full capacity power production of a base load generating facility, Kendall Station will introduce water continuously to the lower basin that will, in most cases, be up to 20ºF warmer than the surrounding, ambient conditions. During some times of the year, the flow of heated water discharged by Kendall Station will contribute more to the lower basin than the natural flow of the river. As will be discussed in more detail in Section 5.6 and 5.7 of this document, water temperatures markedly greater than ambient waters may degrade the aquatic habitat for indigenous fish populations. The protection of suitable aquatic habitat sufficient to maintain balanced indigenous populations of fish is a major focus of this NPDES permit.

2.7 Basin Uses

The basin was originally used as a transportation corridor and industrial center. It has served as a sanitary sewer carrying industrial and domestic waste, including raw sewage. At the present time, the basin still acts as the receiving water for nearly 100 outfalls, including over a dozen permitted Combined Sewer Overflows (CSO) discharges. All of the CSO discharges are untreated, with the exception of discharges from the Cottage Farm CSO treatment facility.

In addition to this function, the basin is also a focal point for recreational activities for surrounding communities. It has been characterized as one of the most heavily used urban recreational areas in the nation. Fishing, sailing, kayaking and power boating are popular in the basin, as well as the use of the parks and open spaces along the banks. Rowing is a major activity in the basin. Each fall, the single largest one-day rowing regatta in the world, the Head of the Charles, draws approximately 5,400 rowers and 300,000 spectators to the basin. Annual Fourth of July Festivities attract over a half million people in and around the basin. The Esplanade, part of the MA DCR's Charles River Reservation, hosts more visitors than any other riverfront park in the nation. The basin also serves as the setting for some of the most prestigious institutions of higher learning in the country.

The New Charles River Basin, one restoration project that will enhance basin uses, will link the Charles River Reservation with Boston Harbor, reshaping the river and its banks in what is referred to as the "lost half mile." It is the goal of the MA DUPR (formerly MDC) to reinvigorate and rediscover this under-used resource as a new recreational opportunity that will helps to connect the 19th Century Metropolitan Park System with the mid-20th Century waterfront.

Project plans include over 40 acres of new parks and greenways, more than one mile of shoreline improvements, and over seven miles of pedestrian, bicycle and ADA-accessible pathways. These new features will allow increased accessibility to Boston Harbor for thousands of park users on the Esplanade and the Charles River path system.

North Point Park is a major component in the New Charles River Basin. Groundbreaking for the "newest jewel in the Metropolitan Park System's Charles River Basin" took place on June 13th, 2002. When complete in early 2004, North Point Park will be the site of a new 9-acre open space with a playground, pedestrian and bicycle paths, extensive trees, shrubs and flower plantings. The park will also include the creation of two islands, five pedestrian bridges, a canal and 1,500 square feet of restored wetlands. The site is located opposite from the Museum of Science in Cambridge, across the O'Brien Highway.

This is one of the many concerted efforts underway by surrounding communities, private organizations, businesses, and local, state, and federal agencies to fully restore the lower Charles River Basin to meet all its designated uses. These efforts have made improvements to the river. In 2002, the lower Charles River Basin was suitable for swimming 71% of the time, during dry weather days (EPA, Clean Charles Progress Report, April 2003). An initiative is under way to restore the basin to “fishable and swimmable” uses by 2005 (US Environmental Protection Agency Clean Charles 2005).

It must be noted that Boston Harbor, the coastal water body that ultimately accepts the flow from the Charles River, has also been the focus of intense activities to restore that water body to meet all its environmental and recreational uses. The Massachusetts Water Resource Authority (MWRA), in cooperation with EPA and state agencies, has invested $3.8 billion in a program to protect Boston Harbor from the sewage produced by communities it serves. The centerpiece of this program is the state-of-the-art mammoth sewage treatment plant located on Deer Island. As water quality improves in Boston Harbor, Anadromous fish that pass through Boston Harbor on their way to and from the Charles River during spawning season will be subjected to less environmental stress from the degraded marine habitat as water quality improves. This has the potential to contribute to stronger spawning runs in future years.

As outlined in Section 2.5 (Water Quality), The Massachusetts Water Quality Standards designate the lower Charles River Basin as a Class B water and has the following language pertaining to uses:

314 CMR, Section 4.05: Classes and Criteria, (1) Classes and Uses – The surface waters of the Commonwealth shall be segmented and each segment assigned to one of the Classes listed below. Each class is identified by the most sensitive, and therefore governing, water uses to be achieved and protected. Surface waters may be suitable for other beneficial uses, but shall be regulated by the Division to protect and enhance the designated uses.

The Charles River is classified as a Class B water and these waters are designated as a habitat for fish, other aquatic life, and wildlife, and for primary and secondary contact recreation.

2.8 References

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3.0 Plant Operations

3.1 Existing Facility and Types of Discharges

The Mirant Kendall Station power plant is engaged in the generation and distribution of electric power. The existing Station has a total of five steam generating boilers fueled by oil and natural gas. The three largest boilers produce steam to generate electricity and the two significantly smaller units are used to produce back-up steam only. Steam is used to generate electricity, for space heating and for various industrial uses in the nearby community. The plant generates electricity through the use of three steam turbine generators with an average annual net output of 64 megawatts (MW). In addition, the plant also operates two jet engine gas turbines fueled by jet fuel that generate electricity during peak electrical consumption to provide an additional 46 MW of capacity, with no associated cooling water required. Therefore, during peak electrical consumption (i.e. summer heat waves), the plant provides up to113 MW. From 1988 through 2001, the plant has operated at reduced levels of electrical generation due to the plant's low efficiency and the high cost of fuel (oil and natural gas). Therefore, the plant is operated as a "peaking plant" meaning that it chiefly operates during periods of peak electrical demand. With the addition of new generator described later, the permittee proposes to operate this plant continuously, or as a "base load" plant.

3.1.1 Cooling Water Discharges

The plant's once-through cooling water system is permitted to discharge up to a maximum of 80 million gallons per day (MGD) of water to the Charles River, not to exceed a monthly average of 70 MGD during the months of April, May and June and an annual average of 70 MGD for the entire year, as required by the existing NPDES permit. The flow of the non-contact cooling water from September 1988 to April 1998 was approximately 50 MGD as a monthly average and the maximum daily flow average for this time period was approximately 58 MGD as estimated from Figure 2-7 of Mirant Kendall's Supplemental Volume I Application of February, 2001. The figure is included in this document as Figure 3.1.1-1.

Water that is needed to cool and condense steam exiting the turbines is withdrawn from the Broad Canal, a channel connected to the Charles River, through three permitted intake structures. The water is circulated through the plant's three condensers where the heat from the condensers is transferred to the water. The maximum permitted increase in water temperature across the condensers is 20º Fahrenheit (F). The heated discharge water is returned to the Charles River through two pipes (called outfall pipes 001 and 002) located on the seawall fronting the Charles River directly east of the plant. These discharges include service waters which are used to cool the generator and associated equipment. In addition, the plant has the option of discharging the heated effluent to the Broad Canal through two pipes (called outfall pipes 003 and 004) for the purposes of melting ice during the winter. (However, since the Broad Canal is no longer used for commercial transportation, these discharge pipes are rarely used now.) The facility also discharges intake screen backwash water to the Broad Canal after removing debris from the three intake screens (outfall pipes number 005, 006 and 007).

3.1.2 Cooling Water Intake Structures

The cooling water intake structure is a multi-tiered system of screens designed to minimize the amount of debris entering the facility. The existing intake water velocities vary from approximately 0.57 to 0.76 ft/s at the intake screens, according to the February 2001 application. There are three intake water screen houses. Six pumps are used to control flow of the cooling water to the condensers – two per condenser and screen house. Each pump is capable on average of producing a flow of approximately 13 MGD. Mirant Kendall does not have variable control speed pumps, but rather can regulate flow by turning on or off any sequence of pumps. Each intake structure includes a trash rack and traveling screen. Trash racks placed across the three inlets cover the six by 10 foot inlets along the Broad Canal. The steel trash rack bars are spaced three inches apart and collect large debris such as plastic and wood fragments that may be in the intake water.

Located downstream of the trash racks are the traveling screens that intersect each inlet's cross-sectional area. The traveling screens are divided into panels six feet by one foot and are located perpendicular to the flow of the water. The screen mesh size is three-eighth (3/8) inch. Currently, the traveling screens are rotated three times per day and cleaned with river water that is returned to the Broad Canal (discharge pipes 005, 006 and 007). Any fish or debris caught on the screens is placed in a holding bin and is later discarded. There is no fish return system.

To control fouling of the intake water system piping, condenser and associated equipment, sodium hypochlorite is added downstream of each traveling screen located in each screen house during cooling water pump(s) operation. The concentration of residual chlorine in the non-contact cooling water is measured daily about 50 feet downstream of the condensers in an access manhole near the Broad Canal.

3.2 Upgraded Facility and Proposed Discharges

3.2.1 Proposed Upgraded Plant

Mirant Kendall proposes to upgrade the existing generation facilities by adding a new combustion turbine generator, specifically a heat recovery steam generator (HRSG), and associated air pollution control equipment and air cooling. Natural gas will be used as the primary source of fuel. Low-sulfur distillate oil will be used as a back-up fuel for up to 720 hours per year. The upgraded facility will continue to use the existing turbines and generators and plant cooling system. The combustion turbine generator will produce approximately 170 MW of power. When the new combustion turbine generator is added to the existing steam generator capacity, the total average annual net output of the plant will be 234 MW. Including the two jet peaking turbines, the new plant will capable of producing up to 283 MW at peak electrical demand, with a 280 MW annual average generation.

Since the plant will be much more energy efficient in generating electricity, it is anticipated that the plant will be operated as a "base-load" plant, meaning that it will operate at a capacity near 234 MW year round and more at certain times of the year. The difference between existing and future operations is that the plant will essentially operate continuously at a level that will produce approximately three times the megawatts (without using the jet peaking engines) than the existing plant was operating at "peak" load for limited times of the year.

To help dissipate heat from the increased heat load of the plant, Mirant proposes to build a "fin fan" cooler on the roof of the new combustion turbine/heat recovery steam generation building. The fin fan cooler, an air-cooling device, will reject waste heat to the atmosphere and will meet the operational cooling needs of the new combustion turbine and associated new auxiliary equipment, such as the fuel gas compressor, without using any additional or existing non-contact cooling water. A comparison of the existing plant and new proposed plant is provided in Table 1.2-1 of the Fact Sheet.

3.2.2 Proposed Cooling Water Discharges

Mirant Kendall proposes to increase the permitted flow of the once-through cooling water by changing the monthly average of 70 MGD to an annual average of 70 MGD. The daily average maximum flow will remain the same at 80 MGD. However, the actual flow of the non-contact cooling water will increase above the historical flow (approximately 50 MGD) to a level approaching the permit limit, as a result of the increased thermal load arising from the upgrades to power plant and from a change to continuous plant operation. This change to an annual average flow of 70 MGD will likely result in higher non-contact cooling flows through most of the year, an associated increase in heat load to the river and likely increases in the potential impacts due to impingement and entrainment (I&E) of aquatic life. The permittee will also be limited to a monthly average of 70 MGD for the months of April, May and June, to protect fish, eggs and larvae during their spawning periods.

Mirant Kendall proposes to use up to 4.7 MGD of the non-contact cooling water withdrawn from the Charles River, to produce approximately 1 MGD of purified water for use in the existing boilers, evaporative cooler, oil burning water injection to reduce nitrogen oxides, power augmentation and production of steam to customers, for use in the turbines as part of the HRSG and as boiler make-up water. By treating this water through the new ultra filter (UF) and reverse osmosis (RO) system, the majority of suspended solids and dissolved solids will be removed from this water. The water to be used for this system will come from the non-contact cooling water once it has been heated and passed through the condensers.

3.2.3 Proposed Cooling Water Intake Structures

3.2.3.a Proposed Use of Barrier Nets

Mirant Kendall also proposes to install fine-mesh exclusion barrier nets with an approach velocity of approximately 0.043 feet per second (fps) in front of the three existing cooling water inlet structures during certain times of the year. The permittee believes that the impingement of juvenile and adult fish is expected to be mostly eliminated with the use of the barrier nets. The anticipated approach velocity of 0.043 fps is about a tenfold decrease from the current rates and is below 0.5 fps.

The proposed design of the barrier net was submitted as part of the initial NPDES application submittal of February of 2001. Based on feedback from the agencies, a supplemental letter was submitted by Mirant, outlining a modified design for the barrier net. The description below is taken from the more recent submittal (Mirant Letter, December 23, 2002). Mirant also clarified elements of the barrier nets and their proposed operation with an e-mail on October 1, 2003, which was a result of questions posed by MACZM and MADFW.

The Barrier Screen System is designed to initially achieve about a ten-fold lower approach velocity and is calculated to be less than 0.5 ft/s even with more than 90% of the screen area completely fouled or unable to pass water. The future approach velocity will be much lower than that of the current installed configuration (which is up to more than 1 fps). The low velocity will be maintained by periodic cleaning as needed based on experience. The barrier nets shall be installed prior to or upstream of all three intake structures and shall be installed in a manner that will preclude any pass through of water around, over or under the nets. The barrier, which is composed of sectional screens, is expected to minimize impingement through its low approach velocity and small mesh size. These two factors would also allow swimming larvae and young-of-the year fish to avoid being pulled into Kendall Station (entrainment) and would reduce the numbers of ichthyoplankton that pass through the barrier and become entrained in the station.

During the summer of 2000, a prototype barrier was placed in front of intake structure #3 and studies were conducted to assess entrainment and impingement of aquatic organisms. The assessment also evaluated the potential for fouling and net durability. Mirant's studies indicated that the reduced approach velocities and the barrier net, on average, reduced impingement and the rate of entrainment. Mirant's study was conducted during the period of May to July of 2000 and its results were provided in Appendix 5-12 of Mirant's NPDES Permit Application, Volume II (February 2001). These results were variable and, in some cases, inconclusive. These trials showed that the barrier was over 80% effective in reducing impingement and entrainment (I&E) of larger larvae but only minimally effective at screening out smaller organisms. Many replicates showed a greater number of eggs and larvae inside the barrier net area, when compared to Broad Canal samples taken at the same time. Additional barrier net performance evaluations are required in the draft NPDES permit

3.2.3.b Screen Panel Maintenance

Each barrier net shall have several sections or panels, each one of which shall be capable of removal for cleaning or replacement. Before a section of barrier net is removed for cleaning or replacement, an impermeable panel shall be put in place behind this section so as to limit the amount of flow that may come through the intake without passing through the barrier net. The nets shall be designed to allow for impinged eggs and larvae to be freed in a manner to maximize their survival If the permittee wants to change any aspect of this barrier net design, it must obtain the prior, written approval of the Regional Administrator and the Commissioner. If the barrier screen panel needs cleaning, repair or replacement, a previously cleaned, replacement screen panel can be inserted into the empty panel position via the outside set of slots. Alternatively, the removed panel, if found to be dirty, may be cleaned. As the screen panels are cleaned the backwash water will flow back to the Broad Canal or Charles River. Once the cleaned or replacement panel has been returned to position, the non-penetrable panel will be removed. This system allows screen panels to be removed, cleaned and replaced (if necessary) while the Kendall Facility is in operation without compromising the function of the barrier. The non-penetrable panel also will stop flow through the removable screen panel, which will reduce pressure on the screen panel and ease its removal.

3.2.3.c Screen Panel Performance

The Intake Barrier Screen system will be installed at the beginning of spawning season, which is the earlier of February 15th or as soon as the Broad Canal ice thaws, in order to minimize finfish impingement and reduce entrainment of ichthyoplankton. The screen panels will remain installed throughout the season of deployment. The integrity of the barrier will be maintained during cleaning and maintenance as described above. Therefore, during spawning season, essentially all of the water taken in by the plant from the Broad Canal will pass through the barrier nets. The screen panels will be removed on November 1st, well after spawning season and historic periods of higher impingement are past.

The conditions of use and water flow in Broad Canal are not expected to present significant threats to the performance of the barrier net system, which is designed to withstand ordinary conditions. The plant will monitor the system by a careful visual inspection from the walkway, looking for evidence of problems, and will pull any screen panel (other than the end panels) for inspection if a problem is evident. The plant will also pull each screen for inspection that has not been pulled for cleaning or inspection in the prior three months of deployment. The plant will maintain records sufficient to document these inspections and appropriate responses.

Except as provided below, all intake water must pass through these nets for this entire period. If the permittee encounters unforeseen clogging or other operational difficulties with the nets, the permittee may pass water through its intakes without the use of nets for the shortest period of time sufficient to alleviate the problem, but not more than 10% of the time the facility is drawing intake water in any calendar month for all intake structures combined. For any continuous period during which intake water does not pass through any of the barrier nets for any intake structure for more than four hours, the permittee shall operate the traveling screens for such structure once per eight-hour shift, per the former standard operating procedure, until the barrier nets are again installed. With each DMR for this time period, the permittee shall report:

• the percentage of time that any part of the nets for each intake structure were not in place during operation of the intake

• Description of technical problem(s) requiring partial or total removal of the barrier

• Percent of barrier removed for each affected intake

• Proposed solution to technical problem(s)

• Projected time to cure such problem(s).

The permit has established I/E reduction goals for this permit along with ongoing reporting and changes as necessary which will lead towards the attainment of these goals and the nets shall be designed to meet these goals. For impingement, this permit sets a goal of a minimum of 80% of impingement mortality reduction as compared to the baseline condition and a goal of a minimum of 60% entrainment reduction as compared to the baseline condition. See the permit for additional details and requirements regarding these goals.

3.3 References

Mirant Kendall, L.L.C. February 2001. NPDES Permit # MA0004898 Kendall Square Station Equipment Upgrade Project, Cambridge, MA, Volumes I and II. Prepared by TRC for Mirant Corporation.

Reynolds, J.P. 2002. 12/23/02 Letter to David Webster, EPA. Performance Management Plan for the Mirant Kendall, L.L.C. Intake Barrier Screen.

4.0 CWA § 316(a) - Determination in Response to Mirant's Variance Application

4.1 Introduction

This section of the document presents EPA's determination in response to Mirant's February 14, 2001 application for alternative thermal discharge limitations under CWA § 316(a) (commonly referred to as "a § 316(a) variance application"). The thermal discharge limits included in the facility's current NPDES permit, issued August 17, 1988, are based on a § 316(a) variance. The current permit includes a maximum daily discharge temperature limit of 105°F and a maximum daily discharge temperature rise over the intake water (or ΔT) of 20°F.

4.2 Legal Requirements and Context

4.2.1 CWA § 316(a)

NPDES permits generally must include the more stringent of effluent limitations derived from technology-based or water quality-based requirements. CWA § 316(a) provides, however, that the regulatory agencies may establish alternative, less stringent thermal discharge limitations in an NPDES permit if certain criteria are met. Specifically, CWA § 316(a) provides, in pertinent part, as follows:

> [w]ith respect to any point source otherwise subject to the provisions of section 1311 of this title or section 1316 of this title, whenever the owner or operator of any such source, after opportunity for public hearing, can demonstrate to the satisfaction of the Administrator (or, if appropriate, the State) that any effluent limitation proposed for the control of the thermal component of any discharge from such source will require effluent limitations more stringent than necessary to assure the pro[t]ection and propagation of a balanced indigenous population of shellfish, fish, and wildlife in and on the body of water into which the discharge is to be made, the Administrator (or, if appropriate, the State) may propose an effluent limitation under such section for such plant, with respect to the thermal component of such discharge (taking into account the interaction of such thermal component with other pollutants), that will assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on that body of water.

33 U.S.C. § 1326(a). See also 40 C.F.R. § 125.70. A determination to approve alternative limitations under this statutory provision is commonly referred to as a "CWA § 316(a) variance." See 40 C.F.R. § 125.71(a) and 125.72 (heading).

4.2.2 Criteria for Assessing § 316(a) Variance Applications

CWA § 316(a) authorizes alternative thermal discharge limits when it is demonstrated to EPA that the limits "will assure the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife in and on that body of water" (sometimes referred to hereinafter as the "BIP"). This criterion is reiterated in EPA regulations promulgated at 40 C.F.R. § 125.73(a).

The terms "protection" and "propagation" are not defined in the statute or regulations. However, the American Heritage Dictionary (2d College Ed. 1982) defines "protection," in pertinent part, as "[t]he act of protecting . . . [or t]he condition of being protected," while it defines "protect" as "[t]o keep from harm, attack, or injury; guard." In addition, it defines "propagation" as "[to i]ncrease or spread, as by natural reproduction." Thus, thermal discharge limits based on a CWA § 316(a) variance must assure that the receiving water's BIP will be safe from harm from the thermal discharge, and that the thermal discharge will not interfere with the BIP's ability to increase or spread naturally in the receiving water.

The CWA also does not define the term "balanced indigenous population." Some clarification of Congress' intent is provided, however, in the CWA's legislative history. The Report of the Conference Committee on S. 2770, the bill that was enacted as the Clean Water Act of 1972 and originated the current § 316(a), stated the following with regard to § 316(a):

> It is not the intent of this provision to permit modification of effluent limits required pursuant to Section 301 or Section 306 where existing or past pollution has eliminated or altered what would otherwise be an indigenous fish, shellfish and wildlife population. The owner or operator must show, to the satisfaction of the Administrator, that a "balanced indigenous population of fish, shellfish and wildlife" could exist even with a modified 301 or 306 effluent limit. Additionally, such owner or operator would have to show that elements of the aquatic ecosystems which are essential to support a "balanced indigenous population of fish, shellfish and wildlife" would be protected.

Congressional Research Service, "*A Legislative History of the Water Pollution Control Act Amendments of 1972, Vol. 1*," 93d Cong., 1st Session, p. 175 (cited hereinafter as the "1972 Legislative History") (Senate Consideration of the Report of the Conference Committee (October 4, 1972)). This indicates that Congress did not intend that a thermal discharger would be able to "take advantage" of pollution-induced harm to the BIP to justify alternative thermal discharge limitations under § 316(a) that would not actually protect the BIP. It also makes clear that Congress intended that elements of the aquatic ecosystem necessary to support the protection and propagation of the BIP would also be protected under § 316(a).[1]

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[1] In the legislative history of the 1977 CWA Amendments, Senator Muskie discussed the meaning of the phrase "balanced indigenous population of fish, shellfish and wildlife" as used in the "interim [national] water quality standard." He explained that:

> As in 1972, it was intended that the interim water quality standard be that condition of aquatic life which existed in the absence of pollution. There is no question that man's activities have radically altered receiving water ecosystems in this country and that alteration is continuing at an accelerated pace in many areas. Restoration of aquatic ecosystems which existed prior to the

Consistent with Congressional intent, EPA's currently effective regulations define "balanced indigenous population" in the following manner:

> The term *balanced indigenous community* is synonymous with the term *balanced, indigenous population* in the Act and means a biotic community typically characterized by diversity, the capacity to sustain itself through cyclic seasonal changes, presence of necessary food chain species and by a lack of domination by pollution tolerant species. Such a community may include historically non-native species introduced in connection with a program of wildlife management and species whose presence or abundance results from substantial, irreversible environmental modifications. Normally, however, such a community will not include species whose presence or abundance is attributable to the introduction of pollutants that will be eliminated by compliance by all sources with section 301(b)(2) of the Act; and may not include species whose presence or abundance is attributable to alternative effluent limitations imposed pursuant to section 316(a).

40 C.F.R.§ 125.71(c) (emphasis in original). It is clear under this definition that a satisfactory BIP under § 316(a) need not in all circumstances match some sort of estimated aboriginal assemblage of organisms. At the same time, however, the BIP must satisfy the listed indicia of an ecologically healthy community of organisms, including that it cannot be dominated by pollution tolerant species or species whose presence or abundance is attributable to § 316(a)-variance based permit limitations or pollutant discharges that will be eliminated pursuant to technology-based effluent limitations under § 301(b)(2). See 44 Fed. Reg. 32894 (June 7, 1979) (Preamble to Revised 40 C.F.R. Part 125 Subpart H); see also 39 Fed. Reg. 36178 (October 8, 1974) (preamble to earlier version of EPA definition regulation containing substantially similar

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> introduction of pollution from man's activities is an important element of the restoration and maintenance of the biological, physical, and chemical integrity of receiving waters. It is an essential aspect of assuring that future generations will have an adequate supply of basic life support resources.
>
> The concept of indigenous does not anticipate the removal of structures from waterways. It does not anticipate the existence of ecosystems which existed in the absence of those structures. But it does fully anticipate the analysis of aquatic populations in terms of man's activities prior to, and subsequent to, pollution.

L. History 1977, p. 448.

definition).

EPA provided further clarification regarding the meaning of BIP under § 316(a) in the case of In the Matter of: Public Service Company of Indiana, Inc., Wabash River Generating Station, 1979 EPA App. LEXIS 4, 1 E.A.D. 590 (November 29, 1979). In Wabash, EPA made clear that in assessing the BIP, EPA must look not only at the community as a whole but also at the effects on individual species of fish that should make up the BIP. 1970 EPA App. LEXIS at 21 ("it is clear that both individual [species] and community considerations are relevant"). EPA explained that

> ... in attempting to judge whether the effects of a particular thermal discharge are causing the system to become imbalanced, it is necessary to focus on the magnitude of the changes in the community as a whole and in individual species; i.e., whether the changes are "appreciable."

Id. at 22. Finally, EPA also made clear that it is not acceptable that a particular discharge will allow the propagation of *some* community of fish with a certain degree of diversity and abundance; the thermal discharge limits must be sufficient to protect *the* BIP as defined in the regulations. As EPA explained in Wabash:

> Section 316(a) must, like any other provision of the Act, be read in a manner which is consistent with the Act's general purposes. Consequently, § 316(a) cannot be read to mean that a balanced indigenous population is maintained where the species composition, for example, shifts from a riverine to a lake community or, as in this case, from thermally sensitive to thermally tolerant species. Such shifts are at war with the notion of "restoring" and "maintaining" the biological integrity of the Nations' waters. Thus, even though it may be difficult or even impossible to define what the precise balanced indigenous population would be in the absence of heat, it is generally sufficient, as the regulations provide that it "will not include species whose presence or abundance is attributable to the introduction of pollutants," such as heat, and that it should be characterized by "non-domination of pollution tolerant species."

Id. at 28-29 (citation omitted).

Another step in applying CWA § 316(a) is to define the "the body of water into which the discharge is to be made" and for which the BIP must be protected. Obviously, many water bodies connect to other water bodies – e.g., a river or bay flowing into the ocean – and a point of reference must be selected for analysis. Neither the statute nor regulations dictate how this should be done. EPA has focused on discrete water bodies, water body segments, or even subareas within a water body segment, that may be influenced by the thermal discharge, appropriately shaping the approach to the facts of each case. In Appalachian Power Company v. Train, the court described (and upheld) EPA's reasoning as follows:

> EPA points out that state water quality standards typically apply to an entire waterway or a relatively large segment of it. By way of contrast, EPA views § 316(a) as providing for consideration of specific site conditions in the setting of thermal limitations for individual power plants. Thus, while a greater level of thermal effluent by a generating unit might well fall within the general requirements of an approved state standard, EPA takes the position that such discharges might nevertheless cause serious harm to a particular spawning ground, for example, located just below the plant's discharge point. It is such specific site conditions to which EPA contends § 316(a) is directed.

545 F.2d 1351, 1372 (4th Cir. 1976).[2] This approach makes ecological sense and is consistent with the CWA's overall purpose of restoring and maintaining the chemical, physical and biological integrity of the Nation's waters.

The statute and regulations are also clear that in applying CWA § 316(a), the permitting agency must take account of the cumulative effects of other stresses to the BIP. First, CWA § 316(a) states that the permitting authority may propose variance-based thermal discharge limitations, "(taking into account the interaction of such thermal component with other pollutants), that will assure the protection and propagation of a balanced, indigenous population . . .." Second, EPA regulations promulgated at 40 C.F.R. § 125.73(a) (emphasis added) states that a discharger's request for a § 316(a) variance "must show that the alternative effluent limitations desired by the discharger, *considering the cumulative impact of its thermal discharge together with all other significant impacts on the species affected*, will assure the protection and propagation of" the BIP. See also 40 C.F.R. § 125.73(c)(1)(i). In the preamble to 40 C.F.R. Part 125 Subpart H, EPA stated:

> Several commentors argued that applicants should not be required to analyze cumulative effects of thermal discharges together with other sources of impact upon the affected species as required by proposed § 125.47 (now 125.72(a)). This issue was addressed in the Administrator's first *Sea brook* decision which concluded that

[2] It should be noted that in the situation described in the quotation, a proposed discharge might satisfy numeric thermal water quality criteria but fail to satisfy § 316(a). In such a case, thermal discharge standards would need to be based on either technology standards or perhaps more stringent water quality-based limits necessary to protect designated uses.

> analysis of cumulative effects is required.

44 Fed. Reg. 32894 (June 7, 1979).

In the *Seabrook* permit appeal decision referenced above, EPA's Administrator stated the following:

> The RA [(i.e., the Regional Administrator)] ruled that a determination of the effect of the thermal discharge cannot be made without considering all other effects on the environment, including the effects of the intake (i.e., entrainment and entrapment); the applicant must persuade the RA that the incremental effects of the thermal discharge will not cause the aggregate of all relevant stresses (including entrainment and entrapment by the intake structure) to exceed the 316(a) threshold. I believe this is the correct interpretation of Section 316(a). The effect of the discharge must be determined not by considering its impact on some hypothetical unstressed environment, but by considering its impact on the environment into which the discharge will be made; this environment will necessarily be impacted by the intake. When Congress has so clearly set the requirement that the discharge not interfere with a balanced indigenous population, it would be wrong for the Agency to put blinders on and ignore the effect of the intake in determining whether the discharge would comply with that requirement.

<u>In re Public Service Company of New Hampshire</u>, 10 TRC at 1261-62. Thus, discharge limits imposed under CWA § 316(a) must be sufficient to ensure the protection and propagation of the BIP, taking into account other environmental stresses to the relevant population.

Another point worth mentioning here is that "mixing zones" *can* be used "as a mechanism for dealing with thermal discharges pursuant to section 316(a) of the Act." *U.S. EPA, Decision of the General Counsel, In Re Sierra Pacific Power Company,* EPA GO 31 (October 14, 1975). Although a "mixing zone" is a permitting concept or tool that may be used in applying State water quality standards, the legislative history of CWA § 316(a) indicates that Congress felt mixing zones could also be used in designing permit limitations based on a CWA § 316(a) variance from applicable technology standards. <u>Id</u>. Of course, to satisfy § 316(a), a mixing zone would need to be designed to ensure the protection and propagation of the BIP. <u>See</u> 39 Fed. Reg. 36178 (October 8, 1974) (Preamble to EPA's earlier § 316(a)-related regulations).

In applying CWA § 316(a), cost or economic issues are not a consideration. The plain language of § 316(a) makes clear that variance decisions are to be based on a determination of the limits needed to ensure the protection and propagation of the BIP. No mention is made of cost considerations being brought to bear. The legislative history also indicates that Congress did not intend costs to be considered in applying § 316(a). 1972 Legislative History, p. 175. Similarly, EPA's regulations clearly do not provide for costs to be a consideration in making a CWA § 316(a) variance determination. See 40 C.F.R. § 125.73. EPA has also interpreted CWA § 316(a) in this manner in practice. See In the Matter of: Public Service Company of Indiana, Inc., Wabash River Generating Station, 1979 EPA App. LEXIS 4,[*41] - [*43], 1 E.A.D. 590 (November 29, 1979). Thus, while costs are to be considered to a certain degree in developing technology-based standards for thermal discharges, which are to be based on the Best Available Technology economically achievable (BAT) under CWA §§ 301(b)(2) and 304(b)(2), costs are not considered in determining whether or not to grant a variance from such limits under § 316(a).

4.2.3 "Burden of Proof," Level of Evidence Required, and Different Types of § 316(a) Demonstrations

The statute plainly places the "burden of proof" in justifying alternative thermal discharge limitations under a CWA § 316(a) variance on the permit applicant. The statute provides that the permitting authority may impose such alternative thermal discharge limits, "*whenever the owner or operator of any such source . . . can demonstrate to the satisfaction of the Administrator (or, if appropriate, the State)* that any effluent limitation proposed [under CWA § 301 or 306] for the control of the thermal component of any discharge from such source will require effluent limitations more stringent than necessary to assure the pro[t]ection and propagation of" the BIP. 33 U.S.C. § 1326(a) (emphasis added). The legislative history underlying § 316(a) confirms the plain meaning of the statutory language. The Report of the Conference Committee on the Clean Water Act of 1972 stated the following, in pertinent part, with regard to § 316(a), "[under the conference agreement thermal pollutants will be regulated as any other pollutant *unless an owner or operator can prove* that modified thermal limit can be applied which will assure 'protection and propagation' of . . . [the BIP]." 1972 Legislative History, p. 175 (emphasis added).

EPA's regulations further confirm that the burden is on the permit applicant to persuade the permitting authority that the non-variance limits are more stringent than is needed and that an alternative set of limitations will be sufficient to protect the BIP. 40 C.F.R. § 125.73(a). Moreover, in the *Seabrook* permit appeal decision quoted above, EPA's Administrator also clearly stated that the burden of proof under § 316(a) lay with the permit applicant. In re Public Service Co. of New Hampshire, 10 TRC at 1261, 1263.

Moreover, it is clear that "the burden of proof in a 316(a) case is a stringent one." Id. at 1264. CWA § 316(a) states that the applicant must demonstrate *to the permitting authority's satisfaction* that the applicable non-variance-based permit limitations are more stringent than necessary to *assure* the protection and propagation of the BIP. Moreover, the statute directs that the permitting authority may include alternative thermal discharge limitations in a permit only if such limits will *assure* the protection and propagation of the BIP. In the legislative history of the

Clean Water Act Amendments of 1977, Senator Muskie[3] stated the following with respect to § 316(a):

> [t]he Congress intended that there be a very limited waiver for those major sources of thermal effluents which could establish beyond any question the lack of relationship between federally established effluent limitations and that water quality which assures the protection of public water supplies and the protection and propagation of a balanced, indigenous population of fish, shellfish, and wildlife, and allows recreational activities, in and on the water.

L. History 1977, p. 642; see also p. 457.

EPA has not, however, interpreted § 316(a) to require absolute certainty before a variance could be granted. In re Public Service Company of New Hampshire, 10 TRC at 1265. In reality, achieving absolute certainty about a § 316(a) determination is likely to be impossible. See Id. EPA has stated, however, that "[t]he greater the risk, the greater the degree of certainty that should be required." Id. at 1265. See also 44 Fed. Reg. 32894 (June 7, 1979).

The above material suggests that EPA should take a rigorous and conservative approach to granting and reissuing variances in order to meet the standard of assuring the protection and propagation of the BIP. Such an approach is appropriate in light of the fact that the applicant for a § 316(a) variance is seeking to be excused from otherwise applicable limitations, and given the CWA's overarching goal of restoring and maintaining the "biological integrity of the Nation's waters," 33 U.S.C. § 1251(a), and attaining "water quality which provides for the protection and propagation of fish, shellfish and wildlife." 33 U.S.C. § 1251(a)(2). EPA's NPDES permit decisions are, of course, subject to the "arbitrary and capricious" standard of review under the Administrative Procedures Act. 5 U.S.C. §§ 701 - 706. In other words, EPA's decisions regarding whether the permit applicant has carried its burden in seeking a § 316(a) variance, and in setting the thermal discharge limitations that are ultimately included in the permit, must have a rational basis and be consistent with applicable law.

With respect to the question of how much evidence is needed to support a § 316(a) variance,

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[3] Senator Muskie's comments from the legislative history have been given great weight by the courts in interpreting the CWA because he was the "principal Senate sponsor of the Act ...." Environmental Protection Agency v. National Crushed Stone Association, 449 U.S. 64, 71 n. 10 (1980). Accord, e.g., Natural Resources Defense Council v. Costle, 568 F.2d 1369, 1374 (D.C. Cir. 1977); American Iron and Steel Association v. Environmental Protection Agency, 526 F. 2d 1027, 1041 (3d Cir. 1975); American Meat Institute v. Environmental Protection Agency, 526 F.2d 442, 451 (7th Cir. 1975).

EPA has explained that, "[N]O hard and fast rule can be made as to the amount of data that must be furnished . . . and much depends on the circumstances of the particular discharge and receiving waters." In re Public Service Company of New Hampshire, 10 TRC at 1264. At the same time, information requirements are likely to increase to the extent that there is greater reason for concern over the protection and propagation of the BIP. As EPA stated in the preamble to its current § 316(a)-related regulations in 40 C.F.R. Part 125, Subpart H:

> Section 125.72 accordingly gives the Director the flexibility to require substantially less information in the case of renewal requests. This does not mean, however, that the Director may not require a full demonstration for a renewal in cases where he has reason to believe that circumstances have changed, that the initial variance may have been improperly granted, or that some adjustment in the terms of the initial variance may be warranted.

44 Fed. Reg. 32894 (June 7, 1979). See also 39 C.F.R. 36177 (October 8, 1977). EPA has stated that it "'must make decisions on the basis of the best information reasonably attainable.'" In re Public Service Company of New Hampshire, 10 TRC at 1265 (quoting 1974 EPA Draft § 316(a) Guidance). At the same time, the Agency has also explained that it "may not speculate as to matters for which evidence is lacking," id. at 1264, and that if "'deficiencies in information are so critical as to preclude reasonable assurance, then alternative effluent limitations should be denied.'" Id. at 1265 (quoting 1974 Draft EPA § 316(a) Guidance). See also In the Matter of: Public Service Company of Indiana, Inc., Wabash River Generating Station, 1979 EPA App. LEXIS 4, [*34] - [*40], 1 E.A.D. 590 (November 29, 1979) (Administrator remanded permit to Regional Administrator where Region had decided to grant variance-based thermal discharge limitations despite lack of data regarding thermal effects under worst case, low flow conditions). The question is what "an informed scientific judgment," id. at 1265, would be in light of the data in the record and absent from the record.

The regulations and guidance provide for several different types of § 316(a) demonstrations. These demonstrations may be structured to utilize existing information and minimize the amount of new information that must be collected. The required demonstrations will likely vary to some extent depending, in part, on whether the variance is sought by a new facility or an existing facility. See 40 C.F.R. § 125.73(c)(1) (two types of demonstrations for existing dischargers); U.S. EPA, "Draft - Interagency 316(a) Technical Guidance Manual and Guide for Thermal Effects Sections of Nuclear Facilities Environmental Impact Statements" (May 1, 1977), p.11 (referred to hereinafter as, "Draft 1977 316(a) Technical Guidance"). See also 39 C.F.R. 36177 (October 8, 1974); In the Matter of: Public Service Company of Indiana, Inc., Wabash River Generating Station, 1979 EPA App. LEXIS 4, [*15], 1 E.A.D. 590 (November 29, 1979).

An existing discharger may base its demonstration on a showing that there has been no "appreciable harm" to the BIP from "the normal component of the discharge taking into account the interaction of such thermal component [of the discharge] with other pollutants and the additive effect of other thermal sources." 40 C.F.R. § 125.73(c)(1)(i). Alternatively, an existing discharger can attempt to show that "despite the occurrence of such previous harm, the desired alternative effluent limitations (or appropriate modifications thereof) will nevertheless assure the protection and propagation of . . . [the BIP]." 40 C.F.R. § 125.73(c)(1)(ii). With respect to the appreciable harm test, EPA has explained that proposed thermal discharge limitations fail the § 316(a) variance test if those limitations would, taking into account other stresses upon the BIP, cause appreciable harm to the BIP in the future. Wabash, 1979 EPA App. LEXIS 4, [*16] - [*17], 1 E.A.D. 590 (November 29, 1979). In addition, thermal discharge limitations which caused appreciable harm to the BIP in the past are not to be renewed under a § 316(a) variance unless those limits are modified to prevent future harm or that other circumstances are demonstrated to have changed so that appreciable harm will not occur in the future.

5.0 Biology of CWA § 316(a) Variance Determination

5.1 Background

As water is withdrawn, heated and discharged to the same water body, once-through cooling systems of power plants have the capability to heat large amounts of water. Water temperature is one of the most important environmental factors affecting aquatic plants and cold blooded animals, such as fish. The heated effluents of steam-electric power plants can cause mortality and other deleterious effects among fish and other aquatic organisms. EPA, DEP and other agencies involved with the permitting of the Mirant Kendall Power Station have significant concerns of potential environmental impacts of station operation, especially resulting from the upgrade of this facility to produce additional electricity and the shift of operation to a continuous, base load facility. These concerns include the effect of heated discharge water on fish at all stages of their life (eggs through spawning adults), increased eutrophication from the upgraded plant's heated effluent and the use of the proposed diffuser in the lower basin of the Charles River. The extent of the heated discharge has been documented through field measurements, including the use of a thematic mapper sensor on the Landsat series of satellites (Mustard, *et al*., 1999).

The water temperature that fish are exposed to has a profound effect on many aspects of their survival, both individually and at the population level. Water temperature affects metabolic rate, energy reserves, growth, reproduction, migration of fish, egg maturation, incubation success, inter- and intraspecific competitive ability and resistance to parasites, diseases and pollutants (Armor, 1991). Water temperature changes may cause behavioral changes which could induce mortality (Pavis, 1991) or increase predation. However, a full understanding of temperature effects is complicated by the recognition that many environmental factors also may simultaneously influence the response of a fish to temperature. These environmental factors include dissolved oxygen levels in the water, photo period, stress level, diel cycles, pH, pollutants, predators, competition, salinity, diet, parasites, diseases, and seasonal changes. The ability of a species of fish to cope with these factors also varies depending on its sex, age and size, life-cycle stage and its genetic adaptation to acclimate to specific geographic areas (for instance, the ability of a fish to adapt to differences in latitude).

Temperature changes can also alter the existing aquatic community. For example, the dominance of various phytoplankton groups occurs in specific temperature ranges. Diatoms predominate at temperatures between 20 ºC and 25 ºC; green algae between 30 ºC and 35 ºC; and blue-green algae above 35 ºC (EPA, 1986; Figure 5.1-1). By increasing the water temperature of a body of water, a given species may be directly or indirectly precluded from that water body. Fish populations may be directly precluded through a shift from a variety of species to only those that can tolerate increased temperatures or large swings in temperature. Potential food sources may change or no longer be available for a given fish species as a result of water temperature increase, causing an indirect elimination of a fish species. This could have dramatic negative effects on a species' population.

Environmental temperature plays a critical role in the health of individual aquatic organisms as well as the entire aquatic community. Aquatic organisms have thermal tolerance limits, optimum growth temperatures, preferred temperatures within thermal gradients in the water column, and temperature limits for gonadal development, migration, spawning and egg incubation. In addition, temperature also affects the physical attributes of water – such as oxygen capacity. The processes that affect natural water temperatures are numerous and it is unlikely that any two bodies of water at the same latitude would have the same thermal characteristics. Since most aquatic organisms' body temperature reflect the water temperature in which they reside, natural conditions of the water body create conditions that are optimum at times, but are generally above or below optimum conditions for physiological, behavioral and competitive functions of the species present in the water body (Natl. Acad. Sci./Natl. Acad. Eng. 1972., p. 151).

Consequently, depending on the magnitude of the temperature change, the composition of the entire aquatic community can be altered so it no longer reflects a balanced community structure. Reduced species diversity and shifts to more pollutant tolerant species are generally considered detrimental to the ecosystem. Developing criteria to limit the addition of heat to a water body is difficult. In considering a thermal variance proposal, the goal of EPA is to determine the appropriate deviation from ambient or natural temperature conditions without adverse effects to the biota and to the balanced indigenous population. In general, a natural seasonal cycle should be maintained where annual spring and fall temperature changes are gradual and large induced daily fluctuations in temperatures are avoided. "...[A] change of even one degree from an ambient temperature has varying significance for an organism, depending upon where the ambient level lies within the [temperature] tolerance range" (Natl. Acad. Sci./Natl. Acad. Eng. 1972., p. 151-2). Furthermore, Coutant states that historic temperature records or, alternatively, the existing ambient temperature prior to any thermal alterations by man, are not always reliable indicators of desirable conditions for aquatic populations. Relying on the existing temperatures or the record of historical temperatures measured in the lower Charles River Basin to determine ambient conditions is even more problematic, since historical river temperatures in the vicinity of the power plant already reflect the increase in temperatures from such thermal sources as the Mirant Kendall power station prior to its upgrade, the upstream Blackstone Power Station (which is currently not discharging appreciable thermal effluent, but is historical source and a potential future source), as well as thermal impacts to the lower basin resulting from the highly urbanized condition of the immediate watershed.

Precisely identifying the timing of events or periods when certain life stages of a given fish species are present in nature is difficult to accomplish because many variables such as water temperature, genetic variation within a species, latitude, weather events, lunar cycles, tides, photo period effects, salinity, flow rates and limited fish passage all influence the timing of such events. Coutant (Natl. Acad. Sci./Natl. Acad. Eng., 1972) indicates, for example, that shifts in spawning dates by nearly one month are common throughout the United States. Because of the variability in nature, EPA's goals in developing the limits set out in the draft permit are to account for the variability in nature while at the same time to set maximum temperatures and changes in temperatures that ensure the Charles River maintains a balanced indigenous population. It is important to note here that EPA and others in the last decade have made steady progress in improving Charles River water quality and habitat for aquatic organisms (see Section 2.7 for additional information). EPA strives to carry these goals forward in the draft permit.

As discussed in Section 2.2 above, the physical characteristics of the lower Charles River Basin are more like a lake or impoundment than a river. Mirant Kendall purports that the use of the proposed bottom diffuser to discharge its non-contact cooling water will break-up the existing salt-wedge and improve dissolved oxygen. EPA is concerned, however, that fully mixing the saltwater wedge with the overlying fresh water, while improving dissolved oxygen conditions at the bottom of the basin, may also elevate the overall salinity of the basin in overlying surface areas, which are currently very low in salinity. Increased salinity throughout the water column in the lower basin may pose an environmental stress to resident fish populations. Fish populations exposed to this environmental stress may be less able to cope with the additional stress of elevated water temperatures in the lower Charles River Basin.

There is a potential for a release of pollutants from the contaminated sediments due to oxidation and fluxing as a result of operating this diffuser. These pollutants include nitrogen, phosphorus, cadmium, lead, mercury, pesticides, PCBs and PAHs. Also, the use of the diffuser will add significant heat to the water column and mix the cool bottom waters with the warm surface waters, resulting in a more homogenous water column that is significantly warmer than existing conditions. Although there may be more dissolved oxygen at depth during certain times of the year, the increase in bottom water temperatures, that is not part of the normal seasonal habitat of a particular species, may adversely affect those species that seek out cool, deeper waters as a thermal refuge during the summer months. It is EPA's goal that such reduction in a cool water refuge, should it occur, not interfere with biological communities or populations to a degree that it is damaging to the protection of the Balanced Indigenous Population (BIP) or other beneficial uses such as recreational fishing. It has been determined by EPA and DEP that the outfall diffuser will not be allowed at this time until further modeling is conducted that demonstrates that its use will not have negative water quality impacts.

EPA is concerned about the proposed increased heat load from Mirant Kendall Station, which may consistently contribute a measurable increase over historical BTU loads (Mirant Kendall Heat Load Data, 2003; Table 5.3-1 of this document). This increased heat load has the potential to further degrade or impair habitat quality, migration of fish, spawning, genetic diversity within a species and community diversity in species of fish and algae and/or phytoplankton. It is difficult to identify specific causes of population impacts on fish and other aquatic organisms because of the variety of factors at work. It can take many years of study for population affects to become apparent. Compounding this problem is the fact that year classes of anadromous fish such as alewife and blueback herring, once they migrate out of the Charles River, face mortality pressure from a number of sources in the marine environment that are not related to conditions in the Charles River. To help address this uncertainty, EPA is requiring biological monitoring to assess impacts to the fish population from the specific activities of the plant. In addition, the temperature limits EPA has selected in the draft permit strive to achieve a margin of safety to ensure a balanced indigenous population.

Since concentrations of dissolved oxygen (See Section 2.5) in the river are necessary to support fish species and other organisms (such as algae and/or phytoplankton), EPA requires that areas of the river designated to protect the balanced indigenous populations must meet the state water quality standards for dissolved oxygen for Class B water (5.0 mg/l or greater).

5.2 References and Supporting Documentation

The U.S. Environmental Protection Agency (EPA), Massachusetts Department of Environmental Protection (DEP), Massachusetts Department of Marine Fisheries (MA DMF), Massachusetts Coastal Zone Management (MA CZM), Metropolitan District Commission (MDC), and National Marine Fisheries Service (NOAA Fisheries) (Agencies) conducted considerable literature reviews, evaluated data from New England streams and rivers, reviewed information submitted by Mirant Kendall and actively engaged Mirant Kendall in numerous discussions to develop temperature limits and other permit requirements. This Determination Document and accompanying Draft Permit and Fact Sheet include extensive lists of references that were consulted as part of the permit renewal process. In addition, an administrative record has been compiled which contains the complete listing of all documents related to the preparation of these documents. The Kendall Station NPDES Draft Permit Administrative Record is available for review by the public at the EPA Region 1 Office, One Congress Street, Suite 1100, Boston, Massachusetts, 02114-2023.

5.3 Capacity of Kendall Station to Thermally Impact the Charles River Under Proposed Operating Conditions

The NPDES Permit previously in effect regulated the Kendall Station Electric Generating Facility when it was characterized as a “peaking facility”. This means that the facility was only called on to generate electricity periodically, usually in response to high electricity demand. In addition to periodic operation, electricity generation at Kendall Station under this operational configuration was often below the maximum the station was capable of producing. This lower electricity generation resulted in a corresponding reduction in the waste heat and cooling water volume withdrawn and discharged to the lower Basin, compared with maximum generation levels. Reduced waste heat and water usage translated to a reduction in potential impacts to the organisms in the lower basin from thermal effects as well as impingement and entrainment. Kendall Station operational data from September, 1988 through August, 1999, documented three of the measurement parameters recorded at the station, as monthly average values. The parameters were the average heat load discharged to the river (MMBTU/hour), the average volume of lower Charles River Basin water used (MGD), and the Delta T (ΔT, change in temperature) of the cooling water discharge (degrees Fahrenheit; Figure 3.3.1-1). These values showed that, especially during the time period from approximately 1992 through 1998, the operation of the station as a peaking facility resulted in monthly average and maximum levels that were consistently below the full capacity of the station. The observed historical average ΔT from 1992 through 1998 was approximately 7.8 ºC (14 ºF), compared with the maximum allowed ΔT of 11.1 ºC (20 ºF). The observed historical monthly average water use from 1992 through 1998 was 50 MGD, compared with the permitted monthly average water use of 70 million gallons (inspection of Figure 3.1.1-1).

Based on information submitted by the permittee as part of the renewal application, the operational configuration of the newly expanded Kendall Station will change from the “peaking” mode of past years to a more fully utilized “baseload” facility (Mirant Kendall NPDES Permit Application, 2001). This means the station will most likely be scheduled to produce a consistent amount of electricity on a continuous basis, rather than being called on to produce electricity only when the generation system demand required it. This change in station operation will likely result in a significant increase in waste heat discharged to the lower basin as well as a measurable increase in cooling water volume used from the lower Charles River Basin over time.

The previous NPDES permit limits for MKS allowed for the temperature of the ambient intake waters of the lower Charles River Basin to be heated as much as 11.1 ºC (20 ºF) (ΔT). The permit also allowed for a water use of a monthly average of 70 million gallons of Charles River water each day (MGD) for non-contact cooling water, with a daily maximum of 80 MGD. As discussed earlier, and based on Figure 3.1.1-1, the station never reached these maximum limits for a continuous, sustained time period.

Information submitted by the permittee indicates that, under proposed baseload operation, the discharge plume from Kendall Station has the capability to extend completely across the Charles River in the widest part of the lower basin. In addition, when river flows are very low, the projected summertime thermal influence of Mirant Kendall's discharges will likely extend from the BU bridge, downstream past the facility, to the New Charles River Dam, a distance of about

3 linear miles (Mirant Kendall, May 2001). The surface acreage of this segment of the river is about 450 acres, a little over 2/3 of the total surface area of the lower Charles River Basin (670 acres).

The new baseload configuration of MKS is proposed to approach the full capacity of electric generation for the station, with a consistent ΔT of 11.1 ºC (20 ºF). This is roughly a 43% increase over the observed historical average ΔT of approximately 7.8 ºC (14 ºF) from 1992 through 1998 (inspection of Figure 3.1.1-1). In addition, full capacity electricity generation is proposed to require Charles River water for non-contact cooling in the range of 70 MGD. This is roughly a 40% increase over the observed historical average water usage of 50 MGD from 1992 through 1998. If the maximum daily water withdrawal of 80 MGD is compared to the historical water usage of 50 MGD, the increase in water usage jumps by 60%.

It is recognized that in the absence of modification to the present intake structure, the increased use of river water by Kendall Station will likely intensify additional, non-thermal impacts to aquatic organisms in the river. These impacts largely involve impingement and entrainment of organisms and will be discussed fully in Section 8 of this document. Only the effect of increased thermal discharge will be discussed here.

Kendall Station's average monthly water withdrawal of 70 MGD roughly equals 108 cfs, and the maximum daily water withdrawal of 80 MGD is approximately 123 cfs (discussed in Section 2.4). Since the average flow of the Charles River near the station is 113 cfs in August (USGS, 1994 through 2002) and the low flow, 7Q10 value for the lower Charles River Basin is approximately 22 cfs, the warm water discharge from Kendall Station will most likely equal the river flow in August and contribute roughly five times the flow of the river during historic low flow conditions. Under these flow conditions, the comparatively smaller volume of ambient river water available will afford a reduced capacity to dilute the much warmer station discharge flow. These comparisons reveal the discharge of Kendall Station to be a major influence that increases temperatures in the lower basin, especially in late summer and under low river flow conditions.

Heat load information was also examined to determine how the change from historic peaking operation of Kendall Station to a base load facility may impact the amount of waste heat discharged to the lower basin. Figure 3.1.1-1 shows that the monthly and daily maximum heat load discharged from the Station from September of 1992 through August 1999 was generally around 250 MMBTU/hour (inspection of Figure 3.1.1-1). The maximum projected heat load of Kendall Station is 556 MMBTU/hour under baseload Station operation (using a ΔT of 11.1 ºC (20 º F) and a water withdrawal of 80 MGD). When the maximum projected heat load is compared with the historical heat load observed in the basin from 1992 through 1999, an overall increase of 122% is observed. This is more than double the heat load recorded from historic data.

Figure 3.1.1-1 is based on a rough estimate of station operation, derived from monthly average data. A more representative analysis of historic Station heat loads discharged to the lower basin from 1998 through 2003, during the crucial summer months, was submitted by the applicant in 2003. This information, calculated from hourly Kendall Station values for ΔT and cooling water usage, is certainly a much more accurate record of the waste heat generated by the station compared with the average monthly calculations used to produce Figure 3.1.1-1. Also, this figure targets only the warmer months of June, July, August and September (referred to as summer months in this discussion), when high ambient river temperatures and lower river flows would likely make the addition of heated water to the basin a greater stressor to the balanced indigenous populations. The six years of summer data is assembled in Figure 5.3-1.

Based on a comparison with a graph submitted by the permittee as part of its application, titled Kendall Square Plant Cooling Water Discharge Temperature Monitoring Record, and referred to as Figure 5.3-2 in this document, the heat load discharged in 1998, 1999 and 2000 more closely resembles the historic heatload seen in the basin in past years, at least since 1990. Therefore, although data was submitted for six summers, the following comparison focuses on the more representative data submitted for 1998 through 2000.

Table 5.3-1 calculated the average monthly heat load number for each month, based on the data from June through September, 1998 through 2000. These monthly averages, which are much lower than the general estimates presented in Figure 3.1.1-1, were then compared with the maximum heat load proposed under future baseload Station operation. The projected increase in heat load which will be discharged to the lower Charles River Basin ranges from an approximate 414% increase in June and August to an approximate 545% increase in September.

A heat load of 556 MMBTU/hr, consistently discharged to the lower basin, especially under low flow conditions, is from nearly five times greater to more than six times greater than the heat load discharged to the lower basin, on average, in past summer years. This significant elevation in heat load has the potential to degrade fish habitat and impede anadromous fish passage, if left unregulated. The enhanced potential of the upgraded Kendall Station to threaten the protection and propagation of balanced indigenous populations requires biologically based temperature limits to be developed and enforced in the lower Charles River Basin.

5.4 Site-Specific Environmental Stressors In The Lower Charles River Basin That Influence Thermal Tolerance Rationale

The objective of the CWA 316(a) thermal variance of the NPDES permit is to allow elevated discharge temperatures from a permitted outfall only to a level that will not impose impacts on the fish, other aquatic life, and wildlife in the receiving water to the point where a balanced, indigenous population will not be maintained and protected. Much scientific work has been done, under controlled conditions, to determine avoidance temperatures, and acute and chronic effect temperatures for a number of fish species. In addition, scientific work has been done to determine increased temperature effects on zooplankton and phytoplankton assemblages. Some of this scientific literature is referenced in this document. It must be noted that the majority of these experiments are designed to measure the environmental stress imposed only by the effects of elevated water temperature. In general, scientific investigators conducting these experiments minimize or remove other potential stressors to the organisms as part of the experimental design. This is understandable, as it is difficult to observe clear cause and effect relationships when more than one environmental factor is varied. However, this controlled laboratory environment is profoundly different from the aquatic environment that populations in the lower Charles River Basin are exposed to. Organisms in the wild are generally subjected to multiple naturally occurring environmental stressors simultaneously. In the environment of the lower Charles River Basin, a number of man-made modifications to the river, and around it, have added additional stressors to the aquatic system. The cumulative effect of these stressors may reduce an organism's ability to cope with any one stress (Leggett and O'Boyle, 1976). This could mean that an environmental stress level which showed no measurable negative effect to a species under controlled laboratory conditions, may induce a measurable negative effect when experienced as one of a variety of stressors in the wild. The cumulative effect of many stressors must be taken into consideration when evaluating thermal limits which are determined from a controlled, laboratory environment. This consideration is supported by regulation. According to CWA § 316(a) and 40 CFR § 125.73(a) and (c), to determine whether the protection and propagation of the balanced indigenous community is being achieved, EPA must consider not only thermal impacts, but impacts on the community from other stressors as well. The legal basis for consideration of other stressors is discussed further in Section 4.2.2. The effect of additional stressors may provide guidance for a maximum thermal limit that is below a limit specified in the literature. EPA believes that determining protective thermal limits which incorporate safety factors to account for multiple environmental stressors is appropriate in the case of the lower Charles River Basin.

The following is a brief summary of some of the additional environmental stressors existing in the lower Charles River Basin. These additional stressors likely diminish the ability of the resident and anadromous fish populations to cope with the stress of thermal discharge to the basin.

5.4.1 Boston Harbor Water Quality

Concerted efforts are under way to improve the water quality of Boston Harbor. However, runoff from urban areas that ring Boston Harbor as well as the outflow from a number of point source discharges from industry, Publicly Owned Treatment Works (POTW) and storm water outfalls still make their way into Boston Harbor, negatively impacting the water quality. Before 1970, non-point source discharges and point source discharges to the harbor were not regulated to the extent they are today. Continued discharge to these waters has, over hundreds of years, degraded the water quality of the harbor. Efforts are underway to reverse this long standing trend and reduce the degradation to the waters of the harbor. However, low dissolved oxygen, contaminated sediments, high levels of nutrients and harmful bacteria, and increased turbidity are some of the water quality parameters documented in the harbor that have been identified as impairments to this body of water (Rex, AC. *et al.*, MWRA, December 2002).

Anadromous fish attempting to return to the Charles River to spawn, including alewife and blueback herring, must swim from off-shore areas through these stressors found in Boston Harbor. Under certain conditions, fish must remain in the harbor for some time, waiting for acceptable environmental cues that fully trigger the instinct to enter the river, such as preferred water temperature for spawning. Once in the harbor, the man-made obstacle of the New Charles River Dam and Locks may, under certain conditions, further delay the entry of the fish to the Charles River. One consequence of these delays is that it increases the species exposure time to degraded Boston Harbor water quality conditions. Fish populations exposed to the environmental stressor of degraded water quality in the harbor may be less able to cope with the additional stress of elevated water temperatures once they enter the Charles River (EPRI, 2000).

5.4.2 The New Charles River Dam and Locks

The New Charles River Dam is located at the mouth of the Charles River, forming a distinct boundary between the freshwater riverine/impoundment environment of the Charles River and the brackish water, coastal environment of Boston Harbor. As mentioned in the previous section, this man-made obstacle may delay or prevent anadromous fish passage into the Charles River for spawning. The dam may also delay seasonal out migration of fish from the river to the harbor.

The fish ladder designed to allow fish to by-pass the dam is not fully operational due to a pump that was previously capable of lifting fish up through the ladder no longer being installed. Additional mechanical problems have resulted in a pronounced diminishing of the capacity of the fish ladder to pass fish. It is thought that the majority of fish moving into or out of the river do not use the ladder (Metropolitan District Commission, MDC, personal communication, 2002).

It appears that the only means for fish to pass through the dam other than through the locks is via the sluiceway adjacent to the fish ladder, which, when operational and operated correctly, may allow fish to pass when the Boston Harbor water level is lower than that in the Charles River.

A protocol was developed to allow operation of the locks in a way that provides an attractant flow for spawning fish in the harbor under certain tidal conditions during the spawning season (Army Corps of Engineers, 1992). This system has been documented to pass fish into or out of the Charles River. Since the operation is influenced by the tidal cycle, there are periods when the locks will not allow fish to pass through the dam. Certain hydrological conditions may also cause the fish passage protocol to be modified or suspended (MDC Supervisor, personal communication). Fish populations exposed to the environmental stressor of delays in spawning migration may be less able to cope with the additional stress of elevated water temperatures once they enter the Charles River. In extreme cases, fish attempting to enter the river may be delayed until environmental factors that trigger spawning (water temperature, photoperiodism) are no longer present. This situation could prevent fish from spawning altogether.

Anadromous fish that would normally enter a river system and proceed upstream if no man-made barrier were present, must sometimes wait for the operation of the locks in order to pass into or out of the Charles River. Fish waiting for passage congregate near the dam in higher relative concentrations, or “pile up.” These dense schools are more susceptible to predation by larger fish and birds that feed upon the schools. Fish congregating near the dam also are susceptible to increased angling pressure from recreational fishermen. Fish populations exposed to the environmental stressor of crowding and increased predation may be less able to cope with the additional stress of elevated water temperatures once they enter the Charles River.

In addition to delaying or preventing the passage of fish into or out of the Charles River, the New Charles River Dam causes another extreme environmental condition at the mouth of the river. The dam forms a distinct barrier separating two measurably different environments, a marine environment and a freshwater environment. In systems where no barrier is present, the mouth of a river is the transition zone, where there is a gradual change in salinity, water temperature, and water quality parameters such as turbidity. This area is a mixing zone, where the freshwater river co-mingles with the estuarine environment and is influenced by the coastal tidal fluctuations and downstream river flow. Anadromous fish entering this transition zone must profoundly alter the way they regulate internal fluids down to the cellular level. A natural, gradual gradient from saltwater to freshwater, and a thermal gradient based on the mixing of the different temperatures of the water systems, is the environmental condition that anadromous fish evolved under. Some anadromous fish, such as American shad, may favor an acclimation period in this transition zone, before moving upstream into a dominantly freshwater environment.

The New Charles River Dam precludes large scale mixing of the saline waters of Boston Harbor and freshwater from the Charles River. There is no transition zone on the scale normally seen at the mouth of a naturally flowing river (the zone can sometimes be measured in miles). If an anadromous fish successfully passes through the locks, it is immediately faced with a markedly different group of water quality characteristics. No acclimation period under intermediate, mixed water quality conditions is possible. Fish populations exposed to the environmental stressor of instantaneous, pronounced changes in water quality may be less able to cope with the additional stress of greatly different water temperatures once they enter or leave the Charles River.

The dam reduces or blocks the natural flow of freshwater to the harbor. Under certain conditions, this has given the basin the characteristics of an impoundment rather than a river system. Under lower flow conditions, the basin may possess minimal downstream current velocities and long residence times for the water contained in the basin (See Section 2.4 of this document). Anadromous fish, once they enter the river, are conditioned to move upstream, or against the current. These spawning fish may find it difficult to orient in an upstream direction if they enter the basin which has the characteristics of an impoundment. This unnatural absence of expected downstream flow may act as a stressor to anadromous fish during spawning and may render the fish less able to cope with the additional stress of elevated water temperatures.

5.4.3 Watertown Dam

The Watertown Dam, located 9.8 miles upstream from the mouth of the Charles River, presents another man-made barrier to anadromous and resident fish species attempting to move upstream or downstream of the dam. While there is an operational fish passage system at this dam, spawning fish have been observed “piling up” below the dam before attempting to use the fish passage system. Suitable spawning habitat upstream of the dam are beyond the reach of fish that do not find their way to the fish passage area. Fish that congregate below the dam, searching for passage, are more susceptible to predation by larger fish and birds that prey upon the densely packed schools. Fish congregating near the dam also are susceptible to increased angling pressure from recreational fishermen. Bait fishermen have been seen capturing numbers of river herring below this dam (MA DMF). Fish populations exposed to the environmental stressor of a constricted, man made fish passage system and increased predation may be less able to cope with the additional stress of elevated water temperatures in the lower Charles River Basin.

5.4.4 Charles River Water Quality

Runoff from urban areas in the Charles River Watershed, as well as a number of point source discharges from industry, Publicly Owned Treatment Works (POTW) and storm water outfalls all drain into the Charles River. Before 1970, non-point source discharges and point source discharges to the river were not regulated to the extent they are today. Historical discharges to the Charles River have over the years degraded the water quality of this river. Efforts are underway to reverse this long standing trend and reduce the degradation to the waters of the river. However, organic enrichment/low DO, noxious aquatic plants, and taste, odor and color problems, along with, contaminated sediments, harmful bacteria, and increased turbidity are some of the water quality parameters documented in the river that have been identified as impairments to this body of water (Breault *et al.*, 2002; Fiorentino, *et al.*, 2000; MA EOEA, September 2003). Anadromous fish attempting to swim upstream in the Charles River to spawn, including alewife and blueback herring, are exposed to these stressors found in the Charles River. Fish populations exposed to the environmental stressor of degraded water quality in the river may be less able to cope with the additional stress of elevated water temperatures once they enter the Charles River.

5.4.5 Eutrophication In The Charles River

The lower Charles River Basin has been designated as an impaired water body by the Commonwealth of Massachusetts because it violates water quality standards for unknown toxicity, priority organics, metals, nutrients, organic enrichment/Low DO, pathogens, oil and grease, noxious aquatic plants, taste, odor and color, and turbidity (MA EOEA, September 2003) Excessive amounts of nutrients present in the river directly and indirectly contribute to this impairment (Draft Permit Fact Sheet, Section 5.0). This eutrophication of the river may contribute to nuisance algal blooms under certain conditions in the summer. Algal blooms may increase shading and turbidity in the river, and lower dissolved oxygen levels and increase pH levels in the water body after daylight hours. Because of the eutrophic condition of the lower basin, cyanobacteria (blue-green algae) blooms have been documented. Certain cyanobacteria produce substances that are toxic to both fish and to zooplankton (Moore, 1996), the food of alosid larvae and juveniles. They also increase the susceptibility of zooplankton to thermal effects (Moore, 1996). Unfortunately, high temperatures create an environment that stimulates blooms of cyanobacteria, which will increase the probability that zooplankton and juvenile alosids will be stressed by cyanobacterial poisons. Both the number as well as the duration of cyanobacteria blooms may increase with the addition of waste heat to the lower basin. The environmental stressor of degraded water quality, a reduction in high quality food availability, and the presence of toxins, all related to nuisance algal blooms, may cause fish populations to be less able to cope with the additional stress of elevated water temperatures in the lower Charles River Basin.

5.4.6 Bridges Across The Charles River

There are ten bridges that span the lower Charles River Basin. As defined earlier, the lower basin is made up of the waters from the New Charles River Dam near the mouth of the river, upstream to the Watertown Dam. One factor that is thought to influence the spawning movement of anadromous fish is the position and duration of sunlight. Shading in a river has been observed to possibly contribute to avoidance behavior in anadromous species (NOAA correspondence, June, 2002). The bank to bank shading from the large number of bridges may play a role as an unnatural stressor which could cause spawning anadromous fish populations to be less able to cope with the additional stress of elevated water temperatures in the lower Charles River Basin.

5.4.7 Aquatic Vegetation and Inshore Habitat

The shoreline area of the lower Charles River Basin, especially in the vicinity of Kendall Station, has been modified with man-made structures. Concrete walls and sloping stone structures have replaced the natural aquatic vegetation and inshore habitat of the basin. A reduction in aquatic vegetation may reduce preferred structure available to resident species for egg deposition and protection of early life stages. Prey items sought by resident and anadromous species in the basin, such as macroinvertebrates, may be less prevalent in areas without aquatic vegetation. Fish populations exposed to the environmental stressor of limited natural structure and reduced opportunity for prey selection may be less able to cope with the additional stress of elevated water temperatures in the lower Charles River Basin.

5.4.8 Sediment Condition In The Lower Charles River Basin

A United States Geological Survey (USGS) study of the substrate of the lower Charles River Basin documented the presence of a wide variety of heavy metals and other contaminants. Some of these contaminants have been measured in the sediment at levels reported to be above “probable-effects levels” (PEL). These levels are likely to be associated with adverse biological effects. (Breault, *et al*., USGS, 2000).

The lower basin thermally stratifies in the summer, resulting in an anoxic hypolimnion as the summer progresses. When the basin remixes from top to bottom in the fall, or “turns over”, contaminants associated with the sediment may migrate into the water column and come in contact with fish species present in the lower basin at that time. In addition, the permittee proposes to construct a deep water discharge diffuser near the bottom, in order to entrain the cool water of the basin. The mixing effects of the diffuser may further induce contaminants into the water column, also causing them to come in contact with fish species present in the basin at that time. Fish populations exposed to the environmental stressor of exposure to contaminants in the water column may be less able to cope with the additional stress of elevated water temperatures in the lower Charles River Basin.

Sediments in the lower Charles River Basin were not found to support large populations of benthic organisms (Breault, *et al*. USGS, 2000 ; EPA, 2001), further limiting prey availability for resident and anadromous fish species inhabiting the basin. Fish populations exposed to the environmental stressor of reduced opportunity for benthic prey selection may be less able to cope with the additional stress of elevated water temperatures in the lower Charles River Basin.

5.4.9 Saltwater Intrusion From Boston Harbor

Operation of the locks at the New Charles River Dam and Locks has been documented to allow a wedge of saltwater from Boston Harbor to seep into the lower Charles River Basin. This dense wedge of salt water settles in the deepest parts of the basin and usually is low in dissolved oxygen (Breault, *et al*., USGS, 2000). The characteristics of this saltwater wedge make it poor habitat for resident species in the basin that prefer lower salinity levels and higher dissolved oxygen values. The volume of the basin occupied by the saltwater wedge, and the amount of time the wedge can be found in the basin can vary markedly from season to season. It is greatly influenced by the frequency of operation of the locks at high tide and the magnitude of the Charles River flow. Resident fish populations exposed to the environmental stressor of reduced available habitat from the saltwater wedge may be less able to cope with the additional stress of elevated water temperatures in the lower Charles River Basin.

In addition, the permittee proposes to construct a deep water discharge diffuser near the bottom, in order to entrain the cool water of the basin. The operation of this diffuser may break up the saltwater wedge along the bottom. This deep water mixing may markedly improve water quality conditions in the deep waters of the basin when the saltwater wedge is present. As discussed in Section 5.1, EPA is concerned, however, that fully mixing the saltwater wedge with the overlying fresh water, while improving dissolved oxygen conditions at the bottom of the basin, may also elevate the overall salinity of the basin in overlying surface areas, which are currently very low in salinity, possibly posing an environmental stress to resident fish populations.
As discussed in Section 5.1, the use of the diffuser may also decrease water quality overall by allowing for the flux or resuspension of certain pollutants present in the sediments.

5.4.10 Seasonal Stratification and Low Dissolved Oxygen

In addition to the stratification documented in the water column of the basin because of the river's freshwater layered over the dense saltwater wedge, the freshwater of the lower basin also stratifies based on temperature. Thermal stratification has been documented in the wide, impoundment-like portion of the lower basin in the summer under low flow conditions. The freshwater in the deeper layer, or hypolimnion, is generally cooler and therefore denser than the water column above it during the warmer months. Dissolved oxygen (DO) present in the isolated hypolimnion is gradually used up through respiration of organisms and decomposition of organic matter. Stratification prevents the deep layer from mixing with more oxygenated waters above. This can ultimately result in low DO levels, or possibly fully anoxic conditions, in a well developed hypolimnion, as the summer progresses. This effect causes resident and anadromous species living in the lower basin to avoid deeper, oxygen depleted depths. In conjunction with this, surface water temperatures tend to rise due to the influence of solar energy, warm summer air temperatures, and the discharge of heated water from Kendall Station. When surface waters rise above preference temperatures of the fish species, and DO levels in deeper waters are below levels preferred for fish respiration, a "habitat squeeze" takes place. The fish are squeezed into a narrowing band of mid-depth water, which is the only portion of the water column that meets their habitat suitability. Fish populations exposed to the environmental stressor of this habitat squeeze may be less able to cope with the additional stress of elevated water temperatures in the lower Charles River Basin.

Taken in the context of the lower basin as a thermally influenced water body, it should be noted that as water temperature increases, the metabolic rate of poikilotherms (cold-blooded organisms) also increases. The cause and effect relationship is fairly consistent with about a 2-3 fold increase in oxygen consumption for every 10 ºC (17.8 ºF) rise in temperature (Schmidt-Nielsen, 1975). Oxygen saturation (the amount of oxygen in water when the latter is fully saturated) in water decreases with temperature, so as the oxygen demand of fish rises with warming, less and less oxygen is available. While the rate of increase in oxygen demand per unit increase rise in temperature may be fairly constant for a particular species, the rate of increase may vary somewhat between species.

As discussed in Section 2.5, a potentially beneficial aspect of the Kendal Station's NPDES Permit proposal may be the impact of a deep water diffuser, designed to discharge up to 50% of the station's heated discharge water. The permittee has submitted information contending that this discharge water, because of its higher temperature and comparatively lower density, is expected to break up the summertime basin stratification, prevent the development of an oxygen depleted, seasonal hypolimnion and allow oxygenated water to circulate to all depths of the basin in the late summer. If this proposed by-product of the deep water discharge is realized, it may reduce or eliminate the habitat squeeze described in this section. This potential benefit must be considered along with possible negative environmental impacts of diffuser operation that can not be ruled out. These potential impacts are noted in Appendix A to the Fact Sheet.

5.4.11 The Effect Of The Current Velocity Of Kendall Station Discharge

When anadromous fish enter the Charles River, they immediately encounter a basin with very slow moving water, especially in comparison to the attractant flow from the Charles River Lock that helped to guide their movement into the system. Their instinctive search for moving water in the basin may cause them to identify the faster moving discharge water from Kendall Station as the upstream current velocity they must swim against. The attractive power of the moving water may be so great that it is enough to over-ride physiologic mechanisms that would otherwise cause these adults to avoid the high temperature of the discharge. A videotape was sent to the regulatory agencies that was made by scuba divers at Kendall's near surface wall discharge during herring upstream migrations. River herring were seen swimming against the flow in the discharge pipe and were also observed attempting to breed in the discharge pipe. It is not known if these were bluebacks, alewives or both. It is acknowledged that any potential acute or chronic effects caused by exposure of the fish to the thermal component of the moving water, as discussed in other sections, is a separate and additional stressor that must be taken into consideration. The attraction of some number of the population to the faster moving water of the Kendall Station discharge may delay or completely inhibit the migration of river herring that are confused by the slow flowing, impoundment-like characteristics of the lower basin. The percentage of the population that is confused by the discharge flow and fails to migrate in time to successfully reproduce is an unknown.

5.5 Evaluating Proposed Thermal Impacts To The Charles River

5.5.1 Evaluation Based on Computer Modeling

As part of its NPDES permit application, the permittee submitted water temperature modeling information and surface temperature projections for the lower Charles River Basin to predict the expected thermal impacts to the lower basin from expanded Kendall Station power generation (Mirant Kendall NPDES Permit Application, Volume I, 2001; Supplemental Surface Water Modeling Report In Support Of Kendall Station NPDES Permitting, 2001). The thermal model used was the Generalized, Longitudinal-Lateral-Vertical Hydrodynamic and Transport (GLLVHT) model. Modeling was performed by TRC and J.E. Edinger Associates. A variety of model simulations were conducted to assess historical and future Kendall Station discharges to the lower Charles River Basin and their effect on river temperature, salinity and dissolved oxygen (Mirant Kendall NPDES Permit Application, Volume I, 2001; Supplemental Surface Water Modeling Report In Support Of Kendall Station NPDES Permitting, 2001).

Although the permittee prepared a hydro-thermal model of the basin, EPA has determined that the model is not acceptable for evaluating receiving water conditions because of concerns with the permittee’s approach used to calibrate the model. For example EPA and DEP do not agree with the permittee’s approach of uniformly adding 2 ºF to the model output to better match observed field conditions (Mirant Correspondence, September 13, 2001). Furthermore, despite EPA’s request, the permittee has not provided documentation to validate the method used to interface the near field and far field mixing associated with operation of the proposed diffuser. Without model validation, EPA does not have confidence that model output is representative of post-diffuser operating conditions.

Rather than address EPA's concerns with the model, the permittee proposed an in-situ, real-time continuous water quality monitoring and compliance program in the receiving waters of the lower Charles River Basin. The monitoring and compliance program is intended to ensure that biologically based protective temperature limits would not be exceeded in a volume of the river sufficient to protect the balanced indigenous populations (BIPs) and that the thermal load from the facility is not causing or contributing to algal blooms in the lower basin. This thermally protected aquatic habitat, referred to in this document and the draft NPDES permit as the Zone of Passage and Habitat (ZPH), will be described in more detail in subsequent sections of the determination document. The modeling information generated was used as a general blueprint to identify possible areas for fixed river monitoring stations. However, modeling runs were not used to identify Kendall Station discharge temperatures which would ensure a ZPH necessary for the protection and propagation of balanced indigenous populations.

5.5.2 Evaluation Based on Thermal Tolerance Limits of Most Sensitive Species

The permittee and review agencies agreed to use an approach to protect aquatic communities in the lower Charles River Basin that was not based on the disputed computer model projections. Instead, thermal limits were established for a sufficient area of habitat in the lower Charles River Basin to protect the species occurring there and allow for the protection and propagation of balanced aquatic communities (Mirant Correspondence, May 11, 2001). Compliance with these limits would be verified through an in-situ, real-time, continuous water quality monitoring and compliance program, using fixed monitoring stations positioned at key locations in the receiving waters of the lower basin (Mirant In Stream Water Quality And Biological Monitoring During Project Operation, Draft Discussion Document, August 30, 2001).

The rationale to support the biologically based, site-specific temperature limits and the span of time necessary for each specific limit were topics at a number of working meetings between regulatory agency representatives and representatives of the permittee. The full, biologically based rationale for the temperature limits and time periods chosen is discussed in Sections 5.6 and 5.7 of this document. The rationale outlining the minimum volume of the lower Charles River Basin is found in Section 5.8.1 of this document.

In general, site-specific biological and water quality data collected in the lower Charles River Basin in 2000 and 2001 and submitted by the permittee as part of the NPDES application (February 2001) were first consulted as a way to gather the necessary information to establish thermal tolerance limits. Supplemental site-specific data from sampling conducted in 2002 and 2003, as well as amended proposals, were routinely submitted by Mirant after the application was delivered. The information, submitted as letters or small data reports, was evaluated as time permitted. This information, and any information submitted during the public comment period, will be fully considered prior to issuing a final permit. Site-specific information from the United States Geological Survey (USGS), the Massachusetts Department of Fish and Wildlife (DFW), the Massachusetts Water Resources Authority (MWRA), the Charles River Watershed Association (CRWA), and the United States Environmental Protection Agency (EPA) were also examined. In addition, personal communication with environmental professionals took place to supplement site-specific data.

Next, published and unpublished biological and water quality data from near-by rivers were reviewed to add to the information needed to establish protective temperatures for the lower Charles River Basin. This type of data was also examined, when available, from generally similar river systems in other regions of North America.

A literature search was conducted by the permittee to assemble scientific data regarding the thermal tolerance values for the different life stages of resident and anadromous fish species. This literature search was supplemented by additional published material that added to the data base of thermal tolerance data used to establish the protective temperature limits for this permit.

This body of information was reviewed as part of the process to establish protective water temperature limits in the lower basin in the areas of the lower Charles basin. The establishment of maximum water temperatures in the permit for the receiving water meets the desired goal of protection and propagation of the balanced indigenous fish populations. As discussed in more detail in subsequent sections, protection of the fish species or life stage that is most sensitive to elevated temperature is a recognized way to ensure that all species found in a water body receiving thermal discharge are protected (National Academy of Science/National Academy of Engineers, 1972). This is the procedure that was followed for this permit. In the discussion in Section 5.6 and 5.7, specific sources were cited when used as a basis for establishing a particular thermal limit or identifying a seasonal time span that a limit must be in effect to protect the most sensitive species. Also, in certain cases, reasons were identified why it was not appropriate to rely on a particular source to establish a temperature limit.

Requiring that appropriate thermal limits must never be exceeded at any time in any area of the lower basin is a conservative way to protect the entire aquatic fish community of the lower Charles River Basin. However, EPA believes it may not be necessary to maintain this level of protection throughout the entire aquatic habitat of the lower basin in order for the BIP to be protected. It also is noted that the permittee has indicated that meeting protective temperatures in all parts of the lower basin, throughout the year, would severely impact the ability of Kendall Station to produce electricity using its once through cooling configuration. The permittee has supplied information proposing that there will most likely be many periods when a majority of the lower basin habitat influenced by the Station discharge will be below the maximum protective temperatures specified in the permit. Taking this information into consideration, and in consultation with the agencies involved in the permit evaluation, EPA and DEP identified a minimum volume, represented by any cross sectional area of the lower Charles River Basin that must always be at or below the protective water temperature limits stated in the permit. This volume, not to drop below a contiguous volume of 50% of the basin, without excessive near surface temperatures, or excessive temperatures near the Boston shore of the lower Basin, will protect the BIP. This thermally protected portion of the aquatic habitat, referred to as the Zone of Passage and Habitat, is fully defined in Section 5.8.1.

5.6 Thermal Tolerance Limits For Resident Fish Species of the Lower Charles River Basin

5.6.1 Resident Species Issues

5.6.1a Quality of Habitat

Fish species that occur in the lower Charles River Basin during their early life stages and grow, reproduce, and reside exclusively in this freshwater environment throughout the year are considered resident species for the purpose of this discussion. Since resident species communities are exposed to the habitat of the lower basin during their entire life cycle, the quality and quantity of the habitat of the lower basin is a central factor affecting the ability of these communities to propagate and achieve a balanced indigenous population (BIP).

Kendall Station operation, by adding heat to lower basin waters, may modify the habitat in ways that contribute to changes in adult resident species behavior. An aquatic habitat degraded by excessive temperatures may increase the metabolism and decrease the overall health of those selected individual fish that have been seen residing in a thermal plume (anecdotal information from power plant personnel and recreational fishermen). In other cases, individual fish avoid the heated habitat completely. Excessive temperature may have an effect on the abundance and variety of prey organisms available to resident fish species, or degrade aquatic macrophytes used for cover by resident species in the basin.

Elevated water temperatures may also contribute to increases in the frequency and intensity of algal blooms. Greatly enhanced primary productivity has been seen to noticeably decrease oxygen levels at night, when these primary producers respire without the oxygen producing benefits of daytime photosynthesis. These night time dissolved oxygen “crashes”, documented in cooling water impoundments (Chimney, *et al.*, 1988), degrade the water quality of the aquatic habitat that resident species rely on. In the Charles River, dissolved oxygen swings of nearly 7 mg/L have been recorded in the basin within a 24 hour period (9.9 mg/L to 3.1 mg/l), with corresponding percent saturation changes from 125.5% to 38.2% (US EPA, November 2002).

5.6.1b Reproductive Impacts

Since resident species, by definition, do not migrate out of the lower Charles River Basin during their life cycle, they have the greatest exposure to temperature effects that may inhibit the normal development of mature gonads in adults. For example, if overwintering temperatures are not permitted to drop to and be maintained at certain critical temperatures, some resident species have been documented to show a reduction in spawning success the following spring (Krieger *et al.*,1983). This effect will be more fully discussed in Section 5.6.3h.

Water temperature is an important cue triggering gonadal developing and the onset of spawning in the spring. Artificially high water temperatures may cause resident species to reach maturity earlier in the spawning season than they would otherwise, and even spawn earlier than they naturally would in the absence of the elevated water temperatures. Spawning of resident species fish has been seen to take place earlier in thermally impacted streams when compared with freshwater fish in near-by streams under ambient conditions (Paller, 1988). This disruption of the timing of spawning may severely decrease the survival rate of the early life stages of the species. Under normal conditions, spawning is timed to allow the newly hatched larvae and young-of-the-year fish to coincide with spring peaks in their favored prey. Early spawning may result in these life stages occurring in the lower basin before their prey is abundant. This would have a serious impact on their survival.

5.6.2 Resident Species Considered

EPA and DEP reviewed scientific literature and data submitted by Mirant Kendall for the following resident species to determine which year round resident species would be the most sensitive to temperature: white perch, yellow perch, white sucker, sunfish species, largemouth bass, smallmouth bass, bluegill, common carp, black crappie, golden shiner, common shiner, white catfish, brown bullhead, chain pickerel, and pumpkinseed. Based on a preliminary review of the information obtained for each of the species, EPA and DEP determined that the species to focus on were white perch, yellow perch, and the white sucker, because these species were among the most sensitive to elevated temperatures for at least part of their life cycle (Table 5.6-1). It must be stressed that temperatures and time periods listed in this table came from a preliminary "first draft" of threshold parameters for these species. The temperature values and time periods identified were used for comparison between the species of interest to determine which resident species appeared to have the lowest threshold to water temperature. The protective temperature limits and time periods ultimately developed were based on a number of sources and discussed fully in Section 5.6.3 of this document. Further review and evaluation determined that yellow perch was the resident fish species most sensitive to temperature for all of its life stages in the Charles River (See EPA Letter to Mirant Kendall, July 16, 2001). This species was identified as an indicator species in this site-specific investigation. The rationale used in this case to protect the BIP is that if the species most sensitive to temperature is protected in a thermally influenced aquatic habitat, other species and life stages that occur in the habitat will be protected as well. This approach has been identified in the literature as one way to protect existing fish communities in a water body that receives heated discharge (National Academy of Science/National Academy of Engineers, 1972). It must be noted that when threshold temperatures were identified for the most sensitive fish species in the Charles River by EPA and DEP, other species or life stages of a species were found to have temperature thresholds only slightly above the critical threshold temperature selected.

5.6.3 Most Sensitive Resident Species Selected By Life Stage

5.6.3a Introduction

Of the fish species found in the lower Charles River Basin that reside in the basin throughout their life cycle (resident species), a review of available information identified the yellow perch (*Perca flavescens*) as being the most sensitive to elevated temperatures at every stage of their development (see Reference Section, 5.12). The Massachusetts Department of Fish and Wildlife (MADFW) has reported the presence of yellow perch in the Charles River. Biological data submitted by the permittee, collected in 1999, 2000, 2002 and 2003 to support the NPDES permit application for Kendall Station, confirm the presence of this species in the lower basin. This species plays an important role in the lower Charles River Basin community and is also targeted by recreational fishermen. The continued protection and propagation of a balanced, indigenous population of yellow perch, as well as other resident species, is one of the goals of the NPDES permit. Determining reasonable, science based water temperature limits for the most sensitive resident species will ensure a suitable thermal habitat for all resident fish populations. This is in keeping with the long-term designated uses of the lower Charles River Basin as a Class B Water, in accordance with the Massachusetts Water Quality Standards.

5.6.3b Protective Temperature For The Most Sensitive Egg Stage

Controlled research conducted on fish eggs taken specifically from the lower Charles River Basin to evaluate the temperature sensitivity of resident species would provide valuable information to determine water temperature limits protective of this life stage in this water body. Resident species fish eggs from the lower Charles River are adapted to the range of ambient temperature conditions typically found in the lower basin, and it is recognized that their sensitivity to elevated temperatures may vary to some extent from the temperature range determined to be protective for the same species eggs tested from a different water body, or from eggs tested using an acclimation temperature or water quality characteristics not representative of the lower Charles River Basin. A review of the scientific literature revealed that no controlled research using resident species fish eggs taken specifically from the lower Charles River Basin was available. Scientific literature that examined the egg stage temperature sensitivity of fish expected to be “resident species” in the lower basin was available. Among the Charles River Basin resident species, the literature review identified yellow perch eggs as the egg stage most sensitive to elevated water temperatures. A discussion of relevant information for yellow perch eggs follows.

Koonce, *et al*. examined the daily mortality rate for yellow perch eggs in the cleavage phase at 3 ºC intervals from 3 ºC through 30 ºC (37.4 - 86 ºF). With a mortality rate of 1.0 representing 100% egg mortality, mortality rates ranged from 0.05, or 5% mortality, at temperatures of 3 ºC (37.4 ºF) and 15 ºC (59 ºF) to 0.16, or 16% mortality, at a temperature of 18 ºC (64.4 ºF). A marked increase in temperature induced mortality was observed in the interval between 18 ºC (64.4 ºF) and 21 ºC (69.8 ºF). At 18 ºC, the mortality rate was 0.16, or 16% mortality, but climbed to 0.70, or 70% egg mortality, at 21º C. (Koonce *et al.*, 1977, Table 2). In this specific case, this pronounced increase in mortality over a 3 ºC temperature rise was identified by EPA and DEP as an important threshold of temperature sensitivity for yellow perch eggs. Unfortunately, the experiment did not publish egg mortality rates for temperatures between 18 and 21 ºC (64.4 and 69.8 ºF). The EPA and DEP view 18 ºC (64.4 ºF) to be a temperature above which greatly accelerated yellow perch egg mortality rates is likely to occur.

The unique characteristics of yellow perch eggs must be taken into consideration when establishing a maximum protective temperature. This maximum temperature will be measured in the water column, while yellow perch eggs are not expected to be in the water column. Yellow perch eggs are characterized as semi-buoyant, adhesive egg masses, produced as a long, gelatinous ribbon of spawn, which is woven among the weeds and brush, or deposited on rock, sand or gravel. These adhesive egg masses do not usually drift in the water column. It is expected that water temperatures the eggs are subjected to at this water-sediment interface will be somewhat lower than temperature points measured from the near surface to near bottom of the water column, especially in late spring. (see Part I.A, Section 14.b.3 of Draft NPDES Permit). During the spring, at times when the warmest temperatures approach 18 ºC (64.4 ºF) or above in the water column, the difference in temperature between these warmer near surface locations and the cooler, near bottom depths associated with the shoreline (where yellow perch eggs likely will reside) has been observed to be as much as 2.8 ºC (5 ºF) (Mirant Kendall Hydrographic Data 1999, 2000, 2002, 2003). However, a more conservative approach is to expect natural ambient daily temperature fluctuations of at least 1.1ºC (2ºF) in the lower Charles River within a 24 hour day (see Figures 5.10.5c-1 through 5.10.5c-5). This fluctuation is caused by changes in air temperature and solar input during a daily 24 hour weather cycle, and is observed in most bodies of water.

In addition, vertical “sea walls” are present along a sizable portion of the shore of the Cambridge side of the river, in the vicinity of the Station. The Boston side tends to display a relatively more gradual slope from the shore to river bottom. This feature may make the Boston side of the river a more suitable habitat for the presence of yellow perch eggs. The Boston side of the basin is the furthest away from the thermal discharge from Mirant Kendall Station, which is located on the Cambridge side of the basin. It is expected to be lees influenced by the Station’s thermal discharge.

The design of the in-situ continuous temperature monitoring and compliance program that will be required by the draft permit must also be considered. Under this monitoring program, the highest temperature measured in the ZPH will likely be a temperature located near the bank-to-bank mid-point of the basin, in six feet of water (Mirant Kendall NPDES Permit Application, 2001). This will result in the majority of the habitat occupied by yellow perch eggs to likely be lower than the temperature limit at all times during the spawning season (Mirant Kendall 2003 Data, Appendix B-2: November 13, 2003). The continuous in-situ temperature monitoring program that is required to demonstrate compliance with the specified temperature limits is fully discussed in Part I.A, Section 14.b. of the draft permit.

Based on the temperature differential information, the likely location of yellow perch eggs, and the design of the in-situ temperature monitoring and compliance program discussed below, it is judged that yellow perch egg habitat will be maintained at or below the protective maximum temperature of 18 ºC (64.4 ºF) when the overall Zone of Passage and Habitat temperature limit does not exceed 19.1 ºC (66.4 ºF) at any one monitoring point.

Additional site-specific studies would provide information on the river temperatures, timing, and duration associated with yellow perch spawning in the lower Charles River Basin to assure that the maximum temperatures selected are protective of conditions necessary for a balanced indigenous population.

5.6.3c Time Period For The Most Sensitive Egg Stage

Yellow perch spawning may begin as early as the latter part of February and continue through early July (Hokanson, 1977) but is generally considered to take place from April to June, when temperatures reach 7 to 13 ºC (44.6 to 55.4 ºF; Krieger *et al.*,1983). Site-specific Charles River ichthyoplankton sampling from 12 May to 30 August, 1999 and 13 March to 6 September, 2000 and Kendall Station entrainment data for the lower Charles River Basin did not document the presence of yellow perch eggs. This is not unexpected. As mentioned in Section 5.6.3b, yellow perch eggs are characterized as semi-buoyant, adhesive egg masses, produced as a long, gelatinous ribbon of spawn, which is woven among the weeds and brush, or deposited on rock, sand or gravel. These adhesive egg masses do not usually drift in the water column. This characteristic of the eggs prevents eggs from being entrained by cooling water intake structures. This characteristic also generally precludes their collection using the conventional technique of filtering the water column with a fine mesh ichthyoplankton sampling net.

Since yellow perch eggs are not pelagic and are not easily collected by standard ichthyoplankton sampling tows, it is problematic to determine the time period when yellow perch eggs are present in the basin and thus determine the appropriate time period a protective temperature must be in place. To determine the egg protection time period, indirect evidence of egg presence was obtained through the documentation of yellow perch larvae in the lower Charles River Basin as early as May 11, 2000 (Mirant Kendall NPDES Permit Application, 2001). In order to fully bracket the time period when eggs may be present in the basin, it was assumed these organisms had recently hatched to the larval stage while in the basin and had undergone a 10 day egg incubation period. The incubation projection is based on a water temperature of approximately 17.8 ºC (64 ºF) and a time versus temperature hatch rate developed by Hokanson in 1977. This would place eggs in the basin in mid-April. The state agency responsible for the protection and well-being of the species has placed the site specific spawning period, where eggs would first be present, from March 20 to April 30 (Keller, MA DFW, personal communication). Site-specific data collection falls within the range identified by MA DFW. Taking this information into consideration, yellow perch eggs are most likely present in the basin from March 20 through May 10. May 10 was selected as the endpoint of the egg time period because it is ten days after the end of the spawning period, when the last of the eggs have hatched to the larval stage.

Based on the discussion above, the maximum temperature that is protective for the survival of yellow perch eggs in the lower Charles River Basin is a maximum temperature in the ZPH of no more than 19.1 ºC (66.4 ºF), which will ensure the protective temperature of 18 ºC (64.4 ºF) at the near bottom habitat in the vicinity of the shoreline, where the eggs reside. This temperature limit must be in place in the lower basin Zone of Passage and Habitat from March 20 through May 10, unless replaced by a lower temperature limit to protect a more sensitive life stage or species occurring in the basin at the same time.

5.6.3d Protective Temperature For Most Sensitive Larval Stage

Controlled research conducted on fish larvae taken specifically from the lower Charles River Basin to evaluate the temperature sensitivity of resident species would provide valuable information to determine water temperature limits protective of this life stage in this water body. Resident species fish larvae from the lower Charles River are adapted to the range of ambient temperature conditions typically found in the lower basin, and it is recognized that their sensitivity to elevated temperatures may vary to some extent from the temperature range determined to be protective for the same species larvae tested from a different water body, or from larvae tested using an acclimation temperature or water quality characteristics not representative of the lower Charles River Basin. A review of the scientific literature revealed that no controlled research using resident species fish larvae taken specifically from the lower Charles River Basin was available. Sampling collection data that documented the presence of residence species larval fish in the lower Charles River Basin were available (Mirant Kendall NPDES Permit Application, 2001). In addition, scientific literature that examined the larval stage temperature sensitivity of fish expected to be “resident species” in the lower basin was available. The literature review identified yellow perch larvae as the larval stage most sensitive to elevated water temperatures. A discussion of relevant yellow perch larvae information follows.

Yellow perch larvae move to open water during the first two months of life (Krieger *et al.,*1983). They have been identified from site-specific ichthyoplankton sampling performed in the lower Charles River Basin in the year 2000 at approximate basin temperatures of 17.8 ºC (64 ºF ; May 11), 19.4 ºC (67 ºF; May 31) and 17.8 ºC (64 ºF; June 7). These temperatures were taken from cooling water intake temperatures from Kendall Station on the respective sampling dates (Mirant Kendall NPDES Permit Application, 2001). Supplemental ichthyoplankton data submitted by the permittee for the year 2002 show yellow perch larvae in the basin at temperatures of 18.9ºC (66F; April 16), 13.3ºC (56F; April 24), 14.4ºC (58F; May 1), 16.7ºC (62F; May 9), 13.9ºC (57F; May 16), 16.7ºC (62F; May 23), 20ºC (68F; May 30), (No Temp Data; June 6), 20ºC (68F; June11), 18.9ºC (66F; June 18), 25.6ºC (78F; June 27), 27.8ºC (82F ;July 2) and 26.1ºC (79F; July10), with the peak occurring on April 24, 2002 (Mirant Supplemental Data, 2002; EPA Clean Charles Unpublished Data, 2003). Temperature data in 2002 was taken from hydrographic temperature monitoring at the BU Bridge, the site considered to represent ambient basin conditions. Ichthyoplankton data submitted for the year 2003, covering the period from May 20 to July 10, 2003, did not collect any yellow perch larvae.

While it is assumed for the purposes of this discussion that yellow perch larvae collected at the temperatures listed above were viable, this assumption was not investigated as part of the sampling program. It could be argued that some percentage of larvae collected may have displayed acute or chronic effects from elevated temperatures, especially during the warmer months. This argument is impossible to prove or disprove. Before any judgment could be made, future ichthyoplankton sampling would have to include an evaluation of symptoms of acute or chronic effects displayed by larval fish collected from the lower basin.

In addition to the site-specific data collected to bracket the full range of temperatures that coincide with the presence of yellow perch larvae, literature sources were consulted to assist in the determination of a protective temperature for the larval stage. Koonce, *et al*. (1977) reported larvae daily mortality rates at 3 ºC intervals from 3 ºC (37.4 ºF) through 30 ºC (86 ºF). With a mortality rate of 1.0 representing 100% larvae mortality, the mortality rate varied between a lower temperature lethal effect of 1.0 (100% mortality) and 0.85 (85% mortality) at 3 ºC (37.4 ºF) and 6 ºC (42.8 ºF), respectively, to upper temperature lethal effects of 0.45 (45% mortality) and 1.0 (100% mortality) at 27 ºC (80.6 ºF) and 30 ºC (86 ºF), respectively (Koonce *et al*., 1977, Table 2).

The Koonce, *et al*. (1977) reference dealt with yellow perch populations assumed to be taken from in or around Duluth, Minnesota. The climate in this region, based on an inspection of daily mean air temperatures from the past 30 years, is approximately 4.4 ºC (8 ºF) cooler than Boston air temperatures during the summer months (NOAA National Climatic Data Center, Provisional Data). This difference in climate may have an effect on the response to water temperature of the populations in these two geographic regions. The mortality rate of 0.45 (45% mortality) for a temperature of 27 ºC (80.6 ºF) could arguably be a higher mortality rate than may been seen for larval populations at 27 ºC (80.6 ºF) in the lower Charles River Basin, where these yellow perch larvae may be able to tolerate higher ambient temperatures. Koonce *et al*. (1977) did not evaluate temperatures between 27 ºC (80.6 ºF) and 30 ºC (86 ºF).

To further refine a temperature somewhere within the range of 27 to 30 ºC (80.6 to 86 ºF), a USFWS publication was consulted. In this publication, Kreiger reported that yellow perch larvae tolerated temperatures up to 28 ºC (82.4 ºF ; Krieger *et al.*,1983). This temperature is approximately the same as the highest ambient lower Charles River Basin temperature that was recorded with larval yellow perch collection in the lower Charles River Basin (July 2, 2002). The measured ambient temperature, 28ºC (82.4ºF), was recorded at the surface at a water quality station at the BU Bridge at 12:13 hours on July 2, 2002 (Mirant Supplemental Hydrographic Data, 2002). Yellow perch larvae were again collected a week later, on July 10, 2002, but ambient temperatures at that time had moderated to 26.1ºC (79F) at the BU Bridge.

Based on the Habitat Suitability Index for yellow perch (Krieger, *et al*., USFWS, 1983) a graph depicting suitable temperatures for adult, juvenile and fry, shows a 100% suitability (1.0 Habitat Suitability score) at a temperature of approximately 23 ºC (73.4 ºF) and 0% habitat suitability (0.0 Habitat Suitability Score) at 29 ºC (84.2 ºF). A temperature of 23 ºC (73.4 ºF) would generally be considered optimal temperature conditions, based on this graph. The change in suitability, as depicted in this graph, changes rapidly with temperature. When setting maximum protective temperatures in the lower Charles River Basin, it is judged that temperature limits can be established which are above the optimum value for a species and still serve to protect a balanced population. The maximum tolerated yellow perch larvae temperature of 28 ºC (82.4 ºF) reflects a habitat suitability of only approximately 17%. While 28 ºC (82.4 ºF) was also recorded as the ambient temperature associated with yellow perch larval collection in early July of 2002, it should not be considered a protective temperature based on that fact alone. Partially based on the low habitat suitability evaluation (Krieger, *et al*., USFWS, 1983), a sustained temperature of 28 ºC (82.4 ºF) in the ZPH is judged to be too high to sufficiently protect yellow perch larvae in the lower Basin. A habitat suitability of approximately 40% corresponds with a temperature of 27ºC (80.6ºF). In this case, based on site specific ambient river temperatures and field collection data, the temperature of 27ºC (80.6ºF) was considered the maximum protective temperature for yellow perch larvae in the lower Charles River Basin.

An examination of hydrographic data reveals that near surface temperatures in the lower basin become warmer than mid-depth and bottom temperatures as the basin begins to thermally stratify in June and July (Mirant Hydrographic Data, 2001, 2002 and 2003). It is judged that setting a maximum temperature limit in keeping with the MA State Water Quality Standards, 28.3ºC (83ºF) in 50% of the ZPH including near surface locations, will be fully protective for yellow perch larvae and achieve a temperature at or below 27ºC (80.6ºF) in the overall ZPH when larval yellow perch are present.

This judgment takes into consideration the in-situ continuous temperature monitoring and compliance program that will be required by the permit. Under this monitoring program, the highest temperature measured in the ZPH will likely be a temperature located near the bank-to-bank mid-point of the basin, in six feet of water (Mirant Kendall NPDES Permit Application, 2001). When the near surface temperature is required to be at or below 28.3ºC (83ºF), this will result in the majority of the ZPH to be lower than the temperature limit for yellow perch larvae at all times during the warmer months (Mirant Kendall 2003 Data, Appendix B-2: November 13, 2003). The continuous in-situ temperature monitoring program that is required to demonstrate compliance with the specified temperature limits is fully discussed in Part I.A, Section 14.b. of the draft permit.

Also, it is important to understand that natural daily ambient temperature fluctuations of at least 1.1ºC (2ºF) in the lower Charles River Basin are routinely expected (see Figures 5.10.5c-1 through 5.10.5c-5). This fluctuation is caused by changes in air temperature and solar input during a daily 24 hour weather cycle, and is observed in most bodies of water. This change in temperature over a 24 hour period will allow a temperature as high as 28.3ºC (83ºF) to be only briefly reached at the warmest point in the ZPH during the warmest part of the day. This will further ensure that the protective temperature of 27ºC (80.6ºF) will be maintained in the majority of the ZPH most of the time.

5.6.3e Time Period For The Most Sensitive Larval Stage

Yellow perch spawning has been determined to begin in the lower basin and adjacent water bodies around March 20 (Keller, MADFW, personal communication). Based on this information and the life cycle of the species, the first larvae will appear ten days later, approximately in early April. The last of the eggs will develop to the larval stage approximately ten days after April 30 (the end of the spawning season; see discussion above), near the middle of May. The development process from larvae to juvenile takes at least two months (Krieger *et al.*,1983). Based on this information from the literature, larvae will be present in the lower basin from approximately April 1 through the middle of July. The limited amount of site specific ichthyoplankton data collected by the applicant documents the presence of yellow perch larvae within this time period. Yellow perch larvae were collected on May 12 and May 18, 1999, and on April 27, May 31, and June 7 in the year 2000 (Mirant Kendall NPDES Permit Application, 2001). Supplemental ichthyoplankton data submitted by the permittee for the year 2002 show yellow perch larvae in the basin on April 16 and 24, May 1, 9, 16, 23 and 30, June 6, 11, 18 and 27, and July 2 and 10, with the peak occurring on April 24 (Mirant Supplemental Data, 2002). Data submitted for the year 2003, covering the period from May 20 to July 10, 2003, did not collect any yellow perch larvae.

Based on the discussion above, the temperature limit of 28.3ºC (83ºF) must be in place in the Zone of Passage and Habitat from April 1 through July 15 to protect yellow perch larvae, unless replaced by a lower temperature limit to protect a more sensitive life stage or species occurring in the basin at the same time.

5.6.3f Protective Temperature For Most Sensitive Juvenile Stage

Controlled research conducted on juvenile fish taken specifically from the lower Charles River Basin to evaluate the temperature sensitivity of resident species would provide valuable information to determine water temperature limits protective of this life stage in this water body. Resident species juvenile fish from the lower Charles River are adapted to the range of ambient temperature conditions typically found in the lower basin, and it is recognized that their sensitivity to elevated temperatures may vary to some extent from the temperature range determined to be protective for the same species of juvenile fish tested from a different water body, or from juveniles tested using an acclimation temperature or water quality characteristics not representative of the lower Charles River Basin. A review of the scientific literature revealed that no controlled research using resident species juvenile fish taken specifically from the lower Charles River Basin was available. Sampling collection data that documented the presence of residence species juvenile fish in the lower Charles River Basin were available (Mirant Kendall NPDES Permit Application, 2001). In addition, scientific literature that examined the juvenile stage temperature sensitivity of fish expected to be "resident species" in the lower basin was available. The literature review identified yellow perch juveniles as the juvenile stage most sensitive to elevated water temperatures. A discussion of relevant information for yellow perch juveniles follows.

The juvenile stage of yellow perch was identified as the resident species in the lower Charles River Basin most sensitive to temperature. Beach seine sampling was conducted in the lower Charles River Basin by the permittee. While the species collected were not specifically identified as juveniles, individual length information was provided, indicating that this sampling method primarily captured juveniles. Sampling took place every other week from July 9 through December 1999. In the year 2000, beach seine sampling was conducted weekly from July through early November. Sampling in 2003 was conducted weekly from mid-June through mid-October. Beach seine sampling documented juvenile yellow perch in the lower Charles River Basin at ambient water temperatures as high as 27 ºC (80.6 ºF) on August 2, 1999 (Mirant Kendall NPDES Permit Application, 2001; Appendix 5). Beach seine sampling in 2000 documented juvenile yellow perch in the lower basin at ambient water temperatures as high as 26.4 ºC (79.5 ºF) on August 10, 2000 (Mirant Kendall NPDES Permit Application, 2001; Appendix 5). Beach seine sampling in 2003 documented juvenile yellow perch in the lower basin at ambient water temperatures as high as 30.2ºC (86.4 ºF) on July 8, 2003. Yellow perch juveniles were also collected in 2003 at 29ºC (84.2ºF) on July 1, 28.6ºC (83.4ºF) on July 8, and 28.4ºC (83.2ºF) on July 15 (Mirant Kendall 2003 Data, Appendix F: November 13, 2003).

A review of the scientific literature on the subject provided additional information. Tidwell (1999) found that yellow perch juveniles exposed to a temperature of 28 ºC (82.4 ºF) showed a marked reduction in survival when compared to those exposed to 24 ºC (75.2 ºF) or 20 ºC (68 º F). The survival rate was only 75% at 28 ºC (82.4 ºF), as compared with 94% and 96%, for 24 º C (75.2 ºF) or 20 ºC (68 ºF), respectively. No experiments were conducted between 28 ºC (82.4 ºF) and 24 ºC (75.2 ºF). This stark contrast in survival rates was taken into consideration, and a temperature limit below 28 ºC (82.4 ºF) was evaluated for the lower Charles River to ensure that a mortality rate approaching 25% would not be experienced by the yellow perch population due to high temperatures. However, yellow perch were collected in the lower basin at temperatures that approached and exceeded 28 ºC (82.4 ºF; Mirant Kendall 2003 Data, Appendix F: November 13, 2003), demonstrating no avoidance behavior or acute effects in that temperature range for at least some individuals. The mere presence of a small number of individual fish at elevated temperatures is not compelling evidence on its own that protective temperature should be set at those elevated levels. Additional scientific studies were consulted to further investigate a protective temperature for yellow perch in the lower basin.

The upper incipient lethal temperature limit for juvenile yellow perch, defined as the temperature where mortality is observed for 50% of the organisms tested, is given as a range between 29.2 ºC (84.6 ºF) and 34 ºC (93.2 ºF) (Hokanson, 1977). The warmer summertime ambient conditions that occur in the lower Charles River Basin periodically approach one of the acclimation temperatures used in the experiment. This acclimation temperature of 25 ºC (77 ºF) for juvenile perch resulted in an incipient lethal temperature of 32.3 ºC (90.1 ºF). In order to protect a balanced indigenous population and provide reasonable aquatic habitat in the Zone of Passage and Habitat, a temperature limit must be identified that will not induce a large degree of mortality, so by definition the value must be below the upper incipient lethal limit identified in the study. Coutant proposed two methods to determine a maximum upper temperature limit for a species. (Natl. Acad. Sci./Natl. Acad. Eng. 1972.). One method uses a calculation that adds one-third of the range between the optimum temperature and the upper incipient lethal temperature for a species and life stage to the optimum temperature. In the case of yellow perch juveniles, the optimum temperature range is given as 20 to 23 ºC (68 to 73.4 ºF) (Krieger, 1983). If 23 ºC (73.4 ºF) is chosen as the optimum temperature and 32.3 ºC (90.1ºF) is chosen as the upper incipient lethal temperature, by following this method, the maximum upper temperature limit is 23 ºC + (32.3 ºC - 23 ºC)/3 = 26.1 ºC (79.0 ºF). In the case of juvenile yellow perch in the lower Charles however, field observations tend to weaken the use of this approach to determine an upper thermal limit for this water body. Lower Charles River Basin ambient temperatures have been documented well above 26.1 ºC (79.0 ºF) in the summer months. Also, during beach seine collections in 2003 in the lower basin, yellow perch were collected on many separate occasions above 26.1 ºC (79.0 ºF; Mirant Kendall 2003 Data, Appendix F: November 13, 2003). Although it is not clear the degree of thermal stress (if any) yellow perch juveniles in the Charles experienced at temperatures above 26.1 ºC (79.0 ºF), this approach does not seem the most appropriate method to determine a protective temperature limit for yellow perch juveniles in the lower basin.

Coutant’s second method to determine a maximum temperature limit involves subtracting 2ºC (3.6ºF) from the incipient lethal temperature as a safety factor to minimize mortality resulting from thermal stress. If 32.3 ºC (90.1 ºF) is again used as the incipient lethal temperature for yellow perch juveniles in the lower basin, under the guidance of this second method, the maximum temperature that would produce a No Acute Effects Level (NOAEL) for the protection of the species at this life stage would be 30.3 ºC (86.5 ºF). The use of 32.3 ºC (90.1 ºF) as the incipient lethal temperature, identified by Hokanson, is thought to be an appropriate assumption, given the uncertainties and other stressors in the basin.

A NOAEL temperature is in most cases higher than the avoidance temperature of a species. Since the temperature of 30.3 ºC (86.5 ºF) does not take into account an avoidance temperature, the Yellow Perch Habitat Suitability Index was again consulted (Krieger, 1983) to consider a suitable temperature that will be below an avoidance temperature. As stated earlier, the yellow perch larvae water temperature identified to provide a 40% habitat suitability was 27ºC (80.6ºF). This same suitability index applies to juvenile and adult yellow perch. Based on temperature measurements taken at the time and location of site-specific yellow perch collection in the lower basin, and the evidence that this water body is one of the warmest rivers in the state, it could be argued that a temperature value of 27ºC (80.6ºF) may likely reflect a habitat suitability greater than 40%, if applied specifically to yellow perch in the lower Charles River Basin.

Taking into consideration Tidwell’s (1999) finding that a marked reduction in survival occurred when yellow perch juveniles were exposed to a temperature of 28 ºC (82.4 ºF), Coutant’s approach, the habitat suitability index, and site specific field data, especially the beach seine field data collected in 2003, a temperature limit of 27ºC (80.6ºF) was judged to be protective for juvenile yellow perch. In order to ensure that this temperature is not exceeded in the near shore habitat utilized by juvenile yellow perch, no temperature in the ZPH must exceed the MA Water

Quality Standard of 28.3ºC (83ºF). The reasoning for this ZPH temperature limit is explained below.

This judgment takes into consideration the in-situ continuous temperature monitoring and compliance program that is required by the draft permit. Under this monitoring program, the highest temperature measured in the ZPH will likely be a temperature located near the bank-to-bank mid-point of the basin, in six feet of water (Mirant Kendall NPDES Permit Application, 2001). This will result in the near shore, Boston side and deeper habitat, both used by juvenile yellow perch, to likely be at least 1.1ºC (2ºF) lower than the 28.3ºC (83ºF) temperature limit at all times during the warmer months (Mirant Kendall 2003 Data, Appendix B-2: November 13, 2003). The continuous in-situ temperature monitoring program that is required to demonstrate compliance with the specified temperature limits is fully discussed in Part I.A, Section 14.b. of the draft permit.

Also, it is important to understand that natural daily ambient temperature fluctuations of at least 1.1 ºC (2 ºF) in the lower Charles River Basin are routinely expected (see Figures 5.10.5c-1 through 5.10.5c-5).   This fluctuation is caused by changes in air temperature and solar input during a daily 24 hour weather cycle, and is observed in most bodies of water. This change in temperature over a 24 hour period will further ensure that the protective temperature of 27ºC (80.6ºF) is maintained in the juvenile yellow perch habitat in the ZPH under a maximum temperature limit of 28.3ºC (83ºF).

Site specific controlled research on the resident community in the lower basin or representative near-by areas could further confirm that this limit is protective. Based on the information from the scientific literature, the data collected in the lower Charles River Basin, and the nature of this in-stream monitoring configuration, EPA and DEP have determined that a temperature limit no greater than 28.3ºC (83ºF) in any part of the ZPH will afford yellow perch juvenile habitat a protective temperature that will not exceed 27ºC (80.6ºF).

5.6.3g Time Period For The Most Sensitive Juvenile Stage

Beach seine sampling by the permittee documented juvenile yellow perch in relatively high numbers from July 1999 through early January of 2000. No beach seine sampling was conducted from February through June, 2000. Beach seine sampling later in 2000 documented juvenile yellow perch in the lower basin from early July through early November (Mirant Kendall NPDES Permit Application, 2001; Appendix 5). Yellow perch juveniles were documented in the basin from June 11 through October 13, 2003 (Mirant Kendall 2003 Data, Appendix F: November 13, 2003). Yellow perch juveniles are presumed to be found in the lower Charles River Basin throughout the year.

Based on the discussion above, the maximum temperature that is protective for the survival of yellow perch juveniles is 28.3ºC (83ºF) and must be in place in the Zone of Passage and Habitat throughout the year, unless replaced by a lower temperature limit to protect a more sensitive life stage or species occurring in the basin at the same time.

5.6.3h Protective Temperature For Most Sensitive Adult Reproductive Condition

Controlled research conducted on adult fish taken specifically from the lower Charles River Basin to evaluate the temperature sensitivity of the reproductive condition of resident species would provide valuable information to determine water temperature limits protective of this life stage in this water body. Resident species adult fish from the lower Charles River Basin are adapted to the range of ambient temperature conditions typically found in the lower basin, and it is recognized that their sensitivity to elevated temperatures may vary to some extent from the temperature range determined to be protective for the same species of adult fish tested from a different water body, or from adult fish tested using an acclimation temperature or water quality characteristics not representative of the lower Charles River Basin. A review of the scientific literature revealed that no controlled research using resident species adult fish taken specifically from the lower Charles River Basin was available. Sampling collection data that documented the presence of residence species adult fish in the lower Charles River Basin were available (Mirant Kendall NPDES Permit Application, 2001; Mirant Supplemental Field Data, 2002 and 2003). In addition, scientific literature that examined the adult stage reproductive condition temperature sensitivity of fish expected to be “resident species” in the lower basin was available. The literature review identified yellow perch adults as the adult fish stage most sensitive to elevated water temperatures. A discussion of relevant adult yellow perch information follows.

If water temperatures in the lower basin are permitted to exceed levels regarded as essential for reproductive organ development, then the future propagation of the lower Charles River Basin fish population could be seriously jeopardized. Gonadal development is dependent, among other factors, on the occurrence of a minimum overwintering water temperature that must be maintained for a specific duration (a “chill period”). Adults must be exposed to this extended period of cold water temperatures to ensure the ripening of eggs (Krieger *et al*., 1983). The acceptable temperature range is considered to be between 4 and 10 ºC (39.2 and 50 ºF). Laboratory experiments conducted in Duluth, Minnesota, indicated that yellow perch collected at 47 º N Latitude and maintained at 4 ºC (39.2 ºF) for 185 days, beginning in October, produced the greatest percentage of viable eggs (75 to 100%; Jones *et al*., 1974). Treatments as high as 10 ºC (50 ºF) resulted in 25% or less production of viable eggs, meaning that 75% or more of the eggs were not viable.

This information was taken into consideration but could not be directly applied to the formulation of a minimum overwintering temperature for yellow perch in the lower Charles River Basin for the following reasons: First, the adult yellow perch population used in the experiment were taken from the Duluth, Minnesota area, a colder environment than the Boston area. The climate in Duluth, Minnesota, based on an inspection of daily mean air temperatures from the past 30 years, is generally cooler than Boston air temperatures (NOAA National Climatic Data Center, Provisional Data), with different water quality characteristics (Minnesota at Latitude 47 ºN), compared with the yellow perch population under consideration in the lower Charles River Basin (approximately 42 º 20' N Latitude). It is likely that these two adult populations have adapted to some extent to the water temperatures and water quality characteristic of their individual climates. Caution should be used when assuming the same response to temperature from these two different adult populations. As seen with some fish species, adults residing in lower latitudes may be generally adapted to warmer temperature ranges than more northern populations.

Second, continuous ambient water temperatures recorded at the cooling water intake of the Kendall Station were examined to gather information on the approximate chill period of the basin. Vertical profile temperature data taken at several stations in the lower basin in March and November of 2000 generally show a uniform temperature from surface to bottom. Some deep water stations (MIT Station, November 6, 2000 at 21 feet, and Old Channel at 24 feet on March 20, 2000) showed evidence of eroding and developing thermal stratification, respectively, but the basin was assumed to be generally isothermal throughout the winter months (Mirant Kendall NPDES Permit Application, 2001; Appendix 3). If the basin is isothermal during the time period under consideration, then temperature values recorded at the Kendall Station Cooling Water Intake Structure could reasonably be thought to represent temperature conditions throughout the basin. The Kendall Station intake structure draws water from approximately the upper eleven feet of the water column. Intake temperatures are measured once this column of water has been mixed. These water temperature data were the only continuous information available to represent winter temperatures throughout the majority of the basin. Examination of these data from 1994 through 2001 showed that temperatures as low as 4 ºC (39.2 ºF) for 185 days, as measured from the Duluth study, do not occur in the lower basin of the Charles River. When the lowest temperatures for all eight years are identified, the greatest continuous span at or below 4 ºC (39.2 ºF) is 122 days. When looking at the average temperature over the eight years, the greatest continuous span at or below 4 ºC (39.2 ºF) is 102 days (Kendall Station Cooling Water Intake Data; Unpublished; Figures 5.9.2-15 to 5.9.2-22). Based on this examination, the 4 ºC (39.2 ºF) temperature threshold for 185 day optimal condition is never achieved in the lower basin. A higher temperature in the 4 to 10 º C (39.2 and 50 ºF) range appears to be more representative of lower Charles River Basin conditions.

A review of yellow perch habitat requirements lists a temperature range of 4 to 10 ºC for a duration of between 145 to 175 days for the maturation of gonads (Krieger *et al*., 1983). Since temperatures of 4 ºC (39.2 ºF) do not occur in the basin at the minimum stated range of 145 days, further examination of the surrogate ambient water temperatures (i.e. Kendall Station Intake temperatures) in the lower basin was conducted. The examination shows that temperatures of 10 ºC (50 ºF) or lower were observed for a duration of between 136 and 163 days from 1994 through 2001 (Figures 5.9.2-15 to 5.9.2-22). The average duration of basin temperatures at or below 10 ºC (50 ºF) was calculated to be approximately 149 days. This average duration was selected as the target for the minimum length of time necessary for the chill period, because natural winter chill period conditions in the basin reach the threshold of an average of at least 145 days. Temperatures lower than 10 ºC (50 ºF) are not sustained long enough in the basin to meet the 145 day minimum chill period. It is recognized that even at a threshold of 10 ºC (50 ºF), the lower Charles River Basin will naturally experience chill period less than 149 days during some years. This will be factored into the permit compliance plan.

Based on the discussion above, the maximum temperature that is protective for the maturation of yellow perch gonads in the lower basin is 10 ºC (50 ºF) and no thermal effluent discharged by Kendall Station shall shorten the duration of this temperature below at least 149 days during the natural overwintering period of approximately early November to late March in the Zone of Passage and Habitat. This temperature limit and duration may be replaced by a lower limit to protect a more sensitive life stage or species occurring in the basin at the same time.

5.6.3i Protective Temperature For The Most Sensitive Adult Spawning Stage

Controlled research conducted on adult fish taken specifically from the lower Charles River Basin to evaluate the temperature sensitivity of the spawning condition of resident species would provide valuable information to determine water temperature limits protective of this crucial life stage activity in this water body. Resident species adult fish from the lower Charles River Basin are adapted to the range of ambient temperature conditions typically found in the lower basin, and it is recognized that their sensitivity to elevated temperatures may vary to some extent from the temperature range determined to be protective for the same species of adult fish tested from a different water body, or from adult fish tested using an acclimation temperature or water quality characteristics not representative of the lower Charles River Basin. A review of the scientific literature revealed that no controlled research evaluating resident species adult spawning conditions using fish taken specifically from the lower Charles River Basin was available. Sampling collection data that documented the presence of residence species adult fish in the lower Charles River Basin were available, although this information did not directly address the spawning condition (Mirant Kendall NPDES Permit Application, 2001; Mirant Supplemental Field Data, 2002 and 2003). However, scientific literature that examined the adult stage spawning condition temperature sensitivity of fish expected to be "resident species" in the lower basin was available. The literature review identified yellow perch adults as the adult fish stage most sensitive to elevated water temperatures. A discussion of relevant adult yellow perch information follows.

Site-specific field observations and collection programs conducted by the permittee in 1999, 2000, 2002 and 2003 did not provide any direct information on protective yellow perch spawning temperatures. Hartel, *et al.*, (2002) and Scott and Crossman (1973) both reported that yellow perch spawning occurs at night in shallow areas, when water temperatures are between 6.7 and 12.2 ºC (44 and 54 ºF). Hokanson (1977) reported that successful reproduction of yellow perch depends on rising temperatures during spawning and early life stages.

Krieger, et al. (1983) reported a spawning Habitat Suitability Index of 1.0 (completely suitable) from approximately 8.5 to 12 ºC (47.3 to 53.6 ºF), which is generally comparable to Hartel, *et al*., (2002) and Scott and Crossman (1973). This temperature was estimated from a habitat suitability index graph (Krieger, et al., 1983; Graph V5, p. 9). When setting maximum protective temperatures in the lower Charles River Basin, it is judged that temperature limits can be established which are above the optimum value for a species (i.e. below a Habitat Suitability Index of 1.0) and still serve to protect a balanced population. In this case, a Habitat Suitability Index of 0.5 was considered for the temperature limit. An index of 0.5 translates to a relative habitat suitability between optimal and completely unsuitable. This point of yellow perch spawning suitability corresponded with a temperature of approximately 15 ºC (59 ºF; Krieger, et al., 1983; Graph V5, p. 9).

Ambient water temperature from the lower Charles River Basin was next examined to assist in establishing an appropriate protective spawning temperature. Nine years of continuous ambient temperature information, measured from the Kendall Station intake location, was reviewed for this purpose. This data, collected from 1994 through 2002, was extensively analyzed to determine an appropriate chill period for yellow perch (see Section 5.6.3h). The analysis revealed that ambient basin temperatures most closely matched the warmest extreme of the acceptable overwintering range. As previously discussed, the overwintering temperature range from the literature was identified as between 4 and 10 ºC (39.2 and 50 ºF). Based on the historical nine year temperature information, an acceptable length of time for the chill period (approximately 149 days) could only be met, on average, at the uppermost end of the recommended temperature range for the chill period, (10 ºC; 50 ºF). It follows that the upper end of the observed temperature range may also be appropriate to identify a protective spawning temperature. Based on the spawning temperatures listed above, temperatures of 12.2 ºC (54 ºF) and 15 ºC (59 ºF) make up the upper (warmest) part of the protective temperature range.

Because rising water temperatures during the spawning season also play a role in successful spawning, this factor was also incorporated into the protective temperature regime. Based on the discussion and data presented in Section 5.9.2a and b of this document, Kendall Station intake temperatures seemed to be a reasonable

approximation of ambient river conditions in the spring.
Applicable hourly water temperature data from the Kendall Station intake structure from January of 1994 through early June of 2002 were examined (Figures 5.9.2-15 to 5.9.2-23). The observation that during the expected spawning period, ambient temperature data from the lower basin shows a steady increase in river temperature, as well as great fluctuations in temperature, further supports the role of rising temperatures during spawning (Mirant Kendall Hydrographic Data 1999, 2000, 2002, 2003; Mirant Kendall Operations Data, Unpublished, 2002). Taking this information into consideration, it was judged that a temperature of 12.2 ºC (54 ºF) was a maximum protective value for yellow perch spawning early in the spawning season, being set to the temperature of 15 ºC (59 ºF), a 5 ºF increase, during the middle of the spawning season, and then set to 17.2 ºC (63 ºF), a 4 ºF increase, for the latter part of the spawning season. Although a spawning temperature of 17.2 ºC (63 ºF) corresponds to a Habitat Suitability Index of approximately 0.2 (Krieger, et al., 1983; Graph V5, p. 9), ambient temperature data recorded during the last segment of the spawning period in the lower basin in 1994, 1996, 2001 and 2002 support this value. This "stair-step" approach of increasing maximum protective temperatures as the spawning season progresses recognizes the need for rising temperatures to ensure successful spawning.

During the early spring spawning season, the difference in temperature between warmer near surface waters and the cooler, near bottom shoreline depths (where yellow perch spawning takes place) has been observed to be as great as 2.8 ºC (5 ºF) (Mirant Kendall Hydrographic Data 1999, 2000, 2002, 2003). Also, it is important to understand that natural ambient daily temperature fluctuations of at least 1.1ºC (2ºF) in the lower Charles River Basin are routinely expected within a 24 hour day (see Figures 5.10.5c-1 through 5.10.5c-5). This fluctuation is caused by changes in air temperature and solar input during a daily 24 hour weather cycle, and is observed in most bodies of water. This daily cycle generally results in the warmest river temperatures being recorded at mid-day or a few hours after noon, while the coolest water temperatures (at least 1.1ºC (2ºF) cooler) would be expected at night, when yellow perch are thought to spawn. In addition, vertical "sea walls" are present along a sizable portion of the shore of the Cambridge side of the river, in the vicinity of the Station. The Boston side tends to display a relatively more gradual slope from the shore to river bottom. This feature may make the Boston side of the river a more suitable habitat for yellow perch spawning activities in the ZPH. The Boston side of the basin is the furthest away from the thermal discharge from Mirant Kendall Station, which is located on the Cambridge side of the basin. Based on the temperature differential information, the likely location of yellow perch spawning, and the design of the in-situ temperature monitoring and compliance program discussed below, it is judged that yellow perch spawning habitat will be maintained at or below the protective maximum temperature of 12.2 ºC (54 ºF), 15 ºC (59 ºF) and 17.2 ºC (63 ºF) when the overall Zone of Passage and Habitat temperature limit does not exceed 13.3 ºC (56 ºF), 16.1 ºC (61 ºF) and 18.3 ºC (65 ºF), respectively, at any one monitoring point.

This judgment takes into consideration the in-situ continuous temperature monitoring and compliance program that will be required by the permit. Under this monitoring program, the highest temperature measured in the ZPH will likely be a temperature located near the bank-to-bank mid-point of the basin, in six feet of water (Mirant Kendall NPDES Permit Application, 2001). This will result in the majority of the habitat used by spawning yellow perch to likely be lower than the temperature limit at all times during the spawning season (Mirant Kendall 2003 Data, Appendix B-2: November 13, 2003). The continuous in-situ temperature monitoring program that is required to demonstrate compliance with the specified temperature limits is fully discussed in Part I.A, Section 14.b. of the draft permit.

Additional site-specific studies would provide information on the river temperatures, timing, and duration associated with yellow perch spawning in the lower Charles River Basin to assure that the maximum temperatures selected are protective of conditions necessary for a balanced indigenous population.

5.6.3j Time Period For The Most Sensitive Adult Spawning Stage

Site-specific field observations and collection programs conducted by the permittee in 1999, 2000, 2002 and 2003 did not provide any direct information on the expected timing of yellow perch spawning efforts. A review of the literature revealed that yellow perch spawning may begin as early as the latter part of February and continue through early July (Hokanson, 1977) but is generally considered to take place from April to June (Krieger, *et al.*, 1983). The state agency responsible for the protection and well being of the species has placed the site-specific spawning period for yellow perch from March 20 through April 30 (Keller, MA DFW, personal communication). For the purposes of this determination, March 20 through April 30 was chosen as the yellow perch spawning season in the lower Charles River Basin.

Until additional site-specific information is collected, and based on the discussion above, the maximum protective temperatures for spawning adult perch in the lower Charles River Basin are 12.2 ºC (54 ºF) early in the spawning season, 15 ºC (59 ºF) during the middle of the spawning season, and 17.2 ºC (63 ºF) for the latter part of the spawning season. It is judged that if no part of the ZPH rises above the maximum temperature limit of 13.3 ºC (56 ºF) from March 20 through April 1, 16.1 ºC (61 ºF) from April 2 through April 14, and 18.3 ºC (65 ºF) from April 15 through April 30, spawning habitat will always be in the protective temperature range. These limits must be in effect in the ZPH for the time periods specified, unless replaced by a lower temperature limit to protect a more sensitive life stage or species occurring in the basin at the same time.

5.6.3k Protective Temperature For Most Sensitive Adult Stage

Controlled research conducted on adult fish taken specifically from the lower Charles River Basin to evaluate the temperature sensitivity of the adult resident species would provide valuable information to determine water temperature limits protective of this life stage in this water body. Resident species adult fish from the lower Charles River Basin are adapted to the range of ambient temperature conditions typically found in the lower basin, and it is recognized that their sensitivity to elevated temperatures may vary to some extent from the temperature range determined to be protective for the same species of adult fish tested from a different water body, or from adult fish tested using an acclimation temperature or water quality characteristics not representative of the lower Charles River Basin. A review of the scientific literature revealed that no controlled research using resident species adult fish taken specifically from the lower Charles River Basin was available. Sampling collection data that documented the presence of residence species adult fish in the lower Charles River Basin were available (Mirant Kendall NPDES Permit Application, 2001). In addition, scientific literature that examined the adult stage lethal temperature limit and avoidance temperature sensitivity of fish expected to be “resident species” in the lower basin was available. The literature review identified yellow perch adults as the adult fish stage most sensitive to elevated water temperatures. A discussion of relevant information regarding adult yellow perch follows.

The adult life stage of yellow perch was identified as the resident species in the lower basin most sensitive to temperature. Two temperature effects must be considered when determining a limit for yellow perch adults. First, a lethal temperature limit must be established to prevent elevated mortality from occurring in the population. Second, a temperature avoidance limit must be evaluated. If yellow perch are not killed by excess heat discharged to the receiving water, but instead leave the lower basin, or move far up-stream to avoid water temperatures they do not prefer, they will be effectively excluded from the habitat at the lowest reaches of the basin. Limited site-specific field collection of yellow perch adults in the Broad Canal of the lower basin was conducted by the applicant (Mirant Kendall NPDES Permit Application, 2001; Appendix 5). During the warmer months of 1999, the highest water temperature where yellow perch were collected in gill nets was 26.1 ºC (79 ºF) on July 9, 1999. The highest water temperature recorded during all gillnet sampling in 1999 was 28.3 ºC (83 ºF), on August 2, 1999, with no yellow perch included in the sample. In the year 2000, the highest water temperature where yellow perch were collected in gill nets was 24.4 ºC (76 ºF), while the highest water temperature recorded during all gillnet sampling in 2000 was 26.1 ºC (79 ºF), on June 27 - 28, and July 5 - 6, 2000, with no yellow perch included in the samples (Mirant Kendall NPDES Permit Application, 2001; Appendix 5). A more expanded gillnet collection program was conducted in 2003. Yellow perch were collected at temperatures as high as 29.3 ºC (84.8 ºF) , 27.8 ºC (82.0 ºF) and (27.2 ºC (81.0 ºF) at the depth of 1 ft, 12 ft and 14 ft, respectively, on July 8, 2003, downstream of the Broad Canal (Mirant Kendall 2003 Data, Appendix B-2 and I, November 13, 2003). While this site-specific data is useful in understanding the maximum preference temperatures of the yellow perch in the lower basin, it is only one component of the body of information used in this determination.

Scientific literature regarding yellow perch report the preferred temperature of the species between 17.6 ºC (63.7 ºF) and 25 ºC (77 ºF) (Krieger *et al*., 1983). Site-specific data reported above documents the presence of the species in the lower basin above this range. As stated earlier, the yellow perch larvae water temperature identified to provide a 40% habitat suitability was 27ºC (80.6ºF). This same suitability index applies to juvenile and adult yellow perch (Krieger *et al*., 1983). Perch have been documented to avoid the thermal outfall of a power plant and preferred nearby lake temperatures of 27.1 ºC (80.8 ºF) (Krieger *et al*., 1983). Additional, site-specific information would allow a better understanding of the appropriate avoidance temperature of yellow perch of the lower Charles River Basin. In the absence of this information, an upper maximum temperature limit was identified for the species as well as a protective avoidance temperature limit based on available information.

There is no site-specific information regarding the upper lethal temperature limits for yellow perch adults that have adapted to the range of ambient temperature conditions in the lower Charles River Basin. The scientific literature places the upper lethal limit for yellow perch at 32.2 ºC (90 ºF) (Krieger *et al*., 1983). Hokanson reported that upper incipient lethal temperatures for summer tests at the acclimation temperature of 25 ºC (77 ºF) resulted in an incipient lethal temperature of 32.3 ºC (90.1 ºF). This value is very similar to the upper lethal limit of 32.2 ºC (90 ºF) identified by Krieger. Coutant (Natl. Acad. Sci./Natl. Acad. Eng.,1972) reported that subtracting two degrees Celsius from the incipient lethal temperature may be considered the upper temperature limit where no acute adverse effects would be seen for an organism. Based on this technique, the limit of 32.2 -2.0 ºC, or 30.2ºC, (86.4 ºF) was seen as the temperature that will restrict thermally induced mortality of yellow perch adults. This is also referred to as the No Acute Effects Level (NOAEL).

While a temperature of 30.2 ºC (86.4 ºF) may prevent mortality, this value does not take into consideration avoidance behavior of adult yellow perch when subjected to elevated temperatures. In order to ensure yellow perch adults are not completely excluded from sufficient habitat due to high water temperatures, a protective temperature limit must take into consideration avoidance behavior brought on by elevated temperatures. Avoidance temperatures are generally lower than NOAEL values.

Keller (personal correspondence, January 2002) reviewed MA Department of Fish and Wildlife river survey data from over 100 streams and rivers in Massachusetts from 1970 through 2001 and could find no documentation of yellow perch adults occurring in waters greater than 27 ºC (80.6ºF). Keller maintained that, given the opportunity to find cooler water, it would be improbable that adult yellow perch would be found in waters greater than 27 ºC (80.6ºF). While the majority of adult yellow perch collected in the lower Basin were found in water that supports this hypothesis, yellow perch were collected below the Broad Canal in the summer of 2003 at temperatures up to 2ºC (3.6ºF) above 27 ºC (80.6ºF). It is not possible to infer the health of these fish collected at temperatures greater than 80ºF or to positively conclude that they were not in these warm areas to avoid other stressors or predators. Also, the documented presence of several individual fish at elevated water temperatures does not by itself support the establishment of a protective limit at that value. This is because there is likely a variability of thermal tolerance among the individual fish that make up a given population. Setting temperature limits based only on individuals that may naturally be able to tolerate warmer temperatures is not thought to be an approach that is sufficiently protective of the population as a whole. However, the presence of these adults in warmer water was not fully discounted when estimating an approximate avoidance temperature for the lower Charles. It must also be taken into consideration that the lower Charles River Basin is among the warmest rivers in Massachusetts.

Yellow perch naturally leave near-shore and surface waters in the summer for the cooler, deeper waters sought as a thermal refuge. When near-surface summer ambient water temperatures in the lower Charles River Basin naturally approach the MA Water Quality Standard limit of 28.3 ºC (83.0ºF), it has been documented that deeper waters (down to approximately 12 feet) are commonly one or more degrees Celsius cooler and generally contain enough dissolved oxygen to provide habitat for adult yellow perch. This is supported by hydrographic vertical profile data collection for temperature and dissolved oxygen in the lower basin (Mirant Kendall NPDES Permit Application, Appendix 3, 2001 ; Mirant Kendall Hydrographic Data, 2002; EPA Clean Charles 2005, 2002 Data; Mirant Kendall 2003 Data, Appendix B-2: November 13, 2003).

Also, it is important to understand that natural daily ambient temperature fluctuations of at least 1.1ºC (2ºF) in the lower Charles River Basin are routinely expected (see Figures 5.10.5c-1 through 5.10.5c-5). This fluctuation is caused by changes in air temperature and solar input during a daily 24 hour weather cycle, and is observed in most bodies of water. This change in temperature over a 24 hour period will further ensure that the protective temperature of 27ºC (80.6ºF) is maintained in the adult yellow perch habitat in the ZPH under a maximum temperature limit of 28.3ºC (83ºF) enforced by the real-time continuous monitoring and compliance configuration included in the draft permit.

Based on this information, when a maximum summer time temperature limit of 28.3 ºC (83.0ºF) is in effect throughout the ZPH in the lower Charles River Basin, the deeper water habitat (below 12 ft.) used by adult yellow perch (Mirant Kendall 2003 Data, Appendix I: November 13, 2003) will likely contain temperatures at or below 27 ºC (80.6ºF). This temperature is considered necessary to prevent avoidance and exclusion of habitat for yellow perch adults residing in the lower Charles River Basin, as well as allow for the maintenance of the BIP of this species. Therefore, a temperature limit of 28.3 ºC (83.0 ºF), enforced at all locations in the ZPH, will result in protective temperatures for adult yellow perch in their expected habitat.

As discussed above, this judgment takes into consideration the in-situ continuous temperature monitoring and compliance program that will be required by the permit. Under this monitoring program, the highest temperature measured in the ZPH will likely be a temperature located near the bank-to-bank mid-point of the basin, in six feet of water (Mirant Kendall NPDES Permit Application, 2001). This will result in the near shore, Boston side and deeper habitat, both used by adult yellow perch, to likely be at least 1.1 ºC (2.0 ºF) lower than the temperature limit at all times during the warmer months (Mirant Kendall 2003 Data, Appendix B-2: November 13, 2003). The continuous in-situ temperature monitoring program that is required to demonstrate compliance with the specified temperature limits is fully discussed in Part I.A, Section 14.b. of the draft permit.

5.6.3l Time Period For The Most Sensitive Adult Stage

Based on the discussion above, the maximum temperature in the lower Charles River Basin that is protective for the survival and propagation of yellow perch adults is 29.3 ºC (83.0 ºF). This maximum temperature for adult perch does not apply to the winter chill period, which is discussed earlier. This limit must be in place in the Zone of Passage and Habitat throughout the year, unless replaced by a lower temperature limit to protect a more sensitive life stage or species.

5.6.3m Summary Of Temperature Limits and Time Periods For Resident Species Protection

All protective temperature limits and time periods for the most sensitive resident species discussed in Section 5.6 have been organized by month, beginning in January, to obtain an overall picture of the necessary temperatures in the Zone of Passage and Habitat in the lower Charles River Basin over the course of a year. Figure 5.6-1 represents this information. The life stages being protected are also identified in the figure. As more site-specific field data is collected from the lower basin, these temperature limits and time periods may be modified. As stated in Section, 5.6.3a, yellow perch (*Perca flavescens*) was identified as being the resident species most sensitive to elevated temperatures at every stage of its development (See Reference Section 5.12).

5.7 Thermal Tolerance Limits For Anadromous Fish Species of the Lower Charles River Basin

5.7.1 Anadromous Species Issues

There are a number of important issues to consider in the evaluation of the temperatures needed to protect the BIP for anadromous fish. These species have different needs for various life stages during various portions of the year. The lower Charles River Basin serves as a passage way and spawning location in the spring, and a development nursery area for eggs, larvae and juveniles from the spring to the winter. Protecting this habitat ensures the protection and propagation of the BIP. Consideration must be given to physiological temperature effects, avoidance, and ensuring food sources are not excluded by a heated zone, while also gauging the effect of the other stressors in the lower basin.

5.7.1a Adult Spawning Migration

One important spawning instinct used by anadromous species relates to the detection of the proper water temperature "trigger" by these fish as a signal to leave the marine environment and enter the freshwater of the lower Charles River Basin to spawn. Anadromous fish preparing to spawn in natural flowing rivers are often observed congregating at the mouth of the river, waiting for the right combination of environmental factors to trigger their instinctive drive upstream. The observation that the temperature of the river at its mouth is a major factor in the timing of the spawning run was made by Cooper (1961) during his work on the Gilbert Stuart Stream in Rhode Island. In the case of the Charles River, timing of the start of the spawning run is further complicated by the dam, which obstructs their passage and represents a sudden change from saltwater to freshwater conditions. A protocol to pass anadromous fish was developed at the New Charles River Dam and Locks in an attempt to minimize the effect of this barrier. The protocol includes allowing an "attractant flow" of freshwater to pass through a lock and into the harbor, to lure anadromous fish into the lock. If the river temperature range passing through the lock is higher than the range a particular anadromous species has evolved to seek as a part of the trigger to begin the spawning run, the fish may not attempt to navigate the man-made structure and enter the Charles River. Highly reduced or completely halted spawning runs resulting from an "attractant flow" temperature that is above the range suitable for an anadromous species to initiate a spawning run has the potential to make the propagation of a balanced population impossible to sustain.

It must also be noted that elevated water temperatures in an attractant flow of freshwater may cause anadromous fish to enter the lower Charles River Basin earlier in the year than they naturally would under ambient water temperature conditions. In this case, spawning may be induced to take place at an earlier date than the species naturally evolved to spawn. This could result in fish eggs hatching to the larval stage at a time before the larvae's food source becomes abundant in the upstream portion of the basin. The early life stages may also be unable to cope with the early season, cooler than expected, water temperatures in upstream spawning areas not influenced by the thermal plume. This premature spawning phenomenon could greatly reduce reproductive success for anadromous species.

5.7.1b Spawning Location

If an anadromous species is not inhibited from entering the lower Charles River Basin because of elevated temperatures in the attractant flow, a possible negative impact of elevated water temperature is still possible. Once in the lower basin, anadromous fish seeking upstream habitat in which to spawn must swim past the thermal discharge of the plant, approximately one mile upstream of the dam. If water temperatures at this point in the river are high enough to cause the spawning fish to avoid the thermal plume, fish may be blocked from traveling to the upstream area. This may halt spawning activity or cause the fish to spawn in the basin, rather than further upstream. Anadromous fish eggs deposited and fertilized in the lower basin face a greater risk of being entrained by Kendall Station. The eggs may also drift past the New Charles River Dam and Locks before developing to a life stage suited for a marine environment. In both cases, spawning activity in the lower basin may increase mortality of the early life stages of the anadromous species.

5.7.1c Out Migration

Those adult anadromous fish that do manage to spawn successfully at upstream locations will be in a weakened condition as a natural consequence of the spawning process. These fish must once again be exposed to the stress of elevated water temperatures during their out-migration from the Charles River, as they swim past the Kendall Station thermal plume and back to the coastal marine environment.

Young-of-year anadromous fish inhabiting the lower Charles River Basin during their first summer possibly look for a decrease in water temperature as one of the environmental cues that trigger their initial fall migration out of the lower basin and into the coastal marine environment. The lower basin habitat effected by the thermal plume of Kendall Station may remain warm enough to delay the migration of young-of-year anadromous fish out of the river. This disruption in the timing of the out-migration of these fish may increase their mortality as they remain in the relatively confined basin, exposed to predation there, for a longer period of time as they wait for these artificially high temperatures to decrease. In addition, any time delay in out-migration will also postpone the opportunity of young-of-year anadromous fish to move to the rich marine food source of coastal waters.

5.7.2 Anadromous Species Considered

The Agencies reviewed scientific literature and data submitted by Mirant Kendall dealing with the following anadromous species to determine which of these species would be the most sensitive to temperature: blueback herring, alewife, American shad, rainbow smelt, and striped bass. American eel, a catadromous species, was also included in the review process. From that list, the Agencies determined that the anadromous species to focus on were blueback herring and alewife, as set out in Table 5.6-1. It must be stressed that temperatures and time periods listed in this table came from a preliminary "first draft" of threshold parameters for these species. The temperature values and time periods identified were used for comparison between the species of interest to determine which anadromous species appeared to have the lowest threshold to water temperature. The protective temperature limits and time periods ultimately developed were based on a number of sources and discussed fully in Section 5.7.3 of this document. Further review and evaluation determined that alewife was the anadromous fish species most sensitive to temperature for all of its life stages in the Charles River (see EPA letter to Mirant Kendall, July 16, 2001). Alewife currently maintain a significant population in the lower basin. This species is an indicator species. The rationale is that if the species most sensitive to temperature is protected in a thermally influenced aquatic habitat, other species and life stages that occur in the habitat will be protected as well. This approach has been identified in the literature as one way to protect existing fish communities in a water body that receives heated discharge (Natl. Acad. Sci./Natl. Acad. Eng., 1972).

Although alewife was selected as the indicator anadromous species for temperature limits in the lower Charles River Basin, the Agencies have given serious consideration to temperature limits needed to protect American shad (*Alosa sapidissima*). This species has been documented in the Charles River system in the past (Colosi, NOAA Fisheries Letter, 2002). MA DMF attempted to reintroduce this species into the system in greater numbers in the 1980's and into the early 1990's. The population has not rebounded and fisheries biologists have been unable to determine the reason(s). Fish sampling by the permittee did not collect adult American shad in 1999, 2000 or 2002.

In this specific case, the Agencies must strive for a balance between the thermal limits necessary to protect American shad and the realization that these limits may force the permittee to modify their operation for the protection of a species that is unlikely to rebound without concerted restocking efforts and other restoration activities in the Charles River. Section 5.7.4 discusses the thermal protection necessary to support American shad and the best way to reasonably apply these requirements to the NPDES Permit for Kendall Station, in light of the unique circumstances surrounding this species in the lower basin.

5.7.3 Most Sensitive Anadromous Species Selected By Life Stage

5.7.3a Introduction

Several fish species found in the lower Charles River Basin spend only part of their life cycle in the basin, or pass through the basin during spawning runs. The majority of these species are classified as anadromous, living their adult life in the offshore or coastal marine environment, and returning to freshwater only to spawn in the same river systems where they hatched and developed. The freshwater habitat they instinctively seek is essential, as it provides the environment necessary for propagation of the species. Anadromous fish that are unable to enter a river to complete a spawning run may not reproduce that year. Man-made barriers in a river that block anadromous fish passage are thought to be a contributing factor to declines in anadromous species. Each river system used by anadromous fish for spawning plays a vital role in the reproduction and maintenance of coastal and offshore populations of anadromous species. In addition, the early life stages of these species reside and develop in this unique freshwater habitat, making river systems an important nursery for anadromous fish.

A comparative review of representative scientific literature identified the alewife (*Alosa pseudoharengus*) as being the anadromous species present in the lower Charles River Basin that is most sensitive to elevated temperatures at every stage of its development (see Reference Section 5.12). Alewife spend part of their life cycle in coastal waters, with a range from Labrador to South Carolina. Alewife reach spawning maturity at age three or four. In spring, the species undertakes an upriver spawning migration into freshwater rivers, such as the Charles River. They generally return to natal aquatic systems (water bodies where they originally hatched and grew from their early life stages) to spawn. It is important to note that alewife and blueback herring will also occupy new river systems or increase in abundance in historically established river systems when improvements in physical or hydrological conditions permit or enhance entry into these rivers (Loesch, 1987). Once spawning is complete, adults return to the coastal areas with the potential to spawn again in later years. Young of the year alewife generally remain in the freshwater rivers for several months before moving to saltwater in autumn (NOAA, 1998). Once an important commercial species, observed declines in commercial landings of alewife and degradation of historic spawning habitat have made it necessary to formulate a management plan for the restoration of this species. This plan is administered by the Atlantic States Marine Fisheries Commission (NOAA 1998).

5.7.3b Documented Presence Of Alewife In The Lower Charles River Basin

The Massachusetts Department of Marine Fisheries (MADMF) has reported the presence of adult alewife in the Charles River, with individual fish swimming up to 9.8 miles upstream in the Charles River, to the Watertown Dam as part of their spawning run (Schwartz, MA FWE, correspondence, October 2003; Figure 5.7.3b-1 and 5.7.3b-2). Alewife have also been observed above the Watertown Dam when fish passage was possible at the fishway, and are expected to travel as far upstream as the base of the Circular Dam at Newton Lower Falls (approximately River Mile 20; Schwartz, MA FWE, correspondence, October 2003). Biological data, including facility impingement data, collected by the permittee in 1999, 2000, 2002 and 2003 to support the NPDES permit application for Kendall Station, confirm the presence of the adult stage of alewife in the lower basin (Mirant Kendall NPDES Permit Application, Appendix 5-1, 2001).

Alewife eggs and larvae were not specifically confirmed to be present in ichthyoplankton samples collected in the basin in 1999, 2000, 2002 and 2003. The alewife egg stage and larval stage are difficult to distinguish from the corresponding life stages of the blueback herring (*Alosa aestivalis*), another species in the Clupeid family documented to be in the lower Charles River Basin. Presumably because of this taxonomic difficulty, clupeid egg specimen collected by the permittee in 1999, 2000, 2002 and 2003 in the Charles River were only identified to the genus level, which included both alewife eggs and blueback herring eggs together as “river herring", or *Alosa* spp. eggs. River herring eggs and larvae were documented from site-specific sampling in the lower Charles River Basin (Mirant Kendall NPDES Permit Application, Appendix 5, 2001). Because adult alewife have been documented in the lower basin during spawning season, some percentage of the river herring eggs and larvae collected were most likely alewife.

Although adult alewife have been collected in the lower basin, the population size of this anadromous species has not been determined with confidence. In a preliminary survey of in-migrating adult river herring (alewife and blueback herring together) in 2002, Mirant Kendall estimated the total river herring population that year to be 45,622 fish (Mirant Kendall Letter, July 28, 2003). Based on sub-sampling of the species as they migrated into the river, the number of alewife alone was estimated to be approximately 8,000 individuals. While this estimate was greater than river herring estimates in the Connecticut and Merrimack Rivers in earlier years (1998 to 2001) the total river herring estimate for 2002 was well below the approximately 203,000 adult river herring number used by the permittee as part of an equivalent adult entrainment loss estimate at Kendall Station for 1999 and 2000 (see Table 8.1.2-3 in this document; Mirant, February, 2001). It is understood that the 2002 estimate was based on a hydroacoustic pilot study sampling protocol that is undergoing revision and refinement. It was noted that anadromous fish potentially entering the river from two smaller boat locks at the dam were not included in the estimate   Also, information from anadromous fish in-migration counting programs from near-by rivers reflect a wide degree of variability in the number of returning adult fish from year to year. Further sampling of in-migrating river herring is necessary to determine a more reliable population estimate.

The permittee also submitted information indicating that measures of anadromous fish populations, such as juvenile abundance and growth, are also appropriate metrics to be explored, rather than focusing solely on the numbers of returning adults. Crecco and Savoy (1984) contend that the number of returning adults is not a good predictor of year class strength, as small numbers of returning adults produce either weak or strong year classes depending on the environmental conditions that determine larval and juvenile survival and growth.

Adult alewife are sought by recreational and subsistence fishermen as bait fish. They are also an important forage fish in systems where they occur. The continued protection and propagation of a balanced population of alewife, as well as other anadromous species found in the Charles River, is one of the goals of the NPDES permit. Protection and propagation of this species are also in keeping with the long-term designated uses of this Class B water.

5.7.3c Protective Temperature For The Most Sensitive Adult Spawning Stage (In-Migration)

Water temperature is one of the primary factors that determine the timing and duration of spawning activity of anadromous species. It is not the only factor, however (Collins, 1952). Since a variety of environmental variables (photoperiodism, salinity, currents, river discharge, severe weather) may also affect spawning, many years of spawning data at a specific river system would be needed to properly characterize the spawning habits of a site-specific spawning school. Also, since new year classes of anadromous fish may not reach spawning maturity for three to five years, a multi-year study is required to characterize the variability among different year classes that return to the same river to spawn over several years.

There have been no long term, site-specific investigations performed to pinpoint the temperature range associated with anadromous species spawning runs in the lower Charles River Basin. Further, there is limited information available from the lower basin which would reveal the water temperatures that may disrupt or halt anadromous fish spawning runs. Based on a general review of the scientific literature dealing with the anadromous species that are known to spawn in the lower basin (see Reference Section 5.12 , for a list of papers consulted), the alewife (*Alosa pseudoharengus*) was determined to be the species most sensitive to elevated temperatures during their spawning run (see Reference Section 5.12).

Unpublished lower Charles River Basin data from the MA DMF provided documentation that alewife migrated past Kendall Station and reached the Watertown fishway on their upstream migration (Brady, unpublished fish collection data, 2002). The Watertown fishway is located at River Mile 9.8. Since the river mile designation is the distance of the Watertown fishway from the mouth of the river, this structure is 9.8 miles upstream from the New Charles River Dam and Locks. In a 1984 study, MADMF identified alewife and blueback herring separately at the Watertown fishway. Alewife were first observed at the Watertown fishway on May 9, 1984. No other anadromous species were present at that time. Sampling on May 23 that year documented both alewife and blueback herring, each comprising 50% of the sample. Alewife were documented in-migrating through June 21, 1984 at the Watertown fishway. In subsequent years of observation at the fishway, alewife and blueback herring were not separately identified, but identified together as river herring. Since alewife spawning typically precedes blueback herring runs in river systems where both species occur (Pardue, USFWS, 1983), it can be argued that the first river herring that arrived at the Watertown fishway in other years of the study were also predominately or exclusively alewife. The first observed appearance of river herring by DMF at the Watertown fishway was May 9 in 1984 (discussed above, these were positively identified as alewife); followed by observations on May 13, 1985; May 14, 1986; May 12, 1987; May 23, 1991; and May 12, 1992 (Brady, 2002).

While this information is helpful in identifying early to mid-May as the most probable time for spawning alewife to arrive at the upstream edge of the lower Charles River Basin, it does not provide information as to when the alewife entered the river from Boston Harbor. The time period when spawning anadromous entered the Charles River and the acceptable range of temperatures of the river water at the mouth that induced the fish to travel upstream are key to determining the impact of the thermal discharge from Kendall Station on spawning. In addition, it is difficult to predict how long it may have taken spawning alewife to travel the 9.8 mile distance to the Watertown fishway once they passed through the New Charles River Dam and Locks and entered the Charles River. This information is necessary to approximate the time period the fish had the potential to encounter the thermal discharge from Kendall Station. Many factors, including water temperature, river discharge, current strength, and weather may influence the travel time of spawning fish (Collins, 1952).

The permittee conducted a blueback herring tracking study in the lower Charles River Basin between May and early July of 2001 to provide information on the behavior of spawning anadromous fish in the lower basin (MRI 2002, Attachment 13). Extensive tracking information was compiled for sixteen blueback herring. Most fish that were tracked swam past the thermal plume from Kendall Station without displaying obvious behavior that would indicate their movement was disrupted. However, a small number of fish were observed meandering in the basin, between the Museum of Science and the Harvard Bridge, for two weeks to a month. There was little evidence of these fish quickly moving upstream past the study area on their way to the Watertown fishway. It is possible these fish remained in the basin to spawn in the vicinity of Kendall Station. This is consistent with the collection of appreciable numbers of river herring eggs in the vicinity of Kendall Station the lower Charles River Basin (Mirant Kendall NPDES Permit Application, 2001, Volume II, Appendix 5-7).

Adult fish gillnet sampling in the lower Charles River Basin by the permittee provided some site-specific information on the time span of alewife spawning and the water temperatures associated with their documented presence in the lower basin. Gillnet sampling in 1999 did not begin until July, well after the probable start of an anadromous species spawning run. In the year 2000, gillnet sampling was conducted on one day in January, and resumed on an approximately weekly schedule from March 6 through October 20, 2000. Alewife were observed first in 2000 on April 10 - 11, 2000, when basin temperatures were approximately 11.7 - 13.3 ºC (53 - 56 ºF). Alewife were present on several sampling dates throughout May, 2000 (May 2 - 3, basin temperature approximately 11.7 ºC (53 ºF); May 10 - 11, basin temperature approximately 18.9 ºC (66 ºF); May 15 - 16, basin temperature approximately 18.3 ºC (65 ºF); May 22 - 23, basin temperature approximately 17.2 ºC (63 ºF)). Alewife were only netted on one other date in 2000, when one fish was collected during a July 31 - August 1 gillnet set, with the basin temperature approximately 22.8 ºC (73 ºF). The late summer date and small size of this fish (95 mm) make it unlikely it was part of the spawning run (Mirant Kendall NPDES Permit Application, 2001; Appendix 5-1). Continuous ambient water temperatures recorded at the cooling water intake of the Kendall Station were used in this case to gauge the lower Charles River Basin temperatures. Until pronounced thermal stratification is seen in the basin in the summer, these temperatures, which reflect a mix of approximately the upper eleven feet of the water column, are likely a reasonable representation of basin conditions (Mirant Kendall Station Operations Data, Unpublished, 2001). It must be noted that under certain hydrological and meteorological conditions in the summer months, intake water temperatures can be approximately 3 ºC (5.4ºF) or higher than actual ambient temperatures in the lower Charles River Basin not affected by Kendall Station's discharge. This is due to re-entrainment of the Kendall Station thermal discharge plume by the intake of the station.

In 1999 and 2000, an average basin temperature was used to estimate the temperatures associated with alewife in-migration. Gillnet sampling in 2003 was supported by vertical profile data at the site of the gillnet deployment on the day of sampling. The depth that the fish inhabited when captured was also documented. This provided for a much more accurate characterization of alewife in-migration temperatures in 2003. Gillnet sampling in 2003 began in early April. Alewife were first collected on April 17, 2003, below the Broad Canal, associated with water temperatures of approximately 10.6 ºC (51.0 ºF). Alewife collection peaked on April 28, 2003 (21 alewife) and May 13, 2003 (21 alewife), also at the gillnet station below the Broad Canal, with associated water temperatures of 13.1 - 13.6 º C (55.6 - 56.5 ºF) on April 28 and 16.1 ºC (61.0 ºF) on May 13, 2003. The last in-migrating alewife were collected on June 3, 2003, with an associated temperature of 17.3 ºC (63.2 ºF). Alewife were not collected again in gillnets until July 29, 2003, at a temperature of 26.8ºC (80.3ºF). These alewife were thought to be out-migrating fish (Mirant Kendall 2003 Data, Appendix B-2 and I, November 13, 2003).

Data from Kendall Station impingement sampling was another way to add information about the site-specific time span of alewife spawning and the water temperatures associated with their documented presence in the basin. It is judged that in this case, using impingement data to generally document the temporal presence of impinged fish is acceptable, but impingement data is not a reliable source of information to formulate fish population estimates. That is because heated effluents result in temperature changes that may cause temporary declines in the critical swimming speed of a fish (i.e., the ability of a fish to swim faster than the intake velocity). Fish passing through the local plume (e.g., during migration upstream) are more likely to not be acclimated to the higher temperature and they will likely have lower swimming speeds than “local fish” (EPRI, 2000). This impact likely affects different species and different size classes within a population to varying degrees. Therefore, impingement sampling is thought to preferentially sample certain individuals.

Impingement sampling was conducted from April through December of 1999. No alewife were impinged on the intake screens in April. Thirty-six (36) alewife were impinged in May, when vertical profile data taken near the station recorded temperatures ranging from approximately 17 ºC (62.6 ºF) in early May to 23 ºC (73.4 ºF) by the end of the month. June 1999 impingement data recorded a high for the year, with 72 alewife being impinged, when temperatures at the cooling water intake monitor ranged from 22.2 ºC (72º F) to 27.2 ºC (81 ºF). This elevated number of alewife could represent alewife that had already spawned and were attempting to out-migrate. The reproductive condition of the impinged alewife was not provided. They may have become impinged while in a post-spawning, physiologically weakened condition. Only four alewife were impinged in July, when basin temperatures ranged from approximately 24 ºC (75 ºF) to 28 ºC (83 ºF). It must be noted that cooling water intake temperatures become less representative of overall basin conditions under stratified summer conditions. (Mirant Kendall NPDES Permit Application, 2001; Mirant Kendall Station Operations Data 2002, Unpublished).

In the year 2000, impingement data was collected from January through November at Kendall Station. No alewife were reported impinged on the intake screens until May, when 66 individuals were impinged. Cooling water intake temperatures ranged from approximately 10.6

ºC (51 ºF) to 20.6 ºC (69 ºF) in May of 2000. Only one alewife was recorded in June, when temperatures ranged from approximately 16.7 ºC (62 ºF) to 26.1 ºC (79 ºF).

Based on the discussion above of the limited, site-specific data set, alewife were seen at the most upstream reach of the lower Charles River Basin from early to mid-May, according to Watertown fishway records. Alewife were seen from April through May at temperatures between approximately 10.6 ºC (51 ºF) and 19 ºC (66 ºF), based on gillnet sampling. As a means of general comparison, observed water temperature in Boston Harbor was 5.8 ºC (42.5 ºF) on March 31, 2000, and an average of 11.1 ºC (52 ºF) for the month of May (Mirant Permit Application, 2001; Table 4-9). Graham (1956) reported that adult alewife acclimated to a temperature of 10 ºC (50 ºF) approached their upper incipient lethal temperature (temperatures at which 50% of the organisms die on continued exposure) at just above 20 ºC (68 ºF). This may indicate that at least during the beginning of the spawning run (April), exposing alewife to temperatures as high as 20 ºC (68 ºF) at the mouth of the lower Charles River Basin may markedly increase adult mortality.

Impingement data recorded alewife in the basin from May through July at temperatures between approximately 17 ºC (63 ºF) and 28 ºC (83 ºF). This time span and temperature range for site-specific data from the lower basin was used only as a general guideline, since it was a data set that covered one to two years in the basin, or provided information from a site at the upstream reach of the basin. Also, the way the 1999 and 2000 data were collected provided no information as to whether the alewife collected were in a "ripe" reproductive condition (at the beginning of their migratory run), or "spent", at the end of their run. Additional site-specific data, some of which was collected in 2002 and 2003 but has not been fully analyzed by EPA and DEP, will help to better characterize the timing, magnitude and river temperatures associated with alewife spawning in the lower Charles River Basin.

Data from rivers north and south of the Charles River, with well documented alewife and river herring spawning monitoring programs in Rhode Island, Massachusetts and New Hampshire, were evaluated to provide further insight on the probable water temperatures and timing corresponding to in-migrating alewife in the near-by Charles River (Table 5.7.3c-1). Work done by Cooper (1961) on a waterbody in southern Rhode Island saw alewife first entering fresh water to spawn at 6.7 ºC (44 ºF) and 9.4 ºC (49 ºF) during two years of observation. The last migrants entered the fresh water when temperatures were 21.1 ºC (70 ºF) and 20.5 ºC (69 ºF) during the same two years, respectively. These temperatures represented maximum daily temperatures measured just above the region of tidal mixing. An increase in observed mortality of alewife in the last few days of the run, when temperatures approached or exceeded 20 ºC (68 ºF), may have been an indicator that temperatures above 20 ºC (68 ºF) were near the upper incipient lethal temperature for these fish (Cooper, 1961).

Data from the Monument River, Bournedale, Massachusetts, showed that from 1990 to 1998, alewife spawning runs ended while river temperatures were between a low of approximately 14 ºC (57 ºF), in 1997, and a high of 21 ºC (70 ºF), in 1996 and 1998. The average highest river temperature that occurred during an alewife spawning run in the Monument River was approximately 18.5 ºC (65 ºF). From 1990 through 1998, the latest date that the run ended was June 4, in 1990 and 1995. The majority of alewife spawning runs over this time period ended by May 28.

Data for 1997 through 2001, from the Parker River in Massachusetts, showed that 99% of the alewife completed their upstream migration when temperatures had reached 18.5 ºC (65 ºF). The range of the end date of the alewife runs for the Parker River was from May 9 to May 19.

Data from the Merrimack River in Massachusetts from 1988 through 2000 showed that 95% of the river herring spawning run was completed with corresponding river temperatures of between 16.7 ºC (62 ºF) and 23.3 ºC (74 ºF). The 23.3 ºC (74 ºF) temperature, seen in 1991, was noticeable higher than the temperatures seen in the other 12 years that were reported. The next highest temperature that corresponded with the completion of 95% of the spawning run in the Merrimack River was a temperature of 18.9 ºC (66 ºF), observed in 1989, 1990 and 1992. The average highest temperature from 1988 through 2000 where 95% of the river herring run was completed was calculated as 18.1 ºC (64.6 ºF).

The Lamprey River in New Hampshire recorded 95% of the alewife run completed at a maximum temperature of 20 ºC (68 ºF) and 19 ºC (66 ºF), in 1999 and 2000, respectively. The alewife run was 99% completed on May 28 in 1999 and May 31 in 2000 (DEP 2002, Unpublished Data Summary).

It is EPA's objective to choose protective temperature limits that will ensure a majority of the anadromous fish are not prevented from entering the lower Charles River Basin to spawn because temperatures above their spawning range are present. Temperature data coinciding with alewife and river herring spawning runs in near-by rivers indicate that the majority of alewife and river herring spawn at temperatures up to 18.3 ºC (65 ºF). While alewife and river herring have been documented to spawn at higher river temperatures, these levels are at the extreme of what the spawning population experiences for any given year examined. It is not advisable to use periodic extreme natural temperature occurrences as the basis to formulate year in and year out temperature limits for a spawning population.

Another method to determine protective in-migration temperatures for spawning alewife is discussed below. Figure 5.7.3.c-1 was prepared to predict avoidance temperatures of adult alewives in the lower Charles River Basin. It was based on a model (Figure 5.7.3.c-2 recommended by a U.S. Fish and Wildlife Publication (Armor, 1991) in evaluating temperature regimes for potential impacts. Avoidance temperatures in Figure 5.7.3.c-1 are based on acclimation temperatures. Acclimation temperatures of alewives waiting to enter the Lower Charles are based on Springtime Boston Harbor temperatures plus 5°F. Site-specific maximum temperature limits for the Lower Charles were taken from this figure.

The input variables used in Figure 5.7.3c-1 greatly effect the determination of the avoidance temperature. The use of higher values yield higher avoidance temperatures. Reasons for choosing each of the input variables for this figure are discussed in later sections of this report.

Description of the U.S. Fish and Wildlife Model: To aid in the development of site-specific temperature limits for the Lower Charles, a generalized model of temperature effects to fish was employed. This model has been adopted by the U.S. Fish and Wildlife Service (Armor, 1991) and has been used by Massachusetts regulators and permittees (e.g., EPA, MA DEP and Brayton Point Station) in evaluating the potential effects of thermal discharges on fish. It is important to understand the basic aspects of this model so that limits in the lower Charles River Basin can be developed that are not detrimental to the existence of balanced indigenous fish populations. Data specific to adult alewife thermal tolerance will be inserted into this model, and the species-specific model will be used to assist in the development of temperature limits for the Lower Charles.

General aspects of the model: The model describes an inner envelope of temperatures that are best for growth and maintenance of the species and life stage of fish under review. As one moves outside of the inner envelope, detrimental effects are encountered. The upper lines (10% mortality; upper incipient lethal temperature where 50% mortality is seen; and the temperature of instantaneous death) describe effects of heat-shock. Each is linked to the acclimation temperature of the exposed fish. In addition, each has a positive slope that changes with acclimation temperature until it reaches an asymptote. Based on the model in Figure 5.7.3.c-2, it is evident that at low acclimation temperatures, the temperature causing a specific effect to the population is lower than under conditions when the acclimation temperature is higher. As most of the data that were used in developing these models were taken from laboratory studies, the acclimation temperature is the temperature at which fish were held (sometimes for several weeks) prior to subjecting them to a higher (or lower) temperature in the toxicity test. In field situations, the acclimation temperature is that temperature, or range of temperatures, to which fish are accustomed prior to exposure to a thermal barrier or plume.

The lower lines in the figure (10% mortality, Lower Incipient Lethal Temperature – the line of 50% mortality to exposed populations) describe effects of cold shock on fish.

Each point in the model is developed from a distribution of test results. Thus, only particular point estimates from results of a toxicity test where effects are seen over a range of temperatures are selected for use in developing the model. This concept will be important to remember in determining final temperatures for the springtime run.

Assumptions and Justifications in Applying the U.S. Fish and Wildlife Model to the Lower Charles: Figure 5.7.3c-1 is a modification of Figure 5.7.3c-2 developed to characterize maximum allowable temperatures of Charles River water in the Lower Basin that will not halt progress of the springtime alewife run. Assumptions made in using specific input data are numbered below. Justifications for each assumption follow.

1) Temperature tolerance responses for alewife adults entering the Lower Charles will be in general alignment with the U.S. Fish and Wildlife model in Figure 5.7.3c-2.

Justification: Until data are collected which prove otherwise for alewives, the U.S. Fish and Wildlife model (Armor, 1991) will be a useful tool, as it has been developed using data from a wide variety of fish species. For many fish that live in temperature zones, a different set of these lines exists for each life stage of the organism in question (i.e., egg, larva, juvenile, spawning adult).

2) It is assumed that alewives entering the lower Charles will respond to changes in temperature (i.e., delta temperatures) in a fashion similar to that of alewives studied by Graham (1956) in Lake Ontario. The ultimate temperature withstood by adult alewives in Graham's and two other studies rose with acclimation temperature until reaching an asymptote. Graham's test conditions more closely parallel conditions in the Charles than those of other studies.

Justification: In several of the Great Lakes, large scale (millions of fish) adult alewife kills occur each spring and are believed to be due to warm shoal waters washing over areas where alewife adults congregate. Death is thought to occur from exposures to large temperature changes that occur over a very short period of time. Alewives appear to be very sensitive to changes in temperature. Two peer-reviewed journal articles exist that evaluated delta temperature effects to alewives in the Great Lakes. Graham (1956) conducted evaluations of delta temperatures that caused mortality to adult alewives in Lake Ontario. Otto, *et al*., (1976) evaluated fish from Lake Michigan. Data from each of these studies are presented below:

Table 5.7.3c-2 Heat Shock and ΔT Data
All Temperature Data in Fahrenheit

Acclimation Temperature	TL50 Otto, *et al*., 1976*	TL50 Graham, 1956	ΔT Incurred Otto/Graham
50	74.3	68 @ 108 hrs exposure*	24.3 / 18
59	74.3	73.4 @ 90 hrs exposure	15.3 / 14.4
68	76.1	73.4 @ 80 hrs exposure	8.1 / 5.4

*Exposure-duration data were not available for TL_{50s} from Otto *et al*.'s work.

Graham transferred fish from acclimation temperatures directly into exposure temperatures. Otto, *et al*., took fish from the discharge canal of a power plant and slowly raised the temperature of test fish at a rate of 0.3 C per minute (about 0.5 F per minute). Both researchers found that lower acclimation temperatures resulted in lower TL50s (the upper test temperatures resulting in death to 50% of the test organisms). Conditions evaluated by Graham are considered to more closely approximate the abrupt transfer of fish from cool, Boston Harbor temperatures, to warmer Charles River temperatures than are conditions evaluated by Otto, *et al.* Thus, acclimation temperatures and corresponding TL50 values from Graham's data are incorporated into Figure 5.7.3c-1.

It should be noted that both Graham's and Otto *et al.*'s tests were conducted on fish that are landlocked whereas fish that enter the Charles are sea-run. The only study available for sea-run fish, however, did not undergo peer-review and was conducted on alewives that enter the Delaware River at about the same latitude as the northern section of Washington, D.C. Because this population is much more southern, they may be less temperature-sensitive than New England populations or fish evaluated by Otto *et al*. or Graham, which were from the same approximate latitude as northern Massachusetts.

3) No-Acute-Effect Levels (NOAELs) for temperature will, in general, be about 2.0°C (3.6°F) lower than the temperature lethal to 50% of fish exposed in toxicity studies (i.e., the TL50). Thus, the NOAELs will have the same slope as the TL50 data set.

Justification: Coutant (Natl. Acad. Sci./Natl. Acad. Eng., 1972), who developed the temperature criteria for EPA, studied results of a wide variety of acute toxicity evaluations. He concluded that, in general, the highest temperature causing no acute effects to fish can be approximated by subtracting 2°C (3.6°F) from the TL50. Unless species-specific values are available, this value appears our best estimate. As No-Effect values are absent from Graham's (1956) work, the temperature of 64.4°F was used to approximate the No-Effect temperature of adult alewives acclimated to 50°F, and a temperature of 69.8°F to approximate the No-Effect temperature of fish acclimated to temperatures ranging from 59-68°F in Figure 5.7.3c-1.

4) Avoidance temperatures (i.e., temperatures in the Charles River that will cause fish to refuse entry into the Charles from Boston Harbor) will have a positive slope that is the same as that for TL50s and NOAELs, but a Y-intercept that is lower. Thus, it is assumed that the line for avoidance temperature will parallel those of other biological responses to temperature.

Justification: For the most part, avoidance temperatures are lower than those that induce toxicity (Stier and Crance 1985; Pardue, 1983; and others in this series). This is not always the case, however. In some situations (e.g., at the Mirant Kendall discharge), fish are attracted to thermal plumes of high velocity that have temperatures higher than those usually avoided. At the Kendall facility, river herring have been videotaped breeding in the discharge pipe. It is believed that spawning at temperatures in the discharge pipe, which are up to 11.1°C (20°F) above ambient river conditions, is detrimental to those individuals and their potential offspring. Adult and egg mortality or chronic effect in this location is considered likely. In these cases, the attraction to high velocity seems to have over-ridden the avoidance response. By contrast, where a simple thermal gradient is offered to fish temperatures avoided are lower than those that induce toxicity, and temperatures preferred are lower than those that induce avoidance (Stier and Crance, 1985; Pardue, 1983 and others in this series). The slope of the avoidance line is different for each species and life stage and we have no data other than that for the very highest values in the avoidance line in Figure 5.7.3c-1. It is assumed that the slope of this line is similar to the acute toxicity line in the absence of more complete data.

5) Data from studies which evaluate temperatures at entry to the run are the most valuable in developing avoidance temperatures for the Zone of Passage and Habitat. As the Zone of Passage and Habitat is so close to the entry point of alewives to the lower basin, it can be considered to be immediately adjacent; thus, each should be given at least the same limits. In order to afford the appropriate protection for fish passage into the Charles River from Boston Harbor, certain temperature limits at this sensitive location have been established lower than the upstream ZPH Monitoring Stations during periods of the critical spawning range. Also, judging from field data, the range of entry temperatures is lower than the range of breeding temperatures.

Justification: In order to develop site-specific temperatures for the Charles which will allow adult alewives to enter the locks in the New Charles River Dam, data relating to this model will be taken from studies which evaluate temperatures at entry to the freshwater system. The reason that this is mentioned is that in other sections of this discussion, in-migration data from points further upstream are evaluated.

The most-detailed study evaluating entry temperatures for springtime alewife runs in New England is that of Richkus (1974) which evaluated runs in 1971 and 1972 in a Rhode Island stream. Richkus noted that alewives spawn at temperatures much higher than those at which they first enter. Thus, the range of entry temperatures is different than the range of spawning temperatures.

One approach is to consider the highest temperatures measured while fish are running well-upstream of the point of entry to the system (e.g., data from the Merrimack fish lift, 26 miles upstream of the mouth of the river), as temperature limits for the point of entry to the system. This may not be a reasonable approach for the following reasons:

a) stream temperatures are consistently rising in the spring;

b) it typically takes several days to weeks for fish to arrive at spawning sites and several days beyond this until they begin spawning. During this time, the temperature on the spawning beds will have risen to levels higher than those at the mouth of the stream when these fish entered the system.

c) Spawning can be extremely stressful (often fatal) to alewives (or other alosids) because they do not feed while in freshwater *en route* to spawning. As a result, fish that enter streams when stream temperatures at point of entry are in the high end of the range for spawning run the risk of arriving at spawning beds when temperatures at these sites are too high to spawn. One expects that there is a genetic component to this: late arrivals will be prevented from producing young the year in question, and run a high risk of succumbing from rigors of the spawning run itself, preventing them from spawning the next season. Thus, fish that do not avoid high entry temperatures will be much less likely to pass on genetic material to the next generation than fish that avoid high entry temperatures.

Based on the above, the range of entry temperatures considered for the model will be lower than the range of breeding temperatures. Evidence of a time lag, hence a temperature difference, between entry and spawning is supported by the fact that out-migrations continue to occur long after in-migrations have ceased.

The draft permit stipulates that temperature monitors at the Charlestown Dam will be used to verify compliance with maximum allowable water temperatures for anadromous fish entering the Lower Charles (Part I.A; Section 14.b). The new Charlestown dam and locks are only about 660 meters (approx. 0.4 miles) from the Old Locks adjacent to the Museum of Science. If temperatures at the Charlestown Dam exceed those given as limits in the Zone of Passage and Habitat they will be considered in violation of the permit. These requirements will be put in place to allow fish to enter the Lower Basin in the spring but not be repulsed from further entry through the Old Locks adjacent to the Museum of Science.

6) The Richkus (1974) study characterized stream temperatures and run strength. He found that the number of alewives moving into the springtime run (both years of the study) in a stream in Rhode Island decreased sharply when temperatures exceeded 64.4°F. Richkus' 64.4°F temperature was used in this model as an estimate of the avoidance temperature for most of the adult alewives at the end of the run into the Lower Charles. The hypothesis that this temperature is a good estimate of avoidance temperatures at the end of the run is evaluated against data from streams in Massachusetts and New Hampshire. Because Richkus' study stream was adjacent to an estuary, it is assumed that acclimation temperatures of fish in this estuary were the same or higher than those experienced at similar dates by fish in Boston Harbor about to enter the Lower Charles.

Justification: In the Richkus study, fish entered the runs at temperatures in the mid-40s (Fahrenheit) in April and continued to run on into early June. Water temperatures in the spawning stream constantly rose over this period. He found that at the end of both runs when water temperatures over the course of the day ranged from the low to the high 60s (Fahrenheit) run strength dropped sharply when temperatures rose above 18°C (64.4°F) . Towards the end of the two runs, peak run strength occurred in the morning when temperatures were below 18°C (64.4°F). This pattern differed from that seen in the earlier portion of both runs when river water temperatures were in the low 40s. At the beginning of the runs, alewife entry was highest in the afternoon when temperatures were highest. From this information he surmised that temperature acted as a “gating factor” either facilitating or hindering entry to the spawning stream.

While Richkus continuously monitored temperatures and could verify that run strength sharply dropped when temperatures over the course of the day rose above this value, other studies (e.g., Cooper, 1961) report run strength against the highest daily temperature. Thus, these researchers would not have caught the temperature at which run strength dropped, and temperatures in their reports may not be the most appropriate data used to set limits for entry temperatures.

Fish from a number of schools typically make up anadromous fish runs. Thus, it is reasonable to believe that some schools find their way to the mouth of spawning streams earlier than others. Schools that arrive early (i.e., in April) will be acclimated to the coolest marine temperatures. Schools that arrive late (i.e., late May) will be acclimated to the warmest marine temperatures. We assume here, for the sake of developing the model in Figure 5.7.3c-1, that the 64.4°F value from Richkus describes a "median" value for avoidance of late arrivals that have acclimated to marine temperatures seen in late May, although most fish in the late runs moved upstream at temperatures below 64.4°F.

Richkus did not provide temperature data for the estuary adjacent to the river entered by alewives in his study. However, we can probably assume that the water temperatures in the estuary at the end of the 1971 and 1972 runs were either the same or warmer than those in Boston Harbor at a similar point in the spring. If we assume that acclimation temperatures for the Lower Charles run are much cooler than those in the Richkus study, we would use an avoidance temperature lower than 18°C (64.4°F) at the end of the Charles River alewife run. As there may be some warming of the Boston Harbor temperatures due to the discharge from the dam (though these may be intermittent at times), the assumption that Boston Harbor temperatures may be somewhat higher than those cited in above is probably not unreasonable.

We can test the hypothesis that Richkus' value of 18°C (64.4°F) is applicable to other populations in Massachusetts and New Hampshire for which there is data. To do this, we must make some assumptions about the Massachusetts and New Hampshire data sets, because the Richkus data, and that from the MA and NH data sets, were collected differently. While Richkus monitored temperatures continuously, temperatures from the Monument River in Massachusetts (see below) are simply the temperature at the time the fish recorder was visited. Those from the Parker and Lamprey are also believed to be recorded at the time counts were made.

The very highest temperatures at which alewives have entered runs in MA and NH (for which there is data) are listed below. It is assumed that, for the most part, the temperatures for the Monument run relate to percentiles beyond the 95th. The proportion of the alewife population that passed at temperatures lower than those listed below for the Parker and Lamprey rivers are listed as percentiles. Two Grand Means were calculated. The first gave equal weight to each of the 19 runs and was generated by summing all Monument River temperatures listed along with the 99th percentile values from the Parker and the Lamprey rivers and calculating the mean. The second was generated by taking the mean for each system (based on the percentiles already named) and calculating the average of the means from each system.

Table 5.7.3c-3: Data from alewife runs in Massachusetts and New Hampshire . Note: Some of this information is also included in Table 5.7.3c-1

Monument River, Bournedale, Massachusetts

Year	Highest River Temperature Reached by end of Run °C	°F	Day of Year at end of Run	Calendar Dates
1990	17.8	64	155	June 4
1991	18.9	66	147	May 27
1992	18.3	65	152	June 1
1993	18.5	65	144	May 24
1994	18	64	144	May 24
1995	20	68	155	June 4
1996	21	70	147	May 27
1997	14	57	148	May 28
1998	21	70	146	May 26
2000	20.5	69	139	May 19
2001	20	68	137	May 17
2002	17.8	64	141	May 21

Parker River, Massachusetts 1997 – 2001
99% of Alewives Passed by 65°F; data from all years combined
Range of dates for end of run: May 9-May 19

Lamprey River, New Hampshire

Year	Max. Temperature when 95% of Run is Complete °C	°F	Max. Temperature when 99% of Run is Complete °C	°F	Date when 99% of Run is Complete
2000	19	66	19	66	May 31
1999	20	67	19.5	68	May 28

Grand Mean of 19 studies: 65.7°F
Grand Mean of 3 systems: 65.9°F

Two pieces of information from the analysis above are important for setting limits in the Charles:

a) The Grand Means of the very highest entry temperatures for all runs in Massachusetts and New Hampshire for which we have data are only 1.3 - 1.5°F higher than the 64.4°F value, taken as the avoidance temperature for the Richkus data; b) Richkus observed fish running at temperatures up to about 21.7°C (71°F), one degree Fahrenheit above the highest entry temperature in the 19 runs reviewed above. However, at 18°C (64.4°F) run strength sharply diminished. Thus we assume that 64.4°F is the avoidance temperature for a large proportion of the fish in Richkus' studies. Because we have no information such as Richkus gathered, indicating when run strength began to diminish for the 19 studies above, and because the temperatures in the table above are all below the highest temperatures observed in the Richkus runs (i.e., 71°F), this model accepts the Richkus value of 64.4°F as an important indicator in the distribution of avoidance temperatures for the end of the run. A small subset of the total population are likely to run at temperatures higher than the 64.4°F value, but it is assumed that a much larger proportion will refuse entry to the Lower Charles at temperatures above this value.

7) Alewives in Boston Harbor attempting to enter the Lower Charles in the spring will be acclimated to temperatures at or near those in the Harbor, rather than to temperatures in the Lower Charles. Because water releases from the Charles are intermittent during low-flow years, and due to tidal exchange, fish in the Harbor will experience great changes in water temperature, and water temperatures near the dam will more closely approximate those in the Harbor than those in the Lower Charles.

Justification: Because acclimation temperatures are important to all the response temperatures in Figures 5.7.3c-1 and 5.7.3c-2, it is important to establish the most likely acclimation temperature for fish entering the Lower Charles. During the spring, operation of the Charles Dam and locks is conducted to provide flood control, to maintain the height of the pool above the dam to allow boat passage and to allow fish passage. When flows are high, sluice water is pumped through the dam along the Cambridge side to keep the height of impoundment above the dam within a certain range for aesthetics and boating upstream. During these times, fish are attracted to the sluice water. However, when flows are low due to lack of rain, operators may completely halt the pumping of water through the dam for a portion of the day. To attract fish to the locks so that they may proceed upstream, operators open up the harbor-side locks, keeping the basin-side closed and pump river water into the locks. At the end of the pumping period, the harbor-side lock is closed, the lock is filled and the basin-side gates are opened.

Due to the procedures used, fish waiting to move upstream will experience large changes in temperature. During low-flow years, fish waiting for the locks to open will be primarily acclimated to Boston Harbor water temperatures. This situation is different than that in other systems that have an estuary. Where an estuary exists, fish can slowly acclimate to warmer water from the freshwater system.

Based on the worst-case situation, where low flows exist during the spring and water flow through the dam is halted, we will assume that alewives are acclimated to temperatures in Boston

Harbor (or temperatures slightly higher), prior to entry to the Boat Locks in the Lower Charles. Allowing a 2.8°C (5°F) rise due to mixing of Charles River and Boston Harbor will not make a difference to the analysis.

8) Avoidance temperatures will be indexed by the NOAEL line in Figure 5.7.3c-1. At the early part of the run avoidance temperatures will be lower than those for the latter part of the run. In April, acclimation temperatures are in the mid 40s to low 50s (Fahrenheit).

Justification: Temperatures below were taken from MWRA station 014 ,which is located about mid-channel in the section of Boston Inner Harbor that lies between the Charlestown docks to the north and the Coast Guard Station near Boston's North End Beach to the south. Data for years 2000 and 2001 were the only available data for springtime and are taken to approximate acclimation temperatures for alewives attempting to enter the Lower Charles in the spring. Both top and bottom temperatures are included to show that differences between the two in early spring are minimal.

Table 5.7.3c-4: MWRA temperature Data from Boston Harbor, Station 014
(Bottom location was at 8-12m below surface)
All temperatures as Degrees Fahrenheit

Date	Boston Harbor Bottom Temp.	Boston Harbor Surface Temp.
April 12, 2000	44	47.8
April 13, 2000	43.1	45.1
April 18, 2001	43.1	45.9
April 19, 2001	43.5	45.6
May 2, 2000	44.7	49.2
May 3, 2000	45.4	48.5
May 9, 2001	52.8	58.2
May 10, 2001	52.9	60.1
May 25, 2000	52.3	56.8
May 26, 2000	52.2	55.9
May 30, 2001	56.7	58.8
May 31, 2001	56.5	57.5

If it is assumed that there is an increase in Boston Harbor temperatures of 2.7°C (5°F) due to discharges (sometimes intermittent) from the New Charles River Dam and that temperatures at the Dam and upstream in the ZPH must kept below these limits to avoid violations, a limit of approximately 15.6°C (60°F) appears appropriate for the last half of April, based on the avoidance line in Figure 5.7.3.c-1. Thus, the application of the USFWS model, with the assumptions and inputs described above, derives a maximum late April temperature of 15.6°C

(60°F) to ensure adequate entry of migrating alewives into the Charles River.

To establish a late April temperature limit that will ensure the protection and propagation of an alewife population, other factors were considered. In this case, a temperature limit of 15.6°C (60°F) for the lower Charles River Basin derived from modeling appears overly conservative when this limit is compared with ambient Charles River temperatures. As discussed fully in Section 5.9.2, continuous temperature data recorded at the Kendall Station Cooling Water Intake has been determined to be a reasonable representation of ambient river conditions in the spring (Mirant Kendall Station Operations Data, Unpublished, 2003). Temperature information from this site represents the most complete long term record of ambient conditions in the lower Basin. When this continuous data, collected hourly, was examined from the April 15 through April 30 time period, in the years of 1994 through 2002, excluding 1999, there were several periods where ambient river temperatures exceed 15.6°C (60°F). Temperatures climbed as high as 19.4°C (67°F) in 2002, and exceeded 15.6°C (60°F) in 1994, 1996 and 2001 (Figures 5.7.3c-3 and 5.7.3c-4).

Also, Kendall Station thermal discharge likely raised basin temperatures downstream of the Facility by approximately 1.7 to 2.8°C (3 to 5°F) above the intake temperatures referenced above. Adding another 1.7°C (3°F) to the ambient temperatures in Figures 5.7.3c-4 would result in temperatures in excess of 15.6°C (60°F) in 1995 and 1998 as well. Assuming that in-migration has not been inhibited to threaten the protection of the BIP for alewife in the Charles from 1995 to 2002, these temperatures appear to be inconsistent with a late April maximum temperature of 15.6°C (60°F).

Special note must be taken of the way these temperatures were recorded at the Facility. Temperature measurements were taken after a column of water, from the surface to 12 ft, was brought into the Facility by large circulating water pumps, fully mixing the water column. Temperature vertical profile data collected in the Broad Canal reveals differences in temperature from the near surface down to 12 ft by the end of April. Any temperature differences would have been mixed into an “average temperature” for the water column by the time it reached the Facility monitoring point. Compliance monitoring, as required in the Draft NPDES permit (Part I.A Section 14 b), calls for in-situ monitoring points at several unique depths. Information from these depths will not be averaged to determine compliance with the established temperature limit (with the exception of winter “chill period” monitoring and the Delta T (ΔT) compliance program). Therefore, intake temperature data is likely lower than what would have been measured upstream of the facility at a discrete, near surface compliance depth (2ft, for example), during the end of April.

While fish collection data for the lower Charles River Basin is only available for 1999, 2000, 2002 and 2003, alewife have been collected as part of the in-migrating anadromous fish run each year. It is unknown if some segment of the in-migrating population was prevented from entering the river due to elevated river temperatures. An initial population estimate of adult alewife in the lower basin was calculated, based on hydroacoustic monitoring and gillnet sampling in 2002. The estimate of 8,000 alewife was seen as a first attempt at gauging the alewife population. Several refinements to the monitoring protocol will be made before another population estimate is attempted. This monitoring, in addition to water quality and biological monitoring, required as part of the NPDES draft permit (Part I.A, Section 14), will provide more information to evaluate protective temperatures for alewife in-migration and spawning.

It must also be recognized that as a spawning run proceeds, natural warming of the river takes place throughout the spring. If a single temperature limit was set at the beginning of the spawning season to reflect early spring conditions, the rapidly warming ambient river temperatures would soon surpass the temperature limit, making the relevance of the early spring limit questionable in later spring, when spawning runs are still taking place. Because of warming springtime river conditions throughout the spawning season, and taking into consideration the permittee’s contention that a small number of spawning migrations of river herrings have occurred in near-by rivers later in the season at relatively warmer temperatures, a stair-step approach to the temperature limits was applied for alewife spawning in the lower Charles River Basin.

In this star-step approach, the allowable maximum spring temperature increases by several iterations during the course of the in-migration period. This stair-step begins at 18.3 ºC (65 ºF) and proceeds through several steps to 22.2 ºC (72 ºF) by the end of the in-migration.

Taking all the information presented in this section into consideration,18.3 ºC (65 ºF) was selected as the maximum temperature limit necessary to protect adult alewife during the period of their spawning run in the lower Charles River Basin. Because there were a wide range of temperatures that coincided with area spawning runs, and it has been documented that waters of the lower Basin rapidly warm in the spring under natural conditions, the stair-step approach over time, described above, was selected to recognize that later in the spawning season, runs were seen to take place at higher temperatures. The selection of a progression of slightly higher temperature limits as the spawning period progresses was based in part on an analysis of historical lower basin ambient temperature data from 1994 through 2001 (Mirant Kendall Station Operations Data, Unpublished, 2001) . River temperature limits for spawning are thus “stair stepped” to 20 ºC (68 ºF), 21.1 ºC (70 ºF), and 22.2 ºC (72 ºF) as the spawning season progresses.

This judgment takes into consideration the in-situ continuous temperature monitoring and compliance program that will be required by the permit. Under this monitoring program, the highest temperature measured in the ZPH will likely be a temperature located near the bank-to-bank mid-point of the basin, in six feet of water (Mirant Kendall NPDES Permit Application, 2001). This will result in the majority of the habitat used by in-migrating adult alewife to likely be lower than the temperature limit at all times during the spawning season (Mirant Kendall 2003 Data, Appendix B-2: November 13, 2003). The continuous in-situ temperature monitoring program that is required to demonstrate compliance with the specified temperature limits is fully discussed in Part I.A, Section 14.b. of the draft permit.

Also, it is important to understand that natural ambient daily temperature fluctuations of at least 1.1ºC (2ºF) in the lower Charles River Basin are routinely expected within a 24 hour day (see Figures 5.10.5c-1 through 5.10.5c-5). This fluctuation is caused by changes in air temperature and solar input during a daily 24 hour weather cycle, and is observed in most bodies of water. This change in temperature over a 24 hour period will further ensure that the protective temperatures listed above are maintained as part of the in-migration habitat in the ZPH under the maximum temperature limit.

Additional site-specific studies would provide information on the river temperatures, timing, and duration associated with in-migrating alewife and other anadromous species in the lower Charles River Basin to assure that the maximum temperatures selected are protective of conditions necessary for a balanced indigenous population.

5.7.3d Time Period For The Most Sensitive Adult Spawning Stage

There is evidence in the literature that male alewife begin the spawning run before females (Chesapeake Bay Text; Cooper, 1961). This is an important characteristic to bear in mind as a protective time period for spawning is considered. If the time period does not cover the beginning of the spawning run, there is the potential for a larger impact on the male segment of the run. If the protective time period does not fully cover the latter stages of the run, there is the potential for a larger impact on the female portion of the run. Over time, repeatedly placing additional negative pressure on one sex or the other may seriously impact the ability of the population to successfully propagate.

It is possible that the duration and intensity of the anadromous spawning run to the Charles River could be changing. Concerted efforts are under way to improve water quality in Boston Harbor and the Charles River (State Of Boston Harbor, 2002, Massachusetts Water Resource Authority, 2003; Master Plan For The Charles River Basin, Metropolitan District Commission 1997). Measurable improvements have already been documented (Clean Charles 2005 Progress Report, EPA 2001; MWRA 2003). In addition, projects are under consideration to improve anadromous fish passage at both the New Charles River Dam and the Watertown fishway. It is reasonable to expect that continued improvement in water quality and anadromous fish passage will improve the spawning success of alewife in future years. As alewife spawning stock size increases in the direction of historic levels, the number of spawning fish entering the lower Charles River Basin will increase, but the duration of the run may also increase (NOAA, 1998). This must be taken into account when addressing the protective time period for alewife spawning.

Limited site-specific data for the lower Charles River Basin certainly place alewife in the basin in early and mid-May. One alewife, arguably of spawning size (277 millimeters) was caught in a gillnet placed in the Broad Canal on April 10-11, 2000 (Mirant Permit Application 2001). It would be difficult to characterize expected alewife spawning time periods based on this observation alone. There is no long term sufficient site-specific data from the lower basin to determine the probable expected beginning and end of the alewife in-migration into the basin. To complicate matters further, Coutant (Natl. Acad. Sci./Natl. Acad. Eng.,1972) stated that spawning dates may commonly shift by as much as one month in rivers throughout the United States. Taking this variability and uncertainty into consideration, EPA used field observations, data from rivers, and a review of the scientific literature to established a beginning and end date for alewife spawning migration into the lower Charles River Basin.

A review of the scientific literature notes that alewife move up freshwater streams from the sea to spawn in a chronological south-to-north progression from March through July. Spawning occurs later as one proceeds north (Pardue, 1983).

In Chesapeake Bay, the onset of alewife spawning migration is typically from early to mid-March through April (Habitat Requirements for Chesapeake Bay Living Resources, Funderburk *et al*., 1991). Cooper (1961) observed alewife entering a southern Rhode Island stream beginning on March 20 in 1959, and March 30, in 1960. Since the Charles River is north of these freshwater systems, it is likely that the beginning of the alewife spawning season would be sometime later than the end of March. Cooper also observed that adults spent from several days to two weeks on the spawning grounds. If alewife were documented approximately 10 miles upstream of the mouth of the Charles River as early as May 9 (in 1984; Brady, 2002) and the observation used by Cooper is applied to the Charles River, it is projected that it would take up to two weeks to travel to the Watertown Fishway and spawn. Under this time line, alewife could have first entered the New Charles River Dam and Locks at the beginning of the last week of April.

The earliest river herring eggs collected by the permittee in the lower Charles River Basin were identified from samples taken in the first week of May in 2002. Since alewife begin spawning before blueback herring, it is reasonable to assume the first river herring eggs observed in the 2002 spawning season were likely alewife eggs. If two weeks is subtracted from this date to account for alewife activities in the lower basin leading up to the egg dissemination, it is possible that the alewife spawning run into the Charles River began as early as mid-April.

Using the last seasonal evidence of river herring eggs as a way to estimate the seasonal end of adult alewife spawning is problematic. This is because of the overlap of blueback herring spawning with alewife spawning. The last river herring eggs observed during the spawning season are likely blueback herring eggs. Since alewife eggs can not be distinguished from blueback herring eggs, the indirect estimate of an “end of spawning” date for alewife is difficult. However, lacking a more precise way to estimate an end date for alewife spawning, the last date of river herring egg presence in the lower basin was examined over the three years of sampling to gauge an approximate end to alewife spawning. In 1999, the last river herring eggs were collected on the week of June 28. Similarly, in 2000, the last river herring eggs were collected on the week of June 26. River herring eggs were seen in 2002 collections until the week of July 23, although there was an absence of river herring eggs on the week of July 10. River herring eggs seen as late as the middle of July are likely blueback herring eggs. It is possible that the late June river herring eggs may be made up of both alewife and blueback herring eggs. Using the conservative approach, it is assumed some alewife eggs were present as late as the last week of June. Subtracting two weeks from this time period places the end of alewife spawning in early June.

To cover variability in spawning activities, especially taking into account the shift of up to one month that may be seen for spawning dates from year to year (Natl. Acad. Sci./Natl. Acad. Eng., 1972), mid-April was chosen as the beginning of the alewife spawning season. This date will ensure that protective in-migration temperature limits are in place during the years where spawning runs attempt to start early in the season. Alewife spawning is thought to be completed by the end of the first week of June.

From April 15 through April 30, a maximum temperature of 18.3 ºC (65 ºF) will be in effect for the protection of alewife in-migration throughout the ZPH. From May 1 through May 22, a maximum temperature of 20 ºC (68 ºF) will be in effect for most areas of the ZPH, with the exception of habitat near the initial in-migration point in the river, just upstream of the New Charles River Dam and Locks. Temperatures at this location (Monitoring Station 8) make up the attractant flow that plays a crucial role influencing the response of alewife to enter the lock and proceed into the river. Because of the large potential effect water in this location has on in-migration, water temperature here must not exceed 18.3 ºC (65 ºF) until after May 14. From May 15 to May 22, the maximum temperature of 20 ºC (68 ºF) will apply to all areas in the ZPH, including Station 8. From May 23 to May 31, a maximum temperature of 21.1 ºC (70 ºF) will be in effect for the protection of alewife in-migration throughout the ZPH. From June 1 through June 7, a maximum temperature of 22.2 ºC (72 ºF) will be in effect for most areas of the ZPH, with the exception of habitat near the initial in-migration point in the river, just upstream of the New Charles River Dam and Locks. As noted above, temperatures at this location (Monitoring Station 8) make up the attractant flow that plays a crucial role influencing the response of alewife to enter the lock and proceed into the river. Because of the large potential effect water in this location has on in-migration, water temperature here must not exceed 21.1 ºC (70 ºF) until after June 7. The selection of a progression of slightly higher temperature limits as the spawning period progresses was based in part on an analysis of historical lower basin ambient temperature data from 1994 through 2001 (Mirant Kendall Station Operations Data, Unpublished, 2001).

5.7.3e Protective Temperature For The Most Sensitive Egg Stage

There have been no site-specific experiments performed to determine the temperature sensitivity of anadromous species' eggs adapted to the range of ambient temperature conditions in the lower Charles River Basin. Based on a general review of the scientific literature dealing with the anadromous species that occur in the lower basin (see Reference Section 5.12 for a list of papers consulted) the alewife egg was determined to be the egg stage most sensitive to temperature during spring and early summer.

The permittee submitted ichthyoplankton collection data from the lower Charles River Basin indicating the likely presence of alewife eggs. Based on the discussion in the previous section, some percentage of the eggs identified from the samples identified as “river herring eggs” were assumed to be alewife eggs. The data were examined to get an initial idea of the ambient river temperature range that coincided with the presence of river herring egg. Due to the observed nature of alewife spawning in advance of blueback herring, river herring eggs collected earlier in the spawning season most likely had a higher percentage of alewife eggs than river herring eggs collected later in the season (NOAA, 1998; Pardue, 1983).

Lower Charles River Basin ichthyoplankton samples were collected weekly in 1999 from mid-May through August,1999, weekly in 2000 from mid-March through early September, 2000, weekly in 2002 from early April through mid-August, 2002, and in 20003 on May 20, weekly from June 11 through June 24, and on July 10, 2003 . In order to approximate representative temperatures in the basin when river herring eggs were present, representative temperatures were matched with dates where river herring eggs were collected in 1999, 2000 and 2002. These water temperatures were taken from cooling water intake temperatures from Kendall Station on the respective sampling dates (Mirant Kendall NPDES Permit Application, 2001; Unpublished Kendall Station Operations Data 2002). The upper eleven feet of the water column enters the intake structure and is mixed. Intake water temperatures were measured once this column of water had mixed. This hourly temperature data was thought to represent a general indication of water temperatures in the basin during the spring. River temperatures on May 12, 1999 were taken from vertical profile data.

In 1999, river herring eggs were found at an approximate basin ambient temperature range from 17 ºC (63 ºF; May 12) to as high as 26.7 ºC (80 ºF; June 28), and in 2000 from 17.2 ºC (63 ºF; May 22) to as high as 25.6 ºC (78 ºF; June 27). River herring eggs in 2002 were collected under a range of ambient river temperatures from a low of 12.8ºC (55 ºF; May 1) to a high of 27.5 ºC (81.5 ºF; July 2). River herring eggs in 2003 were collected under a range of ambient temperatures from a low of 17.5 ºC (63.5º F; May 20) to a high of 26.6 ºC (79.9 ºF; July 10).

The temperature data range provided above is informative as a guide, but three things must be taken into consideration when reviewing this data.

First, the temperatures represented above were not taken from the location of the ichthyoplankton station, but from a station reflecting ambient river conditions during the same time as the sampling.

Second, the viability of the eggs collected in the field was not evaluated as part of the field sampling program. It was not determined what, if any acute or chronic effects might be exhibited by the eggs as a result of developing at warmer temperatures.

Third, as noted earlier in this section, the river herring eggs collected are most likely made up of both alewife eggs and blueback herring eggs. These species, since they spawn in different habitats and at different times, are thought to have different temperature thresholds. Alewife are generally observed spawning in sluggish, more shallow water flows in large rivers, small streams and ponds, approximately three to four weeks before blueback herring spawning begins. Blueback herring spawn in swift flowing, deeper stretches of river and in slower flowing tributaries adjacent to main streams (Pardue, 1983). Scientific literature is not well developed concerning blueback herring temperature tolerance information, but it is assumed their appearance later in the season is an indication they may be able to tolerate higher temperatures than alewife. Because of this, the upper range of temperatures where river herring eggs were collected in the lower Charles River Basin may be made up of mostly blueback herring eggs. Using the presence of river herring eggs to formulate upper temperature limits may result in a maximum temperature limit that exceeds the temperature limit best suited for alewife larvae alone.

To supplement the general guidance provided by the site-specific data, a review of the scientific literature was conducted to determine a protective maximum temperature for the survival of alewife eggs. Kellogg (1982) used fertilized alewife eggs and exposed the eggs to various temperatures to determine the effects of temperature on hatching success. Eggs were obtained by artificially spawning adult males and females from the Hudson River. The study incubated eggs at seven constant temperatures ranging from 12.7 ºC (54.9 ºF) to 29.7 ºC (85.5 ºF). No eggs hatched at 29.7 ºC (85.5 ºF). Maximum hatching success of 83.2% (normalized data treatment) occurred at 20.8 ºC (69.5 ºF). Excluding this maximum hatchling success rate, hatchling success for most other temperature treatments was generally similar, ranging from 67.9% at 23.9 ºC (75 ºF) to 75.8% at 15.0 ºC (59 ºF), with no direct temperature dependent trend. A noticeable decrease of 16.5% in hatchling success is seen from 23.9 ºC (75 ºF) to the next tested temperature of 26.8 ºC (80.2 ºF). The 23.9ºC (75 ºF) temperature treatment of the eggs resulted in a hatchling success rate of 67.9%, compared with the 26.8 ºC (80.2 ºF) hatchling success results of 51.4%. This depressed hatchling success rate, as a response to an elevated temperature, is considered by EPA and DEP to be a success level too low to ensure the reproductive potential for a balanced biological population in the lower Charles River Basin. This is especially true when taking into consideration the overall mortality that alewife eggs are subject to under natural conditions, from predation and other environmental factors, in addition to thermal effects. Also, the hatchling success rate of 67.9% for 23.9 ºC (75 ºF) was more similar to the success rate for the other temperature treatments, with the exception of the maximum success rate, which occurred at 20.8 ºC (69.5 ºF). Taking into consideration the noticeable drop in hatchling success rate at 26.8 ºC (80.2 ºF) and the fact that Kellogg's experiment did not explore temperature effects between 26.8 ºC (80.2 ºF) and 23.9 ºC (75 ºF), the value of 23.9 ºC (75 ºF) was chosen as the maximum temperature that must not be exceeded to protect the survival of alewife eggs and support a balanced indigenous population. Site-specific temperature observed in the Charles River with the presence of river herring eggs (approximately 26.7 ºC; 80 ºF), was measured on June 28, 1999, long after alewife eggs were thought to be found in the "river herring" assemblage. The temperature selected is not a "No

Observable Effect Level" temperature, but rather still appears to have an effect on the hatching success. Although there is an effect on eggs at this temperature, EPA believes this maximum temperature for alewife eggs will assure a balanced population. However, additional site-specific controlled research is needed to further evaluate this maximum temperature.

This judgment takes into consideration the in-situ continuous temperature monitoring and compliance program that will be required by the permit. Under this monitoring program, the highest temperature measured in the ZPH will likely be a temperature located near the bank-to-bank mid-point of the basin, in six feet of water (Mirant Kendall NPDES Permit Application, 2001). This will result in the vast majority of ZPH habitat occupied by alewife eggs to likely be lower than the temperature limit at all times as the spring progresses (Mirant Kendall 2003 Data, Appendix B-2: November 13, 2003). The continuous in-situ temperature monitoring program that is required to demonstrate compliance with the specified temperature limits is fully discussed in Part I.A, Section 14.b. of the draft permit.

Also, it is important to understand that natural daily ambient temperature fluctuations of at least 1.1ºC (2ºF) in the lower Charles River Basin are routinely expected (see Figures 5.10.5c-1 through 5.10.5c-5). This fluctuation is caused by changes in air temperature and solar input during a daily 24 hour weather cycle, and is observed in most bodies of water. This change in temperature over a 24 hour period will further ensure that the protective temperature of 23.9 ºC (75 ºF) is maintained in the alewife egg habitat in the ZPH.

5.7.3f Time Period For The Most Sensitive Egg Stage

As discussed earlier, Coutant (Natl. Acad. Sci./Natl. Acad. Eng., 1972) stated that spawning dates for anadromous species may commonly shift by as much as one month in rivers throughout the United States. Shifting spawning dates from year to year will naturally effect the timing of egg presence in the lower Basin. It is difficult to account for this variability in the establishment of the time period for the protective alewife egg temperature.

Based on the presence of in-migrating adult in the lower Basin and other nearby rivers and based on when river herring eggs have been observed in the basin, a time frame for the occurrence of alewife eggs can be estimated. River herring eggs were found in the lower Basin each week from the onset of sampling on the week of May 12 through the week of June 28, 1999. In the year 2000, weekly ichthyoplankton sampling began the week of March 13, 2000. River herring eggs first appeared in samples on the week of May 15, 2000, and were present each week of sampling through the week of June 26, 2000. In the year 2002, weekly ichthyoplankton sampling began the week of April 9, 2002. River herring eggs first appeared in samples the week of May 1, 2002, and were present each week until the week of July 23, 2002, with the single exception of the week of July 10, 2002. In 2003, sampling began on May 20, 2003 and river herring eggs were collected at that time. River herring were collected in all ichthyoplankton sampling events through the end of sampling, on July 10, 2003. Based on this field data, the earliest eggs collected were probably alewife eggs, since they spawn earlier in the season than blueback herring. This would suggest early May as the time period where protective temperatures must be in effect. Since in two of the four years, sampling did not begin until mid-May, it is possible that alewife eggs may first appear in the lower Basin early than the beginning of May. Also, river herring eggs collected later in the season, during the warmer months, are most likely blueback herring eggs. While the site-specific sampling is used as a guide to determine when alewife eggs are present in the lower Basin, another approach was also used as part of the evaluation.

The timing of adult alewife spawning was evaluated to assist in defining the time period of expected alewife egg presence. Adult alewife are expected to enter the lower Charles River Basin beginning around April 15. Spawning may begin about one week later, placing the first fertilized eggs in the basin as early as April 22. Since adult alewife are expected to end their spawning run in the lower Charles River Basin around June 7, lower Charles River Basin temperatures from June 7 through June 14, from 1994 through 2001, were examined to determine probable incubation times for the last of the fertilized alewife eggs in the system. These temperatures were taken from Kendall Station cooling water intake temperature measurements. The average maximum temperature during this period was 22.8 ºC (73 ºF) and the average minimum temperature was 19.4 ºC (67 ºF). The average temperatures for all the years combined during this time period was approximately 20.5 ºC (69 ºF) (Mirant Kendall Station Operations Data Unpublished, 2002). This temperature range is most closely associated with a literature reference citing a 3.7 day incubation period at 21.1 ºC (70 ºF; Pardue, 1983). Adding 4 days after the appearance of the last fertilized alewife eggs onto the last spawning date of June 7 would place the last eggs hatching to the larval stage in the lower basin around June 11. This would make the likely time period when alewife eggs are present in the lower Charles River Basin from April 22 through June 11.

Based on the discussion above, the maximum temperature that is protective of alewife eggs in the lower basin is 23.9 ºC (75 ºF). This limit must be in place from April 22 through June 11, unless replaced by a lower limit to protect a more sensitive life stage or species occurring in the basin at the same time.

5.7.3g Protective Temperature For Most Sensitive Larval Stage

There have been no site-specific experiments performed to determine the temperature sensitivity of anadromous species larvae adapted to the range of ambient temperature conditions in the lower Charles River Basin. Based on a general review of the scientific literature dealing with the anadromous species that occur in the lower basin (see Reference Section 5.12 for a list of papers consulted), the alewife larvae was determined to be the larval stage most sensitive to temperature during the early summer.

The permittee submitted ichthyoplankton collection data from the lower Charles River Basin confirming the presence of alewife larvae on May 12 and 18 of 1999, but only indicated the likely presence of alewife larvae as "*Alosa* spp." at other times. Using the same argument outlined in the discussion in the anadromous egg section of this report, some percentage of the larvae identified from the samples as "*Alosa* spp." were assumed to be alewife larvae. The data were examined to get an initial idea of the ambient river temperature range that coincided with the presence of the larvae. Due to the observation that alewife spawn in advance of blueback herring, but also overlap with blueback herring spawning (NOAA, 1998; Pardue, 1983), Alosa larvae collected earlier in the spawning season were most likely made up of a higher percentage of alewife larvae than later in the season.

Lower Charles River Basin ichthyoplankton samples were collected weekly in 1999 from mid-May through August,1999, weekly in 2000 from mid-March through early September, 2000, weekly in 2002 from early April through mid-August, 2002, and in 20003 on May 20, weekly from June 11 through June 24, and on July 10, 2003 . In order to get an idea of water temperatures in the basin when alewife larvae were present, representative basin temperatures were matched with dates when alewife larvae or *Alosa* spp. larvae were collected. These water temperatures were taken from cooling water intake temperatures from Kendall Station on the respective sampling dates (Mirant Kendall NPDES Permit Application, 2001; Unpublished Kendall Station Operations Data 2002). The intake structure draws water from approximately the upper eleven feet of the water column. Intake temperatures were measured once this column of water had mixed. This hourly temperature data provided a general indication of water temperatures in the basin.

In 1999, alewife larvae (*Alosa* pseudoharengus) were identified at a basin temperature of approximately 17 ºC (63 ºF; May 12) and 18.6 ºC (65.5 ºF; May 18). River temperatures on these dates were taken from vertical profile data, because intake temperatures were not available. This is the only instance where alewife larvae were identified distinctly. In all subsequent sampling, larva were identified as *Alosa* spp., or river herring larvae. As discussed previously, identifying alewife and blueback herring larvae together as river herring is understandable but problematic, as alewife are generally expected to spawn earlier and tolerate lower temperatures than blueback herring.

In the year 1999, *Alosa* spp. larvae were found at an approximate basin temperature range of 19.4 ºC (67 ºF; May 25) to as high as 28.3 ºC (83 ºF; July 6). *Alosa* spp. larvae were found in weekly samples from May 25 through July 26, 1999.

In the year 2000, *Alosa* spp. larvae were found at an approximate basin temperature range of 9.4 ºC (49 ºF; April 27) to as high as 27.2 ºC (81 ºF; August 10). *Alosa* spp. larvae were found in weekly samples on April 27, but were not found again until May 11, when they appeared in weekly samples from May 25 through August 28, 2000.

Kendall Station entrainment sampling conducted by the permittee documented the presence of *Alosa* spp. larvae from May 10, 2000, every week through July 31, 2000. Larvae were again seen on August 14 and 21, 2000. The lowest temperature coinciding with the presence of these larvae was 16.7 ºC (62 ºF; May 21 and 25) and the highest temperature was 26.1 ºC (79 ºF; July 5 and 6).

In the year 2002, *Alosa* spp. larvae were found at an approximate basin temperature range of 12.8ºC (55ºF; May 1) to as high as 27.6 ºC (81.7ºF; Jul 2). *Alosa* spp. larvae were found in weekly samples starting on April 16, and continued to appear weekly through July 23, 2002. They appeared in weekly sampling one more time, on August 6, 2002

In the year 2003, *Alosa* spp. larvae were found at an approximate basin temperature range of 17.5ºC (63.5ºF; May 20) to as high as 26.6 ºC (79.9ºF; Jul 10). *Alosa* spp. larvae were found when sampling first began on May 20, and continued to appear in every sampling event through July 10, 2003.

The temperature data range provided above is informative as a guide, but three things must be taken into consideration when reviewing this data.

First, the temperatures represented above were not taken from the location of the ichthyoplankton station, but from a station reflecting ambient river conditions during the same time as the sampling.

Second, the viability of the larvae collected in the field was not evaluated as part of the field sampling program. It was not determined what, if any acute or chronic effects might be exhibited by the larvae as a result of developing at the water temperatures that were present.

Third, as noted earlier in this section, the river herring larvae collected are most likely made up of both alewife larvae and blueback herring larvae. These species, since they spawn in different habitats and at different times, are thought to have different temperature thresholds. Scientific literature is not well developed concerning blueback herring temperature tolerance information, but it is assumed their appearance later in the season is an indication they may be able to tolerate higher temperatures than alewife. Because of this, the upper range of temperatures where river herring larvae were collected in the lower Charles River Basin, mostly later in the season, may be made up of mostly blueback herring larvae. Using the presence of river herring larvae to formulate upper temperature limits may result in a maximum temperature limit that exceeds the temperature limit best suited for alewife larvae alone.

To supplement the general guidance provided by the site-specific data, a review of the scientific literature was conducted to determine a protective maximum temperature for the survival of alewife larvae which would assure a balanced population.

First, a study of the larval stage of another anadromous species, American shad, was reviewed. Creeco and Savoy (1985) studied shad in the Connecticut River. The research showed a strong correlations among warmer water temperatures, lower river flows, and enhanced growth of the larval herring. The target range of warmer temperatures that were correlated with better growth of the shad was not identified.

A more specific study, dealing with temperature impacts specifically on larval alewife, was next examined. Kellogg (1984) reported 100% mortality of alewife yolk-sac larvae when exposed for 24 hours to temperatures of 32 to 33ºC (89.6 to 91.4 ºF) after being acclimated at 14 to 15 ºC (57.2 to 59 ºF). These acclimation temperatures coincide with lower Charles River Basin temperatures observed during the initial appearance of Alosa spp larvae (thought to be predominately alewife) in 2000 and 2002, and may not be fully representative of basin temperatures seen by the majority of Alosa spp larvae in the basin (Mirant Kendall NPDES Permit Application, 2001; Unpublished Mirant Kendall Station Operations Data 2002). The 50% mortality rate (TL50) for larvae in this experiment was about 31 ºC (87.8 ºF). Temperatures around 30 ºC (86 ºF) resulted in alewife larvae mortality slightly above the average control mortality for the experiment. A 12 day exposure of alewife larvae recorded the highest growth rate and the highest mortality rate at 29.1 ºC (84.3 ºF). The author attributed at least some of the high mortality to thermal stress.

The U.S. Fish and Wildlife Service Suitability Index value for eggs and larvae of bluebacks and alewives reports a value of 27 ºC (80.6 ºF) as the daily average temperature where suitability is zero. Larval alewives are expected to be upstream of the Watertown dam, but some are also expected downstream. Most bluebacks are expected to remain in the lower basin. The mid-point for 50% habitat suitability of blueback eggs and larvae (Pardue *et al*., 1983) is 25.5 ºC (77.9 ºF, approximately 78 ºF) as a daily average. By comparison, water temperatures in excess of 26.7 ºC (80.1 ºF) were found to be unsuitable for hatching of eggs and eventual development of Atlantic shad larvae (Bradford *et al*, 1966). As shad and blueback larvae are expected to be present about the same time, the 25.5 ºC (approximately 78 ºF) daily average temperature was evaluated as a protective temperature limit for the period of larval occurrence of these two species.

The daily average protective temperature limit of 25.5 ºC (approximately 78 ºF) is problematic. This daily average value is not compatible with the in-situ limit, measured in the river, under the monitoring program designed for the lower Charles River Basin. Part II.A., Section 14 of the draft NPDES permit requires a temperature limit to be calculated from four hour block average temperatures at several key locations in the lower basin. Taking into consideration the natural temperature fluctuations in the lower Charles River Basin, especially in the spring, when temperatures can vary more than 2.8 ºC (5 ºF) in a given 24 hour period, the temperature limit of 25.5 ºC (approximately 78 ºF) is not fully appropriate for use as a “four hour” temperature limit without modification, under the required monitoring and compliance program.

In addition, ambient river conditions in the lower Charles River Basin, discussed fully in Section 5.9, routinely exceed temperatures of 25.5 ºC (77.9ºF) in late June and July, when protective temperatures for alewife larvae would likely still be in place (Mirant Kendall Hydrographic Data 1999, 2000, 2002, 2003; Mirant Kendall Operations Data, Unpublished, 2002). This may be an indication that in this warm water basin, a temperature limit of 25.5 ºC (77.9ºF) throughout the Zone of Passage and Habitat may not be appropriate.

A study done by Ecological Analysts, Inc. (1978) recorded a 95% survival rate of one day old yolk-sac larvae after being exposed to 27.9ºC (82.2º F) for 24 hours, with an acclimation temperature of 20 ºC (68 ºF) (See Ecological Analysts, Inc., Table 6.2-4, 1978). This acclimation temperature better represents the conditions thought to be seen by the majority of alewife larvae in the basin during late spring and early summer.

First, a 24 hour toxicity test is considered a relatively short-term test. Longer-duration tests would typically be expected to induce further toxicity. Larvae essentially drift in the water column and cannot move up and down to any great extent on their own. Thus, the probability that larvae will remain in water at elevated temperatures once they enter a plume in the Zone of Dilution in the lower basin is fairly high. Under low-flow conditions in the lower Charles River Basin, it likely takes over 250 days for a particle of water to travel from the Facility's outfall to a location downstream just out of the basin, past the New Charles River Dam and Locks (TRC Supplemental Information, 2002). Based on this, there is a concern that if temperatures throughout the ZPH were to remain at 27.9ºC (82.2º F) for 24 hours continuously, a mortality rate within the ZPH of approximately 5% of the larvae could be expected. This situation would not be acceptable in the ZPH. It is judged that the unique in-situ monitoring and compliance required by the draft permit will ensure that and temperature limit established for the ZPH would not be maintained in the majority of the basin for a time period approaching 24 hours. The reasons for this are discussed below.

Based on a review of the site-specific data (river herring larvae collected at the same time ambient temperatures were recorded as high as 28.3ºC (83ºF) and scientific literature discussed above, a temperature of 27.2 ºC (81.0 ºF) was judged to be a reasonable protective temperature for alewife larvae, given the following conditions. First, it is recognized that to be protective, this temperature must not be uniformly present throughout the majority of the ZPH. Second, the temperature must not be reached for a continuous time period approaching 24 hours. Based on the unique and restrictive in-situ temperature compliance program required by the permit as well as the ambient temperature characteristics of the lower basin, both discussed in more detail below, it is judged that a maximum temperature limit of 28.3ºC (83ºF) set in the ZPH will ensure that temperatures lower than 27.2 ºC (81.0 ºF) will be achieved in a large portion of the ZPH for a majority of the time, even within a single 24 hour daily cycle. This condition will be protective of alewife larvae throughout the ZPH in the lower basin to assure a balanced population.

This judgment takes into consideration the in-situ continuous temperature monitoring and compliance program required by the permit. Under this monitoring program, the highest temperature measured in the ZPH will likely be a temperature located near the bank-to-bank mid-point of the basin, in six feet of water (Mirant Kendall NPDES Permit Application, 2001).

If the temperature limit of 28.3ºC (83ºF) is required not to be exceeded at a near surface Monitoring Point, this will result in the majority of the habitat in the ZPH to likely be lower than the temperature limit of 28.3ºC (83ºF) at all times during June and early July (Mirant Kendall 2003 Data, Appendix B-2: November 13, 2003). The continuous in-situ temperature monitoring program that is required to demonstrate compliance with the specified temperature limits is fully discussed in Part I.A, Section 14.b. of the draft permit.

Also, it is important to understand that while natural ambient river temperature fluctuations in the spring have been documented to vary more than 2.8 ºC (5 ºF) in a given 24 hour period, temperature changes of at least 1.1ºC (2ºF) in the lower Charles River Basin are always expected in late June and early July, when the temperature limit is likely to be approached (see Figures 5.10.5c-1 through 5.10.5c-5). This fluctuation is caused by changes in air temperature and solar input during a daily 24 hour weather cycle, and is observed in most bodies of water. This change in temperature over a 24 hour period will further ensure that the actual temperatures in the ZPH will, at the extreme, only briefly touch upon the temperature limit of 28.3ºC (83ºF) during the hottest part of the day, in a small portion of the ZPH, while most temperatures remain consistently lower than the 27.2 ºC (81.0 ºF) temperature judged to be protective for alewife larvae.

5.7.3h Time Period For The Most Sensitive Larval Stage

Site-specific data from the lower Charles River Basin was reviewed to assist in formulating the time period appropriate for the protection of alewife larvae in the lower basin. In the year 2000, *Alosa* spp. larvae were found in weekly samples on April 27, 2000, but were not found again until May 11, when they appeared in weekly samples from May 25 through August 28, 2000 (Mirant Kendall NPDES Permit Application, 2001). In 2002, river herring larvae were first found on April 16, 2002, and last collected on August 6, 2002. The collection of river herring larvae at such an early date in 2002 is further documentation of the year-to-year natural variability in timing of a given spawning run. Sampling in 1999 and 2003 did not begin until mid-May, likely after the first appearance of river herring larvae (Mirant Kendall Supplemental Environmental Sampling, 2003). It is recognized that the river herring (*Alosa* spp.) larvae collected in August of 2000 and 2002 were likely made up exclusively of blueback herring larvae, since this species generally spawns later in the season than alewife. However, there is no way to verify this. This data set was used only as a guide in determining the protective time period. To make any projections based on site specific data alone, the collection would need to span several years in order to bracket the environmental variability seen in the system. In addition, since both alewife and blueback herring larvae were combined in the level of taxonomic identification reported in this data set, it is difficult to isolate with certainty only the time period of alewife larvae presence.

If adult alewife are expected to begin entering the lower Charles River Basin around April 15 and one week is allowed for the first spawning to take place, fertilized eggs will first be present in the basin around April 22. Lower Charles River Basin temperatures from April 22 through April 30, from 1994 through 2001, (excluding 1999 because no data was available), were examined to determine probable incubation times for fertilized alewife eggs. These temperatures were taken from Kendall Station cooling water intake temperature measurements. The average maximum temperature during this period was (59 ºF) and the average minimum temperature was (53 ºF). The average temperatures for all the years combined during this time period was approximately (56 ºF) (Mirant Kendall Station Operations Data, Unpublished 2002). This temperature range is most closely associated with a literature reference citing a 6 day incubation period at 15.5 ºC (60 ºF; Pardue, 1983). Adding 6 days onto the appearance of the first fertilized alewife eggs would place the first larvae in the lower basin around April 29. This generally coincides with the first appearance of river herring larvae in site-specific sampling of the lower Charles River Basin in the year 2000.

When calculating the presence of alewife eggs in the lower basin, June 11 was identified as the latest date that eggs hatched to the larval stage. This date would then be the last date that alewife yolk-sack larvae would be present in the lower basin. A USFWS document (Pardue, 1983) reported that larvae at this stage take about two to five days for the yolk-sack to be absorbed and another two to three weeks before the they move from the larval stage to the juvenile stage. To ensure that all of the larval time span range was covered by the appropriate protective temperature, the longer of these time ranges was used. Five days was combined with twenty-one days (three weeks), and this twenty-six day time span was added to June 11. This method results in a time period from April 29 to July 7 as the time frame for the protection of alewife larvae at a maximum temperature of 28.3ºC (83ºF) in the ZPH of the lower Charles River Basin. This limit must be in effect during this time period, unless replaced by a lower limit to protect a more sensitive life stage or species occurring in the basin at the same time.

5.7.3i Protective Temperature For Most Sensitive Juvenile Stage

There have been no site-specific experiments performed to determine the temperature sensitivity of anadromous species at the juvenile stage adapted to the range of ambient temperature conditions in the lower Charles River Basin. Based on a general review of the scientific literature dealing with the anadromous species that occur in the lower basin (see Reference Section 5.12 for a list of papers consulted), the alewife juvenile stage was determined to be the juvenile stage most sensitive to temperature.

Beach seine sampling, which is expected to target juvenile fish when they are near shore, was conducted by the permittee every other week from July 9 through December 1999. In the year 2000, beach seine sampling was conducted weekly from July through early November. In 2002, beach seine sampling was conducted weekly from May 22 through November 14. In 2003, beach seine sampling was conducted weekly from June 11 through October 13, 2003 .

Sampling in 1999 documented juvenile alewife at ambient water temperatures between 23 ºC (73.4 ºF; August 30) and 27.8 ºC (82 ºF; July 19). The only available temperatures for the July

19, 1999 sampling were from cooling water intake measurements from Kendall Station. As will be more fully discussed in Section 5.9 of this document, temperatures measured at the intake structure in the summer are thought to be higher than ambient river temperatures in the basin due to potential re-entrainment of the thermal plume. However, since the intake monitoring point represents the temperature of approximately the top 11 feet of river water mixed together by the intake pumps, it is possible that a near surface temperature taken at a discrete depth could possibly be higher than the intake temperature value, even with the thermal plume influence. So, it is likely that the intake temperature used as a surrogate for the beach seine location temperature does not accurately reflect conditions at the near shore environment where this seining was conducted. Temperature measurements during beach seine sampling in 2000, 2002 and 2003 were recorded at the sampling site where the fish were collected (Mirant Kendall NPDES Permit Application 2001; Appendix 5; Mirant Kendall Supplemental Field Data, November 5, 2002 Letter, Appendix C; Mirant Kendall Supplemental Field Data, 2003; Appendix F).

Beach seine sampling in 2000 documented juvenile alewife in the lower basin at ambient water temperatures from 22.1 ºC (71.7 ºF; July 27) to 26.4 ºC (79.5 ºF; August 10) (Mirant Kendall NPDES Permit Application, 2001; Appendix 5).

Beach seine sampling in 2002 documented juvenile alewife in the lower basin at ambient water temperatures from 12.5ºC (54.6ºF; October 17 at night) to 28.3ºC (82.9ºF; August 15 at night) (Mirant Kendall Supplemental Field Data, November 5, 2002 Letter, Appendix C).

Beach seine sampling in 2003 documented juvenile alewife in the lower basin at only two of the seven stations where sampling was conducted. Alewife were collected at water temperatures at the sampling sites from 19.2ºC (66.6ºF; October 1) to 26.6 ºC (79.8ºF; July 15 at night) (Mirant Kendall Supplemental Field Data, 2003; Appendix F). It must be noted that very small numbers of alewife were collected when the sampling site displayed the high end of the temperature ranges identified above.

In summary, field collections in the Charles River record juvenile herring at temperatures as high as 27.8 ºC (82 ºF) in 1999 and 28.3 ºC (82.9 ºF) in 2002, two of the lowest flow and warmest years in the decade. However, those temperatures appear to be outliers. Data submitted by the permittee from 2002 and 2003 show that three out of 513 alewives caught in 2002 (< 0.01%) were caught at temperatures above 27.2 ºC (81 ºF). Thirty-five of 513 alewives (~7%) were caught above 26.7ºC (80 ºF). In 2003, none of the several hundred alewives were caught above 26.7 ºC (80 ºF). Based upon site-specific data, there seems to be a case for a protective temperature in the Charles River of approximately 26.7 to 27.2 ºC (80 to 81 ºF).

The site-specific field data provided by the permittee was useful as a guide. It was considered along with a review of the scientific literature to determine a protective maximum temperature for the survival of alewife juvenile to help assure a balanced population, as well as a temperature that will not exclude potential habitat

There is no site-specific Charles River scientific literature regarding the upper lethal temperature limits for alewife juveniles that have adapted to the range of ambient temperature conditions specifically in the lower basin. Kellogg (1982) provided information on the temperature preference of young alewife (not from the Charles River), using specimen in an advanced post-larval and early juvenile stage. The experiments were conducted over a 33 hour period. The mean preferred temperature was 26.3 ºC (79.4 ºF). This temperature corresponds closely with the optimum temperature for growth and early development, 26.4 ºC (79.6 ºF)(Kellogg, 1982). When setting maximum protective temperatures in the lower Charles River Basin, it is judged that temperature limits can be established which are above the optimum value for a species and still serve to protect a balanced population.

A study done by Ecological Analysts, Inc. (1978) recorded a 95% survival rate for young-of-the-year alewife after being exposed to 29.3 ºC (84.7 ºF) for 24 hours, with an acclimation temperature of 23 ºC (73.4 ºF). This acclimation temperature corresponds to the conditions alewife young-of-year were collected in the lower basin during beach seining in 1999, 2000, 2002 and 2003 (Mirant Kendall NPDES Permit Application, Appendix 4, February 2001; Mirant Kendall Hydrographic Data, 2002; EPA Clean Charles 2005, 2002 Data; Mirant Kendall 2003 Data, Appendix B-2: November 13, 2003). If 29.3 ºC (84.7 ºF) was chosen as the maximum temperature for the protection of juvenile alewife, a 5% mortality rate may likely be expected in the ZPH if this value is maintained through a large part of the ZPH for long periods of time. This temperature, while having an acute effect on alewife, likely also triggers avoidance behavior of alewife. For most species, an avoidance temperature is generally expected to be below any acute effects level. For these reasons, a protective temperature for alewife juvenile would be expected to be below 29.3 ºC (84.7 ºF)

In addition to protecting juvenile alewife by establishing a water temperature that will not cause pronounced mortality, a temperature must be established that will also allow juveniles to grow, feed and develop in the Zone of Passage and Habitat. If a temperature is established that protects against pronounced mortality, but causes juveniles to avoid the area, the temperature is not protective of the habitat.

Guidance documents from the Atlantic States Marine Fisheries Commission (ASMFC; 1985) and the Chesapeake Bay Program (Klauda, *et al*., 1991) contain recommendations for alosid juveniles. The ASMFC document recommends that mean daily temperatures for American shad, bluebacks and alewives go no higher than 26.7°C (80°F)(Table 5.7.3i-1). The Chesapeake Bay document recommend that temperatures (assumed to be an instantaneous maximum) for alewives and blueback herring not exceed 28.0°C (82.4°F) (Table 5.7.3i-2).

Table 5.7.3i-1 Fishery Management Plan for American shad and River Herrings

Fisheries Management Report No. 6 of the Atlantic States
Marine Fisheries Commission, October, 1985

Summer (nursery) Mean Daily Temperature:
between 12.8°C and 26.7°C (55°F and 80°F)

Table 5.7.3i-2 Habitat requirements for Chesapeake Bay Living Resources:
Alewife and Blueback Herring
Second Edition, 1991

Habitat requirements for early juveniles:

Suitable:10-28 °C (50-82.4 °F)
Preferred:17-24 °C (62.6-75.2 °F)

These recommendations, when standardized to a four hour average temperature, probably result in a similar upper suitable temperature limit between approximately 27.2 and 27.8 ºC (81 and 82 ºF).

Guidance from the third source, U.S. Fish and Wildlife Service (Pardue, 1983), was developed to determine when/how to establish parameters for river herring and shad freshwater habitat to improve stocks. Pardue (1983) found that "Juvenile alewives were collected from areas with water temperatures up to 25 ºC (77 ºF), but they avoided higher temperatures. Optimal temperatures for alewives are considered to be between 15ºC and 20 ºC (59 ºF and 68 ºF). All other temperatures are less than optimal." There is no reference for this information regarding collection temperatures, but in reading the justification for this particular variable, the author cites personal communication with M.W. Street, who was involved in the anadromous fisheries controlled research program for the northern coastal region (Atlantic) and who is referenced for a number of publications on alosids.

The habitat suitability model (Pardue, 1983) lists optimal habitat temperatures for juveniles similar to those reported above, giving these temperatures a suitability of 1.0. They assume that there is a linear decline in suitability from 20ºC to 30ºC (68 ºF to 86 ºF), with 30ºC (86 ºF) receiving a zero suitability value (Table 5.7.3i-3).

As the information from the habitat suitability model is considered, it should also be noted that according to beach seine field data collected in the lower Charles River Basin, a small number of alewife juveniles were collected at temperatures as high as about 27.8ºC (82ºF) in 1999 and 28.3ºC (82.9ºF) in 2002 (Mirant Kendall Permit Application, Section 5, 2001; Mirant Kendall Supplemental Field Data; Appendix C, November 5, 2002).

Table 5.7.3i-3 U.S. Fish and Wildlife, 1983
Juvenile Alewives, Suitability Index

Temperature	Suitability	
5°C (41°F)	0.0	(Completely Unsuitable)
15-20°C (59-68°F)	1.0	(Completely Suitable)
30°C (86°F)	0.0	(Completely Unsuitable)

50% Suitability, Juvenile alewives = 77°F

Juvenile alewife from Lake Michigan were found to have a maximum No Adverse Effects Level (NOAEL) at 29.0°C (84.2°F), but showed a preferred temperature no higher than 25°C (77°F) (Otto *et al.*,1976.; Table 5.7.3i-4)

Table 5.7.3i-4 Otto *et al.*,1976. Lethal and preferred temperatures of the alewife, (Alosa pseudoharengus) in Lake Michigan. Trans. Am. Fish. Soc. 1976 (1):96-106. Tab 9 from Mirant.

YOY alewives transferred directly from acclimation temperature to test temperature.

Acclimation 24-26 °C (75.2-78.8 °F)

	Test Temperature	Survival (%)	Median Survival time (min.)
NOAEL	29.0°C (84.2°F)	100	
LOAEL	30.0 °C(86 °F)	90	
	31.0 °C(87.8°F)	90	
	32.0 °C(89.4°F)	60	520
	32.5 °C(90.5°F)	0	180

Preferred temperatures: YOY alewives extend only to 25 C (77F) (Otto *et al.*,Fig. 7).

It is important to remember the vital role of surface and shoreline habitat to juvenile alewife, especially when considering conditions in the lower Charles River Basin (see Section 5.4). In least-impacted systems, juvenile alosids feed throughout the water column, along the shoreline and on the bottom. As discussed in other sections of this document, densities of benthic organisms in the lower basin are at very low levels, probably due to anoxia at the bottom during the warmer months of the year as well as to extremely high sediment-metals concentrations thought to be toxic to benthic organisms (see Sections 5.4.8-10). It is likely that juvenile alosids in the lower basin have possibly lost a percentage of their feeding habitat due to anthropogenic pollution in the sediments. With the loss of benthic habitat, surface and shoreline areas have become all the more important to juvenile alosids living in the lower basin. A temperature limit must be selected that will not further exclude them from feeding habitat at the surface and along parts of the shoreline.

Based on a review of the site-specific data and scientific literature discussed above, a temperature of 27.2 ºC (81 ºF), was judged to be a reasonable protective temperature for alewife juveniles, providing the following provisions are met. First, it is recognized that to be protective, this temperature value must not be maintained throughout the majority of the ZPH. Second, the temperature must not be reached for long periods of time. Third, the near surface and shoreline habitat must not maintain this temperature for long periods of time. Based on the unique and restrictive in-situ temperature compliance program required by the permit as well as the ambient temperature characteristics of the lower basin, both discussed in more detail below, it is judged that a maximum temperature limit, enforced for all parts of the ZPH, of 28.3ºC (83ºF) will ensure that temperatures lower than 27.2 ºC (81 ºF) will be achieved in a large portion of the ZPH for a majority of the time. This condition will be protective of alewife juveniles throughout the ZPH in the lower basin to assure a balanced population.

This judgment takes into consideration the in-situ continuous temperature monitoring and compliance program required by the permit. Under this monitoring program, the highest temperature measured in the ZPH will likely be a temperature located near the bank-to-bank mid-point of the basin, in six feet of water (Mirant Kendall NPDES Permit Application, 2001). If the temperature limit of 28.3ºC (83ºF) is required not to be exceeded at a near surface Monitoring Point, this will result in the majority of the habitat in the ZPH to likely be lower than the temperature limit of 28.3ºC (83ºF) at all times during the summer (Mirant Kendall 2003 Data, Appendix B-2: November 13, 2003). The continuous in-situ temperature monitoring program that is required to demonstrate compliance with the specified temperature limits is fully discussed in Part I.A, Section 14.b. of the draft permit.

Also, it is important to understand that while natural ambient river temperature fluctuations in the spring have been documented to vary more than 2.8 ºC (5 ºF) in a given 24 hour period, temperature changes of at least 1.1ºC (2ºF) in the lower Charles River Basin are always expected in the summer months, when the temperature limit is likely to be approached (see Figures 5.10.5c-1 through 5.10.5c-5). This fluctuation is caused by changes in air temperature and solar input during a daily 24 hour weather cycle, and is observed in most bodies of water. This change in temperature over a 24 hour period will further ensure that the actual temperatures in the ZPH will, at the extreme, only briefly touch upon the temperature limit of 28.3ºC (83ºF) during the hottest part of the day, while most temperatures remain consistently lower than the 27.2 ºC (81 ºF) temperature judged to be protective for alewife juveniles.

5.7.3j Time Period For The Most Sensitive Juvenile Stage

Beach seine sampling, which is expected to target juvenile fish when they are near shore, was conducted by the permittee every other week from July 9 through December 1999. Juvenile alewife were present in the lower Charles River Basin at every sampling date from July 9 through August 30, 1999.

In the year 2000, beach seine sampling was conducted weekly from July through early November. Juvenile alewife were only documented on July 27 and August 10 during the entire sampling period (Mirant Kendall NPDES Permit Application, 2001; Appendix 5). This sampling was conducted during the day. In subsequent sampling years, beach seining was also conducted at night, resulting in the collection of a higher percentage of alewife (Mirant Kendall Supplemental Field Data, November 5, 2002 Letter, Appendix C).

In 2002, beach seine sampling was conducted weekly from May 22 through November 14. Alewife were first collected on May 22 and last observed on October 17.

In 2003, beach seine sampling was conducted weekly from June 11 through October 13, 2003 . Alewife were first collected on June 11 and last collected on October 13.

Juvenile alewife may reside in the lower ends of rivers where spawning occurred, but may also move upstream in summer (Pardue, 1983). Field data showing the presence of alewife in late May in 2002 could possibly have collected adult alewife moving to the near shore areas to spawn.

The time frame for the likely development of earlier life stages of alewife in the lower Charles River Basin, described above, was used as the basis to estimate the earliest likely appearance of juvenile alewife. As discussed earlier, the first alewife larvae in the lower basin are thought to appear around the end of April (see Section 5.7.3h). A USFWS document (Pardue, 1983) reported that larvae at this stage take about two to five days for the yolk-sack to be absorbed and another two to three weeks before the they move from the larval stage to the juvenile stage. This could place the earliest presence of juvenile alewife in the lower basin during the early part of June. Until additional site-specific data is collected to better characterize when juvenile alewife first appear in the lower basin, June 12 was judged to be the time period when appreciable numbers of alewife appear.

To characterize the last date that juvenile alewife are present in the lower basin, site-specific sampling in the basin was reviewed. Sampling documented the presence of alewife through mid-October. It is assumed that by the end of December, alewife juveniles in the lower Charles River Basin have migrated out into Boston Harbor. Taking this information int consideration, juvenile alewife are expected to inhabit the lower basin from June 12 through December 31. As discussed above, further site-specific sampling is necessary to refine this time period. As discussed above, a maximum temperature limit of 28.3ºC (83ºF) must be in place for the protection of juvenile alewife. This limit must be in effect during this time period, unless replaced by a lower limit to protect a more sensitive life stage or species occurring in the basin at the same time.

5.7.3k Summary Of Temperature Limits and Time Periods For Anadromous Species Protection

All protective temperature limits and time periods for the most sensitive anadromous species discussed in Section 5.7 have been organized by month, beginning with the first appearance of anadromous species during the year, to obtain an overall picture of the necessary temperatures in the Zone of Passage and Habitat in the lower Charles River Basin over the course of a year. Figure 5.7-1 represents this information. Blank time periods of the figure correspond to those times when anadromous species are generally not thought to occur in the basin. As more site-specific field data is collected from the lower basin, these temperature limits and time periods may be modified. As stated in Section, 5.7.3a, alewife (*Alosa pseudoharengus*) was identified as being the anadromous species most sensitive to elevated temperatures at the stages of their development where they inhabit the lower Charles River Basin (see Reference Section 5.12).

5.7.4 Consideration of Temperature Limits For American Shad Protection

5.7.4a Introduction

Protection of American shad (*Alosa* sapidissima) is of concern in the preservation of fish habitat and populations in the lower Charles River Basin. The American shad (*Alosa* sapidissima) is the largest of the three species of the genus Alosa that has been documented in the Charles River. The typical adult size of American shad adult migrants in the nearby Connecticut River is 1.5 to 7 lbs. Partly because of its size, the shad is a popular game fish. Adult shad are commercially fished in the Connecticut River and are a local delicacy during the spring.

Shad represent an important historical component of the balanced indigenous population of the Charles River. In Massachusetts, the American shad historically entered virtually all coastal streams. Damming, dredging, pollution, and other alterations of Massachusetts waters, caused large declines in the mid-1800s. During this time period, shad were eliminated from the Charles river. Since the mid- 1950's, with new or improved fishways and fish-lifts, shad numbers have increased dramatically in other Massachusetts Rivers, especially in the Connecticut and Merrimack rivers; with 393,000 per year passed at Holyoke alone between 1981-1991. Re-introductions of American shad into the Charles River have met with minimal success. (Hartel, *et al*.,2002).

Although the Charles River historically contained an abundant population of ecologically, commercially, and recreationally important American shad (NOAA Fisheries correspondence to DEP, dated October 21, 2002), this species currently exists in very low numbers in the Charles River. American shad have not been collected during fish sampling in 1999, 2000, 2002 and 2003 in the vicinity of Kendall Station (Mirant Kendall NPDES Application and Supplemental Field Data, 2001-2003). A 27 inch (total length) American shad was caught in the spring of 2002 at the Rt. 16 bridge (Newton/Watertown), suggesting that a remnant population of shad may still breed in the Charles River. (Phillips Brady, MADMF pers. comm. to G. Szal, MADEP, July, 2002).

Restoration efforts were undertaken periodically by the DMF from 1971 to 1992 to reestablish the American shad fishery in the Charles River (DMF correspondence To DEP, dated September 30, 2002). As stated earlier, these efforts did not achieve their desired goals. One potential problem is negotiation of the New Charles River Dam and Locks. Although structures at this dam and locks were designed and built to accommodate American shad, along with other anadromous fish, the fish passage structure at this dam has never functioned as designed and thus shad migration may be precluded (MDC, M. Doolittle, personal communication). Both DMF and the National Marine Fisheries Service (NOAA Fisheries) have identified the inoperable fishway and inadequate use of the locks for passing anadromous fish as problematic and continue to work with other state and federal agencies to correct these problems. Other factors that may be suppressing a stable population of American shad include the absence of a staging area at the mouth of the river with intermediate temperatures and salinity levels, difficulty in negotiating the Watertown dam fishway, nutrient input from a variety of sources, and heat effects from discharges such as Mirant Kendall, which may be affecting the ability of larvae and juveniles to feed and grow in the lower basin.

The reason or reasons for the poor results of the restoration program have not been determined with certainty. While no restocking activity is currently underway, the DMF is committed to American shad restoration in the Charles River (DMF correspondence To DEP, dated September 30, 2002). Further, both DFW and NOAA Fisheries have formally contacted DEP to express their support for the incorporation of protective temperature limits for American shad in the NPDES permit for the Mirant Kendall facility (DMF correspondence To DEP, dated September 30, 2002; NOAA Fisheries correspondence To DEP, dated October 21, 2002).

EPA and DEP believe that the apparent absence of American shad in any appreciable numbers in the lower basin is due to significant physical, thermal or chemical changes in the basin. As discussed above, along with thermal changes due to the Mirant Kendall facility, there are other possibly significant factors that may be limiting the propagation of shad in the Charles River. In the case of American shad in the Charles River, there is sufficient uncertainty regarding these factors that EPA and DEP are postponing the inclusion of protective in-stream temperatures derived from shad-specific information in this permit until these factors are better understood or until other barriers to shad propagation have been mitigated or both, as determined by EPA and DEP

Notwithstanding EPA and DEP’s decision to postpone including shad-specific critical temperature in this permit, EPA and DEP have evaluated thermal limits for the propagation of American shad separately in a manner similar to the evaluation of protective thermal limits for the other anadromous fish species. Thus, the following overall information review is instructive to understanding the best way to ensure the proper management of this species in the lower basin.

It is noted that the American shad protective temperatures discussed below tend to be lower than protective temperatures for other anadromous fish in the Charles River and lower than recent summer temperatures. This is not inconsistent with heat being the significant factor precluding the propagation of shad in the Charles. EPA and DEP also considered that the permittee, in response to an EPA comment on the Final Environmental Impact Statement, provided evidence from other New England Rivers to support the permittee's contention that factors other than temperature were responsible for the lack of a robust population of American shad in the lower Charles River Basin.

5.7.4b Temperature Discussion For Selected American Shad Life Stages

There have been no historical site-specific experiments performed to determine the temperature sensitivity of American shad eggs, larvae and juvenile adapted to the range of ambient temperature conditions in the lower Charles River Basin when the species occurred there in appreciable numbers. Conducting these experiments at the present time would be problematic, as three years of larval and adult fish collection by the permittee in the lower basin have not identified any American shad. A review of the scientific literature dealing with the American shad egg, larval and juvenile stage of development was conducted to determined the overall temperatures necessary for the protection and propagation of this life stage.

Two guidance manuals have been prepared for American shad and were consulted to characterize temperature effects to this species. The first was published in 1985 by the U.S. Department of the Interior's Fish and Wildlife Service (Stier and Crance, 1985) for American shad along the Atlantic coast of the U.S. The second (Klauda *et al.*, 1991) was published by a group of federal and university biologists for the Chesapeake Bay region.

Stier and Crance used a panel of eleven fishery biologist experts to develop habitat suitability indices. Their work was reviewed by two additional biologists outside of the U.S. Fish and Wildlife Service. The results of the analysis for non-migratory larvae and juveniles produced the index shown in Table 5.7.4-1.

Table 5.7.4-1 U.S. Fish and Wildlife Service 1985, Suitability Index for Larval and Juveniles Shad (non-migratory):

Temperature	Suitabili1y	
7.2 ºC (45 ºF)	0.0	(Completely Unsuitable)
15.6-23.9 ºC (60-75 ºF)	1.0	(Completely Suitable)
29.4 ºC (85 ºF)	0.0	(Completely Unsuitable)

An assumption of the index is that between 7.2 ºC (45 ºF) and 15.6 ºC (60 ºF), and between 23.9 ºC (75 ºF) and 29.4 ºC (85 ºF) degrees, respectively, there is a linear rise and a linear decline in the suitability of those temperatures as habitat. To ensure that the habitat quality is not unsuitable, a value much less than 29.4 ºC (85 ºF) would have to be selected, based on these recommendations.

Stier and Crance's 29.4 ºC (85 ºF) value for shad is similar to an ET 100 (Effect Temperature to 100% of organisms tested) value and appears to be based on work of Bradford *et al*. (1966). Bradford *et al.*,found that when shad eggs were incubated at 29.4 ºC (85 ºF) a 95% hatch rate resulted, but 100% of the larvae hatched were crippled (malformed). The next lowest temperature evaluated by Bradford *et al.*,was 26.7 ºC (80 ºF). This exposure temperature produced 86% viable larvae, but the long-term health of these larvae after the exposure was not reported. These researchers concluded that the LD_{50} would lie somewhere between 26.7 ºC (80 ºF) and 29.4 ºC (85 ºF) and suggested that the exact figure would depend on pre-conditioned temperature.

Klauda *et al.*,(1991a) used Stier and Crance's analysis and new information on field surveys of American shad to develop habitat requirements for the Chesapeake Bay area. The summary of habitat requirements listed in Table 5.7.4-2 is a duplication of the published summary.

Table 5.7.4-2 Klauda *et al*. (1991)
Habitat Suitability for American Shad Larvae and Juveniles
In the Chesapeake Bay Area:

Life Stage	Temperature
Larva	15.5-26.1 ºC (59.9 - 79 ºF)
Juvenile	15.6-23.9 ºC (60 - 75 ºF)

Klauda *et al*., recommend a maximum temperature of 23.9 ºC (75 ºF) to ensure habitat quality for juvenile American shad. The authors cite Dovel, 1971, on early life stages of shad in the Upper Chesapeake Basin where larvae and juveniles were collected. Temperatures over which fish were collected ranged from 10-25 ºC (50-77 ºF); 93% of the fish collected were taken at 21 ºC (69.8 ºF), possibly indicating that cooler temperatures were preferred. Although the authors cite another study (Marcy and Jacobson, 1976) in which young shad were able to avoid effluent temperatures greater than 30 ºC (86 ºF) by swimming below the plant outfall, the maintenance of high temperatures in the upper water column of the lower basin could possibly keep juveniles from feeding at depths where they can see their prey. Recommendations of Klauda *et al*., are for maintenance of habitat. The maximum value recommended by Klauda *et al*. (1991a) for juvenile shad habitat 23.9 ºC (75 ºF) is the same as the maximum recommendation of Stier and Crance for a suitability index of 1.0.

Recommendations of Klauda *et al*. (1991a) for temperature requirements of American shad juveniles are much lower than those recommended by the same authors (Klauda *et al*., 1991b) for alewives. The authors' recommendation for alewife juveniles is 28 ºC (82.4 º F), while that for shad is 23.9 ºC (75 ºF), about 4 ºC (7.4 ºF) lower.

The U.S. Fish and Wildlife Service Suitability Index value for eggs and larvae of bluebacks and alewives reports a value of 27 ºC (80.6 ºF) as the daily average temperature where suitability is zero. Larval alewives are primarily expected to be upstream of the Watertown dam, but some are also expected downstream. Most bluebacks are expected to remain in the lower basin as are any shad that might spawn below the Watertown Dam. The mid-point for 50% habitat suitability of blueback eggs and larvae (Pardue *et al*., 1983) is 25.5 ºC (77.9 ºF, approximately 78 ºF) as a daily average. By comparison, water temperatures in excess of 26.7 ºC (80.1 ºF) were found to be unsuitable for hatching of eggs and eventual development of Atlantic shad larvae (Bradford *et al*, 1966). As shad and blueback larvae are expected to be present about the same time, the 25.5 ºC (approximately 78 ºF) temperature should be considered for the period of larval occurrence of these two species.

5.7.4c Protective Temperature For American Shad Egg Stage

Based on a review of the scientific literature discussed above, water temperatures in excess of 26.7 ºC (80.1 ºF) were found to be unsuitable for hatching of eggs and eventual development of Atlantic shad larvae (Bradford *et al*, 1966). As stated previously, the factors precluding shad propagation in the lower basin must be understood with more certainty and measures must be taken to mitigation of one or more of these factors. Once one or more of these steps is underway or accomplished, as determined by EPA and DEP and there is increased confidence that the reestablishment of American shad is feasible, this protective temperature will be established as a permit condition for Kendall Station.

5.7.4d Protective Temperature For American Shad Larval Stage

Based on a review of the scientific literature discussed above, 25.5 ºC (78 ºF) was selected as the maximum temperature that would be protective for American shad larvae. As stated previously, the factors precluding shad propagation in the lower basin must be understood with more certainty and measures must be taken to mitigation of one or more of these factors. Once one or more of these steps is underway or accomplished, as determined by EPA and DEP and there is increased confidence that the reestablishment of American shad is feasible, this protective temperature will be established as a permit condition for Kendall Station.

5.7.4d Protective Temperature For American Shad Juvenile Stage

The primary sources of information used in developing site-specific criteria for consideration with regard to juvenile American shad are summarized below:

Temperatures above 23.9 ºC (75 ºF) have been shown to result in major community alterations in lentic zooplankton communities (Moore, 1996). Since the lower basin is likely to have impoundment like characteristics in the summertime, due to very low flows, it may be expected that the zooplankton community in the lower basin, will be altered when long-term temperatures

(7 days or more) average above 23.9 ºC (75 ºF). Zooplankton in the lower basin is most likely the food base of larval and juvenile alosids, including American shad.

Recommendations of the U.S. Fish and Wildlife Service (Stier and Crance, 1985) for 50% habitat suitability are 26.7 ºC (80 ºF) for juvenile shad and 25 ºC (77 ºF) for 50% suitability of habitat for alewife juveniles. The U.S. Fish and Wildlife maximum temperature for optimum growth of alewife juveniles is 20 ºC (68 ºF); that for zero suitability is 30 ºC (86 ºF) where heat shock has been observed in peer reviewed laboratory studies (Otto *et al*., 1976) although heat shock has also been seen at 29.4 ºC (85 ºF).

The maximum temperature recommendations for juvenile American shad habitat in the Chesapeake Bay region (Klauda *et al*., 1991) is 23.9 ºC (75 ºF); the comparable figure for alewives is 28 ºC (82.4 ºF).

There is scant data on avoidance temperatures for alosids. The U.S. Fish and Wildlife Service publication states that juvenile alewives avoided temperatures above 25 ºC (77 ºF), but no primary reference is provided for this figure. It should be considered that the 26.7 ºC (80 ºF) figure might be too high: it is 3ºF higher than that recommended for alewife juveniles and 5 ºF higher than that recommended for the Chesapeake. The Chesapeake figure appears to be based on preferred temperatures, but the avoidance temperature for alewife juveniles might be close to this figure. MRI's seining data for the lower basin is inconclusive, as there is question regarding the species caught. The highest ambient water temperatures at which bluebacks were caught (data available to date) was about 26.7 ºC (80 ºF), and this value was probably an instantaneous temperature. A lower temperature might be appropriate if a daily average were used, but it must be considered that there may be fairly wide temperature fluctuations at the surface if a daily average were used. If the criterion of 26.7 ºC (80 ºF) this should allow American shad juveniles, along with most alosid juveniles, to feed at or near the surface during most of the diel cycle.

Based on a review of the scientific literature discussed above, 26.7 ºC (80 ºF) was selected as the maximum temperature that would be protective for American shad juveniles. As stated previously, the factors precluding shad propagation in the lower basin must be understood with more certainty and measures must be taken to mitigation of one or more of these factors. Once one or more of these steps is underway or accomplished, as determined by EPA and DEP and there is increased confidence that the reestablishment of American shad is feasible, this protective temperature will be established as a permit condition for Kendall Station.

5.7.4e   Time Period For American Shad Life Stages

American shad begin to spawn in natural systems when river water temperatures reach about 12 ºC (54 ºF) and spawning ends when temperatures exceed 20 ºC (68 ºF) (Weiss-Glanz *et al*., 1986). In the Connecticut River, shad juveniles (>35 mm fork length) begin to appear in state of Connecticut waters as earl as late June and are found in abundance by mid-July (Thomas Savoy, CT DEP, Division of Marine Fisheries, pers. comm. to G. Szal, June 11, 2002). Since larvae take about 4-5 weeks to transform to juveniles, larvae should be appearing in the Connecticut River in mid-May. In the absence of additional information, it may be assumed that the appearance of larvae and juveniles in the Charles River is similar in timing to that in the Connecticut River. Based on this information it appears that larvae would need protection from May 15th to June 30th, and that juveniles would need protection from June 15th through the end of October.

As stated previously, the factors precluding shad propagation in the lower basin must be understood with more certainty and measures must be taken to mitigate of one or more of these factors. Once one or more of these steps is underway or accomplished, as determined by EPA and DEP and there is increased confidence that the reestablishment of American shad is feasible, these protective temperatures and corresponding time periods will be established permit conditions for Kendall Station.

5.8 Temperature Limits

5.8.1 Temperature Limits and Time Periods for Zone of Passage and Habitat Based On All Fish Species

5.8.1a Most Sensitive Temperature Limits And Duration

Protective temperature limits and time periods for the most sensitive resident species (Section 5.6) and the most sensitive anadromous species (Section 5.7) were combined and organized by month, beginning in January, to obtain an overall picture of the protective temperatures required in the lower Charles River Basin over the course of a year. When two different temperature limits were identified for the same time period, the lowest protective temperature was used as the permit limit, for as long as it applied. Figure 5.8.1-1 represents this information. The life stages being protected are also identified in the figure. Table 5.8.1-1, which is also listed as Attachment A of the NPDES draft permit package, lists these temperatures and the real time monitoring stations in the lower basin where compliance will be established. As more site-specific field data is collected from the lower basin, these temperature limits, time periods and station locations may be modified.

5.8.1b American Shad Protective Temperatures

Also presented in Figure 5.8.1-1 are the protective temperature limits identified for American shad. The basis for these limits is presented in Section 5.7.4. Based on the discussion of thermal tolerances of different life stages of American shad (Section 5.7.4) it seems likely that the addition of waste heat to the lower basin is one of the factors influencing the presence of American shad. However, this is not the only environmental factor that may be affecting the abundance of American shad in the lower Charles River Basin.

5.8.1c Percentage Of Habitat Where Thermal Limits Must Apply

The thermal limits identified for the most sensitive resident and anadromous species, based on the biology of the fish species present in the lower Charles River Basin, are established to maintain aquatic habitat in the lower basin that is deemed sufficient to protect these species and allow the propagation of the balanced indigenous populations (BIPs). It is desirable that the maximum volume of the basin practicable should maintain temperatures at or below the protective thermal limits. Since Kendall Station operation may not allow 100 % of the lower Basin to meet these protective temperatures, a minimum volume of the basin was identified where protective thermal limits must not be exceeded in order to protect the BIP. Much discussion and deliberation with the permittee and the Agencies, including MADEP, MACZM, MA DMF, MDC, and NOAA Fisheries, was undertaken to quantify this minimum acceptable volume in the lower Charles River Basin. Because some thermal effects in the immediate area of the discharge would pose acute effects to drifting organisms, these limits do not represent a mixing zone as defined by the DEP mixing zone policy (314 CMR 4.03 (2)). A fundamental component of any protective management plan is to maintain a sufficient avenue or zone in the water body with a suitable habitat to allow the migration or free movement of fish or other aquatic life. In consultation with the agencies noted above in the permit evaluation, EPA and DEP have determined that sound environmental management directs that a minimum of 50% of the lower basin, measured at any cross section from the Zone Boundary Transect, (a transect just just upstream of the Longfellow Bridge), to the New Charles River Dam and Locks, would be a prudent minimum area where the protective thermal limits of the permit must be maintained. The Zone Boundary Transect was identified by the permittee as the location in the basin of the upstream edge of a proposed zone of mixing (Mirant Kendall, February, 2001).

In order to achieve the requirement of a prudent minimum area where the protective limits must be maintained, a minimum of 50% of any cross sectional, bank-to-bank area of the lower Charles River Basin must meet the protective thermal limits. While there is some flexibility regarding the shape of the protected area, it must always include certain monitoring points considered important for habitat protection and representative of the bounds of this area, as shown in Draft Permit Attachment D. Therefore, temperatures at these monitoring points must be at or below the protective water temperature limits stated in the permit. When, as a minimum, this much of the aquatic habitat meets the biologically based thermal limits, it is judged that the BIP will be protected. This thermally protected portion of the aquatic habitat is referred to as the Zone of Passage and Habitat (ZPH) and is formally defined as the contiguous volume of the lower Charles River Basin where water temperatures are at or below the thermal limits in effect on a particular day, while also meeting criteria of the State Water Quality Standards (e.g. dissolved oxygen ≥ 5 mg/l). The lower Basin must always maintain a thermally protected ZPH that will never make up less than 50% of the volume of the lower Charles River Basin, from the Zone Boundary Transect to the New Charles River Dam and Locks, to support the protection and propagation of the BIP.

Stated another way, the permit allows up to 50% of the cross section of the lower Charles River Basin, from the Zone Boundary Transect to the New Charles River Dam and Locks, to reach temperatures which could cause an avoidance reaction, a reduction in growth or reproductive potential, or even death to aquatic life, as long as a certain near-surface section of the Boston side meet protective temperatures. Further, the monitoring points that verify that 50% of the cross section meet the temperature limits must be contiguous.

Vital habitat that has been identified as part of the near surface water column must not be entirely eliminated from the ZPH by allowing less dense, higher temperature water to “float” in a layer on the surface and occur from bank to bank for long periods of time (See Section 5.10.4 for supporting information). To ensure these near surface water layers do not consistently maintain temperature readings above protective limits, the two (2) foot depth water quality Monitoring Point at Station 3 (closest to the Boston shore), as well as the six (6) foot depth water quality Monitoring Points at both Station 3 and Station 4, must meet the temperature limit established for the ZPH for that time period, regardless of the size of the ZPH (see Section 5.10.3b and 5.10.4). This requirement will be in effect throughout the time period that anadromous fish are present in the lower basin. The time period is from April 15 through October 31.

Resident species of the lower basin also occur throughout the water column and must be guaranteed access to near surface waters in the ZPH. To ensure at least a part of the upper water column does not thermally exclude resident species, the temperature readings of the two (2) foot depth water quality Monitoring Point at Station 3 (closest to the Boston shore) must meet the temperature limit established for the ZPH for that time period, regardless of the size of the ZPH (see Section 5.10.3b and 5.10.4). This requirement will be in effect to ensure that resident species are not completely excluded from the near surface waters by high water temperatures from November 1 through April 14.

Conversely, a Zone of Dilution (ZD) will also be allowed in the lower Charles River Basin as part of the thermal variance. The ZD is defined as the volume of the lower basin where biologically based, protective water temperatures are exceeded. At no time will the ZD take up more than 50% of the volume of the lower basin from the Zone Boundary Transect to the New Charles River Dam and Locks . Verification of the 50% minimum volume requirement of the ZPH, will be achieved through an in-situ, real-time, continuous water quality monitoring and compliance program, using fixed monitoring stations positioned at several key locations in the receiving waters of the lower Basin. An array of temperature and dissolved oxygen monitors, evenly spaced vertically and horizontally along the cross sectional area of the lower basin transect determined likely to be most influenced by the thermal plume from the Kendall Station, will be a compliance transect which will document that the ZPH characterizes a minimum of 50% of the river. If at least half of the Monitoring Points along this transect (In-Zone Transect) meet the maximum temperature limit, and these points are all adjacent to each other, then at least 50% of the cross-section of the river at this transect will meet the ZPH characteristics. In this case, monitoring points are considered adjacent or contiguous to one another if they are not separated by a monitoring point that does not meet the thermal limit in effect. Specific information regarding the placement of the in-situ, real-time monitors in the lower basin is included in Section 5.10. A detailed narrative of how the temperature limits are applied to the lower basin is included in Attachment A of the permit.

5.8.2 Temperature Limits Relating to Delta T

5.8.2a Definition Of Delta T Based On State Surface Water Quality Standards

Regarding the magnitude to which receiving waters can be heated by a man-made discharge, Massachusetts State Water Quality Standards set maximum delta T (ΔT, change in temperature) values of 1.7 ºC (3 ºF) and 2.8 ºC (5 ºF) for lakes and rivers, respectively for a Class B Warm Water Fishery. The ΔT is considered the difference between the temperature of the water receiving the thermal discharge and the unaffected, ambient stream temperature, represented by an upstream temperature. For the most part, the lower basin adjacent to Kendall Station is impoundment-like, meaning that it is relatively wide and deep, with a reduced flow compared with upstream reaches of the lower Basin. Because it generally possesses low flow characteristics, one could argue that requiring a maximum ΔT of 1.7 ºC (3 ºF) would be an appropriate approach and be in keeping with State Water Quality Standards, to ensure the protection and propagation of the BIP residing in this Class B body of water. However, since the overall reach of the lower Charles River Basin is identified as a river, the more conservative ΔT of 1.7 ºC (3 ºF) will be set aside and the river water quality standard ΔT of 2.8 ºC (5º F) will be used as a protective guidance limit in the following ΔT discussion. Because the permittee most likely would be unable to meet a ΔT of 2.8 ºC (5 ºF) at the point of discharge, or at the boundary of a mixing zone conforming to water quality standards, a 316(a) thermal variance, as allowed under the Clean Water Act, has been requested by the permittee and granted under the conditions of this NPDES permit.

5.8.2b Permittee's Approach to Delta T Limit

5.8.2b-1 Permittee's Original Proposal

The permittee, Mirant Kendall, as part of their original NPDES application submitted in February of 2001, initially outlined a thermal discharge approach designed to meet the DEP mixing zone policy (314 CMR 4.03 (2)) "during the entire spring migration, the majority of the time throughout the fall, and throughout the winter" (Mirant NPDES Application, p. 1-5, February 2001). As part of this operational approach, Mirant proposed that Kendall Station would meet a ΔT of 2.8 ºC (5 ºF) at the edge of a proposed mixing zone, by setting an alert reporting level when daily maximum temperatures exceeded a ΔT of 2.2 ºC (4 ºF) at mixing zone boundaries, and an action threshold when the ΔT of 2.8 ºC (5 ºF) is reached at the mixing zone boundaries (Mirant NPDES Application, Table 1-3, February 2001). Much discussion regarding a protective ΔT has taken place between the permittee and the agencies since the initial NPDES application was submitted. While a mixing zone as described in the Massachusetts Surface Water Quality Standards Implementation Policy for Mixing Zones (January 1993) is not included as part of the draft permit, this ΔT component at the edge of a zone of dilution was consistently supported by the agencies and is adopted into this permit as a 316(a) variance condition necessary to protect the BIP.

In addition, the permittee has submitted thermal projections for the lower Charles River Basin that show that "the percentage of [river volume] above the 2.8 ºC (5 ºF) water quality standard for ΔT is negligible" (Mirant Correspondence and Attachment, September 13, 2001). The permittee also presented a graph, listed here as Figure 5.8.2b-1, depicting that less than 1% of the volume of the lower basin would contain temperatures greater than 2.8 ºC (5 ºF) above ambient conditions during the warm weather month of August. As discussions with the permittee continued, the permittee modified their position on the issue of limiting a ΔT to 2.8 ºC (5 ºF).

5.8.2b-2 Permittee's Modified Proposal

Mirant subsequently submitted field data showing river herring distributed in a water column within which the temperature varied between 2.8-4.5 ºC (5-8 ºF), from surface to bottom. The permittee used this information to support the position that "a ΔT limit of less than 8 ºF in the modified permit is not warranted..." (Mirant Letter, November 5, 2002). However, EPA and DEP are not convinced that sampling a water column with a gill net and collecting the same species of fish at different depths possessing different temperatures along a 4.5 ºC (8 ºF) vertical gradient is sufficient evidence that the individual fish collected had traveled between water column layers of different temperatures and were routinely exposed to a 4.5 ºC (8 ºF) change in temperature. It is possible that each adult river herring collected under these conditions may have sought individual temperature layers that they separately preferred, based on size, or overall condition. The fish collected may have remained at their respective temperature layers for the majority of the time. Also, vertical profiles for temperature were not taken periodically throughout the extended time period that the gill net was deployed. During this 12 or 24 hour deployment period, when the gill net was "fishing," it is possible that the relative depth and thickness of water temperature layers may have changed. Under this scenario, the fish that were captured in the gill nets may have been following water of a certain temperature that then changed once they were captured. Therefore, these fish could no longer move in the water column to follow their preferred temperature. In the absence of additional information, EPA and DEP do not consider the gill net data to represent a compelling argument to raise the ΔT above 2.8 ºC (5 ºF).

In a letter submitted by the permittee on January 9, 2003, a similar argument was once again made that under stratified lower basin conditions, fish have been documented to face vertical temperature differences of 8.4-10.1 ºC (15-18 ºF), based on a maximum temperature difference measured between a depth of 6 feet and a depth of 18 feet in the lower basin on August 1, 2002. As stated above, EPA and DEP see no evidence that fish willingly travel across these depths and routinely experience these extreme temperature changes. While it has been observed that fish will leave one temperature strata and swim deeper or toward the surface when other strong instincts come into play (in pursuit of prey, to escape predators, or to seek desirable light levels, for example) this vertical movement is not without stress. Fish that become exposed to thermal stress because they are driven to pursue prey, escape predators or seek a more favorable habitat despite their thermal preference, may successfully respond to the thermal stressor or may experience chronic or acute effects resulting from the movement. There is expected to be a wide range of response based on individual variability and age, life stage and overall condition of the fish The existence of a vertical temperature difference above 2.8 ºC (5 ºF) in stratified depths of the lower basin (possibly with the contribution of Kendall Station operation) is not convincing evidence that a man-made increase in temperature greater than 2.8 ºC (5 ºF) is protective.

In the January 9, 2003 document, Mirant also proposed a ΔT gradient based on three upstream/downstream spatial blocks. Monitoring Station 1 (near the Boston University Bridge) temperatures would be compared with Monitoring Station 2 temperatures; Station 2 temperatures would be compared with the average of Monitoring Station 3 and 4 temperatures; and the average of Station 3 and 4 temperatures would be compared with Monitoring Station 8 temperatures (See Figure 5.8.2b-2 and Section 5.10.2 for Monitoring Station locations). All comparisons would be made with monitors located at a depth of three feet, and each comparison was proposed to maintain a ΔT no greater than 2.8 ºC (5 ºF). Under low flow conditions, and assuming a wide upstream and downstream spread of the thermal plume, when the ambient upstream temperature of the Charles River (Station 1) is compared with the furthest downstream ΔT measuring point at Station 8, this protocol could theoretically result in a combined, overall ΔT of 8.4 ºC (15 ºF). Mirant's argument supporting this approach maintains that it is more biologically relevant to space out the ΔT zones, since fish are not likely to travel past all three zones (nearly a three mile distance) within a relative time frame. EPA and DEP disagree with this approach to define the ΔT. This view is based partially on results of the alewife sonic tracking study conducted by the permittee. While this study did not involve a large number of fish (28 fish in 2002, with complete tracking records for 20 of those fish), there were indications that some number of fish attempting to travel upstream past the Kendall Station thermal plume were able to swim from the area of the New Charles River Dam past the Harvard Bridge in a relatively short time period. For example, one fish was located at Cambridge Station at 11:00 am and Harvard Station at 11:24 am, while another fish was located at Cambridge Station in the morning and Harvard Station by the afternoon (MRI Charles River Sonic Tracking Study, February 6, 2003). Also, under high river flow conditions in the basin, when the thermal discharge plume is more compact and oriented downstream, the rationale for separating the ΔT monitoring into three blocks is no longer applicable.

5.8.2c Delta T Discussion Based On Scientific Literature Review

The ΔT limit of 2.8 ºC (5 ºF) has been generally accepted as a reasonably protective thermal limit, and has been included in numerous NPDES permits and state water quality standard regulations. However, Mirant Kendall has questioned this limit and proposed a ΔT for the lower Charles River Basin outside of a zone of dilution that is overall greater than this widely accepted limit. Site-specific arguments made by the permittee were briefly referenced in the preceding section. EPA and DEP remained concerned about a number of biological effects associated with significant spacial and temporal temperature changes which are potentially detrimental to the BIP of the lower basin. A discussion of some of these biological effects to fish is presented below, based on scientific literature.

5.8.2d Charles River Features That Contribute To Thermal Stress of Migrating Anadromous Fish

Because the New Charles River Dam separates the Charles River from the ocean, fish moving into or out of the Charles River experience a substantial change in temperature in moving from one system to the other. This issue is also discussed in Section 5.4.2 of this document. Heated water, discharged from Mirant Kendall's facility, increases the temperature differences between the two bodies of water and increases the potential for thermal shock to anadromous fish.

Mirant's discharge location near the mouth of the lower Charles River Basin can be problematic for anadromous fish entering the system. Because the Charles River is separated from the marine environment by the New Charles River Dam, there is no estuary for the lower Charles River Basin. In more natural systems, an estuary plays an important role as the zone where fresh water and salt water mix, resulting in a pronounced area with intermediate salinity and temperature characteristics. Migratory fish, such as river herring and shad, that move between marine and freshwater are able to "stage" in the estuary. During staging, they slowly acclimate to changes in both salinity as well as temperature prior to both moving upstream to spawn and moving back to the sea. This action minimizes physiologic stress. Increased levels of physiologic stress caused by a poor or degraded staging area can result in compromised functional responses or even death. Fish that are subjected to this stress may be more vulnerable to predation or may halt migration.

During the spring, if flows are high, there may be some limited degree of staging taking place at the outlet of the New Charles River Dam. However, the locks are not continuously kept open during this time and fish on the Boston Harbor side of the dam will likely be exposed to fluctuating salinity and temperature. In addition, if springtime flows are low, tidal flushing could quickly eliminate a staging area. Thus, as fish enter the locks, the change in temperature as well as salinity may be both sudden and substantial. Due to the abnormalities imposed on the system because of the dam, even without the added heat discharged from Kendall Station, temperature differences between ocean and freshwater may be having a negative effect on the survival and reproductive success of in- and out-migrating fish.

Other environmental factors can cause this rapid change in temperature which fish in the lower basin are exposed to as they move past the dam. For example, the exposure of alewife to rapidly changing temperatures from the effect of warm summertime temperatures on shallow shoreline areas has been documented in the Great Lakes. A review of the effect of rapidly changing temperature on this land locked species may assist in the evaluation of temperature changes on Charles River anadromous species and is presented below.

5.8.2e Effect Of Temperature Change on Great Lakes Alewife Populations

Alewife population crashes in the Great Lakes have been associated with rapid changes in temperature. In Lake Ontario there are massive, annual die-offs of landlocked alewife adults in the spring. Miller (1930) noted that "in many instances a large mortality has followed a day of complete calm and high temperature." During the spring and early summer, there is an invasion of warm shoal waters to the depths where alewives occur. Changes in water temperature at these depths can be sudden due to offshore winds.

Alewives are not indigenous to the Great Lakes, but found their way into these waters through the system of canals and locks installed for boat traffic in the St. Lawrence Seaway from the Atlantic Coast. Because alewives did not evolve in the Great Lakes, the ability of alewife to adjust to temperature fluctuations encountered in these waters during springtime spawning events appears to sometimes be minimal. In a similar fashion, the ability of this species to survive abnormally-large temperature changes, such as those upstream and downstream of the New Charles River Dam where thermally-enhanced waters exist above the dam, may also be an area of concern.

Graham (1956) linked the population crashes in Lake Ontario to the alewife's inability to adjust to abrupt changes in temperature. He found that the ΔT tolerated by adult alewives gets increasingly smaller as the acclimation temperature increased to 20 ºC (68 ºF). The 20 ºC (68 ºF) value is important, as most spawning of alewives in the Great Lakes takes place in shallows prior to the time when water temperatures reach 20 ºC (68 ºF). The 68 ºF temperature that induced LC_{50s} in Graham's work is very close to the temperature marking the final days of most alewife entry to freshwater spawning streams in Massachusetts and New Hampshire. DEP accessed data from 34 river herring runs in Massachusetts and New Hampshire. For the sixteen runs (one run per year on each of the Monument, Parker and Lamprey Rivers) known to be comprised only of alewives, 99% of all fish passed when water temperatures were below 20 ºC (68 ºF). In addition, 95% (averaged across all runs) of the river herring for each of the 34 runs passed at temperatures of 18.3 ºC (65 ºF) or less. Work conducted in Rhode island (Richkus, 1974) supports the above: over 95% of adult alewives entered the spawning run in the Annapatucket River, Kingston, RI at temperatures below 20 ºC (68 ºF).

Graham correlated the die-offs with field observations of large temperature fluctuations and he postulated that adult alewives were unable to withstand the ΔT incurred. Subsequent laboratory evaluations on temperature tolerance (see Table 5.8.2e-1) bolster his hypothesis. Populations of alewives also undergo die-offs in certain areas of Lake Michigan during the spring and early summer. Otto *et al*. (1976) conducted experimental work similar to that by Graham on alewives from Lake Michigan.

The results of ΔT effects observed by both Graham and Otto *et al.* are presented below. The acclimation temperatures listed in this chart are the temperature at which alewife adults were held (and acclimated) prior to exposure to test temperatures. The TL_{50} in these charts is the test temperature at which 50% of the test organisms died.

Table 5.8.2e-1: Heat Shock and ΔT
Data from Graham (1956) and Otto *et al*. (1976)

All Temperature Data in Fahrenheit

Acclimation Temperature	**TL_{50} Otto *et al*.***	**TL_{50} Graham**	**ΔT Incurred Otto/Graham**
50	74.3	68@ 108 hrs exposure*	24.3/18
59	74.3	73.4 @ 90 hrs exposure	15.3/14.4
68	76.1	73.4 @ 80 hrs exposure	8.1/ 5.4

*Exposure-duration data were not available for TL_{50s} from Otto *et al*.'s work.

It should be noted that although final TL_{50} data differ in the two data sets, ΔTs producing 50% mortality (ΔT Incurred) in both data sets become increasingly smaller as the acclimation temperature approaches 20 ºC (68 ºF).

Results above show only LC_{50} data. Other effects may have been observed but not reported. Temperatures that would cause no effect to alewife from Otto's research were, in general about 1 ºC (1.8 ºF) lower than LC_{50} values. By contrast, Coutant (Natl. Acad. Sci./Natl. Acad. Eng., 1972) found that a 2 ºC (3.6 ºF) buffer between LC_{50} data and a No-Effect level was common for most fish. Taking Coutant's research and Otto's results into consideration, a temperature of 1.1 ºC (2 ºF) (slightly higher than 1 ºC but less than 2 ºC), lower than LC_{50} data above is considered to be one estimate of an acceptable ΔT.

Differences in results of Otto *et al*. and Graham may stem from the fact that fish used by Otto *et al*. came from the discharge canal of a power plant (in Waukeegan Illinois) and were acclimated to higher temperatures. Fish used by Graham were taken directly from natural populations in Lake Ontario (Port Credit, Ontario). In addition, transfer to test temperatures was abrupt in Graham's study while Otto *et al*. changed temperatures 0.3 ºC /min. in the test chambers. Therefore, fish entering the Charles will not have been acclimated to artificially high temperatures as they were Otto *et al.'s* work. In addition, the change in temperature from Boston Harbor to the Charles River will be abrupt. Thus, it is assumed here that Graham's data are the more relevant of the two data sets when evaluating conditions in the Charles.

Mirant has questioned whether or not studies conducted in the Great Lakes would be applicable to Massachusetts due to: a) potential latitudinal differences in stock genetics which could alter temperature tolerance; b) the lack of movement by fish in the Great Lakes between the sea and freshwater; and c) earlier maturation of alewives from the Great Lakes. Each of these is discussed below as latitude, salinity, and age, respectively.

Latitude: The latitude of Waukeegan Illinois where Otto *et al*. took their alewives for the experiments is comparable to Massachusetts; the latitude of Port Credit Ontario where Graham obtained fish for his experiments is comparable to the southern side of Lake

Winnepesaukee, NH. Thus, latitudinal difference in temperature tolerance does not appear to be an issue.

Salinity: Organisms that are undergoing stress from changes in one variable are often less able to tolerate stress from another. As a result, combined effects of salinity and temperature changes should make Charles River populations less able to tolerate temperature changes than fish in the Great Lakes. Fish moving between the ocean and the Charles undergo a rapid change in salinity that creates an abnormal stress on their renal (kidney) system. This appears to be a significant concern with regard to American shad (see below). Alewife adults and juveniles appear to withstand salinity changes without effect (Richkus, 1974) but information regarding combined effects of salinity and temperature changes on alewives do not appear to be available. Because abrupt changes in salinity are expected to worsen the ability of fish to tolerate temperature changes, it seems reasonable to assume that ΔTs inducing LC_{50s} in Graham's and Otto *et al*.'s experiments are minimum values and that ΔTs smaller than those observed by Graham and Otto may induce mortality to ocean migrants into freshwater.

Age: Otto *et al*. also conducted thermal tolerance studies of young-of-the-year alewives. These fish were able to withstand greater increases in temperature than were 14-16 cm adults. No data appear to be available for larger adults, which are typical of those seen in the Charles. However, it seems unreasonable to expect that the trend seen by Otto *et al.* between young-of-the-year and adults (i.e., decreasing tolerance to increases in temperature with age) is reversed as adults increase further in size. Thus, data from Otto *et al*. and Graham should not be discounted due to concern over age-related differences.

5.8.2f Effect Of Temperature Change on East Coast Alewife Populations

Large-scale mortalities of alewives are not limited to the Great Lakes. Cooper (1961) studied sea-run alewives that migrated in and out of the Pausacaco Pond and river area in Rhode Island. During the period that they were studied, about 3/8 of the in-migrants to this system failed to out-migrate and were supposed dead. Cooper linked the loss of late-migrating adults alewives to Graham's research on ΔTs:

> "mortality of salt water alewives in the Pausacaco Pond and river area could be due to either the inability of the alewife to acclimate rapidly to rising or fluctuating temperatures..., or the persistence of an upper lethal temperature within most of the pond area. There was a total of four days at the end of the spawning run when the water temperature exceeded 20 ºC (68 ºF) (upper lethal temperature of the fresh water alewife, Graham, 1956). This theory is supported by the observation in the field that expected numbers of returning, late migrants did not occur."

Cooper's observations and Graham's work suggest that in-migrating alewives are most susceptible to ΔT rises toward the end of the run. As freshwater temperatures approach the 20 ºC (68 ºF) mark, a rapid change of temperature of just 2.8 ºC (5 ºF) could result in a loss of over half the adults exposed.

Controlled laboratory studies on east coast fish species appears to show that alewives can tolerate much greater ΔTs than is seen in work presented above. Temperature-tolerance laboratory experiments were conducted by Ecological Analysts (EA) (1978) on a wide variety of fish for several electric companies in support of 316(a) demonstrations. Their data (which was not peer-reviewed) suggest that much higher ΔTs can be tolerated by in-migrating adults. For this study, EA collected adult fish from the Delaware River. The 96-hr LC_{50} was 28.4 ºC (83.1 ºF) for fish acclimated to 14.5 ºC (58.1 ºF). This value is 5 ºC (9 ºF) higher than the values reported by Otto *et al*. (1976) and Graham (1956) and is at least 5.6 ºC (10 ºF) higher than temperatures associated with large-scale adult mortalities witnessed by Cooper in RI fish. Latitudinal differences between the Delaware River fish and those studied by the other three research groups mentioned may at least partially account for the differences in thermal tolerance mentioned. To migrate up the Delaware River, alewives must enter the mouth of Delaware Bay, which is at about the same latitude as the upper portion of the beltway around Washington D.C. Thermal requirements of this population may be quite different than those from Rhode Island or more northern populations.

American shad, another species being considered for protection through the 316(a) evaluation, are also expected to encounter difficulties negotiating the entry into the Charles. These fish have not been found in any appreciable number in the Charles. Shad have been shown to encounter substantial problems in moving to freshwater systems if they are not first allowed a short acclimation period. Leggett and O'Boyle (1976) found that a rapid decrease in salinity accompanied by a 5-6 ºC (9-10.8 ºF) temperature increase caused significant mortality in American shad. In laboratory studies, other researchers (Dodson *et al*., 1972) have documented that American shad need about 1-2 days within the saltwater-freshwater interface to physiologically adjust to the change in osmolarity associated with the springtime spawning run. As such, a substantial portion of the shad population may encounter osmoregulatory difficulties when moving into the Charles. High ΔTs, i.e., those exceeding the 5-6 ºC (9-10.8 ºF) rise used by Leggett and O'Boyle, would be expected only to exacerbate losses of in-migrating shad.

5.8.2g Springtime Delta Ts Across The New Charles River Dam

When an anadromous fish enters the Charles River from Boston Harbor, the depth the fish is found at when the passage lock opens may have a major impact on the magnitude of the ΔT the fish will experience. Marine Research Inc. (MRI), consultants to Mirant, have captured alewife adults throughout the water column (depths 1-8 m) via 24-hr, springtime (April 4-May 22, 2002) net-deployments after entering the lower basin. Blueback herring adults, another anadromous species, have also been captured throughout the water column (2-10 m) in the Charles. Based on literature information, these fish would be expected to be lower in the water column during the day and closer to the surface at night.

Alewives and bluebacks both seek to stay at light levels that are great enough to allow them to maintain a school through visual contact and selectively feed on large-bodied zooplankton, but low enough to keep their visual exposure to predators to a minimum (literature reviewed in Dixon, 1996). Alewife and blueback adults (and juveniles) have been found to move up and down in the water column in an "isoluine," a range of light intensity, over the course of a 24-hour cycle. Alewife adults have been found in fairly deep (60-80 fathoms; Bigelow and Schroeder, 1953), clear oceanic waters in the daytime, as well as near the surface at night. Blueback juveniles have been found at the surface during the day in turbid waters (Warinner *et al.*, 1970; Burbridge, 1974) but at much greater depths during the day in clear waters (Loesch *et al.*, 1982; Dixon, 1996).

Temperature data from a station in the Charles River and one in Boston Harbor were compared to evaluate temperature differences between the two systems in order to ascertain the potential for heat-shock and cold-shock to alosid adults migrating in and out of the Charles. Two Massachusetts Water Resources Authority (MWRA) stations were used for this analysis. The first of these stations, 006, is located in the lower Charles River Basin at the edge of the B.U. boathouse, downstream of the B.U. bridge. Near-surface (0.3 m depth) temperatures were used from station 006, rather than bottom temperatures, because there were more years of surface-water temperatures for this station than there were years in which bottom temperature data were collected. Temperature differences between surface (measured at 0.3 m) and bottom (measured at 3 m) were minimal throughout the two years when data were collected (see Figures 5.8.2g-1 and 5.8.2g-2) signifying that the water column was well-mixed at this station during those years. Station 006 was chosen to represent the reference condition prior to BTU input from the facility. A 2.8 ºC (5 ºF) ΔT was added to the 006 data to represent temperatures expected in the Zone of Passage and Habitat located along the Boston side of the Charles.

Temperature data from Station 006 were compared to bottom (8-12 m depth; Figures 5.8.2g-3 and 5.8.2g-5) and surface (0.3 m; Figures 5.8.2g-6 to 5.8.2g-8) temperature data from Station 014 in Boston Harbor. Station 014 is located about mid-channel in the section of Boston Inner Harbor that lies between the Charlestown Docks to the north and the Coast Guard Station near Boston's North End Beach to the south. ΔTs assumed to be encountered by anadromous fish are calculated as the difference between the expected temperature for Station 006 plus 2.8 ºC (5 ºF)(expected Facility ΔT in the Zone of Passage and Habitat) and the temperatures at Station 014. For the purpose of this analysis, it is assumed that temperature changed linearly between monitoring dates.

Currently, little is known regarding adult alewife, blueback or shad temperature acclimation prior to entry into the New Charles River Locks. In addition, only a small temperature database exists with which to evaluate ΔTs. Two approaches are used here. The first compares water temperatures at 8-12m depth from the Boston Harbor Station (014) to data from the Charles River Station (006). Because alewives typically migrate into freshwater in the afternoon (Cooper, 1961), it is likely that in-migrating fish from Boston Harbor are coming from deeper waters. Thus, using Station 014 data from 8-12m depths seems appropriate. The second method compares surface (0.3 m) temperature data from Station 014 to data from Station 006 and is assumed here to approximate the "best case" (i.e., least impact) scenario.

Based on Figures 5.8.2g-3 to 5.8.2g-5, in-migrating alewife adults would be expected to suffer from heat shock at certain times during the run. Data in this figure depict ΔTs experienced by alewives that acclimated to near-bottom temperatures in Boston Harbor and moved into the Zone of Passage and Habitat in the Charles. During in-migration over the years 1999 and 2000, ΔTs during certain periods of the run would have exceeded those considered to be "safe" (i.e., 9 ºC (16 ºF) ΔT when acclimated to 10 ºC (50 ºF) (see above)). During both years, when expected temperatures in the Zone of Passage and Habitat approached approximately 20 ºC (high 60's ºF), ΔT's were in the range of 11.2 ºC (20 ºF) in 1999 and 10.1 ºC (18 ºF) in 2000. If, during these years (or during 2001) alewife adults moved through the Zone of Dilution instead of the Zone of Passage and Habitat, it would be expected that they would have experienced a high mortality rate, even if they were to have first acclimated to temperatures in the Zone of Passage and Habitat.

Any increases in the allowable ΔT beyond 2.8 ºC (5 ºF) would increase the frequency and duration of those periods in which heat shock would be expected. If alewife adults acclimate to surface temperatures in Boston Harbor prior to moving into the Charles, ΔTs do not appear to be problematic (Figures 5.8.2g-6 to 5.8.2g-8). At least for the three years that data were available, ΔTs were within the range tolerated by alewives according to data from Graham and Otto *et al*. (Table 5.8.2e-1). However, if these fish swam into the Zone of Dilution, safe ΔTs during in-migration would have been exceeded.

5.8.2h Avoidance Behavior Likely Related To Delta T

The sensing of a pronounced change in temperature (ΔT) that is below a lethal effect may none-the-less still induce potential adverse behavioral effects on alewives. The effects could include preventing them from breeding. Cooper (1961) noted that a ΔT of 6.2 ºC (11 ºF) was associated with halted upstream movement of alewives and a return to brackish water. Fish experiencing this ΔT were moving from estuarine water that was in the 12-13 ºC range (50's ºF) into freshwater. Cooper states that on several occasions, the water temperature in the stream leading to the spawning pond varied as much as 6.2 ºC (11 ºF) in a twelve hour period. Adults encountering this warmer water would "immediately return to brackish water after being subjected to such a temperature change." Cooper states further that "most of these fish returned unspawned." Since the majority of late-spawning alewives are females, the loss of these fish to the spawning run has a much greater effect than had they been males, as one male can fertilize the eggs of many females.

Sonar-tracking of a small number of blueback herring by MRI, appears to show that some bluebacks may have trouble negotiating passage upstream of the portion of the basin generally influenced by the Kendall Station discharge Mirant Kendall . Some of the fish released above the New Charles River Dam wandered in the area downstream of the Mirant discharge for weeks

(MRI Charles River Sonic Tracking Study, February 6, 2003). It is unknown what percentage of alosid in-migrants are affected in this manner. The thermal plume from the station may play a leading role contributing to this observed behavior. Bluebacks are supposedly more tolerant of heat effects than the closely-related alewife. If bluebacks had problems navigating past the Mirant discharge due to the effects of the thermal plume, there is a concern that alewives would also have problems.

5.8.2i Cold Shock To Out-Migrating Adult Fish

An unknown proportion of the adult alewife stock, as well as the stocks of other anadromous species, have been documented passing the Kendall Station to breed in upstream waters. Out-migrating adults must make it past the Kendall discharge and its associated area of warming prior to entering Boston Harbor. Currently, the range in time that fish will linger in the area warmed by Kendall's discharge before they find their way out into Boston Harbor is unknown. During low-flow periods, fish may be disoriented and be unable to find an outlet due to a lack of physical cues, such as appreciable downstream river velocities. It is assumed here that during their outward migration the anadromous fish will acclimate, at a minimum, to temperatures in the Zone of Passage and Habitat. Some may acclimate to higher temperatures in the Zone of Dilution. To assess effects of cold-shock when these fish enter Boston Harbor, ΔTs between the Zone of Passage and Habitat and those in Boston Harbor are compared to cold-shock information from the literature.

Otto *et al*. (1976) conducted ΔT studies of alewives relative to cold shock. The data from these experiments are provided in Table 5.8.2i-1.

Table 5.8.2i-1: Cold-Shock Mortality in Adult Alewives from Lake Michigan Data from Otto *et al*., 1976

Acclimation Temperature	Test Temperature	Survival	"Safe" ΔT
5 ºC (42 ºF)	2.5 ºC (36.5 ºF)	0%	
10 ºC (50 ºF)	2.5 ºC (36.5 ºF)	0%	
	5 ºC (41 ºF)	30%	<5 ºC (<9 ºF)
15 º C (59 º C)	3 ºC (37.4 ºF)	10%	
	6 ºC (42.8 ºF)	60%	
	8.0 ºC (46.4 ºF)	100%	7 ºC (12.6 ºF)
21 º C (69.8 ºF)	5.0 ºC (41 ºF)	0%	
	6.0 ºC (42.8 ºF)	50%	
	7.0 ºC (44.6 ºF)	0%	
	8.0 ºC (46.4 ºF)	60%	
	10.5 ºC (50.9 ºF)	70%	< 10.5º C (<18.9º F)

Because the Charles River warms up faster than Boston Harbor in the springtime, out-migrants will most likely experience much greater ΔTs than they did when they entered the Charles. Early migrants may be more likely to undergo cold-shock on the way out of the Charles because ΔT inducing mortality from cold shock is much smaller at low acclimation temperatures than at higher acclimation temperatures.

5.8.2j Water Temperature Data from the Charles River and Boston Harbor

Out-migration temperature ΔTs (see Figures 5.8.2g-3 to 5.8.2g-5 and Figure 5.8.2g-6 to 5.8.2g-8) between the Charles River and Boston Harbor can be compared to those in Table 5.8.2i-1 to determine the possibility of cold shock to out-migrating alewife adults in the spring and early summer. Adults are expected to leave the system from April through June.

Upon leaving the Charles, alewives may move to deep waters or stay at the surface. If they migrate in the daytime, they would be expected to move to deep waters to stay within the preferred isolume; if they leave at night, they may remain in shallow waters until light levels increase. In 2001, out-migrants acclimated to 13.9 ºC (57 ºF). The ambient water temperature of the Charles in the second week of April would have encountered about an 8.4 ºC (15-16 ºF) drop in temperature upon entering Boston Harbor bottom waters (Figure 5.8.2g-5). Judging from Table 5.8.2i-1, about 40% of fish migrating to depths of 8-12 m in Boston Harbor would have succumbed to cold shock. Fish entering surface waters of Boston Harbor would have experienced about a 6.7 ºC (10-13 ºF) temperature drop, which would have induced mortality to a smaller portion of this group. Fish that had acclimated to temperatures in the Zone of Dilution would have experienced higher mortality rates. Years 1999 and 2000 would, likewise have been problematic to out-migrating alewives in the beginning of the season, but only if they returned to deeper waters in Boston Harbor. Late migrants, acclimated to 20 ºC (68 ºF) Charles River water in the third week of May, 1999, would have encountered an 11.2 ºC (20 ºF) drop in temperature when returning to Boston Harbor waters at depths of 8-12 m. In 1999, about the same time in May, fish making this trip likely experienced about an 10.1 ºC (18 ºF) drop. Judging from Otto's work, these temperature changes had the potential to be lethal to about 30% of the fish making the trip each of the two years mentioned. Those out-migrating to surface waters of the Harbor were likely expected to survive the drop in temperature.

Under these conditions, it is unknown whether fish would be aware of excessive changes in temperature that are physiologically stressful and whether they would avoid ΔTs that may cause them harm. Such conditions include: 1) dam location at the mouth of the Charles– fish may not be able to sense the entire change in temperature that they will be exposed to until they are released from the locks into the Charles; 2) out-migrants will have no way to determine the extent of temperature changes they will experience until they have committed to moving out of the Charles back to sea; 3) in-migrating fish moving up the Cambridge side of the lower basin may be trapped due to environmental changes (wind intensity or direction change, for example) which could alter temperatures along the wall, in a similar fashion to alewives that undergo massive die-offs in the Great Lakes; 4) alternatively, these in-migrants may be drawn towards the wall discharge because they sense the velocity of the plume and are searching for a current to swim against; 5) lastly, when periods of low flow exist in late spring, fish may not be able to navigate upstream due to very low river velocities. These fish could easily wander into the Zone of Dilution and become unable to find a way out. Kendall's bottom diffuser discharge, if approved, could mix the water column to the extent that moving below the plume from the Cambridge side becomes impossible for anadromous fish.

Alewife adult fish kills due to cold shock will be difficult to evaluate and will probably go unnoticed. Cooper (1961) noted that alewife adults sink when they expire. Due to poor visibility in the Charles, kills due to heat shock would not likely be detected either. In the marine environment, benthic scavengers typically abound and could quickly consume alewives that succumb to cold shock. This action, coupled with poor visibility in Boston Harbor, would render all but fairly intensive diver surveys inadequate to document cold-shock kills of out-migrating alewives.

5.8.2k Other Potential Effects Of Springtime ΔTs:

Allowing a ΔT of 2.8 ºC (5 ºF) in the Zone of Passage and Habitat advances the season of in-migration by about two weeks, on average, based on available MWRA data (range: 1.5 to 3 weeks; see Figures 5.8.2g-3 to 5.8.2g-5). Populations of migratory fish suffer mortality at each life stage from a variety of stressors. Changing the timing of adult migration patterns by artificially warming the tailwaters of a migratory river may have unforeseen effects. Whether or not these effects seriously impact alewife or other alosid populations cannot be measured because there is not a significant body of "pre-impact" data to which changes induced by Kendall Station's thermal discharge can be compared. In river systems with a natural estuary, adult alewives move into freshwater when water temperatures range from about 7.2-11.1 ºC (45-52 ºF) and stop entering these systems when temperatures rise to about 18.3-20 ºC (65-68 ºF) (unpublished data from Parker River and Bourndale runs in MA and from Lamprey River, NH). When additional ΔTs alter this regimen, adults will prematurely encounter water temperatures above the apparent 20 ºC (68 ºF) limit weeks before they would have if the system did not have a heated discharge. These fish may turn back from migration as was seen in the system in RI studied by Cooper (1961).

The forces of natural selection do not only operate on adults and their ability to withstand certain temperatures and/or changes in temperatures. They also operate on young through their ability to feed, grow and avoid predation. Young that are born when times are propitious, with high availability of certain zooplankton populations, and/or absence of certain predators, will fare better than those born when these conditions are less than adequate. The effect of ΔTs on the outcome of these types of interactions has not been evaluated.

Effects of unnatural warming on adult anadromous fish in the Charles have, likewise, undergone little or no evaluation. Because anadromous fish have evolved to migrate and spawn under a certain range of stream temperatures, river systems thermally advanced due to a heated discharge at the mouth of a river will induce a certain portion of the fish to enter the system early. Alosid migrants stop feeding when they enter freshwater and only begin feeding again on out-migration. Pre-mature entry into the anadromous run may lead to a decrease in vigor among early migrants because they will have to wait for waters upstream of the discharge to reach temperatures suitable for spawning. Depending on the length of this wait, the probability that these fish will successfully compete with later migrants for breeding areas or partners may be significantly reduced. Latecomers to the run may be stopped from breeding altogether. Sensing high temperatures downstream of Mirant's discharge, these fish may out-migrate without breeding, even though temperatures upstream of the discharge might be suitable for breeding for another couple of weeks. Increases in the currently allowable ΔT would likely intensify there impacts.

5.8.2l Extended Duration Of High Temperatures And Effects On Zooplankton

ΔTs protract the period of summertime high temperatures. Raising the temperature of the lower Charles River Basin by 2.8 ºC (5 ºF) will lengthen the period over which high temperatures exist in the summertime. Sustained high temperatures are expected to have negative effects on algae and zooplankton which, in turn, may impact larvae and juvenile alosids which use the lower basin as a nursery area in the summer and fall. Each of these issues is discussed below.

<u>Effects to Primary Consumers</u>: A recent review of heat effects to zooplankton was completed by Moore *et al*. (1996). A number of studies reviewed by these authors showed that when water temperatures are maintained at 25 ºC (77 ºF) or greater, zooplankton communities in northeastern U.S. lakes undergo substantial changes in composition. First, increased heat generates conditions favorable to blue-green algae. As blue-greens increase in numbers, the food quality of zooplankton decreases. Changes in the food quality were found to affect the outcome of interspecific zooplankton interactions which, in turn, affected compositional make-up of the zooplankton community. Commonly, zooplankton assemblages exposed to prolonged (7-10 days or longer) temperatures in excess of 25 ºC (77 ºF) became dominated by small-bodied forms. In addition, the simple presence of certain species of blue-green algae (many of which are found in the lower Charles Basin) has been shown to negatively affect the ability of certain zooplankton species to withstand increased temperatures, probably due to the release of toxins by the blue-green algae (Moore, pers. comm. to G. Szal, 2002).

As temperatures increase, so do metabolic and feeding rates of fish. ΔTs due to a heated discharge will induce early onset of increased feeding of fish due to earlier-than-usual high temperatures. Although reproductive rates of zooplankton are also increased, prolonged high temperatures were found to increase the rate of loss of larger zooplankton forms which are selectively eaten by fish. Moore *et al*. state that size reductions in zooplankton assemblages in northeastern U.S. lakes are likely to "alter water clarity, nutrient regeneration and fish abundances."

The lower Charles River Basin is functionally a lake in the summertime due to highly reduced flows. As a result, zooplankton communities in the lower Charles likely respond in a similar fashion to those in other northeastern lakes and ponds reviewed by Moore *et al.* Zooplankton are the primary food-base of alosid larvae and an important component of the juvenile alosid food base. Alterations to the zooplankton community of the type described above are expected to negatively affect larval and juvenile alosid growth and/or survival rates in the lower basin.

The effect of an altered zooplankton community on larval and juvenile alewives and bluebacks in the lower basin is difficult to estimate. Early life stages of these fish species remain in the lower basin from June through the late fall. A loss of large forms of zooplankton would be expected to decrease alosid larval and juvenile growth rates while increases in heat will raise metabolic rates, further reducing the rate of larval and juvenile growth.

Based on MWRA data from 1999-2001 (Figures 5.8.2l-1 to 5.8.2l-3), there would be a substantial effect of a ΔT of 2.8 ºC (5 ºF) relative to the 25 ºC (77 ºF) value cited by Moore *et al*. Without additional heating below MWRA Station 006 (i.e., without Mirant's discharge or other additions of heat), temperatures in the lower basin in excess of the 25 ºC (77 ºF) figure would have lasted for 4 weeks in 1999 (a drought year), one week in 2000 and zero weeks in 2001. With a ΔT of 2.8 ºC (5 ºF) added to the MWRA station 006 data set, temperatures in the Zone of Passage and Habitat would have been in excess of 25 ºC (77 ºF) each summer for a period of about 3 months (11-12 weeks) for each of the three years evaluated (1999-2001). The period of continuous high temperatures, greater than 25 ºC (77 ºF), in the Zone of Dilution would be lengthened even further. The warming effect of the discharge will not be stopped at the upstream and downstream ends of Mirant's Zone of Passage and Habitat (i.e., slightly upstream of the Longfellow Bridge and at the downstream end of the Science Center canal). Based on modeling submitted by Mirant, during low river flows thermal effects in the summer will extend from the new Charles River Dam upstream to the B.U. Bridge (about 3 linear miles), though the magnitude of the effect decreases with distance from the point of discharge. Because the surface area of the lower basin downstream of the B.U. bridge is about 2/3 of the surface area of the entire lower basin, a large component of the larval and juvenile population of alosid fishes in the Charles could be negatively affected by the present ΔT of 2.8 ºC (5 ºF). Further increases beyond the present ΔT limit of 2.8 ºC (5 ºF) would extend both the duration of high temperature events as well as the volume of the lower basin that is affected.

5.8.2m Extended Presence Of Alosids In Freshwater

A ΔT of 2.8 ºC (5 ºF) in the Zone of Passage and Habitat, combined with a higher ΔT in the Zone of Dilution, may lengthen the period of juvenile presence in the lower basin. This is because out-migration is triggered when ambient river temperatures fall below a critical temperature, approximately 14.5 ºC (the high 50s ºF) for alewives. Effects of extended presence of blueback or alewife juveniles in freshwater have not been widely studied. Crecco *et al*. (1983) reported that American shad mortality rates in the nursery areas range from 1.8-2% per day. These authors projected that the longer juveniles stay in the nursery, the lower the survival of the year class. It is assumed by EPA and DEP that this general range of mortality would likely apply to alosids commonly found in the lower basin as well. ΔT from Mirant's discharge in the final few miles of the Charles would likely have a negative effect on alosid recruitment to this system because they are thought to increase the duration that alosid juveniles remain in the Charles.

5.8.2n Summary of Delta T Discussion

A wide range of topics was included in the exploration of the appropriate magnitude of a ΔT sufficient to ensure the protection and propagation of the balanced indigenous population in the Zone of Passage and Habitat in the lower Charles River Basin. The subjects discussed are summarized below:

1) Charles River Features: Because the New Charles River Dam separates freshwater from seawater, and due to the intermittent operation of the locks, the Charles River has no estuary. Fish entering the Charles River from Boston Harbor may experience sudden and substantial changes in both temperature and salinity. Abrupt changes in temperature have been shown to induce mortality to the species of alosids that inhabit the Charles. Combined effects of abrupt salinity and temperature changes induce substantial mortality in American shad.

2) Heat Shock From Springtime Delta Ts: There may be a high potential for heat-shock effects to in-migrating alewives at certain times during the upstream run into the Charles, depending on where and when they acclimate to Boston Harbor temperatures. Field and laboratory investigations on alewife adults in the Great Lakes have shown that the potential for heat shock is high during certain times in the spring and appear to explain massive die-offs of adults caught in waters experiencing wide fluctuations in temperature. These studies have been supported by work with alewives in Rhode Island. There is a probability that in-migrating alewives will suffer from heat shock changes over the course of the migratory run and the probability is likely highest towards the latter part of the run. Fish that enter Kendall's Zone of Dilution are at greatly increased risk from heat shock.

3) Avoidance Behavior Likely Related To Delta T: Alewives in Rhode Island were found to halt their run at the same time that temperature differences between the estuary and breeding pond reached 6.2 ºC (11 ºF) in the final weeks of the run. ΔTs between Boston Harbor and the Charles are often of this magnitude or greater. Because mixing between Boston Harbor water and Charles River water may take place in the New Charles River Locks, fish may not experience the full ΔT difference between the Charles and Boston Harbor until they enter the Charles River proper. If this is the case, towards the end of the run, fish experiencing ΔTs greater than 6.2 ºC (11 ºF) may cease their migration and leave the system. If, on the other hand, Charles River water temperatures are detected by fish in Boston Harbor, a 6.2 ºC (11 ºF) or greater ΔT may stop fish from migrating into the Charles. The percent of the population that is turned away from upstream migration due to ΔTs is unknown. Any increases in the present ΔT limit of 2.8 ºC (5 ºF) allowed in the Zone of Passage and Habitat will worsen this situation.

4) Cold Shock To Out-Migrating Adult Fish: It appears that, given a 2.8 ºC (5 ºF) ΔT limit for Mirant in the Zone of Passage and Habitat, a certain segment of the out-migrating adult alewife population would succumb to cold-shock due to the lack of an estuary. Out-migrating adult alosids will experience a temperature drop when they enter Boston Harbor. As the magnitude of the temperature difference between the Charles River and Boston Harbor increases, the probability that fish will succumb to cold shock increases. The probability of death from cold shock changes with the acclimation temperature, and fish out-migrating at the beginning of the run are most likely to suffer cold-shock. Because the Charles River heats up faster than Boston Harbor, fish leaving the Charles after spending several weeks there will experience a much greater change in temperature than when they entered the Charles. Any further increases in the ΔT limit will increase the probability that fish will succumb to cold shock upon returning to Boston Harbor.

5) Thermal Plume May Play A Role In Blueback Herring Behavior : Sonar-tracking of a small number of blueback herring released from the New Charles River Locks has shown that a subset of these fish wandered downstream of Kendall's discharge for weeks.

6) Delta Ts Pre-Maturely Advance The Season Of In-migration: Raising the temperature of the lower section of the Charles by 2.8 ºC (5 ºF) is thought to advance the season available for adult in-migration by about two weeks, on average. Since anadromous fish coming from the sea cannot be forewarned of this advance in the temporal window allotted to migration, a portion of the population may be kept from migrating due to Charles River temperatures that are prematurely high. Early migrants could be expected to enter the system prematurely and would need to wait until temperatures upstream of the Zone of Passage and Habitat become warm enough for spawning. Because alosid adults do not eat when migrating upstream, early migrants will use energy stores prematurely and lose vigor. These fish will likely be at a competitive disadvantage to achieve successful spawning, and in extreme cases, to survive the spawning effort, compared to later migrants.

7) Summertime Impacts To Zooplankton, Larval And Juvenile Fish: A Delta-T of 2.8 ºC (5 ºF) in the summer is expected to have negative effects on zooplankton and alosid larvae and juveniles. When water temperatures in northeastern U.S. lakes are $\geq$ 25 ºC (77 ºF) for more than 7-10 consecutive days, substantial changes to zooplankton communities typically take place (Moore *et al*., 1996). These changes have been partly linked to changes in algal populations due to prolonged high temperatures and negative effects to zooplankton and feeding fish have been shown to result from these changes. Without a ΔT of 2.8ºC (5 ºF) from Kendall (or other additions of heat), temperatures in the lower basin over 1999-2001 would have exceeded 25 ºC (77 ºF) for 4,1 and 0 weeks. With a ΔT of 2.8 ºC (5 ºF), temperatures in the lower basin would have exceeded 25 ºC (77 ºF) for 3-months (11-12 weeks) each of the three years. Any increases in the ΔT will extend high-temperature events even further.

8) Negative Effects To Alosids: A ΔT may play a negative role in juvenile alosid survival. Increases in ambient river temperatures will prolong the period that juvenile alosids remain in freshwater,

because these fish only out-migrate when water temperatures drop down to approximately 14.4 ºC (high 50's ºF). For example, American shad mortality rates in nursery areas are significant (1.8-2% / day). The longer juveniles stay in the nursery, the lower the survival of the year class. Effects of prolonged presence of blueback and alewife juveniles (which are documented to use the lower basin as a nursery) in freshwater have not been studied. As ΔTs increase, so does the length of juvenile presence in the lower Charles River Basin.

9) Effect of Multiple Stressors on Populations: While it difficult to quantify, the effect of multiple stressors on fish populations must be taken into consideration when evaluating a protective ΔT for the lower Charles River Basin. For example, multiple stressors are well known to increase the risk of serious illness or death in human beings and are a major consideration when reporting air pollution warnings (those with breathing difficulties, and the very old), in making recommendations for flu vaccinations (very young, old or immune impaired), and in accepting patients for surgery. These and a long list of other interactive physiological variables are factored into risk assessments for humans. The same scenario, i.e., of interaction between different abiotic and biotic factors influencing survival, is well studied in aquatic systems as well. The effect on resident and anadromous fish species of certain specific stressors that occur in the lower basin, discussed in Section 5.4 of this document, were judged by EPA and DEP to play a role in considering an appropriate ΔT limit for the lower basin.

5.8.2.o Delta T Determination

The overall objective of applying the § 316(a) regulations to the permitting process is to allow a variance from water quality standards when there is sufficient information that standards may be relaxed without negatively impacting the BIP. Based on the discussion and biologically based concerns identified in Section 5.8.2., it seems likely that raising the maximum allowed ΔT above the limit of 2.8 ºC (5 ºF) in the Zone of Passage and Habitat would have a further negative impact on the balanced indigenous populations of anadromous species in the lower basin. EPA and DEP have interpreted the maximum ΔT of 2.8 ºC (5 ºF) to apply when comparing ambient water temperature conditions in the lower Charles River Basin with temperatures in the ZPH. Establishing a ΔT of 2.8 ºC (5 ºF) in the Zone of Passage and Habitat, in addition to the maximum temperature limits established in the permit, will minimize the stress of elevated temperatures on the balanced indigenous populations in the lower basin related to thermal shock, premature beginning of the spawning run, cold shock and longer residence time for juveniles in the basin, among other factors discussed previously.

In addition, as discussed in Section 5.8.2b, in 2001, the permittee submitted modeled thermal projections that indicate the operation of Kendall Station will not be greatly impacted if a maximum ΔT of 2.8 ºC (5 ºF) is incorporated into the NPDES permit for the Zone of Passage and Habitat. The results predicted that less than 1% of the volume of the lower basin contain temperatures greater than 2.8 ºC (5 ºF) above ambient conditions.

5.9 Comparison Of Historic Lower Charles River Basin Temperatures With Thermal Limits For 50% Of River

5.9.1 Introduction

Temperature limits established for the protection and propagation of the most thermally sensitive species found in the Charles River Basin took into consideration temperatures observed in the basin. However, supporting rationale for these temperature limits also took into consideration scientific literature that did not specifically test individual fish collected from the lower Charles River. One way to support whether this temperature limit approach is appropriate for the lower Charles River Basin is to compare the temperature limits with actual historical ambient temperature data from the lower basin. This was generally done throughout the discussions in Section 5.6.3 and 5.7.3, using data from 1999, 2000, 2002 and 2003. The temperature limits and ambient conditions are compared here in a comprehensive manner, using additional temperature data to provide a clearer picture of how the temperature limits relate to ambient river temperatures.

It must be noted that the thermal limits described for the lower basin, based on biological criteria, are required to be met only for the Zone of Passage and Habitat considered to be protective for resident and anadromous species of the lower Charles River Basin. While this zone must make up no less than 50% of any cross sectional, bank to bank, area of the lower basin that is influenced by the thermal plume of Kendall Station, the thermal limits do not have to be met in all areas of the basin.

5.9.2 Evaluation Of Kendall Station Cooling Water Intake Temperatures As Surrogate For Ambient River Conditions

5.9.2a Introduction

Historical river temperature data were collected by the permittee from a continuous water temperature monitor located inside the cooling water intake pipe at Kendall Station. Temperature measurements were taken once the Circulating Water Intake Pumps had mixed the water and moved it into the station. Temperatures were recorded every hour. (Mirant Kendall NPDES Permit Application, 2001; Unpublished Kendall Station Operations Data, 2002 and 2003). Calibration information and temperature monitor performance has not yet been verified by EPA or DEP. The intake structure draws water from approximately the upper eleven feet of the water column. Intake temperatures were measured inside the station, once this column of water had been mixed by the circulating water pumps. This hourly temperature data provided the only available long term, continuous, historical record of water temperatures for the lower basin. Caution was exercised when evaluating intake temperature data as being representative of ambient river temperature conditions of the lower basin for the following reasons.

First, when pronounced thermal stratification is seen in the basin in the late summer, warmer water is present in the upper ten to fifteen feet of the basin, and cooler water occupies lower depths of the basin (Mirant Kendall NPDES Permit Application, Appendix 3, 2001 ; Mirant Kendall Hydrographic Data, 2002; EPA Clean Charles 2005, 2002 Data; Mirant Kendall 2003 Data, Appendix B-2: November 13, 2003). As stated earlier, intake temperatures reflect a mix of water temperatures from approximately the upper eleven feet of the water column. Under these conditions, intake temperatures are not seen as a reasonable representation of water temperatures for a sizable portion of the basin which is deeper than eleven feet. (Unpublished Mirant Kendall Station Operations Data 2002).

Second, impoundment like features of the lower basin (little or no "downstream" water movement) sometimes result in the re-entrainment of the warm water discharge at Kendall Station at the intake location. In most circumstances involving a power generating facility with an upstream intake structure and a downstream thermal discharge point in a river, water temperatures recorded by a facility at the upstream intake point can be used to determine the ambient water temperatures of the river. This is because power generating facilities using once through cooling water systems are designed so the intake structure does not re-entrain the warm water thermal discharge of the facility. Re-entrainment of warm water at this type of facility can reduce the efficiency of electric generation and cause discharge temperatures to spiral above maximum temperature limits. However, in the case of Kendall Station, it was revealed through station operation information that under low river flow conditions, coupled with certain meteorological events, the heated plume from the Kendall Station discharge spread out to the upstream area of the Broad Canal and was re-entrained at the CWIS. This occurrence raised the measured intake temperatures above the ambient river conditions. Intake temperatures recorded under these conditions would be higher than ambient conditions in the river, and could not be used to determine how appropriate the established temperature limits are for the lower basin. In order to confirm under what general circumstances the re-entrainment of the thermal plume occurred, station intake water temperature data was compared with water temperature data measured in other parts of the basin.

5.9.2b Comparison of Kendall Station Intake Temperatures With Temperatures Upstream

Station intake temperatures were compared with hourly temperatures recorded from a USGS monitor at the Watertown Dam from August 1999 through September 2000. (Figure 5.9.2-1; Unpublished Kendall Station Operations Data 2002; USGS Provisional Data 2002). Modeling results from the permittee generally predicted a 2 ºC (3.6 ºF) increase in temperature from the Watertown Dam to the wider, downstream part of the lower basin. The figure shows that temperatures from the Watertown Dam sometimes showed good agreement with the intake station. Station intake temperatures were generally never greater than 2 ºC (3.6 ºF) above the Watertown Dam temperatures. The two sets of temperatures generally followed the same trend. Watertown Dam temperatures tended to show a greater temperature swing than intake temperatures when large changes in temperature occurred over a short period of time (March of 2000; Figure 5.9.2-1). The greater magnitude of the temperature swings at the Watertown Dam were likely a result of the smaller volume of water and shallow depths near the Watertown Dam. A smaller volume of more shallow water would be effected more quickly by changes in air temperature and overall weather conditions.

Unfortunately, Watertown Dam temperature data was not available for the latter part of June, all of July, and early August in the year 2000. This is the time period when low river flows may have caused the thermal plume from Kendall Station to be re-entrained at the intake. Figure 5.9.2-2 focuses on the June to September, 2000, time period of the previous figure. Visual inspection of Figures 5.9.2-1 and 5.9.2-2 show a much lower temperature consistently recorded at Watertown Dam for the majority of time when data was available in August of 2000. The upstream temperature, while displaying daily temperatures swings of up to 2.8 ºC (5 ºF), appeared to be approximately 2.8 ºC (5 ºF) cooler than the intake temperature. Influence from the thermal plume at Kendall Station is a possible explanation of the higher temperatures seen at the station intake.

More recent continuous temperature data was submitted by the permittee for the time period of August and September of 1999 and May through August of 2002 . The 1999 data was collected in the vicinity of the Boston University Bridge (BU Bridge), and represented an average of the upper water column conditions. The station location near the BU Bridge is considered to be far enough upstream from Kendall Station that it is not under the influence of the station's thermal discharge. Continuous temperature data from May through August of 2002 was collected at the BU Bridge and also at the Harvard Bridge. Basin water in the vicinity of the Harvard Bridge has been shown to be effected by the Kendall Station thermal plume under certain environmental conditions. When this river temperature data was compared with Kendall Station intake temperatures for the same time period, (Figure 5.9.2-3 for 1999; Figure 5.9.2-4 for 2002), the BU Bridge temperatures and the Harvard Bridge temperatures were seen to be cooler than corresponding intake temperatures. During some periods, the upstream temperature was up to 2.8 ºC (5 ºF) cooler than the intake temperature. Figure 5.9.2-3 also includes discrete temperature data collected by the Massachusetts Water Resources Authority (MWRA). Each discrete data point represented data calculated from an average of a near surface and near bottom temperature reading in the water column in the vicinity of the upstream background station (BU Bridge). The discrete MWRA temperatures seem to be slightly cooler than the facility intake temperatures (Figure 5.9.2-3).

Comparisons were also made between Kendall Station intake temperatures and discrete temperature data collected by the Massachusetts Water Resources Authority (MWRA) in the lower basin from 1997 through 2001 (Figures 5.9.2-5 to 5.9.2-9). As discussed above, each discrete data point represented data calculated from an average of a near surface and near bottom temperature reading in the water column in the vicinity of the upstream background station (BU Bridge). The comparison of intake temperatures and MWRA temperatures showed agreement during the spring and fall (historically higher flow time periods). However, as seen in previously examined data sets, Kendall Station intake temperatures are again higher than the MWRA temperatures during the summer months. Based on the USGS record of Charles River flow from 1994 through 2002, the time period from mid-June through September generally brackets the lowest flow periods observed in the river system (Figure 2.4-1; USGS Provisional Data).

Historical discrete temperature data collected at the BU Bridge background station by the Charles River Watershed Association (CRWA) were also examined. These temperatures were taken from the surface of the river during daylight hours, where solar radiation can have a compounding effect on the temperature of the top foot of the water column. These near surface values were not judged to represent ambient conditions in the overall water column at this background station. This data set was not included in the ambient river temperature investigation.

5.9.2c Historical Ambient Temperature Determination

Based on the available temperature data examined in the lower Charles River Basin, continuous water temperatures recorded at the Kendall Station Intake are a generally reliable indicator of ambient conditions in the basin in the spring, fall and winter, provided normal seasonal river flow conditions are seen. In the summer, however, when river flows are seasonally low and the basin is thermally stratified, intake temperatures can not be relied upon to closely reflect ambient river conditions. For the sake of further discussion, continuous temperature data from the station intake were removed from consideration as ambient river conditions from mid-June through August. During this time period, discrete MWRA temperature data were used to represent summer ambient river conditions. Figures 5.9.2-10 to Figure 5.9.2-14 represent this historical ambient temperature determination.

5.9.3 Comparison Of Ambient River Temperatures With Established Temperature Limits

Based on the discussion and data presented in Section 5.9.2a and b, Kendall Station intake temperatures seemed to be a reasonable approximation of ambient river conditions in the fall, winter and spring. Kendall Station intake temperatures could not be relied upon to closely reflect ambient river conditions from mid-June through August. As a substitute, discrete temperatures measured in the vicinity of the upstream background station, near the BU Bridge, were included for the mid-June through August time period, when available.

Applicable hourly water temperature data from the Kendall Station intake structure from January of 1994 through early June of 2002 were compared with the temperature limits established for the Zone of Passage and Habitat (Figures 5.9.2-15 to 5.9.2-23). Areas where no intake temperature line was plotted reflected missing or suspect data. Also, intake temperatures from mid-June through August, which were not judged to reflect ambient river conditions, were excluded from the comparison, and discrete temperatures from the upstream background station were included when available.

To further refine the comparison of the preliminary temperature limits with spring and summer ambient conditions, available background temperatures obtained from several sources were also plotted against the limits.

Data was assembled in Figures 5.9.2-24 to 5.9.2-30 that, while not directly comparable to Kendall Station intake temperatures, may be more representative of ambient river conditions in the Charles River. This is because these temperatures do not represent an average temperature calculated from more than one depth in order to mimic the way the intake measurement is derived (temperature taken after an eleven foot column of water is withdrawn and mixed). Instead, temperatures in Figures 5.9.2-24 to 5.9.2-30 were measures at only one, near surface point in the water column. The majority of the temperature measurements were taken near the Boston University (BU) Bridge, which is the proposed background station. Data was taken from May through August from 1997 through 2003. Data sources include EPA, Massachusetts Water Resources Authority (MWRA), and Mirant Kendall. Monitoring information from only one position in the water column is in keeping with compliance monitoring protocol of the draft permit, which currently requires temperatures to be continuously recorded at discrete depths throughout the basin (see Section 5.10). The maximum temperature limit for the ZPH is also included in these figures as a point of reference.

It must be noted that the frequency of data collection in Figures 5.9.2-24 to 5.9.2-30 is not sufficient to fully evaluate ambient river conditions throughout each summer where data is available. Where continuous temperature data is available, notable changes in river temperature have been measured over the course of several days. Since these temperature records represent one reading on a given day, with several days in between readings, it is possible peaks and valleys in the ambient temperature record were not captured through this type of monitoring. This underscores the realization that temporal gaps in this data set may compromise the ability to fully characterize ambient river conditions in the Charles.

Unless otherwise noted in the figures, MWRA data was generally collected before 11 am at a depth of approximately one foot, EPA data was taken near mid-day at a depth of approximately one foot, and Mirant data was collected at various times of day at a depth of approximately three feet.

Blackstone Electric Generating Station, upstream of the BU Bridge, discharged heated water to the Charles River sporadically until November of 2001. The hours of Blackstone operation for each day of May through August of 1999 only were available for the current analysis. This data is plotted along with temperature information. In some cases, Blackstone operation correlates with increasing temperatures in the vicinity of the BU Bridge (Figure 5.9.2-26).

Limited continuous temperature data near the BU Bridge (Monitoring Station 1) from a single, near surface point in the water column was also compared with the temperature limit in effect in the ZPH. This information runs sporadically in the summer months from July 1998 through August 2001, and is included in Figures 5.9.2-31 through 5.9.2-36.

In the majority of time periods over the years examined, basin temperatures were below the temperature limits established for the Zone of Passage and Habitat. It can be argued that this observation supports the position that the temperature limits established for this NPDES permit are not overly conservative for this site-specific body of water. Without the influence of the heated discharge from Kendall Station, the temperatures established as protective for resident and anadromous fish in the basin are in most cases above historical ambient temperatures in the basin.

There are a few notable exceptions. First, in all years where temperature data is available for early April and late October (every year except 1999), ambient temperatures exceed the 10 ºC (50 ºF) limit at either the beginning or the end of this overwintering "chill period" temperature limit. Therefore, flexibility in the start time for the chill period is build into the compliance approach of the permit to address this situation. Section 5.10.6c of this document and Attachment A of the draft permit have a full description of this approach.

Also, there were periods in 1995, 1996, 1998, 1999, 2000, 2001 and 2002 where ambient basin conditions approached or briefly exceeded the thermal limits for short periods during the April to early June spring spawning period. Coutant (Natl. Acad. Sci./Natl. Acad. Eng., 1972) noted that natural environments can briefly reach temperature extremes without apparent detrimental effect to the aquatic life. EPA and DEP feel that it would be inadvisable to use a briefly reached temperature extreme measured in the lower Charles River Basin as a basis to set a water temperature limit that could then be attained and maintained artificially for longer periods. While temperature limits were not modified to accommodate these ambient river temperature spikes, provisions were once again made in the permit compliance approach which would take these natural conditions into consideration. Section 5.10.6b of this document and Attachment A of the draft Permit have a full description of this approach.

Comparison of historic lower Charles River Basin ambient temperatures with temperature limits established for the Zone of Passage and Habitat show that the temperature limits established for the protection and propagation of resident and anadromous fish populations are not normally (without the thermal influence of Kendall Station) exceeded in the lower basin and therefore are not unreasonable for this site-specific body of water.

5.10 Specific Monitoring In Permit Necessary To Comply With Zone Of Passage and Habitat Limits

As part of Mirant Kendall's NPDES permit application, lower Charles River Basin water temperature modeling information and surface temperature projections were submitted to predict the expected thermal impacts to the lower basin from expanded Kendall Station power generation (Mirant Kendall NPDES Permit Application, Volume I, 2001; Supplemental Surface Water Modeling Report In Support Of Kendall Station NPDES Permitting, 2001). The thermal model used was the Generalized, Longitudinal-Lateral-Vertical Hydrodynamic and Transport (GLLVHT) model. EPA and DEP required verification of certain aspects of the modeling approach. Proposed additional modification to the model is fully discussed in Section 5.5.1 of this demonstration document. Rather than perform additional modifications to the GLLVHT model in order to use the results to establish discharge temperature limits in the permit, the permittee and review agencies agreed to use a different approach. Thermal limits were established for a sufficient area of habitat in the lower Charles River Basin to protect the species occurring there and allow the propagation of balanced aquatic communities (Mirant Correspondence Dated 5/11/01 from Norm Cowden to various addressees). Under a 316 (a) thermal discharge variance as authorized by the Clean Water Act, a Zone of Dilution (ZD) has been established for the draft permit. In this site-specific case, taking into consideration the physical characteristics of the receiving water body and the aquatic communities that are present or expected to occur, the ZD will comprise no more than 50% of any cross sectional, bank to bank area of the lower Charles River Basin. This zone is granted a variance from temperature limits and mixing zone requirements specified in the Massachusetts Water Quality Standards. The limits of the ZD are more fully described in Section 5.8.1c.

In addition, in this site-specific case, taking into consideration the physical characteristics of the receiving water body and the aquatic communities expected to occur, a protective Zone of Passage and Habitat (ZPH) is also established as a counterbalance to the ZD. The ZPH must make up a minimum of 50% of any cross sectional, bank to bank area of the lower Charles River Basin. Specific biologically based temperature limits must be met throughout the year in the ZPH. This subject is also discussed in Section 5.8.1c.

Real-time documentation of the quality and quantity of the ZPH is a core requirement to ensure the propagation of balanced populations of aquatic species in the lower Charles River Basin. In order to document that real time in-situ temperature and other relevant water quality limits are being met in the ZPH, a water quality monitoring and compliance plan was established for the receiving waters of the discharge. This plan creates a real-time, continuous monitoring system at key locations in the lower Charles River Basin.

Since dissolved oxygen levels prescribed in the Massachusetts Water Quality Standards are not considered part of the thermal variance being granted, dissolved oxygen measurements are also monitored to ensure the ZPH is comprised of habitat that is usable to resident and anadromous fish communities of the lower basin. Usable aquatic habitat is defined as meeting the prescribed state water quality standard of 5.0 mg/l or greater of dissolved oxygen for the Class B receiving waters of the lower basin.

In order to gather definitive information that thermal limits established for the ZPH are indeed protective of all life stages of a balanced biological community under expanded Kendall Station operation, fish sampling at all life stages is also included in the monitoring plan.

Periodic water quality monitoring and water chemistry analysis have also been included in the monitoring plan to evaluate the effect of the thermal discharge on conditions in the water column of the lower basin.

5.10.1 Fixed-Station Parameters

5.10.1a Temperature Monitoring

Temperature is the single most pervasive environmental factor affecting poikilothermic (cold blooded) animals (Stickney, 1979). A number of studies indicate that water temperature is a dominant factor regulating year class strength in percids, the family which includes the yellow perch (Koonce *et al*., 1977). Water temperature plays an important role in fish gonadal development, reproductive behavior, metabolic rate, and avoidance or attraction behavior.

The entire basis for the 316(a) thermal variance is to establish temperature limits that, while perhaps not as strict as the state water quality standards for the receiving water body, are still judged to be protective for the overall biological community. In this particular case, because of concerns associated with the predictive model (see Section 5.5.1), end of pipe discharge temperatures from Kendall Station were not documented to be a reliable predictor of resulting basin water temperatures. In order to ensure that protective temperature limits are met at specific locations in the Zone of Passage and Habitat, a real-time temperature monitoring and compliance system in the receiving water is essential. That is why it is included as a requirement for the NPDES permit for Kendall Station.

5.10.1b Dissolved Oxygen Monitoring

The receiving waters of the Kendall Station cooling water discharge have been documented to undergo seasonal summer stratification, resulting in a hypolimnion that may meet the temperature limits established in this permit, but are below water quality standards for dissolved oxygen (DO). Any area identified as being part of the Zone of Passage and Habitat must possess DO levels that meet state water quality standards (5.0 mg/l or greater). To ensure prescribed DO levels are met at specific locations in the Zone of Passage and Habitat, real-time DO monitoring in the receiving water is recommended. Because real-time, continuous monitoring for dissolved oxygen will likely involve intense maintenance efforts to keep the probes functioning properly, EPA and DEP may entertain an alternative monitoring method to obtain dissolved oxygen information. If conducted with proper frequency, periodic vertical profile monitoring for dissolved oxygen at specific stations may meet the requirements of the permit without the need for continuous real-time monitoring. EPA and DEP welcome comments, including a detailed proposal, that would specify an alternate DO monitoring option. As a component of the draft permit, continuous real-time DO monitoring is included as a requirement for the NPDES permit for Kendall Station.

5.10.2 Fixed-Station Locations

5.10.2a Station 1 (Downstream Of The Boston University Bridge (BU), 15 Foot Depth), (Background) - Temperature, DO

In order to determine background conditions in the lower Charles River Basin which are not under the influence of the Kendall Station cooling water discharge, a fixed station location was established upstream of the plant. Historic water quality information showed that the thermal plume sometimes traveled upstream of the Station discharge, upstream of the Longfellow Bridge, being measured as far upstream as the Harvard Bridge and beyond (Figure 5.8.2b-2). That is why a background location near the Boston University Bridge was chosen. The cooling water intake structure of Kendall Station withdraws water from the top eleven feet of the water column. To attain the depth needed to characterize the column of water used by the Facility, the background station was moved downstream from the BU Bridge, to where the depth of the river approximated 15 feet. It is judged that a monitor placed at the 12 foot depth will have little interference or contamination of the probes with the bottom (especially the dissolved oxygen probe) if the probe is approximately three feet above the water-sediment interface. This is why a depth of 15 feet was selected. This monitoring station, downstream of the Boston University Bridge, was established approximately at the mid-point of the river. Since the Kendall Station intake structure withdraws a column of water from the surface to approximately 12 feet, Monitoring Points at Station 1 are positioned at a depth of 2 feet, 6 feet and 12 feet. The intent is to place the Monitoring Points in the water column to best characterize the water quality of the column of water withdrawn by Kendall Station.

Two monitoring stations were originally proposed by the permittee and agreed to by EPA and DEP for continuous background monitoring near the Boston University Bridge. Each continuous monitoring station that can not be attached to a preexisting structure will consist of a substantial buoy, at least three feet in diameter, floating at the surface. After informal discussions with the permittee and the Charles River Rowing Association, among other user groups of the lower Charles River Basin, the background monitoring requirement was modified to one station to reduce buoy interference with boating congestion. It has been judged that sufficient background water temperature and dissolved oxygen information will be collected from one monitoring station at this location. However, with the elimination of redundancy of background data collection points, strict compliance with the missing data protocols described in Part I.A, Section 14.b.8 of the draft permit become particularly important at Monitoring Station 1.

EPA and DEP are aware that the Cottage Farm Combined Sewer Overflow (CSO) Facility discharge is located just upstream of the Boston University Bridge and the proposed location of Monitoring Station 1. Discharge from this facility could potentially compromise the objective of Station 1 to record ambient river temperatures in the Charles River. The Cottage Farm Facility discharges water via a bottom diffuser into the Charles River only during storm events (17 projected events per year ; MWRA, 2004). Consideration was given to moving Station 1 upstream of the Cottage Farm discharge, but was not done at this time for the following reasons. First, the area upstream of the Boston University (BU) Bridge is more riverine, with a different water quality profile compared with the slower moving, wide, lower basin below the BU Bridge. Also, there are other CSO discharges further upstream of the Cottage Farm facility, which would likely pose the same potential to effect the ambient temperature monitoring objective of the background station during storm events. Continuous river temperatures recorded at Monitoring Station 1 will be closely examined during storm events to determine the extent of the effect of the CSO discharge on this monitoring location.

In addition, there is an electricity generating station located upstream of the Boston University Bridge, on the Cambridge side of the river. Located on Blackstone Street, the facility does not currently discharge waste heat to the Charles River. The thermal effluent from this facility, when in operation, discharges heated water downstream of the Blackstone Station, through a diffuser pipe located in the middle of the river, along the bottom. If a thermal discharge from this facility does resume in the future, it would likely have a greater effect on the ability of Monitoring Station 1 to measure ambient temperature conditions in the river if the monitoring station is relocated upstream of the Boston University Bridge. EPA and DEP will evaluate the appropriateness of the location of Monitoring Station 1 at the time the Blackstone Street Facility resumes a thermal discharge to the river.

5.10.2b Station 2 (Zone Boundary Station) Temperature, DO

This fixed monitoring stations was established at approximately 50% of the distance from the Boston side along a bank to bank transect that coincided with the predicted upstream edge of the discharge plume of Kendall Station (Figure 5.8.2b-2). The placement of this station along the transect is designed to obtain a real-time assessment of the water quality conditions at a key location of the predicted upstream zone boundary of the thermal plume. It must be confirmed that the upstream migration of the thermal plume from Kendall Station, during very low flow conditions, or under certain meteorological conditions, does not result in temperatures that are not protective in greater than 50 % of the cross-sectional area at this representative point upstream of the Longfellow Bridge. In order to confirm this, Monitoring Points at Station 2 will be established as compliance points for temperature. This transect location was initially determined through predictions of the thermal model (GLLVHT) submitted by the permittee, which was not formally accepted by the EPA or DEP. Additional water quality profile data will be collected throughout the basin as part of the draft permit conditions. This information will be used to produce contour maps of temperature, DO, and other parameters. Station 2 may be relocated based on data collected at that time.

The primary purpose of the monitoring of the upstream edge of the thermal plume is to evaluate the degree of thermal influence, and possible thermal blockage of fish movement, to the upstream areas of the lower Charles River Basin. Especially during low flow conditions in the river, when this section of the lower basin can more closely resemble an impoundment, or when certain meteorological conditions are present, the environmental impact and extent of the upstream edge of the thermal plume will be of concern. Also, the ability to identify the upstream edge of the thermal plume will assist in calculating the overall area of habitat affected by increased water temperatures.

At this station, water quality monitors will be positioned at depths of two (2) feet, six (6) feet, twelve (12) feet, twenty-four (24) feet, if depth permits, and three (3) feet above the bottom. The objective is to place monitors at several representative depth locations, including near surface, above the stratified summer thermocline, below the thermocline, and near the bottom of the basin. These depths were selected to obtain a representative vertical profile of the water column in order to determine usable fish habitat and acceptable fish passage throughout the depth of the basin.

Three monitoring stations were originally proposed by the permittee in order to monitor the upstream edge of the thermal plume at this location, initially referred to as the Zone Boundary

Transect. The permittee initially submitted these monitoring station locations, particularly the three upstream zone boundary transect stations, in order to gather water quality data from the edge of a proposed mixing zone. Because the upstream boundary of a mixing zone does not need to be fully characterized, three upstream stations are no longer required. However, one upstream continuous monitor is necessary to ensure that fish passage and sufficient useable habitat is maintained to assure the protection and propagation of the BIP under low flow conditions.

In addition, it must be considered that the construction of any continuous monitoring station will consist of a substantial buoy, at least three feet in diameter, floating at the surface. After informal discussions with the permittee and the Charles River Rowing Association, among other user groups of the lower Charles River Basin, the monitoring effort at the Station 2 transect was reduced from three stations to one station. This was done, in part, to reduce buoy interference with boating congestion. It has been judged that sufficient water temperature and dissolved oxygen information will be collected from one monitoring station at this location.

Thermal limits in effect for each time period in the ZPH must be met at all Monitoring Points at Station 2 to ensure fish passage and habitat protection.

5.10.2c Stations 3, 4, 5 and 6, (In Zone Transect) - Temperature, DO

These four fixed monitoring stations were established along a bank to bank transect predicted to be most impacted by the thermal plume, downstream of the cooling water discharge plume of Kendall Station (Figure 5.8.2b-2). The placement of the stations along the transect is designed to obtain a real time area assessment of the water quality conditions of the entire cross section. This transect location was determined through predictions of the thermal model (GLLVHT) submitted by the permittee, which was not formally accepted by the EPA or DEP. Additional water quality profile data will be collected throughout the basin as part of the draft permit requirements. This information will be used to produce contour maps of temperature, DO, and other parameters. These station locations may be adjusted based on data collected at that time.

Real-time continuous water quality monitoring of the receiving water body at this location is essential to ensure that water temperatures that are not protective of the most sensitive species do not occupy more than 50% of the cross sectional (bank to bank, surface to bottom) area of the lower Charles River Basin at any point from the Zone Boundary Transect to the New Charles River Dam and Locks. EPA and DEP have determined that water temperatures that exceed biologically based protective temperatures for resident and anadromous fish communities and that occupy more than 50% of the cross sectional area along any point of the lower Charles River Basin will eliminate an unacceptable amount of fish habitat and will inhibit the movement of fish. This includes resident species trying to reach habitat upstream and downstream of the Kendall Station discharge, as well as anadromous species attempting to swim past the station to upstream spawning areas. Because these impacts on fish communities would degrade the protection and propagation of balanced indigenous fish populations, they will not be allowed to occur at any time in the lower basin. The model predicted that this transect would be the most thermally impacted area of the river. Real-time, continuous water quality monitoring at this key location in the basin will assess uninterrupted compliance with protective temperatures. When protective temperatures are met at 50% of a contiguous cross-sectional area at this location, habitat further away from this maximum impact area will likely experience protective temperatures in greater than 50% of the area. Therefore, continuously meeting the 50% threshold at this transect will protect fish populations in the ZPH throughout the basin. In addition, the all temperature Monitoring Points at Station 3 (Boston side) must meet the thermal limits in place for the corresponding time period to ensure that unacceptably high water temperatures do not extend across the surface of the river to the Boston side. The entire surface to bottom water column at Station 3 must be part of the ZPH at all times, to provide necessary shoreline habitat for resident and anadromous species in the lower Basin.

At each station of the In Zone Transect (below), water quality monitors will be positioned at depths of two (2) feet, six (6) feet, twelve (12) feet, twenty-four (24) feet, if depth permits, and three (3) feet above the bottom. The objective was to place monitors at several representative depth locations, including near surface, above the stratified summer thermocline, below the thermocline, and near the bottom of the basin. These depths were selected to obtain a representative vertical profile of the water column in order to determine usable fish habitat and acceptable fish passage throughout the depth of the basin. Additional water quality profile data will be collected throughout the basin as part of the draft permit requirements. This information will be used to produce contour maps of temperature, DO, and other parameters. Station depth locations may be adjusted based on data collected at that time.

As mentioned previously, the ZPH includes at all times, all monitoring points at Station 3 (Boston side). In addition, at this transect, the ZPH includes, at all times, all monitoring points at Station 4, with the exception of the 2 ft monitoring point.

5.10.2d Station 7 - Old Charles River Dam Lock - Temperature, DO

This fixed monitoring station, located at the mid-point of the lock of the original Charles River Dam, now the site of the Boston Museum of Science, was placed at this location to monitor the water quality at a significant man-made constriction placed in the lower Charles River Basin (Figure 5.8.2b-2). Most aquatic organisms passing upstream from the area of the New Charles River Dam to the main part of the basin must navigate through this constricted concrete lock. If water quality in this narrow channel does not meet prescribed water quality limits, fish passage in the lower basin, both upstream and downstream of this site, could be prevented. This would, at the very least, hamper and ultimately reduce the upstream migration of anadromous fish species and result in a negative impact on the reproductive potential of these species in the lower basin.

This monitoring station will have water quality monitors positioned at depths of two (2) feet, six (6) feet, and twelve (12) feet (one foot above the bottom if canal will not accommodate a twelve (12) foot depth at the selected location). The objective is to place Monitoring Points at several representative depth locations, including near surface, above any potentially stratified layer of the concrete canal, and below any potential thermocline in the lock. These depths were selected to obtain a representative vertical profile of the water column of this man-made passage way in order to ensure there is acceptable fish passage.

The monitoring station will be located at the halfway point of the total length of the lock. Due to the narrow passage in the lock and continuous boat traffic, a free floating buoy supporting the monitoring probes can not be located in the lock. Instead, the monitoring points will be affixed to the wall of the lock at the prescribed depths, well away from boat traffic.

Thermal limits in the ZPH must be met at two contiguous Monitoring Points (2 ft and 6 ft or 6 ft and 12 ft) at Station 7 to ensure fish passage during the entire period that Station 7 is deployed (April 1 - October 31 of each year).

5.10.2e Station 8 - Upstream of the New Charles River Dam and Locks - Temperature, DO

This fixed monitoring station was located just upstream of the New Charles River Dam and Locks at the mouth of the Charles River. The locks and fish passage structures located at this dam are the first barriers anadromous fish must navigate on their way into the lower Charles River Basin. The temperature of the water passing from the Charles River into Boston Harbor is a key environmental signal to anadromous fish that gather in the harbor, waiting for acceptable conditions to attempt their upriver spawning migration. It has been observed that once anadromous fish sense environmental conditions conducive to spawning and enter the river, they will likely remain in the river and continue their spawning run (Cooper, 1961). However, the instinct to enter the river and move from the marine environment into the freshwater river system is a crucial action that is by no means assured. This monitoring station will measure on a real-time, continuous basis the water quality flowing past the dam and into the harbor, which serves as an attractant flow for schooling anadromous fish in the harbor. This station will provide information to ensure that water with excessive temperature or other degraded water quality characteristics are not part of the attractant flow from the dam.

This station will have water quality monitors positioned at depths of two (2) feet, six (6) feet, twelve (12) feet, and twenty-four (24) feet. (Figure 5.8.2b-2). The objective is to place monitors at several representative depth locations, including near surface, above the stratified summer thermocline, below the thermocline, and near the bottom of the dam. These depths were selected to obtain a representative vertical profile of the water column just upstream of this man-made barrier to passage, in order to determine the characteristics of the water quality being released through the dam to Boston Harbor as an attractant flow. Water can be pumped from the bottom of the dam into the locks. Also, when the locks are utilized to pass boat traffic, water from different depths of the water column may travel through to Boston Harbor. In order to bracket expected anadromous species in-migration and out-migration time periods from April 1 through October 31, this station will serve as a compliance point to ensure that temperatures from the lower Charles River Basin are in the range that would deny a reasonable opportunity for fish to enter or leave the basin without causing an avoidance response or mortality.

In order to afford the appropriate protection for fish passage into the Charles River from Boston Harbor, certain temperature limits at this sensitive location (Monitoring Station 8) have been established lower than the upstream ZPH Monitoring Stations during periods of the critical spawning range. Also supporting this approach is the judgement based on field data that the range of entry temperatures is lower than the range of breeding temperatures for anadromous species.

The ZPH includes, at all times that the Monitoring Station is required, all monitoring points at Station 8.

5.10.2f **Station 9** - Boston Harbor Near New Charles River Dam and Locks - Temperature, DO

This fixed monitoring station was located in Boston Harbor, but still within the influence of river water discharged from the New Charles River Dam and Locks. The locks and fish passage structures located at this dam are the first barriers anadromous fish must navigate on their way into the lower Charles River Basin. The temperature of the salt water in Boston Harbor, as well as the influence of the freshwater passing from the Charles River into Boston Harbor, are key environmental signals to anadromous fish that will only come into the harbor under certain temperature conditions and will only attempt to travel past the dam under certain water temperature conditions in the river. It has been observed that once anadromous fish sense environmental conditions conducive to spawning and enter a river, they will likely remain in the river and continue their spawning run (Cooper, 1961). However, the instinct to enter the river and move from the marine environment into the freshwater river system is a crucial action that is by no means assured. This monitoring station will measure on a real-time, continuous basis the water quality of Boston Harbor and also measure the influence of river water flowing past the dam and into the harbor to serve as an attractant flow for schooling anadromous fish in the harbor. This station will provide information to ensure that water with excessive temperature or other degraded water quality characteristics are not part of the attractant flow from the dam.

This station will have water quality monitors positioned at a depth of two (2) feet, six (6) feet, twelve (12) feet, and twenty-four (24) feet. (Figure 5.8.2b-2). The objective was to place monitors to obtain a representative vertical profile of the water column of the harbor and measure the effects of the water being released through the dam to Boston Harbor as an attractant flow. Real-time temperature data from Station 9 will not be used for the purpose of permit compliance.

5.10.3 Frequency Of Data Collection

Temperature and dissolved oxygen data from the water quality monitors at all nine stations will be transmitted and available for viewing in a real-time, continuous manner (see Attachment F of NPDES Permit). This will ensure that timely action can be taken in the operation of Kendall Station if water quality limits are about to be exceeded. Timely action to maintain protective river temperatures in the Zone of Passage and Habitat will be essential in order to allow ongoing spawning migration to continue without interruption. In situ protective temperature limits are being required in this permit in lieu of more stringent effluent temperature limits from the Kendall Station discharge derived from a conservative modeling approach. This approach stems from the decision of EPA and DEP to obtain actual receiving water temperatures to demonstrate compliance rather than reaching consensus with the permittee on an appropriate hydrodynamic model. This approached is discussed in Section 5.5.1 and 5.5.2 of this document.

Some spawning migration runs can occur in a brief pulse, involving a large number of anadromous fish. A short- lived pulse of fish movement could likely comprise the majority of the spawning effort in the Charles River for a given year, particularly when the effect of additional stressors in this system (described in Section 5.4 of this document) is considered. A thermal blockage event that coincided with a brief, intense spawning pulse, would have a serious negative effect on the spawning success of anadromous species for the year. If environmental data were available only on a weekly or monthly basis, rather than on a real-time continuous basis, Kendall Station operation could possibly raise temperatures in the Zone of Passage and Habitat (ZPH) to unacceptable levels without immediate detection. This thermal blockage could prevent or severely restrict the upstream passage of a pulse of spawning anadromous fish. Even in the case where the spawning anadromous fish successfully move past the station discharge, the added stress and any possible delay in upstream migration may still have measurable effects on the propagation of the fish community . Under a system with anything less than real-time data reporting, several days would elapse before the temperatures in the ZPH were downloaded and examined and the blockage condition discovered. Under this delayed reporting system, by the time the blockage event was discovered, it would be too late to modify Kendall Station operation in time to minimize the impact of the thermal discharge on any attempted in-migration of anadromous fish. That is why a real-time system is important to the protection and propagation of the aquatic resources of the lower basin.

Real-time, continuous dissolved oxygen monitoring is necessary to properly characterize what area of the water body can be identified as part of the Zone of Passage and Habitat. Areas of the lower basin that satisfy protective water temperature requirements can only be considered acceptable as part of the Zone of Passage and Habitat when the dissolved oxygen levels also meet the minimum standards required for fish species occurring in the basin. In this site-specific case, the Class B State Water Quality Standard (WQS) of a minimum of 5.0 mg/l is the appropriate threshold that must be met for any part of the lower basin to be considered as part of the Zone of Passage and Habitat. Because DO levels may change quickly, and at least a 50% area of any cross sectional area of the lower basin must meet the requirements of the ZPH, real-time, continuous DO monitoring is necessary.

In addition, chlorophyll *a* monitoring data must be available on a real time basis in order to quickly identify the beginning of an algal bloom in the lower Charles River Basin. Timely information regarding the onset of an algal bloom will help assure that the eutrophication WQS is attained and the BIP is not compromised by nuisance algal blooms.

5.10.3a Duration Of Real Time Sampling

The temperature increase (ΔT) of the receiving waters of the lower Charles River Basin in the Zone of Passage and Habitat (ZPH) over the measured background temperature of the river must be reported as a compliance condition of the NPDES Permit. This temperature increase may not be over 2.8 ºC (5 ºF) in a defined section of the ZPH. In order to document that this ΔT remains at or below 2.8 ºC (5 ºF) in the ZPH, Stations 1 (background temperatures), and Stations 2, 3, 4, 5 and 6 must continuously record and transmit real-time temperature data throughout the year for the duration of the permit. While it is assumed, based on the permittee's modeling efforts and field data collection, that the Monitoring Points at Stations 5 and 6 will likely be in the ZD rather than the ZPH, for the majority of time the Facility is operating, this assumption must be documented with the collection of real-time, continuous data at these stations. In order to document that the ΔT remains at or below 2.8 ºC (5 ºF) in the ZPH, Stations 7 and 8 must continuously record and transmit real-time temperature data during their deployment from April 1 through October 31 of each year, for the duration of the permit.

To document that temperature and dissolved oxygen values do not impede the passage of anadromous fish species from the New Charles River Dam and Locks to areas upstream of the Kendall Station discharge, all monitoring stations listed in Section 5.10.2a to f must be in real-time, continuous operation for the parameters listed above from April 1 (just before the beginning of the anadromous fish spawning run in the lower Charles River Basin) through October 30 (end of out-migration of anadromous species). This does not include the chlorophyll *a* monitors.

To document that temperature and dissolved oxygen values do not reach levels that eliminate more than 50% of acceptable fish habitat for resident and anadromous fish occurring in the lower basin, Monitoring Stations 2, 3, 4, 5 and 6 must be in real-time, continuous operation for the parameters listed above throughout the year, for the duration of the permit. To determine the difference between water quality conditions influenced by Kendall Station operation and water quality conditions from upstream, background conditions, Station 1 must also be in real-time, continuous operation for the parameters listed above throughout the year, for the duration of the permit. These monitors are also necessary to document the quality and duration of the overwintering habitat conditions necessary for yellow perch gonadal development. Since Stations 7, 8 and 9 are collecting data primarily to ensure that anadromous fish movement in to and out of the lower basin is not restricted by elevated water temperatures or low dissolved oxygen readings, these monitoring stations are only required during the presence of anadromous fish in the basin (April 1 through October 30).

To document chlorophyll *a* concentrations in the lower Charles River Basin during the time period when algal blooms have occurred, continuous, real-time chlorophyll *a* monitors must be maintained at Stations A, B, and C from May 1 through September 30.

5.10.3b Time Averaging

Since individual aquatic organisms perceive their surroundings under continuous, real-time conditions, the reporting of water quality parameters as instantaneous units of temperature and dissolved oxygen would be the most conservative and meaningful way to evaluate the degree to which an aquatic habitat meets protective criteria for a balanced indigenous population of fish. However, the permittee requested EPA and DEP to consider averaging temperature data over discrete time units up to 12 hours. In this site specific case, EPA and DEP granted temperature and dissolved oxygen data to be averaged within discrete four hour blocks. Time averaging the water quality data in this manner will dampen the natural fluctuations in water temperature seen on a daily basis in the lower basin caused by solar radiation and overnight cooling. This will provide the permittee with a more stable temperature basis to predict trends and allow sufficient time for the permittee to take operational action to reduce thermal input to the river when necessary. Based on a review of historical continuous temperature data collected in the lower Charles River Basin from 1994 through 2002, granting a four hour average temperature for the purpose of permit compliance will not compromise the protection and propagation of a balanced population in this water body. Temperature data will be averaged within six established, four hour periods during every calendar day, before being compared with temperature limits in effect at the time (00:00 [midnight]-03:59, 04:00-07:59, 08:00-11:59, 12:00-15:59, 16:00-19:59, 20:00-23:59). Since fish migratory pulses and other fish behavior can occur in intense but brief pulses, lasting only a few hours, it would not be appropriate to consider time averaging units greater than four hours and still be confident that water quality conditions are being adequately documented in a way meaningful to the aquatic organisms in the lower basin.

In order to create a real-time continuous dissolved oxygen data base that will be comparable to the real-time, continuous temperature database being generated, the same time averaging periods will apply to dissolved oxygen readings as well (midnight-03:59, 04:00-07:59, 08:00-11:59, 12:00-15:59, 16:00-19:59, 20:00-23:59). Low dissolved oxygen levels in the deeper waters of the basin are of primary concern. Because the dissolved oxygen content of the deeper waters of the basin may decline over the course of days, rather than hours, the establishment of a four hour average dissolved oxygen value for the purpose of permit compliance will not compromise the protection and propagation of a balanced population in this water body.

Because real-time, continuous monitoring for dissolved oxygen will likely involve intense maintenance efforts to keep the probes functioning properly, EPA and DEP may entertain an alternative monitoring method to obtain dissolved oxygen information. If conducted with proper frequency, periodic vertical profile monitoring for dissolved oxygen at specific stations may meet the requirements of the permit without continuous real-time monitoring for DO. EPA and DEP welcome comments, including a detailed proposal, that would specify an alternate DO monitoring option.

5.10.4 Near Surface Habitat Protection

5.10.4a Station 3 Near Surface Monitor Compliance Point To Protect Near Surface Habitat

The placement of the water quality monitors along the river transect (Stations 3 through 6) were designed to be evenly spaced both horizontally across the river and vertically from near surface to near bottom. These monitoring locations within the crucial cross sectional area allow a reasonable determination of what percentage of the bank to bank, surface to bottom area of the transect meets the protective water quality and temperature limits established for any respective time period. The EPA and DEP recognize, however, that under certain conditions, 50% or more of the key cross sectional areas of the river could theoretically meet the minimum percentage aspect of the permit, but still contain an entire near surface, bank to bank part of the transect zone with consistently higher temperatures than allowed in the Zone of Passage and Habitat (ZPH). For example, the entire portion of the cross-sectional area from 10 feet deep to the bottom (approximately 26 feet) could possibly meet temperature and dissolved oxygen limits required by the permit. This would technically meet a 50 % minimum cross-sectional aspect of the permit, but at the same time allow the entire, bank-to-bank surface layer, from the surface to a depth of 10 feet, to exceed the protective temperatures. Because the near surface and near shore habitat is identified as a valuable habitat for fish in the lower basin, additional requirements are included in the draft permit to ensure that the entire bank-to-bank span of the upper water column (0 to 3 foot depth) does not contain temperatures considered to be above protective levels, regardless of what the total cross-sectional area percentage at that time is gauged to be.

The surface layer of the lower basin appears to be critical habitat for juvenile bluebacks and alewives. The following information on habitat usage of these alosids is important in identifying the location in the water column where site-specific temperature limits will be most protective.

Blueback herring juveniles were studied by Dixon (1996) in several rivers in Virginia. Juveniles were caught in increasing numbers at the surface (0.5 to 1.5 meters) in "pushnets" mounted in front of boats as the evening progressed to sunset and afterwards. Light intensity when fish were caught at the surface ranged from 1.5 to .001 micro-Einsteins/square meter/second ($\mu E/m^2/s$; full daytime light intensity with clear skies was about 2400 $\mu E/m^2/s$). During daylight hours, blueback juveniles were essentially absent from the surface. As evening approached, capture rates increased to a maximum at about 45 minutes after sunset. Light intensity 45 minutes after sunset during the period of highest capture rates was between . 0 1 and .00 1 $\mu E/m^2/s$.

Other alosids, including alewives and American shad, have also been shown to have a diel vertical migration in the water column and rise to the surface at night. Loesch *et al*. (1982) found that surface catches of young-of-the-year of American shad, bluebacks and alewives in the Mattaponi River in Virginia were significantly greater at night. Conversely, bottom catches were significantly greater in the daytime. Lindenberg (1976) also reported vertical diel movement in juveniles of both alewives and blueback. The phenomenon is apparently widespread among alosids and Blaxter (1986) and others (see Dixon, 1996 for a review) report similar behavior for the Atlantic herring, an oceanic alosid.

There appears to be several reasons for this vertical migration. Dixon states that others who have studied clupeids (Woodhead, 1966; Whitney, 1969; Blaxter, 1986) postulate that pelagic schools of these fish "must balance the conflicting demands of feeding and predator avoidance, and both of these demands are influenced by the availability of light. Low light conditions aid in predator avoidance but hinder visual detection of zooplankton, the primary prey of juvenile alosids." Alosids that can see their food can actively select large zooplankton, the preferred food. Those that cannot must essentially swim with their mouths open, a much less efficient method of feeding.

A certain minimum amount of light appears to be necessary for the maintenance of a pelagic school, according to Dixon (1996). Juveniles move within the isolume where light is sufficient for prey detection and also allows enough visual contact necessary to maintain a school. Schools move up into higher strata as light intensity decreases and eventually reach the surface at night. Alosid juveniles have been seen by Dixon (pers. comm. to G. Szal, June, 2002) and others to "dimple" the water surface at night over a wide area indicating that they were no longer maintaining a school.

Because light levels continue to decrease after dusk, one might expect juvenile alosids to stop feeding as the evening progresses. However, this may not be the situation in the lower basin of the Charles. Blaxter (1966) found the visual threshold (<10% of individuals feeding) of larval and juvenile Atlantic herring to be .0001 $\mu E/m^2/s$. He states that feeding of Atlantic herring was observed under full moonlight when light intensity was about. 00 1 $\mu E/m^2/s$. It could be inferred from this that feeding in clupeids would not proceed through the night during most of the moon's cycle, but Moore (pers. comm. to Szal, June, 2002) found night-time incident light levels in the middle of Jamaica Pond (in Boston's Jamaica Plain), throughout the night, to fall in the range of .01 to.001 $\mu E/m^2/s$. These light intensity levels are within the isolume of alosid feeding. High night-time light levels were due to the proximity of city lights. Light levels in the lower Charles River Basin, wedged between Cambridge and Boston, would also be expected to be influenced by city lights, perhaps more so at the edges of the basin. In the absence of additional information, it is reasonable to assume that alosid surface feeding may take place throughout the night in the lower Charles River Basin.

Curiously, Dixon (1996) states that the results of his work and that of Loesch *et al*. (1982) conflict with results from work conducted in the early 1970s. Two other researchers (Warinner *et al*., 1970; and Burbnidge, 1974) found more river herring at the surface than in lower water depths during daytime sampling in the Potomac and James rivers. Dixon hypothesized that changes in water clarity in the Potomac and James rivers since the 1970s may explain these inconsistencies: "Minimally effective sewage treatment during he 1960s and early 1970s is believed to have caused eutrophication, including major phytoplankton and algal blooms in tidal freshwater areas with greatly reduced light penetration." By comparison, the Mattaponi River, one of the three rivers studied by Dixon (1996) and Loesch (1982), was originally selected for study by Loesch (1982) "because it is relatively clear and might amplify any effects of light intensity on the vertical distributions of juvenile Alosa." Dixon found the minimum critical isolume (0.01 to.001 $\mu E/m^2/s$) in the Mattaponi to fall between 4.3 and >5 meters depth in full sunlight (about 2000 $\mu E/m^2/s$). Since turbidity greatly affects the depth to which light can penetrate into water, it would be expected that the daytime catch of juvenile alosids in turbid rivers would be greater in the upper water column, whereas daytime catch at the surface in clear-water rivers would be minimal.

Differences in surface-layer daytime catch rates between clear and turbid rivers could possibly have direct implications for setting temperature limits in the lower Charles River Basin. It is likely that the 1.5- 0.001 $\mu E/m^2/s$ isolume in the lower basin is reached at points in the water column that are quite near the surface, even in the daytime. MRI, contractors to Mirant, routinely caught river herring in beach-seine nets along the banks of the lower basin in the daytime (Kendall NPDES Application, Volume II, February 2001). In the Hudson River, another turbid system, juvenile shad and blueback herring are also caught during daylight hours near the surface in beach seines (Cathy Hattala, NY DEC, pers. comm. to G. Szal, June 10, 2002). Lower Charles River Basin waters are highly colored and have high solids concentrations, especially after storm events. The water body has also been documented to suffer from algal blooms. All of these contribute to poor light penetration. Judging from the information presented above, it seems reasonable to assume the daytime presence of juvenile river herring and shad in the upper water column the lower basin.

Based on the objective of maintaining the BIP for anadromous fish in the lower Charles River Basin, some portion of the nursery area for alosid larvae and habitat for alosid juveniles throughout the summer and early fall must be protected against temperatures that exceed avoidance levels of juveniles throughout the day and night. Information from the scientific literature identifies the upper water column as an important zone needing protection. To ensure that this valuable, near surface section of the water column is not consistently eliminated from the potential usable habitat of fish in the lower basin, at least one monitoring point in this zone must be included in the ZPH (the 2 ft Monitoring Point at Station 3), regardless of the percentage of monitoring points along the transect that meet the ZPH criteria.

In addition, most alosid larvae, at least in the early stages, have little ability to migrate up or down in the water column and are essentially carried in the current when there is one (Dixon, pers. comm. to Gerald Szal). Consequently, it may be assumed that alosid larvae occurring in the lower basin need protection from excess temperatures throughout the water column. Requiring that the near surface Monitoring Point at Station 3 be part of the ZPH during this critical time will protect the habitat needed throughout the water column for these organisms.

The protection of the upper water column during this time period will also allow resident species of the lower basin to utilize the near surface habitat. Adult largemouth bass use the near surface habitat to seek prey (Stuber *et al*., 1982). Yellow perch, another resident species in the lower basin, are frequently associated with shoreline (littoral) areas in lakes and reservoirs where there are moderate amounts of vegetation present (Krieger *et al*.,1983). As discussed previously, the lower basin maintains the characteristics of an impoundment, especially under low flow conditions. The relatively limited amount of vegetation associated with the shoreline of the lower basin makes this habitat all the more valuable for yellow perch. The protection of the near shore habitat by requiring that all Monitoring Points at Station 3 (closest to the Boston side) always meet the temperature limit will ensure that the near shore habitat is not thermally excluded from use by resident species as well as anadromous species.

5.10.5 Delta T Compliance Program

5.10.5a Introduction

EPA and DEP have concluded that the difference in temperature between the upstream reference site where ambient temperatures are recorded (Monitoring Station 1), and the Zone of Passage and Habitat Monitoring Stations, must be no more than 2.8ºC (5.0ºF). See Section 5.8.2 for a full discussion of the selection of the Delta T value. Because of the unique temperature and flow characteristics of the lower Charles River Basin, the most appropriate mechanism to verify compliance with a Delta T of 2.8ºC (5.0ºF) was the subject of much deliberation. The measurement protocol and calculation used to determine the Delta T in the ZPH is based on an average of temperature measurements in the water column and an averaging time period.

A standard format to determine the Delta T from a thermal source discharging to a river would likely have the following design. A temperature monitoring station would be located upstream of the thermal source, in an environment as similar to the discharge areas as possible. This monitoring station must in no way be influenced by any part of the thermal plume that is discharged from the source. The least complex scenario would be the reach of a river with continuous downstream flow, unaffected by tidal cycles. In this way, river water would not have the potential to move upstream with an incoming tide, carrying the thermal plume to the ambient temperature monitor. Under these assumptions, the ambient temperature monitoring station would likely be located at, or very close to, the intake structure of the facility, thus keeping to a minimum the introduction of environmental variables that might ultimately have an effect on the Delta T calculation.

A downstream monitor or monitors would be located in the thermal plume at a location determined to be the nearest point to the discharge where the change in temperature would be regulated to be no higher than 2.8ºC (5.0ºF).

The objective of the Delta T compliance program is to ensure that there is not an increase in temperature in the ZPH that is greater than 2.8ºC (5.0ºF), when compared with ambient river temperature. It is important to note that this compliance Delta T must be caused by the facility's thermal discharge. Additional thermal effects not caused by facility operation, but rather caused by some environmental factor that effects the temperature or temperature response time at the Delta T compliance stations, must somehow be factored out or dampened. If this situation is not addressed, the Delta T calculation has the potential to indicate a Delta T far greater than 2.8ºC (5.0ºF), when the discharge from Kendal Station was only responsible for a percentage of the Delta T that would indicate compliance with the 2.8ºC (5.0ºF) limit. Conversely, there could also be a situation where a facility discharge is in fact resulting in a Delta T greater than 2.8ºC (5.0ºF), but environmental factors or the way the Delta T is calculated may mask this Delta T to a value below 2.8ºC (5.0ºF).

While the Delta T compliance format for Kendall Station generally follows this framework, the unique temperature and flow characteristics of the lower basin were seen to be environmental factors that likely would result in a Delta T that does not always accurately reflect the thermal impact of the facility. Certain modification to this basic format of the Delta T monitoring and compliance program were incorporated in order to address these issues. EPA and DEP considered information and proposals submitted by the permittee when establishing this Delta T compliance program.

5.10.5b Unique Temperature And Flow Characteristics Of The Lower Basin

The first challenge to establishing a sound Delta T compliance program in the lower basin relates to the impoundment-like nature of the basin. Under low flow conditions, the basin exhibits very little downstream flow, as only a small volume of river water is released into Boston Harbor via the New Charles River Dam and Locks (see Section 2.4). Under these conditions, the thermal plume from Kendall Station has been documented to influence areas far upstream of the facility, as far as the Harvard Bridge (Section 5.10.2a). In order to maintain an ambient temperature station that is not influenced by the thermal plume at any time, a site was selected in the vicinity of the Boston University Bridge. This site, Monitoring Station 1, is approximately 1.5 miles upstream of the facility's discharge point (Figure 5.8.2b-2). This distance is one environmental factor that is problematic when establishing the Delta T program.

In addition to the necessity of being relatively far from the thermal discharge point, the design is further complicated because Monitoring Station 1 is situated in a comparatively narrow and shallow (approximately 15 feet deep), riverine portion of the basin. In contrast, the section of the basin where the thermal discharge is released is a wide, deep (approximately 25 feet) impoundment-like area of the basin (Figure 5.8.2b-2), containing a greater volume of water than the ambient river temperature location (Station 1). Under moderate to low river flow conditions, current velocity in this open, deeper portion of the basin is less than that observed at Station 1. The different relative volume, depth and movement of water between Monitoring Station 1 and other stations used to determine the Delta T are additional environmental factor that are problematic when establishing the Delta T program.

Finally, the deeper water that makes up the ZPH, especially at Monitoring Stations 2, 3 and 4, has been documented to thermally stratify during the warmer months (Section 5.4.10). While changes in temperature with depth have also been recorded at Monitoring Station 1, the thermocline is usually not as pronounced and has been noted at a different depth when compared with temperature vs. depth profiles for the same time period in the area of Monitoring Stations 2, 3 and 4 (Mirant Kendall NPDES Permit Application, Appendix 3, 2001 ; Mirant Kendall Hydrographic Data, 2002; EPA Clean Charles 2005, 2002 Data; Mirant Kendall 2003 Data, Appendix B-2: November 13, 2003).
The differences observed in thermal stratification between Monitoring Station 1 and other stations used to determine the Delta T is yet another environmental factor that is problematic when establishing the Delta T program.

5.10.5c Time Average for Delta T Calculation

The distance between Monitoring Stations 1 and other monitoring stations used to verify Delta T compliance could possibly have a confounding effect on the calculation. A warm or cool slug of water moving downstream in the basin as a result of a storm event may influence Monitoring Station 1 many hours before it is observed at downstream Monitoring points.

The smaller volume of water in the area of Monitoring Station 1 compared with other Monitoring Stations used to determine Delta T could also possibly have a confounding effect on the calculation. Extreme air temperatures or solar intensity will likely effect temperatures at Station 1 sooner and possibly result in a greater temperature response than seen at downstream stations, at least in the short term (Less than 12 hour). Because of the greater volume of water, the deeper areas downstream would require a greater amount of time to display the same temperature response measured at Monitoring Station 1, under the same environmental conditions.

Time differences between daily temperature peaks at the Monitoring Station 1 area and the ZPH area which support this contention have been documented. Continuous temperature monitors were placed near the BU Bridge (Monitoring Station 1) and downstream, in the ZPH, and recorded hourly temperature data from July 23 to August 23, 2002 (Mirant Supplemental Data, 2002) The information for the entire time period was graphed for comparison in Figures 5.10.5c-1. Figures 5.10.5c-2 through 5.10.5c-5 were included to focus in on smaller time intervals within the July 23 to August 23, 2002 time period, in order to better detect temporal differences between the BU Bridge and the ZPH locations. Kendall Station thermal discharge was relatively uniform during this time period and was not thought to have greatly influenced the timing of these daily temperature peaks and depressions. Rather, the timing of these peaks were in response to air temperature and solar intensity.

A general inspection of this continuous temperature data revealed several instances where a peak or low point in temperature at one location was not seen at the other location for from two to six hours. Table 5.10.5c-1 lists several of the comparisons.

Table 5.10.5c-1. Comparison Of Continuous Temperature Data From Station 1 and ZPH Area. Based on Figure 5.10.5c-1.

Date	Temp Peak At Station 1	Temp Peak At ZPH
July 30, 2002	78.5ºF at 4 pm	82.1ºF at 10 pm
August 1, 2002	84.6ºF at 5 pm	82.5ºF at 12 noon
August 5, 2002	82.3ºF at 3 pm	86.2ºF at 7 pm
August 14, 2002	81.3ºF at 6 pm	85.7ºF at 11 pm

While more examples can be observed from the data in Figure 5.10.5c-1 through -5, Table 5.10.5c-1 gives an overview of the variability in temperature comparisons from the two locations. Note that temperature peaks are not always seen at Station 1 first. Also, Station 1 is not always the cooler of the two stations, as would be expected.

The maximum observed time difference between the two stations was approximately six hours. It should be noted that this information was based on only one month of continuous temperature data. In order to dampen the effects of a time difference of up to six hours between Monitoring Stations used to calculate a Delta T for the facility, rolling averages and block average calculations were explored. Rolling averages (i.e. the most recent temperature measurement is added to the average temperature calculation as the oldest temperature value is discarded) could still incorporate a peak temperature into the rolling average calculation at one station before it is observed at another station, resulting in an inaccurate Delta T calculation. Since the peak temperature points in the ZPH varied widely, from noon to 11 pm, a block average of 12 hours (example 6 am to 6 pm) would not always capture both temperature peaks in a 12 hour block average calculation to determine Delta T.

There is only a limited amount of continuous temperature data available, encompassing only one season (summer), from the areas of the lower basin where the Delta T compliance points will be located. In order to ensure that environmental factors listed above that would likely affect the calculation of a representative Delta T are addressed, EPA and DEP have selected a 24 hour block averaging period (00:00 [midnight] to 23:59) to be used in the calculation of the Delta T compliance program. All temperature data over this 24 hour period will be averaged at Station 1 and compared with the 24 hour temperature average at each of the Monitoring Stations in the ZPH. No ZPH average 24 hour temperature will be allowed to be greater than 2.8ºC (5.0ºF) above the 24 hour average temperature at Station 1. Temperatures averaged every four hours and calculated to monitor Delta T throughout the day will also be presented in real time, although these interim values will not have a compliance limit. The four hour values will be included to determine how high the Delta T rises within a 24 hour compliance period.

It should be pointed out that the use of a 24 hour temperature average is being considered only in the case of the Delta T calculation because it is the view of EPA and DEP that this is approach is a reasonable way to address differences between the Background Station (Monitoring Station 1) and the other stations that can not be controlled. These differences are exclusively related to the calculation of a Delta T in this site-specific case and do not apply to any other compliance limit specified in the draft permit. All other compliance limits are designed to protect physiological and behavioral effects that occur on a finer time scale.

The permittee proposed time averaging periods of weeks or over a season when calculating the Delta T compliance value. Under a long term Delta T average calculation, it would be possible for the ZPH to experience Delta T values well in excess of 2.8ºC (5.0ºF) for extended periods. The facility could then, in theory, reduce operation during other periods in the extended averaging time block to maintain an overall Delta T calculation of 2.8ºC (5.0ºF) for this extended averaging period. The potential ramifications to the lower basin under this approach (reaching maximum temperature limits earlier in the season, increasing the chance of heat shock or cold shock to anadromous species (see Section 5.8.2)) resulted in a judgment from EPA and DEP that extended time periods for Delta T calculation are not appropriately protective.

5.10.5d Average of Water Column Measurements

Due to differences in the way thermal stratification takes place at Station 1 in comparison with downstream ZPH stations, a direct comparison between Monitoring Points at the same depth over a 24 hour period was thought to be problematic in establishing a sound Delta T calculation. Vertical profile data for temperature clearly reveals the potential for wide variation in the 12.0 ft. depth Monitoring Point at Station 1 when compared with the 12.0 ft. depth Monitoring Point at ZPH Monitoring Station (CZM Data Analysis, 2003). Because this environmental characteristic of the lower basin could not be sufficiently addressed to provide for a representative Delta T, the Monitoring Points at the 12.0 ft. depth were removed from the Delta T calculation.

Temperature measurements at the 2 foot and 6 foot depth Monitoring Points have also been documented to change dramatically at Station 1 when compared with the same depths at the ZPH locations. The 24 hour average time block will address this environmental factor not related to Facility operation. To ensure this variability does not compromise a representative Delta T calculation, and to account for the uncertainty resulting from the lack of continuous temperature data for the fall, winter and spring seasons, the following provision to the Delta T calculation was established. Monitoring Points at a depth of 2.0 ft. and 6.0 ft. will be averaged at Station 1, over a 24 hour block period (00:00 [midnight] to 23:59), and compared with the 2.0 ft. and 6.0 ft. depth average of each Monitoring Point in the ZPH , over the same 24 hour block period (00:00 [midnight] to 23:59), to determine Delta T compliance. The Delta T limit must be met at a minimum, at Monitoring Stations 2 and 3, Monitoring Station 4 (if both the 2.0 ft. and the 6.0 ft. are included in the ZPH), and Monitoring Stations 7 and 8.

5.10.6 Permitted Allowances For Elevated Ambient Temperatures

5.10.6a Introduction

In most cases during the year, when the ambient river temperature measured at Monitoring Station 1 meets or exceeds the maximum temperature limit in effect during that time period, no additional heat will be added to the ZPH by the Facility. For example, if the temperature limit in effect is 18.3ºC (65ºF) and the Station 1 background temperature rises to 18.9ºC (66ºF), then no temperature in the ZPH can be greater than 18.9ºC (66ºF). Table 5.8.1-1 further describes this protocol.

However, certain limited cases have been identified in Sections 5.10.6b and 5.10.6c, where additional flexibility is warranted, based on documented ambient temperature data.

5.10.6b Spring Allowances From April 15 Through June 7

During the time period of April 15 through June 7, temperature limits were established to protect anadromous fish migration through the lower Charles River Basin. Based on historical temperature data from the basin (see Section 5.9), this time period is characterized by quickly warming and cooling basin temperatures (ambient temperature spikes) in response to fluctuating ambient conditions of the spring season. These temperature spikes are most likely in response to brief, abnormally warm air temperatures, periods of increased solar input, and fluctuations in river flow that occur at different times in the spring.

Since the basin's ambient temperatures spike quickly and fluctuate considerably during this time period, a "stair step" approach of gradually increasing temperature limits as spring progressed was applied to the temperature limit regime. This approach takes this natural warming phenomenon into consideration, while still protecting anadromous fish spawning migration. However, an examination of the historical basin temperature data compared with the established limits (Section 5.9) demonstrate that even with the stair step approach, temperature limits are sometimes exceeded by background ambient temperatures for brief periods.

The historic hourly water temperature data used for this comparison was recorded from a temperature monitor located at the Kendall Station cooling water intake structure for the years 1994 through 2001 (Mirant Kendall NPDES Permit Application, 2001; Unpublished Kendall Station Operations Data 2002). The intake structure draws water from approximately the upper eleven feet of the water column. Intake temperatures were measured once this column of water had mixed. This hourly temperature data provided a general indication of water temperatures in the basin during the spring time period. Section 5.9 of this document has a more complete discussion of the use of this database to approximate historical ambient temperatures in the lower basin.

During the majority of the year, when ambient water temperatures increase and decrease in a more stable pattern, the permit forbids any increase in heat load in the ZPH above ambient conditions when the ambient conditions reach the temperature limit. However, Kendall Station will be provided some measure of operational flexibility during the time period of April 15 through June 7, when these ambient water temperature spikes have been documented. During this time period, the permittee will be allowed to raise the water temperature in the ZPH up to 1.1 ºC (2 ºF) above ambient water temperatures, once ambient conditions meet or exceed the temperature limit in effect at the time. Therefore, this would be a delta T of 2 ºF.

The number of times the permittee is allowed to heat the ZPH up to 1.1ºC (2 ºF) above ambient conditions under these unique circumstances is based on a review of the historical basin temperatures. From April 15 through June 7, ambient water temperatures exceeded, for brief periods, the temperature limits now established in this permit on a minimum of two days in four of the years examined from 1994 through 2001 (Mirant Kendall NPDES Permit Application, 2001; Unpublished Kendall Station Operations Data 2002; Section 5.9). Ambient temperature conditions exceeded established limits on two days in 1995, seven days in 1998, eight days in 1999, and three days in the year 2000. It should be noted that the 1999 data set was missing five weeks of data (April 15 through May 23, 1999) over the period examined. Since 1999 was a warm year for the lower basin, additional, unrecorded ambient temperature values that exceeded the established limits likely occurred in 1999. Rather than use the highest number of recorded days where ambient temperatures exceeded established limits (eight days in 1999), EPA considered all four years when spring basin temperatures exceeded established limits, and chose a more conservative number of allowances of six (6) days to be allowed.

This will provide the permittee the option of using up to six (6), non-continuous days each year, from April 15 through June 7, to add up to 1.1ºC (2 ºF) over ambient conditions to the ZPH, once the ambient temperature of the basin has reached or exceeded the temperature limit in effect. To ensure that all six (6) 24 hour periods are not used within a brief time frame, only three (3) 24 hour exceedence periods will be allowed in any four week period. Unused days may not be carried over to future years. If all six days are used during this period, the permittee will not be allowed to add any additional heat load to the ZPH above ambient water temperature, as long as the ambient water temperature is at or above the temperature limit in effect at that time. Because these observed ambient temperature spikes are generally short in duration, allowing a reduced ΔT of 1.1 ºC (2 ºF) in the ZPH (rather than the ΔT of 2.8 ºC (5ºF) usually in effect) will provide the permittee some operational flexibility without having a serious negative effect on the aquatic community.

5.10.6c Winter Allowances At The Onset And End Of The Winter Chill Period

An additional allowance above ambient conditions will also be allowed at the onset and near the end of the winter chill period, during the first half of November and the last half of April (Section 5.6.3h). These allowances were included after a review of ambient river conditions in the lower Charles River Basin as recorded at the Kendall Station Intake from 1994 through 2001. (Figures 5.9.2-15 through -22; Mirant Kendall Station Operational Data, 2002). Temperature data from individual years show that there is variability regarding the start and end of the 10ºC (50ºF) water temperature threshold. For example in 1994, 1995, 1997, 2000 and 2001, ambient temperatures in the basin had not dropped to 10ºC (50ºF) by November 1, the proposed start of the chill period (Figures 5.9.2-15,-16,-18, -21 and -22). A natural delay in the start of the chill period, caused by a warm fall season, will also effect the end date of the 149 day chill period.

At both the beginning and end of the chill period, if ambient river temperatures have not cooled to the expected temperature of 10ºC (50ºF), Kendall Station is allowed to add heat to the ZPH of up to 1.1 ºC (2 ºF) above ambient conditions. While this is a reduction in the Delta T of 2.8 ºC (5ºF) usually in effect, it does provide the Facility with some operational flexibility when the background temperature has exceeded the maximum temperature in effect for the chill period.

Based on a review of the ambient temperature data, a background temperature at Station 1 in excess of 10ºC (50ºF) in early November or mid-April is a short lived phenomenon. Allowing the Facility to introduce heated discharge that would raise the temperature in the ZPH up to 1.1 ºC (2 ºF) above ambient conditions in this case was not considered a serious threat to adult yellow perch gonadal development.

5.11 Kendall Station Contingencies To Meet Thermal Limits

With its letter of December 23, 2002, the permittee proposed a River Temperature Compliance Program to manage operations of the Kendall Repowered Station in a manner that allows the water temperature in the lower basin of the Charles River to remain within permitted limits. This program is described below. Alternatively, Section 5.11.3, offers a BTU heat load proposal for public comment. This proposal was suggested by the permittee and would require the reduction of electricity generation to specific percentages of maximum heat load, based on the exceedence of certain instream temperatures.

5.11.1 Notification Thresholds

These will be thresholds at which EPA and DEP will be notified that an action threshold has been approached. In each case, the Notification Threshold will be 2 degrees F lower than the corresponding Preventive Action Threshold.

5.11.2 Action Thresholds

The permittee has proposed two levels of action triggered as temperatures approach permit violations. The first of which is called the Precautionary Action and the second is called Preventive Action. There are several operational alterations that may take place within each of these Action Thresholds. These operational alternations may move from one action threshold to another over time based on operational experience.

The Precautionary Action threshold will take place when an in-stream temperature is 2 degrees Fahrenheit below the NPDES permit limit. They are designed to decrease the plant heat loading to the river without significantly altering the electrical output of the facility.

Precautionary Actions including the following:

- Checking and potentially cleaning the condenser tube sheets to remove any fouling that may be present. This action does not appreciably limit the heat loading to the river. This action does make sure that the plant is operating at its maximum circulating water flow to maximize river diffusion and to minimize the absolute temperature rise across the condensers.

- Begin selling additional steam to the extent that this option is available.

Preventive Action Thresholds will take place should the river temperature continue to climb toward temperature limits required by the NPDES permit. These actions are designed to reduce heat rejection to the river by altering the operations and potentially the electrical output of the facility. The Preventive Actions will take place most likely in the order listed below:

- Reduce the output of the facility during off peak conditions.

- Begin taking the combustion turbine offline off peak starting with a few hours of shutdown and increasing the number of shutdown hours until the desired temperature levels are reached.

EPA and DEP acknowledge this protocol, submitted by the permittee, as an overview of actions that may be taken as maximum temperature limits are approached. It must be made clear, however, that the Facility must take responsible action necessary to prevent exceeding all temperature limits in effect during a given time period, regardless of whether the Facility is considered to be in "off peak conditions". Any violation of a thermal limit must be reported, and will be carefully evaluated to determine an appropriate enforcement action.

5.11.3 BTU Heat Load Proposal

The following is not part of the draft permit or fact sheet. This proposal is available along with the draft permit for public comment. It is an alternative to provisions in the draft permit to meet instream temperature limits. In this alternative proposal, the permittee may be allowed to operate the plant in a way that will require curtailment of electricity generation as a permit condition to ensure instream ΔT limits and instream temperature limits are not exceeded. This approach may be allowed to provide the permittee with the flexibility it needs to be able to forecast a minimum guaranteed amount of electricity to submit as a bid to the administrator of power distribution in the area (ISO-New England). Since the business conditions in Massachusetts require the permittee to pledge to generate a fixed amount of electricity a day ahead of time, Mirant favors a compliance system that will allow for more certainty in forecasting short term electricity production.

This alternative is based on a proposed alternative approach submitted to EPA by the permittee, although some of the details have been changed. The following will serve to provide the permittee with the business flexibility it needs while assuring that the balanced indigenous population (BIP) will be maintained in and on the receiving water. The heat load targets are based on a maximum, permitted heat load of 13,344 million British Thermal Units (BTU) per day (100% heat load), which is derived from the maximum plant flow of 80 MGD and the limited ΔT across the condensers of 11.1 ºC (20 ºF). Because of the uncertainty and lag in time before triggering an adjustment in power production, the threshold temperatures in this alternative are set lower than those in the draft permit and what the permittee had requested.

<u>Alternative permit approach for comment</u>

See the flow chart at Figure 5.11-1 which shows how this approach would work. At 8:00 each morning, the permittee will review the 4 hour average temperatures at each one of the instream temperature monitors for the preceding 24 hours. These averages will be compared to a set of temperature thresholds and higher temperature caps. The temperature caps are the actual instream temperature limits found in Attachment A of the permit and described in this document, while the temperature thresholds are 3 ºF less than each temperature cap. If any of the temperature thresholds were exceeded for any of the temperature monitoring stations located in the Zone of Passage and Habitat (ZPH), for any of these 4 hour averages, the permittee is required to cut down to the next lower heat load range by 12:00 midnight (16 hours later). This heat load level may not be exceeded for any one hour during the reduced generation period. For example, if more than half of the measured/reported heat load values of that day were above 75% of the maximum heat load, the permittee would be required to cut back its heat load to no more than75% of the maximum heat load, measured hourly, beginning at midnight. If more than half of the measured/reported heat load values of that day were above 50% of the maximum heat load, the permittee would be required to cut back its heat load to no more than 50% of the maximum heat load, measured hourly, beginning at midnight. If there are no temperature caps or thresholds exceeded the following day, then the permittee may continue producing electricity up to its maximum heat load.

In any situation where a temperature threshold is exceeded, the permittee may also be in compliance with this requirement if the plant maintains a max ΔT of 1.7 ºC (3 ºF) above background (as a 4 hour average) in the ZPH and no more than a 1.2 ºC (2 ºF) ΔT above background at Monitoring Stations 2 and 8. This alternative compliance will not be an option if a temperature cap is exceeded, as discussed below.

If the 4 hour average comparison shows that any of the temperature caps are exceeded, the permittee will cut down to 10% of the plant's maximum heat load beginning at midnight. From the 10% level, there are 3 options for the next day. Another cap exceedence would keep the plant at 10%. A threshold exceedence would allow the plant to go up to the next level (up to 50% of maximum heat load) and no cap or threshold exceedence would allow the plant to operate up to its maximum heat load.

Along with its monthly Discharge Monitoring Report (DMR) the permittee shall also provide a chart and/or a written analysis of any exceedences of temperature caps and thresholds and what subsequent actions it took. The permittee shall clearly document how it achieved compliance with this alternative heat load proposal by citing specific days of temperature exceedences and by explaining whether it followed this requirement by cutting heat load or maintaining ΔTs instream.

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6.0 § 316 (a) Variance Determination

According to CWA § 316(a), as codified at 40 CFR 125 subpart H, thermal discharge effluent limitations in permits may be less stringent than those required by applicable standards and limitations if the discharger demonstrates that such effluent limitations are more stringent than necessary to assure the protection and propagation of a balanced, indigenous populations (BIP) of shellfish, fish and wildlife in and on the body of water into which the discharge is made. This demonstration must show that the alternative effluent limitations desired by the discharger, considering the cumulative impact of its thermal discharge together with all other significant impacts on the species effected, will assure the protection and propagation of a balanced indigenous populations of shellfish, fish and wildlife in and on the body of water into which the discharge is made.

As a practical matter, EPA has with some permits simply developed permit limitations under a Section 316(a) variance if a set of limitations were determined to be sufficient to assure protection and propagation of the BIP. In such cases, determining the technology-based and water quality-based limitations would have served no practical purpose. Similarly, in some cases, EPA has determined water quality-based conditions without determining the technology-based requirements, when EPA had reason to believe that it was clear that the water quality-based requirements would be more stringent than the technology-based standards.

In this case, the permittee has requested a variance pursuant to Section 316(a) and has proposed specific thermal discharge limitations that would apply under such a variance. In reviewing this variance request, maximum instream temperatures were established for the receiving basin to meet the desired goal of protection and propagation of the balanced indigenous fish populations. The protection of the fish species or life stage that is most sensitive to elevated temperature is a recognized way to ensure that all species found in a water body receiving thermal discharge are protected.

Based on the analysis summarized in Section 5 of this document, EPA does not approve of the 316(a) variance proposed by the permittee. However, based on the analysis in Section 5, EPA has determined that a 316(a) variance from certain aspects of the Massachusetts Water Quality Standards (WQS) is appropriate and adequately protective of the BIP. The key aspect of the Massachusetts WQS subject to this variance is the mixing zone policy which calls for no lethal affects in the Zone of Initial Dilution (ZID). EPA assumes that this variance based effluent limit which will maintain the instream temperatures described in permit Attachment A is less stringent than either a water quality based or technology based permit without a comprehensive derivation of such water quality based or technology based limits.

It should be noted that the variance-based thermal limits in this permit are largely consistent with Massachusetts WQS. Specifically, the permit requires the following and no 316(a) variance is required for these aspects of the Massachusetts WQS:

- Site specific temperature limits for spring and winter periods;

- Maintenance of a Zone of Passage of at least 50% of the cross sectional area of the Charles River;

- A maximum ΔT of no more than 5°F between a background station and six different points in the vicinity of the discharge, including within the Zone of Passage and Habitat (ZPH);

- A minimum dissolved oxygen level of 5.0 mg/l at any point in the ZPH; and

- A maximum summer temperature of 83°F in the ZPH.

To assure protection of the BIP with this variance, the permit mandates continuous instream monitoring to ensure compliance with temperature, delta T and other requirements necessary to assure the protection and propagation of the BIP. The results of this monitoring will be used during the future reissuance(s) of the permit or any permit modifications.

Thus, the draft permit grants a §316(a) variance to allow the discharge of heat to the Charles River, in a manner that is less stringent than the mixing zone policy contained in the Massachusetts Water Quality Standards, but nonetheless assures the protection of the BIP. EPA is granting the §316(a) variance based on available data while acknowledging that additional data must be collected and analyzed. Accordingly, the draft permit requires the limits as set out in Attachment A and the gathering and analysis of additional information as specified in the draft Permit, to determine whether or not Mirant Kendall continues to meet the standards for the §316(a) variance. The results of this new, increased monitoring will be considered during the next permit reissuance process and any permit modifications.

7.0 Cooling Water Intake Requirements - CWA § 316(b)

7.1 Introduction

The following sections present EPA's determination with respect to the application of CWA § 316(b), 33 U.S.C. § 1326(b), to the new NPDES permit for Mirant Kendall Station (sometimes referred to hereinafter as "MKS" or the "Facility"). CWA § 316(b) governs requirements related to cooling water intake structures (CWISs) and requires "that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact." The operation of CWISs can cause or contribute to a variety of adverse environmental effects, such as killing or injuring fish larvae and eggs by entraining them in the water withdrawn from a water body and sending them through the facility's cooling system, or by killing or injuring fish and other organisms by impinging them against the intake structure's screens.

In the absence of detailed applicable regulations, for many years EPA has made CWA § 316(b) determinations on a case-by-case, Best Professional Judgment (BPJ) basis, both for new facilities and for existing facilities with regulated CWISs. EPA promulgated new final § 316(b) regulations providing specific technology standard requirements for *new* power plants and other types of *new* facilities with CWISs. 66 Fed. Reg. 65255 (Dec. 18, 2001) (the Phase I Regulations). These regulations do <u>not</u>, however, apply to *existing* facilities such as MKS.

EPA has also developed regulations applying CWA § 316(b) to large, existing power plants (the Phase II Regulations). These final regulations were signed by the Administrator on February 16, 2004 but they are <u>not</u> yet effective, because the effective date is 60 days after the date of publication in the Federal Register and publication has not occurred as of the date of this writing. In the absence of applicable regulations, EPA continues the existing practice of applying § 316(b) on a case-by-case, BPJ basis to existing facilities such as MKS. This satisfies currently applicable legal requirements. At the same time, because the final Phase II Regulations have been signed and now appear likely to be in effect at the time of final permit issuance to MKS, EPA finds it reasonable to consider the requirements of the Phase II Regulations in developing CWA § 316(b) limits on a BPJ basis for this draft permit.

In making determinations under CWA §316(b), EPA must consider environmental/ecological issues, engineering issues, economic issues related to the cost of implementing CWIS technology options, legal issues, and, ultimately, policy issues regarding the final choice of appropriate steps to minimize adverse environmental effects. These issues, as well as the permit conditions arising from our CWA § 316(b) determinations, are addressed below.

State legal requirements, including state water quality standards, also may apply to the development of permit conditions for cooling water intake structures. State water quality standards set designated uses for water bodies within the state and specify narrative and numeric criteria that the water bodies must satisfy. Permit conditions must be designed to satisfy applicable criteria and protect designated uses, including those for fish habitat. CWA §§ 301(b)(1)(C) and 402(a) require that permits include "any more stringent limitation, including those necessary to meet water quality standards, treatment standards, or schedules of compliance, established pursuant to any state law or regulations (under authority of section 1370 of this title [(i.e., CWA § 510)]) . . ., or required to implement any applicable water quality standard established pursuant to this chapter." 33 U.S.C. § 1311(b)(1)(C). Section 301(b)(1)(C)'s mandate applies regardless of whether EPA or a state is the permit issuing authority and, for an EPA-issued permit, applies regardless of whether the state expressly demands that such conditions be placed in the permit. In addition, CWA §510 clearly authorizes states to impose more stringent water pollution control standards than dictated by the federal statute, at least where the statute does not expressly forbid such tougher state standards. In the regulations governing the development of water quality standards, 40 C.F.R. § 131.4(a) states that, "[a]s recognized by section 510 of the Clean Water Act, states may develop water quality standards more stringent than required by this regulation." The Supreme Court in PUD No. 1, 511 U.S. at 705, cited to this regulation in support of the view that states could adopt water quality requirements more stringent than federal requirements.

The Supreme Court has also held that once the CWA § 401 state certification process has been triggered by the existence of a discharge, then the certification may impose conditions and limitations on *the activity as a whole*, not merely on the discharge, to the extent needed to ensure compliance with state water quality standards or other applicable requirements of state law. Thus, the Court stated:

> The text [of CWA § 401d)] refers to the compliance of the applicant, not the discharge. Section 401(d) thus allows the State to impose "other limitations" on the project in general to assure compliance with various provisions of the Clean Water Act and with "any other appropriate requirement of State law." . . . Section 401(a)(1) identifies the category of activities subject to certification – namely, those with discharges. And § 401(d) is

> most reasonably read as authorizing additional conditions and limitations on the activity as a whole once the threshold condition, the existence of a discharge, is satisfied.

PUD No. 1, 511 U.S. at 711-12. Thus, for example, a state could impose certification conditions related to cooling water intake structures on a permit for a facility with a discharge, if those conditions were necessary to assure compliance with a requirement of state law, such as to protect a designated use under state water quality standards. See Id. at 713. This also confirms that in setting *discharge* conditions to achieve water quality standards, a state can and should take account of the effects of *other* aspects of the activity that may affect the discharge conditions that will be needed to attain water quality standards.

In sum, the limits in EPA-issued NPDES permits that address cooling water intake structures must satisfy both CWA § 316(b) and any applicable state requirements, such as water quality standards.[4] The Massachusetts Department of Environmental Protection (MA DEP) has primary responsibility for determining what permit limits are necessary to achieve compliance with state law requirements. Since the NPDES permit that EPA expects to issue to MKS will be subject to state certification under CWA § 401, the permit will also need to satisfy any conditions of such a certification. EPA anticipates that the MA DEP will address its certification after issuance of this draft permit but before issuance of the final permit.

7.2 Legal Requirements and Context

7.2.1 The Statutory Language

CWA § 316(b) is the statute's only provision that directly requires regulation of the withdrawal of water from a water body, as opposed to regulating the discharge of pollutants into water bodies. Rather than addressing all types of water withdrawal, however, this provision addresses only cooling water intake structures and provides that:

> [a]ny standard established pursuant to section 301or section 306 of this Act and applicable to a point source shall require that the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact.

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[4] See also 40 C.F.R. §§ 125.80(d) and 125.84(e) (provisions in Phase I regulations mandating that cooling water intake structure requirements in permit also must satisfy any more stringent state requirements); and 40 C.F.R. §§ 125.90(d) and 125.94(e) (parallel provisions in the preliminary draft of signed final Phase II regulations posted on EPA's website at www.epa.gov/waterscience/316b).

33 U.S.C. § 1326(b). The plain meaning of this language is that Congress wanted EPA to ensure that the best technology available for minimizing adverse environmental impacts from CWISs would be utilized by plants withdrawing cooling water from the Nation's water bodies.

The legislative history related to CWA § 316(b) is relatively sparse, but what there is tends to reinforce the plain meaning of the language used in the statute. In the House Consideration of the Report of the Conference Committee (October 4, 1972) on the final version of the 1972 CWA Amendments, Representative Clausen stated that "Section 316(b) requires the location, design, construction and capacity of cooling water intake structures of steam-electric generating plants to reflect the best technology available for minimizing any adverse environmental impact." Congressional Research Service, "*A Legislative History of the Water Pollution Control Act Amendments of 1972, Vol. 1*," 93d Cong., 1st Session, p. 264 (emphasis added) (cited hereafter as "1972 Legislative History"). In addition, the Senate Consideration of the Report of the Conference Committee (October 4, 1972) for the final 1972 CWA amendments evidences Congressional awareness of the problem of fish being harmed by power plant CWISs. Id. at pp. 196-99, 202.[5] As mentioned above, and discussed in more detail below, in the absence of applicable national regulatory guidelines concerning the application of the BTA standard under § 316(b), EPA applies § 316(b)'s requirements on a case-by-case, BPJ basis. This is consistent with CWA §§ 402(a)(1)(B) and 402(a)(2) and longstanding EPA practice upheld by the courts.

7.2.2 EPA Regulations under CWA § 316(b)

Until recently, the only EPA regulations addressing § 316(b) essentially repeated the text of the statute and supported the application of § 316(b) on a case-by-case, BPJ basis in the absence of applicable national guidelines. *See* 40 C.F.R. §§ 401.12(h) and 401.14. *See also* 40 C.F.R. § 125.3 (regulation addressing the analogous situation of effluent discharges and requiring development of permit limits based on BPJ in the absence of national standards).

On December 18, 2001, EPA promulgated final § 316(b) regulations providing specific national technology standard requirements for new power plants and other types of *new* facilities with CWISs. 66 Fed. Reg. 65255 (Dec. 18, 2001). These "Phase I Regulations" replace the BPJ, case-by-case approach for the facilities that they cover. They do not, however, apply to *existing* facilities, such as the Mirant Kendall Station.

On February 16, 2004, EPA signed Notice of Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities. (See Preliminary Pre-Publication

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[5] Accord *In the Matter of Public Service Company of New Hampshire (Seabrook Station, Units 1 & 2)*, 10 ERC 1257, 1262 (U.S. EPA, NPDES Permit Application No. NH 0020338, Case No. 76-7, June 17, 1977); *Decision of the General Counsel No. 41 (In Re Brunswick Steam Electric Plant)* (June 1, 1976), pp. 200-01.

Draft of the Signed Final Phase II Regulations posted on EPA's website at www.epa.gov/waterscience/316b). These Phase II Regulations will apply to large, existing power plants and will become effective 60 days after the date of publication in the Federal Register. As of the date of this writing, however, publication has not yet occurred and these regulations are *not* in effect. As a result, until the new Phase II Regulations are effective, EPA continues its longstanding practice of applying CWA § 316(b) on a case-by-case basis to existing facilities.

Nevertheless, EPA has also considered the new Phase II regulations in developing the draft permit's BPJ limits under § 316(b) because (a) EPA has determined that if the Phase II Regulations were effective, they would apply to MKS, and (b) the Final Phase II Regulations have been signed and we do expect that they are likely to be effective by the time of issuance of a final permit to MKS. At the same time, if the Phase II Regulations are not in effect at that time for some reason (e.g., they have been stayed or remanded as a result of the litigation that has been threatened regarding the Regulations), then the final permit could still potentially be issued on a BPJ basis.

7.2.3 Requirements of the Phase II 316(b) Rule

The Final Phase II Regulations were signed by the EPA Administrator on February 16, 2004, and an unofficial pre-publication version has been posted on EPA's website (at www.epa.gov/waterscience/316b/). These regulations identify five different options from which a Phase II existing facility may choose an approach to achieving compliance with the requirements of the regulations. Application requirements vary based on the compliance alternatives selected and, for some facilities, include development of a Comprehensive Demonstration Study. Under this final rule, EPA has established performance standards for the reduction of impingement mortality and, under certain circumstances, the reduction of entrainment. The performance standards consist of ranges of reductions in impingement mortality and/or entrainment (e.g., reduce impingement mortality by 80 to 95 percent and/or entrainment by 60 to 90 percent). The application of performance standards is based on several factors, including the type of water body on which the facility is located, the facility's utilization rate, and the proportion of the volume of the water body that is withdrawn by the facility. Under the rule, the performance standards can be met by design and construction technologies, operational measures, restoration measures, or some combination thereof.

The Phase II Regulations prescribe a number of interrelated decisions to be made by EPA and the permittee during a multi-step process of options selection and information collection, submission and review leading up to permit issuance. For example, the rule requires EPA to evaluate – using information from the permittee's application, its bi-annual status reports, or other sources – the performance of any technologies, operational measures, and/or other measures that the permittee may have already implemented. As another example, if the permittee chooses to propose restoration measures as part of its approach to satisfying the applicable performance standards under the rule, EPA will need to evaluate the proposal and determine its acceptability under the rule, as well as how it would be monitored if approved. Clearly, working through all these issues could be a difficult, time-consuming process. (See Pre-Publication Draft of Final Phase II Regulations, Preamble at pp. 236 - 42 (discussion of time needed for application process).

At the same time, it must be remembered that not only are the new Phase II Regulations not yet in effect, but the permittee has not yet submitted a complete information submission addressing all of the new requirements under the Phase II Regulations. The regulations directly address this type of problem, however, in a manner designed to allow ongoing permitting to continue without undue delay because of the new regulations. The regulations provide a reasonable approach to the transition from BPJ permitting to permitting under the new regulatory standards that allows the permitting authority to continue issuing new permits with § 316(b) limits based on BPJ under certain circumstances. EPA believes these circumstances apply in the case of the MKS permit. Therefore, EPA may set CWA § 316(b) permit limits for the new draft permit based on BPJ not only because the Phase II Regulations are not yet in effect, but also because doing so would be consistent with the requirements of the Phase II Regulations if they were in effect.

Specifically, 40 C.F.R. §§ 125.95(a)(2)(i) and (ii) in the pre-publication draft of the Phase II Regulations state the following (emphasis supplied):

> (i) You must submit your NPDES permit application in accordance with the time frames specified in 40 CFR 122.21(d)(2);
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> (ii) If your existing permit expires before [Insert date 4 years after date of publication in the FR], you may request that the Director establish a schedule for you to submit the information required by this section as expeditiously as practicable, but not later than [Insert date 3 years and 180 days after date of publication in the FR]. *Between the time your existing permit expires and the time an NPDES permit containing requirements consistent with this subpart is issued to your facility, the best technology available to minimize adverse environmental impact will continue to be determined based on the Director's best professional judgment.*

Applying this regulation to this case, one sees that the existing permit for MKS expired many years ago (in 1993) and that, consistent with 40 C.F.R. 122.21(d)(2), the permittee also timely filed its permit application many years ago. In addition, the permittee has not to date submitted all of the information required by the Phase II Regulations and we do not expect the permittee will have done so by the time EPA is ready to issue the final permit to MKS. Therefore, even if the new Phase II Regulations were in effect, they would authorize EPA to issue the current *draft* permit to MKS with § 316(b) limits that "continue to be determined based on the Director's best professional judgment." Moreover, if the new Phase II Regulations are in effect by the time the Agency issues a new *final* NPDES permit to MKS – which EPA expects will be the case – EPA would also be authorized by 40 C.F.R. §§ 125.95(a)(2)(i) and (ii) to issue the final permit to MKS on a BPJ basis.

Under the Phase II Regulations, such a final permit with BPJ-based limits under CWA § 316(b) would also be likely include a schedule by which the permittee would provide the complete information submission required by the regulations as expeditiously as practicable but not later than three years and 180 days from publication of the regulations. EPA is not proposing such a schedule in the draft permit because the Phase II Regulations are not yet in effect and the permittee has not requested such a schedule. However, the Agency reiterates that the schedule should be as expeditious as practicable and can extend no longer than 3 years and 180 days from the date of publication of the regulations. EPA requests comments from the permittee and any other interested party regarding whether such a schedule is desirable and what the terms of such a schedule should provide.

The approach to permitting in the face of the period of transition from the current BPJ approach to developing CWA § 316(b) permit limits to developing permit limits under the new Phase II regulations is a reasonable and appropriate scheme which seeks to prevent undue delay to ongoing permitting as a result of the new regulations. This approach is consistent with the CWA's goal of continued progress toward achieving the restoration and maintenance of the chemical, physical and biological integrity of the Nation's water bodies. *See* 33 U.S.C. § 1251(a)(1). It is also consistent with the fact that the statutory deadline for achieving compliance with CWA § 316(b) standards was July 1, 1983, which has already passed. *See* EPA GCO 41. It also especially makes sense in this case because EPA Region 1, the involved state agencies, the interested public and the permittee have already been working on this permit development (including the development of § 316(b) limits) for a number of years. Indeed, the permittee has conducted a pilot study on the barrier net intake technology that it has proposed for MKS. Moreover, this permit involves important issues to be addressed other than cooling water intake requirements (e.g., thermal discharge conditions), so that delaying permitting because of the new Phase II Regulations under CWA § 316(b) would be highly problematic. Furthermore, developing the current BPJ-based permit would also provide a proper foundation for the permit's limits in the event that the Phase II Regulations are not in effect for some reason at the time of final permit issuance.

Of course, EPA's current action involves issuance of a draft permit for public review and comment. Therefore, EPA will be considering comments received from the public, including the permittee. These comments may address the manner in which EPA interprets the Phase II Regulations. They also may involve the submission of materials to try to address the permit application requirements of the Phase II Regulations. If such materials are submitted, EPA could then consider whether to alter the permit's § 316(b) requirements in some manner in light of requirements of the Phase II Regulations.

In addition, it should be pointed out that EPA is hopeful that there will not be major controversy over the draft permit's § 316(b) requirements since they are based on the use of a technology (i.e., a proposed barrier net system) that was proposed by the permittee itself. EPA is proposing that performance standards for the reduction of impingement mortality and entrainment be applied to that technology to track the standards applicable to freshwater rivers in the Phase II Regulations. We think that achieving these standards is practicable and would result in minimization of adverse environmental impact and would satisfy the minimum requirements of the Phase II Regulations. We have also considered applying a performance standard only for impingement mortality reduction, or having no performance standards at all, but we have determined that the approach proposed in the Draft Permit would better satisfy the requirements of CWA § 316(b) on a case-by-case basis, as well as the performance standards specified in the Phase II Regulations, if they were presently applicable. EPA welcomes comments on this approach. EPA also welcomes comments on whether compliance with the final permit should be assessed on the basis of a Technology Implementation and Operations Plan (TIOP) as described in the pre-publication draft of the Final Phase II Regulations and, if so, what that TIOP would involve.

The remainder of Chapter 7 of the Determination Document provides the legal background that has guided EPA when making case-by-case 316(b) determinations. This background is relevant for the case-by-case BTA determination based on BPJ being conducted under 40 CFR 125.95(a)(2)(ii), and would also be relevant in the event the new Phase II regulations are not effective on the date of final permit issuance.

7.2.4 CWA § 316(b) Determinations on a Case-by-Case, BPJ Basis

In the absence of regulations specifying national technology guidelines for CWISs, EPA has been applying CWA § 316(b) on a case-by-case, BPJ basis. A December 28, 2000, EPA Headquarters memorandum also instructed EPA Regional offices to continue using certain specific existing guidance documents in developing their case-by-case, BPJ § 316(b) decisions. See EPA Memorandum from Michael B. Cook, "Implementation of Section 316(b) in National Pollutant Discharge Elimination System Permits," December 28, 2000. EPA is authorized to develop permit conditions on a case-by-case, BPJ basis by CWA §§ 402(a)(1)(B) and 402(a)(2).[6]

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[2] United States Steel Corp. v. Train, 556 F.2d 822, 850 (7th Cir. 1977); Hudson Riverkeeper Fund, Inc. v. Orange and Rockland Utilities, Inc., 835 F. Supp. 160, 165 (S.D.N.Y. 1993); EPA Office of General Counsel "Information Memorandum - Judicial Review of Section 316(b) Regulations- Appalachian Power Co. v.

Specifically, EPA stated that the May 1, 1977, "Draft: Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b)" (the "May 1977 Draft § 316(b) Guidance"), "continues to be applicable pending EPA's issuance of final regulations under section 316(b)." Id. p. 1. See also 66 Fed. Reg. 65262 (Dec. 18, 2001). The May 1977 Draft § 316(b) Guidance (at p. 5), in turn, cross-references to the EPA's "Development Document for Best Technology Available for the Location, Design, Construction and Capacity of Cooling Water Intake Structures for Minimizing Adverse Environmental Impact," (EPA 440/1-76/015-a) (April 1976) (the "EPA 1976 Development Document"), for guidance regarding technological issues and additional information regarding intake impacts. See also 66 Fed. Reg. 65261-62 (Dec. 18, 2001). The December 28, 2000, EPA Memorandum also pointed to the following two "background papers" as providing potentially useful information for permit writers: (1) "Preliminary Regulatory Development, Section 316(b) of the Clean Water Act, Background Paper No. 3: Cooling Water Intake Technologies" (1994) (the "1994 EPA Background Paper No. 3"); and (2) "Draft Supplement to Background Paper No. 3: Cooling Water Intake Technologies" (1996) (the "1996 EPA Supplement to Background Paper No. 3"). Finally, the December 28, 2000, EPA Memorandum also instructed that past permit determinations could also be a useful source of information for current permit writers.

While directing permit writers to certain potentially helpful information, EPA Headquarters also cautioned in the December 28, 2000, Memorandum against over-reliance on the past documents. Thus, EPA stated the following (at p. 2) (emphasis added):

> [p]lease note that the draft 1977 guidance and the two background papers do not impose legally binding requirements on EPA, the State, or the regulated community, and may not apply in a particular situation based on the circumstances. EPA and State decision-makers retain the discretion to adopt approaches on a case-by-case basis that differ from applicable guidance where appropriate. Any decisions on a particular facility should be based on the requirements of section 316(b).

7.2.5 Factors to Consider in Making CWA § 316(b) Determinations

CWA § 316(b) mandates that the design, location, construction and capacity of a CWIS reflect

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Train and Virginia Electric and Power Co. v. Costle (4th Circuit)," p. 3. See also 40 C.F.R. § 125.3 (relating to development of effluent discharge standards); Texas Oil & Gas Ass'n v. United States EPA, 161 F.3d 923, 928-29 (5th Cir. 1998) (BPJ effluent discharge standards); Natural Resources Defense Council v. U.S. E.P.A., 859 F.2d 156, 195 (D.C. Cir. 1988) (BPJ effluent discharge standards).

the Best Technology Available (BTA) for minimizing adverse environmental impact. However, there are no applicable statutory or regulatory definitions of the terms "available," "Best Technology Available," "adverse environmental impact," or "minimize," as they are used in § 316(b).

7.2.5a "Available" Technologies

In applying the BTA standard under CWA § 316(b), EPA obviously must decide which technologies are "available." Neither the Act nor current regulations expressly define this term. In addition, EPA guidance under CWA § 316(b) has not identified exactly how to determine when a technology should be considered to be "available."

Looking to the dictionary definition, "available" is defined in the American Heritage Dictionary (2nd Ed. 1982) as, "accessible for use; at hand." This suggests that, at a minimum, under CWA § 316(b) any technology that might be either directly required or indirectly required as the result of a flow or design limitation must be technologically feasible. A particular technology's feasibility could be demonstrated by an example of its use at another facility. Feasibility also might be established through other means such as, for example, appropriate pilot or bench-scale testing. Thus, in past investigations of potential CWIS-related technologies for minimizing adverse environmental impacts, EPA has evaluated technologies in use or under research for CWISs and technologies being used for other purposes that could be adapted for CWISs. See 1994 EPA Background Paper No. 3, pp. 1-1, 2-1, 2-5, 3-1; 1996 EPA Supplement to Background Paper No. 3, pp. 1-2.[7]

EPA has also in the past interpreted CWA § 316(b) to intend an economic "practicability" test for BTA options. " Although the CWA § 316(b) makes no mention of considering costs, economic practicability can be understood to be implicit within the meaning of the term "available." EPA also found support for the conclusion that Congress intended a limited consideration of cost in a single passage from the sparse legislative history of § 316(b). Specifically, in the House Consideration of the Report of the Conference Committee, Representative Clausen stated that:

> [t]he reference here [in § 316(b)] to "best technology available" is intended to be interpreted to mean the best technology available commercially at an *economically practicable cost*.

1972 Legislative History, p. 264 (emphasis added). Citing to Representative Clausen's remarks, EPA stated the following in the preamble to the Final CWA § 316(b) regulations issued in 1976, but later remanded to the Agency:

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[7] See also "EPA 1976 Development Document, pp. 175-77, 193.

> The brief legislative history of section 316(b) states that the term "best technology available" contemplates the best technology available commercially at an economically practicable cost. As with the statute, this language does not require a formal or informal "cost/benefit" assessment. Rather, the term "available commercially at an economically practicable cost" reflects a Congressional concern that the application of "best technology available" should not impose an impracticable and unbearable economic burden on the operation of any plant subject to section 316(b). Since the regulations require a case-by-case determination of the best available technology, consideration of the economic practicability of installing that technology must necessarily be conducted on a similarly individualized basis.

41 Fed. Reg. 17388 (April 26, 1976) (Final CWA § 316(b) regulations withdrawn by EPA after remand by federal court). Thus, EPA believed that Congress had intended an economic practicability test to be applied to BTA determinations under § 316(b). Applying such a test to a facility-specific case-by-case, BPJ determination, as opposed to a national guidelines determination, would mean that the cost of proposed BTA actions should not be financially impossible for a plant to implement and remain in business (i.e., "should not impose an impracticable and unbearable economic burden" on plant operations).[8]

7.2.5b "Best" Technology Available

CWA § 316(b) requires that the design, construction, location and capacity of CWISs reflect the "best technology available for minimizing adverse environmental impact." In the 1976 preamble to the Proposed Final CWA § 316(b) regulations, EPA explained that this meant that EPA's "effort must be to select *the most effective means* of minimizing . . . adverse effects." 41 Fed. Reg. 17388 (Final CWA § 316(b) regulations later withdrawn by EPA after remand by federal court) (emphasis added). This is consistent with the common meaning of the term "best," which is defined by the *American Heritage Dictionary (2nd Ed.)* (1982), as "surpassing all others in excellence, achievement, or quality . . .."

The above-described interpretations of the terms "available" and "best" in CWA § 316(b) are consistent with and supported by analogy to EPA's application of the "Best Available Technology economically achievable" (BAT) technology standard for the development of effluent guidelines under CWA §§ 301(b)(2)(A) and 304(b)(2)(B). To be sure, the *BAT* effluent

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[8] Consistent with this understanding, the American Heritage Dictionary (2nd Ed.) (1982), defines "practicable" as, "capable of being effected, done or executed; feasible."

discharge standard is not identical to the *BTA* standard for cooling water intake structures.[9] Nevertheless, Congress used the same words for both standards, albeit combined in different ways, and it is fair to analogize to the BAT standard in seeking guidance for how to apply the terms "best" and "available" in the BTA standard.

In applying BAT, EPA has determined that it should look to the single "best" performing plant in the industry –in terms of effluent reductions– to determine the "best available" technology.[10] In addition, however, EPA has also determined that it may look to any viable "transfer technologies" (that is, technology from another industry that could be transferred to the industry in question), as well as technologies that have been shown to be viable in research even if not yet implemented at a full-scale facility.[11] This is consistent with EPA's past work under § 316(b) as described above.

Therefore, to determine whether the location, design, construction, and capacity of a particular CWIS reflects the "Best Technology Available" for minimizing adverse environmental impacts, EPA will look to the best-performing CWIS to see what it achieves. Given that MKS is an existing fossil fuel-burning plant that would require retrofitting to achieve any *technologically-driven* improvements,[12] EPA will look in this regard to what technologies have been retrofitted to

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[9] See, e.g., *In the Matter of Public Service Company of New Hampshire (Seabrook Station, Units 1 & 2)*, 10 ERC 1257, 1261 (Permit Appeal Decision by Administrator of EPA) (June 17, 1977). See also 65 Fed. Reg. 49065 (August 10, 2000) ("EPA notes that 'Best Technology Available' (BTA) is a distinct standard under the CWA.").

[10] E.g., Texas Oil & Gas Ass'n v. United States E.P.A., 161 F.3d 923, 928 (5th Cir. 1998); Association of Pacific Fisheries v. Environmental Protection Agency, 615 F.2d 794, 816-17 (9th Cir. 1980); American Meat Institute v. E.P.A., 526 F.2d 442, 462-63 (7th Cir. 1975).

[11] These determinations, arising out of CWA legislative history, have been upheld by the courts. E.g., American Petroleum Institute v. E.P.A., 858 F.2d 261, 264-65 (5th Cir. 1988); Pacific Fisheries, 615 F.2d at 816-17; BASF Wyandotte Corp. v. Costle, 614 F.2d 21, 22 (1st Cir. 1980); American Iron and Steel Institute v. E.P.A., 526 F.2d 1027, 1061 (3d Cir. 1975); American Meat Institute, 526 F.2d at 462-63.

[12] Although EPA may consider "flow reduction" as a "technology", EPA understands that improvements could be made without actually changing technology by simply reducing the amount of cooling water used by Kendall. Such reductions without technology changes would, however, require cutbacks in the generation of electricity. Requiring such cutbacks, sometimes on a seasonal basis, has been required in some permits. See, e.g., Bulletin, Marine Resources Advisory Council, Vol. IX, No. 4, "Effects of Power Plants on Hudson River Fish," (requirements for plant included scheduled plant outages); *In the Matter of Florida Power Corporation, Crystal River Power Plant, Units 1, 2 and 3, Citrus County, Florida* (Findings and

other existing fossil fuel-burning plants to better minimize adverse environmental impacts from their CWISs. In addition, EPA could look to any technologies that can be shown to be feasible for use at the Facility, even if they have not previously been used to retrofit an existing facility. For example, in this regard, EPA could look to technologies being used at new power plants to determine if they would be feasible for retrofit at the Facility. Indeed, use of a relevant technology at a new plant could well provide stronger evidence of the feasibility of a technology than technologies "transferred" from another industry or established only at the research or pilot-testing level.[13]

Of course, when each CWA § 316(b) decision is made on a case-by-case basis, EPA must also consider whether any particular technology is truly feasible for use at the specific facility in question (in this case, Mirant Kendall Station) given the particular facts of that facility. For example, while the fact that a technology works at a particular power plant might suggest that it could also work at Kendall, it still might not *actually* be feasible at Kendall due to site-specific issues such as, for example, space limitations. If it is not actually feasible at the Facility, then it would not be the "best technology available" for the Facility.

7.2.5c "Adverse Environmental Impact"

The term "adverse environmental impact" (AEI) as used in CWA § 316(b) is not defined in either the statute or existing regulations. As such, neither the statute nor the regulations expressly limit the extent of adverse environmental impacts that may be considered. As mentioned above, the legislative history behind CWA § 316(b) is sparse, but in the House Consideration of the Report of the Conference Committee for the final 1972 CWA Amendments, Representative Clausen stated that "Section 316(b) requires the location, design, construction and capacity of cooling water intake structures of steam-electric generating plants to reflect the best technology available for minimizing *any* adverse environmental impact" (emphasis added). 1972 Legislative History, p. 264. This language suggests that all adverse environmental impacts should be considered and minimized.

Consistent with Representative Clausen's remarks, EPA's May 1977 Draft § 316(b) Guidance states as follows (at p. 15):

> [a]dverse aquatic environmental impacts occur whenever there

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Determinations Pursuant to 33 U.S.C. § 1326; NPDES Permit No. FL 0000159), p. 8. Accordingly, the permittee in this case has evaluated flow reductions as a result of operational shutdowns as a potential alternative means of satisfying CWA § 316(b). See February 2001, Kendall Square Station Equipment Upgrade Project, Vol. I, Section 6.4.1.

[13] In one sense, one can think of a technology used at a *new* power plant as a potential "transfer technology" for use at *existing* plants.

> would be entrainment or impingement damage as a result of the operation of a specific cooling water intake structure.

The May 1977 Draft § 316(b) Guidance (at p. 15) goes on, however, to state that, "[t]he critical question is the magnitude of any adverse impact." The guidance document then explains that "[t]he magnitude of an adverse impact should be estimated both in terms of short term and long term impact" with reference to the following factors: (1) "absolute damage;" (2) "percentage damage;" (3) absolute and percentage damage to any endangered species; (4) absolute and percentage damage to any "critical aquatic organism;" (5) absolute and percentage damage to commercially valuable and/or sport fisheries yield; and (6) "whether the impact would endanger (jeopardize) the protection and propagation of a balanced population of shellfish and fish in and on the body of water from which the cooling water is withdrawn (long-term impact)." Thus, the May 1977 Draft § 316(b) Guidance indicates that in assessing the magnitude of the adverse effect, EPA is to consider both the number of individual organisms killed or injured (i.e., "absolute damage") and the percentage of the overall population of species that are damaged (i.e., "percentage damage"). It is also clear that "percentage damage" should be considered at levels below that which would cause the complete collapse of the population. In other words, consideration of "percentage damage" is not limited to cases of 100% damage.[14]

The May 1977 Draft § 316(b) Guidance also indicates that in trying to assess adverse impact, permitting agencies should also consider the overall sensitivity of the source water to adverse biological impacts from cooling water intake structures. The Draft Guidance explains (at pp. 11-12) that:

> Some general guidance concerning the extent of adverse impacts can be obtained by assessing the relative biological value of the source water body zone of influence for selected species and determining the potential for damage by the intake structure. For a given species, the value of an area is based on the following considerations: 1. principal spawning (breeding) ground; 2. migratory pathways; 3. nursery or feeding areas; 4. numbers of individuals present; and 5. other functions critical during the life

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[14] See also In the Matter of Public Service Company of New Hampshire, *et al.* (Seabrook Station, Units 1 and 2), 10 Env't Rep. Cas. (BNA) 1257, 1262 (EPA June 17, 1977);(CWA § 316(b) standard requiring that CWISs reflect BTA for minimizing adverse environmental impact differs from § 316(a) standard requiring that thermal discharge limitations protect balanced indigenous populations of fish, shellfish and wildlife, and § 316(b) may require further minimization of adverse impacts even if balanced indigenous populations would not be undermined). Accord *Decision of the General Counsel No. 63*, p. 371, 382 (July 29, 1977) (In re Central Hudson Gas and Electric Corporation, *et al.*); *Decision of the General Counsel No. 41*, 197, 201-02 (June 1, 1976) (In re Brunswick Steam Electric Plant).

> history. A once-through system for a power plant utilizes substantially more water from the source water body than a closed recirculation system for a similar plant and thus would tend to have a higher potential impact. A biological value/potential impact decision matrix for best intake technology available could be:
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> * * *
>
> An open system large volume intake in an area of high biological value does not represent best technology available to minimize adverse environmental impact and will generally result in disapproval.
>
> Exceptions to this may be demonstrated on a case by case basis where, despite high biological value and high cooling water flow, involvement of the biota is low or survival of those involved is high, and subsequent reductions of populations is minimal.

In a similar vein, the preamble to the 1976 proposed Final CWA § 316(b) regulations, which were later remanded to EPA by Fourth Circuit Court of Appeals, explained that, "[t]he potential for adverse environmental effects associated with cooling water systems may depend upon such factors as size and type of water body and relative magnitude of flow withdrawn for cooling." 41 Fed. Reg. 17388 (April 26, 1976). Of course, the general type of water body is only one factor to consider, and case-specific analyses of the environmental effects of each particular plant are still required for permit development as explained above. See also 41 Fed. Reg. 17388-89 (Final CWA § 316(b) Regulations later withdrawn by EPA after remand by federal court) (assessing adverse effects depends on consideration of multiple factors, including type of water body, number of organisms killed or damaged, and overall damage to the ecosystem).

It should be understood that AEI is not limited to cases of substantial harm to resident populations of fish species or to entire communities of organisms. Setting such a high threshold for the existence of AEI, would not be supported by the statutory language, the legislative history or the other materials discussed above. While there may be some *de minimis* threshold level of impacts below which EPA will not consider AEI to have occurred. EPA has interpreted the §316(b) technology standard to require minimization of adverse environmental impacts whether or not they are "significant," as long as the applicable economic tests are satisfied (the "wholly disproportionate cost" test is discussed below). Furthermore, as discussed above, the May 1977 Draft § 316(b) Guidance (at p. 15) clearly indicates that adverse environmental impacts include more than just "substantial population effects." Thus, EPA has not stated that losses of numbers of individuals need not be addressed or that population reductions need not be addressed unless they are "substantial."

The Draft Guidance does make clear, however, that EPA must assess the *magnitude* of the adverse impact. See also EPA 1976 Development Document, pp. 13, 175. Moreover, EPA has been clear that the magnitude or seriousness of the adverse impacts should be assessed on a case-by-case basis taking into account the facts related to the ecosystem and natural resources in question. See 41 Fed. Reg. 17388 (April 26, 1976); May 1977 Draft § 316(b) Guidance, p. 11-15. Thus, a given level of losses from an otherwise healthy ecosystem or fish population might be less environmentally significant than similar or even smaller losses from a stressed ecosystem or fish population. Having decided that the magnitude of the adverse effects should be assessed, EPA has then taken the approach that more serious adverse impacts warrant more serious expenditures for reductions based on a "wholly disproportionate" cost test.

This approach is well illustrated in the Seabrook permit appeal decision, in which the EPA Administrator explained:

> . . . the RA [i.e., EPA Regional Administrator] may have meant only that some consideration ought to be given to costs in determining the degree of minimization to be required. I agree that this is so – otherwise the effect would be to require cooling towers at every plant that could afford to install them, regardless of whether or not any significant degree of entrainment or entrapment was anticipated. I do not believe that it is reasonable to interpret Section 316(b) as requiring use of technology whose cost is wholly disproportionate to the environmental benefit to be gained.

In re Public Service Company of New Hampshire, 10 TRC at 1261. Thus, it was the "wholly disproportionate cost" test that prevented an across-the-board cooling tower (or closed-cycle cooling) requirement, and *not* the argument (namely, that no adverse environmental impacts exist and require minimization until substantial harm to entire populations of fish have occurred).

7.2.5d "Minimizing" Adverse Environmental Impacts

In past decisions, EPA has determined that the term "minimize" should be understood to have its common meaning, which is, "reduce to the smallest possible amount, extent, size, or degree." *American Heritage Dictionary (2nd Ed.)* (1982). See also 41 Fed. Reg. 17387-88 (Proposed Final CWA § 316(b) regulations later remanded to EPA by federal court and withdrawn by EPA); *Decision of the General Counsel No. 63* (In re Central Hudson Gas and Electric Corporation, et al.), p. 371, 381 (July 29, 1977); *In the Matter of Public Service Company of New Hampshire, et al. (Seabrook Station, Units 1 and 2)*, 10 Env't Rep. Cas. (BNA) 1257, 1260 (EPA June 17, 1977); *Decision of the General Counsel No. 41 (In re Brunswick Steam Electric Plant)*, 197, 203 (June 1, 1976). Based on the language and structure of CWA § 316(b), EPA has also determined that CWISs must reflect the BTA for minimizing adverse environmental impacts, whether or not those adverse impacts are considered to be significant. *Decision of the General Counsel No. 41*, at 203 ("The [cooling water intake] structures must reflect the best technology available for *minimizing* . . . adverse environmental impact – significant or otherwise.") (emphasis in original); *Decision of the General Counsel No. 63*, at 381-82 ("Under Section 316(b), EPA may impose the best technology available . . . in order to minimize . . . adverse environmental impacts – significant or otherwise."). In other words, once adverse impacts are beyond some *de minimis* level, there is no particular threshold of significance which must be crossed before the adverse impacts must be minimized by the application of BTA.[15]

Still, the May 1977 Draft § 316(b) Guidance is clear that EPA does not regard CWA § 316(b) to require the complete elimination of all entrainment or impingement in all cases. The Guidance states (at p. 3):

> 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.

Thus, although EPA has read CWA § 316(b) to intend that greater than *de minimis* levels of entrainment or impingement may be considered an "adverse impact," and that such impacts must be reduced to the smallest amount possible (i.e., be "minimized") through the application of BTA, this may or may not require the elimination of all impacts in any given case. Less than complete elimination of all adverse effects could be appropriate if the effects are considered *de minimis,* if further reductions are not feasible with available technology, or if the cost of attaining these additional reductions would be wholly disproportionate to the benefits of doing so.

7.2.5e Economic Considerations in CWA § 316(b) Determinations

EPA has interpreted CWA § 316(b) to authorize it to consider, to a limited extent, the cost of the options when making determinations of what constitutes BTA for minimizing adverse environmental impacts. First, as discussed in detail above, cost is considered in terms of "practicability." This can be understood as part of meeting the "availability" component of BTA. Second, as briefly mentioned above, an option's costs are also to be considered under the wholly disproportionate cost test. This is discussed further below.

The text of CWA § 316(b) makes no express mention of considering costs in any way in

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[15] The significance or magnitude of the impacts comes into play, however, when considering whether the cost of undertaking actions to further minimize impacts is justifiable.

determining BTA requirements. Nevertheless, EPA found support for the conclusion that Congress intended a limited consideration of cost in a passage from the legislative history of § 316(b). Specifically, in the House Consideration of the Report of the Conference Committee on the 1972 CWA Amendments (Oct. 4, 1972), Representative Clausen stated that "[t]he reference here [in § 316(b)] to 'best technology available' is intended to be interpreted to mean the best technology available commercially at an economically practicable cost." 1972 Legislative History, p. 264. This suggests that in Representative Clausen's view, economic practicability should be considered but does not, on its face, indicate that a comparison of costs and benefits should determine the result of a § 316(b) determination.

Recognizing the focus of Representative Clausen's remarks, EPA cited them in support of the following conclusions in the preamble to the 1976 proposed Final CWA § 316(b) regulations:

> The brief legislative history of section 316(b) states that the term "best technology available" contemplates the best technology available commercially at an economically practicable cost. As with the statute, this language does not require a formal or informal "cost/benefit" assessment. Rather, the term "available commercially at an economically practicable cost" reflects a Congressional concern that the application of "best technology available" should not impose an impracticable and unbearable economic burden on the operation of any plant subject to section 316(b). Since the regulations require a case-by-case determination of the best available technology, consideration of the economic practicability of installing that technology must necessarily be conducted on a similarly individualized basis.

41 Fed. Reg. 17388 (final CWA § 316(b) regulations later withdrawn by EPA after remand by federal court). Thus, EPA made clear that it believed that Congress intended an economic practicability test to be applied to BTA determinations under § 316(b), but made equally clear that a cost/benefit analysis was not required.

EPA later adopted a new test involving a limited consideration of costs and benefits. In a permit appeal decision involving the Seabrook, New Hampshire nuclear power plant, the Administrator reiterated much of what EPA had stated in the preamble to the regulations regarding both the absence of any cost/benefit analysis requirement and the need for costs to be economically practicable. Significantly, however, the Administrator also affirmed that no measures should be required as BTA "whose cost is wholly disproportionate to the environmental benefit to be gained." Specifically, the Administrator stated the following:

> ... the Agency's position, that cost benefit analysis is not required under Section 316(b), is correct. Section 316(b) provides flatly that cooling water intakes shall "reflect the best technology

> available for minimizing adverse environmental impact." ... Indeed, but for one bit of legislative history [citation to Representative Clausen's remarks omitted], there would be no indication that Congress intended costs to be considered under Section 316(b) at all. I find, therefore, that insofar as the RA's decision may have implied the requirement of a cost/benefit analysis under Section 316(b), it was incorrect.
>
> However, the RA may have meant only that some consideration ought to be given to costs in determining the degree of minimization to be required. I agree that this is so – otherwise the effect would be to require cooling towers at every plant that could afford to install them, regardless of whether any significant degree or entrainment or entrapment was anticipated. I do not believe that it is reasonable to interpret Section 316(b) as requiring the use of technology whose cost is wholly disproportionate to the environmental benefit to be gained.

In re Public Service Company of New Hampshire (Seabrook Station, Units 1 and 2), 10 TRC 1257, 1261 (NPDES Permit Application No. NH 0020338, Case No. 76-7; June 17, 1977) (Decision of the Administrator). In Seacoast Anti-Pollution League (SAPL) v. Costle, 597 F.2d 306, 311 (1st Cir. 1979), the First Circuit Court of Appeals noted EPA's evaluation of costs and cited to Congressman Clausen's remarks to support the proposition that, "[t]he legislative history clearly makes cost an acceptable consideration in determining whether the intake design reflect[s] the best technology available."

EPA has not, however, specified any particular method for determining whether an option's costs are "wholly disproportionate" to its benefits under CWA § 316(b). Whether assessed qualitatively or quantitatively, or both, an option's costs would have to be substantially greater than its benefits before those costs would be deemed "wholly disproportionate" to the benefits. Where to "draw the line" is a policy judgment left to the sound discretion of EPA in making its case-by-case § 316(b) decisions. The appropriate judgment regarding the point at which the costs of a technology become wholly disproportionate to its benefits might vary from case to case based on the type and extent of the adverse impacts to be addressed and the degree of certainty or uncertainty regarding the costs and benefits.

7.2.6 Cumulative Impacts

In assessing the impact from a CWIS, EPA must consider both the impacts from the operation of the CWIS alone and its impacts considered *in conjunction with* other environmental stressors. In other words, BTA determinations under § 316(b) must consider any adverse cumulative effects of the operation of the CWIS. EPA cannot determine the adverse effects of the CWIS in isolation from other stresses on the same environment. For example, the loss to a CWIS of a certain number of organisms, or a certain percentage of a population organisms, might be a more serious adverse impact in an environment already suffering from other adverse impacts than it would be in an otherwise healthy ecosystem. As EPA has concluded, "it would be wrong for the Agency to put blinders on." *Public Service Company of New Hampshire*, 10 TRC at 1262 (Decision of Administrator of EPA). In the end, any such cumulative effects must be considered on a case-by-case basis to assess the magnitude of the adverse effects of CWIS operation and the appropriateness of requiring certain expenditures to minimize those impacts.

7.2.7 Aspects of BTA for CWISs

CWA § 316(b) spells out four aspects of a CWIS that must reflect the BTA for minimizing adverse environmental impacts. These are the CWIS's design, location, construction and capacity. Each of these factors is discussed below.

7.2.7a Location

The term "location" has been interpreted by EPA to refer to the water body or the segment of the water body in which the CWIS is located.[16] The EPA 1976 Development Document (at p. 15) states that "[t]he most important locational factor influencing the intake design is the nature of the water source from which the supply is taken." In addition, "location" has been interpreted also to refer to where the intake is located *within a particular water body*, such as its location within the water column, its location relative to the shore line, its location relative to the point of the thermal discharge, or its location relative to any particularly sensitive areas in the water (e.g., migration routes, spawning areas, etc.). Id. at Section II, pp. 15 - 26, 178-79. See also EPA Background Paper No. 3, p. 2–3; 1977 Draft CWA § 316(b) Guidance, p. 6; Public Service Company of New Hampshire, 10 TRC at 1263-64, 1270-72.

"Location" has sometimes been referred to as the most important factor in minimizing adverse impacts from a CWIS, because many adverse impacts can be avoided simply by not siting the intake in areas of sensitive or important natural resources.[17] However, adjustment of the "location" of a CWIS to minimize adverse environmental impacts is likely to be easier for a new

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[16] The term "location" is not defined in either the CWA or current EPA regulations. In the 1976 Proposed Final CWA § 316(b) regulations, EPA proposed defining "location" as the "position or site occupied by the cooling water intake structure." 41 Fed. Reg. 17390 (April 26, 1976) (proposed 40 C.F.R. § 402.11(b)). As discussed above, however, these regulations were later withdrawn after remand to EPA by a federal court.

[17] "Plant siting and the location of the intake structure with respect to the environment can be the most important consideration relevant to applying the best technology available for cooling water intake structures. Care in the location of the intake can significantly minimize adverse environmental impacts." EPA 1976 Development Document, p. 178.

facility than an existing facility. Nevertheless, "location" must be considered for existing facilities because it may be possible in some cases to reduce impacts by replacing an existing CWIS with a new one at a new location. Of course, the cost of such a "retrofit" would need to be considered, as well as any additional adverse environmental impacts that might result from "construction" of the new CWIS. See EPA 1976 Development Document, p. 169.

7.2.7b Design

EPA has interpreted the "design" component of BTA for CWISs to refer to various elements that make up the CWIS itself.[18] These elements include various screening systems ranging from "trash racks" to other screening technologies intended to try to keep fish or even larvae or eggs from being drawn into the plant. Systems to be considered could include physical screening systems as well as "behavioral" screening systems. In addition, various fish bypass and return systems intended to minimize the adverse impacts of impingement could be considered under the design element. Finally, consideration may also be given to various types of pumps and intake technologies, such as velocity caps, that influence the volume and velocity of water drawn into the plant. See EPA 1976 Development Document, pp. 27 - 143. See also EPA 1996 Supplement to Background Paper No. 3. Design elements should be considered for both new and existing facilities, though the technical feasibility and economic considerations may differ for each, especially given that new equipment for an existing facility will require retrofitting. EPA 1976 Development Document, pp. 142-43.

7.2.7c Construction

The term "construction" has been interpreted by EPA to apply to the physical aspects of installing the CWIS.[19] EPA review of construction-related CWIS impacts has considered

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[18] The term "design" is defined in neither the CWA nor current EPA regulations. In the 1976 Proposed Final CWA § 316(b) regulations, EPA proposed defining "design" as "the arrangement of elements that make up the cooling water intake structure." 41 Fed. Reg. 17390 (April 26, 1976) (proposed 40 C.F.R. § 402.11(c)). However, these regulations were later remanded to EPA by a federal court and the Agency then withdrew the regulations. See also Preliminary Pre-Publication Draft of Final Phase II Regulations (available on EPA website, as indicated above), 40 C.F.R. § 125.95.93 (definition of "design and construction technology").

[19] The term "construction" is not defined in either the CWA or current EPA regulations. In the 1976 Proposed Final CWA § 316(b) regulations, EPA proposed defining "construction" as the "process of physically constructing the cooling water intake structure, including site preparation." 41 Fed. Reg. 17390 (April 26, 1976) (proposed 40 C.F.R. § 402.11(d)). However, these regulations were later withdrawn by EPA after they were remanded by a federal court. See also Preliminary Pre-Publication Draft of Final Phase II Regulations (available on EPA website, as indicated above), 40 C.F.R. § 125.95.93 (definition of "design and construction technology").

damage to the area of the ecosystem impacted by the process of installing the CWIS and its long-term placement in the ecosystem.[20] EPA has also considered the effects of turbidity generated by construction activities and erosion around the area of the CWIS, as well as any adverse effects from the disposal of material dredged or excavated from the area in which the CWIS will be placed. See EPA 1976 Development Document, pp. 145 - 47. If considering potential retrofits to a CWIS, consideration must also be given to whether construction of the retrofitted equipment will reflect the BTA for minimizing adverse environmental effects.

7.2.7d Capacity

The term "capacity" as used in CWA § 316(b) has been defined to refer to the volume of cooling water drawn through the intake.[21] The velocity of the water drawn into the plant may also be considered under this factor (as well as under the design factor). In *Decision of the General Counsel No. 41*, at 200 - 01, EPA's General Counsel stated the following:

> ... it seems clear to me that the term "capacity" in § 316(b) means the volume of water withdrawn through a cooling water intake structure. This conclusion is supported by the commonly understood meaning of the term "capacity" [footnote to dictionary definition of "capacity" referring to "cubic contents; volume" omitted], the definition of the term in the regulations [footnote omitted], and the legislative history of the Federal Water Pollution Control Act Amendments of 1972.
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> In the course of debating the conference report of the Act on October 4, 1972, the Senate was well aware of the dangers

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[20] The latter consideration obviously overlaps with the consideration of location. EPA has noted that the various aspects of BTA for CWISs listed in CWA § 316(b) can overlap considerably. See EPA 1976 Development Document, p. 15.

[21] The term "capacity" is defined in neither the CWA nor current EPA regulations. In the 1976 Final CWA § 316(b) regulations, EPA proposed defining "capacity" as the "maximum withdrawal rate of water through the cooling water intake structure." 41 Fed. Reg. 17390 (April 26, 1976) (proposed 40 C.F.R. § 402.11(e)). The preamble to the regulations explained that "[the] relative magnitude of flow withdrawn for cooling" was one of the key factors to consider in evaluating the adverse impact from a CWIS. It further stated that "entrainment . . . realistically cannot be separated from intake structure capacity and location," and that "the extent of entrainment and impingement damage is in many cases correlated with the amount of water withdrawn . . .." Id. at 17388, 17389. Further, in discussing compliance dates, EPA stated that "the available technologies of cooling water intake structures for minimizing adverse environmental impacts . . . are closely related to capacity (volume of flow) . . .." Id.

> posed to aquatic life by the withdrawal of large volumes of water through cooling water intake structures [footnote omitted].

Accord *Decision of the General Counsel No. 63*, at p. 381, n. 10; *In re Public Service Company of New Hampshire*, 10 TRC at 1262 (Decision of Administrator of EPA). See also *Supplement to Background Paper No. 3* (September 3, 1996), p. A-3; *Background Paper No. 3* (April 4, 1994), p. 2-3; EPA 1976 Development Document, p. 153.

As with the other factors, "capacity" must be considered in making CWA § 316(b) determinations for both new and existing facilities. As EPA stated in *Decision of the General Counsel No. 63*, at p. 381, n. 10:

> Since the magnitude of entrainment damage is frequently a function of the amount of water withdrawn, the only way that massive entrainment damage can be minimized in many circumstances is by restricting the volume of water withdrawn or by relocating the intake structure away from the endangered larvae. The latter approach is often not feasible. Thus, in certain cases, the only means of minimizing serious entrainment damage is to restrict the volume of water withdrawn.

See also *In re Public Service Company of New Hampshire*, 10 TRC at 1264 (Decision of Administrator of EPA); EPA 1976 Development Document, p. 178; EPA Draft CWA § 316(b) Guidance (May 1, 1977), p. 13 ("Reducing cooling water flow is generally an effective means for minimizing potential entrainment impact . . . [and i]n fact, . . . may be the only feasible means . . . where potentially involved organisms are in relatively large concentration and uniformly distributed in the water column").

8.0 § 316 (b) Discussion - Cooling Water Intake Structure Impacts

8.1 Biological Impacts of Kendall Station Impingement and Entrainment

Section § 316(b) of the Clean Water Act addresses the adverse environmental impacts of a cooling water intake structures (CWIS) at facilities requiring NPDES permits. EPA recognizes that there are multiple types of impact associated with CWIS, which range from the individual to the ecosystem level. Water withdrawal from a CWIS results in impingement on the intake screens of fish and other aquatic life that are too large to pass through this barrier, resulting in injury or mortality to the organisms. Also, CWISs cause adverse environmental impacts by killing or injuring fish eggs and larvae and other small aquatic life as a result of entraining them in water drawn through, and discharged from, the plant's cooling system.

In addition to direct impingement and entrainment losses associated with the operation of an individual CWIS, the adverse environmental impacts of a CWIS may also potentially include its contribution to cumulative, overall degradation of the aquatic environment in combination with other stressors impacting the water body at issue (see Section 5.4 of this document for a discussion of Charles River stressors). This type of cumulative effect is a concern with respect to the lower Charles River Basin. First, the CWISs at MKS are not the only ones withdrawing water from the basin. For example, Blackstone Station is a power plant located upstream of Kendall Station which also withdraws water from the basin through a cooling water intake structure. Second, the basin is already designated as impaired by the DEP. The impairments include organic enrichment/low dissolved oxygen (DO), noxious aquatic plants, and taste, odor and color problems, along with contaminated sediments, harmful bacteria, and high turbidity. Third, as discussed elsewhere in this document, MKS is proposing to increase its thermal discharges to the basin. This increase discharge poses potential threats to aquatic life and the ecosystem by altering water temperatures, which can contribute to the other water quality problems noted immediately above (e.g., growth of noxious aquatic plants and DO depletion, etc.). The draft permit proposes limits for thermal discharges that are designed to assure the protection and propagation of the balanced indigenous population of organisms in and on the lower Charles River Basin, but the extent to which such discharges are allowed and cause threats may constitute a cumulative adverse effect in combination with effects from CWISs and other stressors.

The overall cumulative effects of multiple CWIS withdrawals, increased thermal discharges at MKS and existing impairment of the lower basin are not assessed in detail or quantitatively in the current § 316(b) analysis for the MKS permit. This is due to a lack of detailed information that would allow such an analysis. Thus, EPA has considered these cumulative effects in only a qualitative sense, as discussed above. As additional information is gathered in the lower basin through the required environmental monitoring program, however, the cumulative impact of the adverse effects of the Kendall Station CWIS may be further assessed within the context of these additional basin impacts.

Based on what the permittee initially submitted as part of the permit application, the new baseload configuration of the Kendall Station is projected to approach the full capacity of electric generation for the station. This will consistently require Charles River water for non-contact cooling in the range of 70 MGD. This is roughly a 40% increase over the observed historical average water usage of 50 MGD from 1992 through 1998 (estimated from Figure 3.1.1-1). If the maximum daily water withdrawal of 80 MGD is compared to the historical water usage of 50 MGD, the increase in water usage is 60% (estimated from Figure 3.1.1-1). Left unregulated, the 40 - 54% increase in water withdrawal from the lower Charles River Basin will increase the potential impact of the station on all life stages of fish that occur in the vicinity of the Kendall Station cooling water intake structure by increasing impingement and entrainment of these organisms.

8.1.1 Impingement Impacts From Kendall Station

8.1.1a Introduction

Impingement of organisms occurs when water is drawn into a facility through its CWIS and organisms too large to pass through the protective screens and unable to swim away become trapped against the screens and other parts of the intake structure. The quantity of organisms impinged is a function of the intake structure's location, design, capacity and approach velocity, and the abundance of organisms of various species in the general vicinity of the CWIS.

8.1.1b Factors Effecting Impingement From Kendall Station

Intake structure location can vary by geographic location and water depth. EPA's Guidance Document for Best Technology Available for the Location, Design, Construction and Capacity of Cooling Water Intake Structures for Minimizing Adverse Environmental Impact (1976) recommends selecting locations to avoid important spawning areas, juvenile rearing areas, fish migration paths, shellfish beds or areas of particular importance for aquatic life.

In the case of Kendall Station, the CWIS is located in the Broad Canal. The canal is a man-made inlet that extends approximately 700 feet perpendicular to the Charles River and is about 15 feet deep. The canal does not exhibit a net flow past the Kendall Station CWIS. The location of the CWIS, out of the path of any anticipated upstream or downstream migration of anadromous fish, is seen as a factor which may reduce the potential for impingement of these anadromous species. However, the permittee has observed anadromous fish in the canal, along with adult resident species such as largemouth bass and sunfish. This observation demonstrates that impingement of anadromous fish is not eliminated at the CWIS, even though it is located outside the main river.

Water depth is another important characteristic of a water intake structure. Structures that rest directly on the bottom may tend to impinge more fish than intakes that are drawing water from mid-water column. This is typically because pelagic fish are stronger swimmers than benthic fish. The intake at Kendall Station spans from the surface to approximately 12 feet deep. The canal is reported to be 15 feet deep, so the potential for impingement of benthic fish, such as white suckers, by the CWIS cannot be ruled out.

The speed of water entering the intake structure through the screens is called the approach velocity. Typically, the greater the approach velocity, the greater the potential for impingement. Some species of fish actually cue to water movement and will be attracted to fast moving water. Thus, intakes with high approach velocities may artificially attract fish to these structures. In addition, high approach velocities reduce the ability of a fish to escape, once it is pulled into the structure. Once impinged, the pressure of the high flowing water holds the fish and other organisms in place against the screens, causing injury and possibly death. Kendall Station presently operates 3 intake structures in the Broad Canal, each with an intake velocity measured at between 0.57 to 0.76 feet per second (fps). This is considered well within the likely approach velocity range to result in fish impingement.

The seasonal abundance of fish and other creatures affects the quantity of organisms impinged. During times of high abundance of juvenile fish, impingement rates can be expected to increase. Juvenile fish are more susceptible to impingement than adults, because they are generally present in greater quantities than adults and are weaker swimmers. Also, fish subjected to increased levels of seasonal stress may be weaker and more easily impinged. For example, fish that are weakened upon the completion of spawning (spring) or are exposed to abnormally cool (winter) or abnormally warm (summer) water conditions will become stressed. This stress could cause fish to be unable to escape the approach velocity of a CWIS, resulting in elevated levels of impingement.

Gill nets were set in 1999 and 2000 in the Broad Canal to collect primarily adult fish in the vicinity of the Kendall CWIS. While this collection did display a change in abundance of fish with season, the presence of juvenile fish in the canal was not specifically investigated.

8.1.1c Impingement Losses

In order to develop a baseline condition of current impingement losses at the plant, the permittee conducted sampling as explained below to determine the relative abundance of fish species that may be influenced by the CWIS. Beach seining was conducted at beach sampling stations in the river to obtain information on juvenile fish residing in the general vicinity of the CWIS. Gill nets were set in 1999 and 2000 in the Broad Canal to collect adult fish information in the immediate vicinity of the Kendall Station CWIS.

8.1.1d Beach Seine Sampling

Beginning on July 9 and continuing biweekly through December 1999, finfish were sampled by the permittee in the lower Charles River using a mesh nylon beach seine. Collections were also completed once in January 2000 before ice became widespread. From July to mid September hauls were made at two locations. To obtain additional spatial coverage, particularly for juvenile river herring, two stations were added by the permittee in September 1999. Each haul was standardized to the extent possible by walking one-third of the net perpendicular to shore, turning parallel to shore while deploying the middle third, then returning to shore while deploying the final one-third. Beginning in July 2000 and continuing weekly through early November these four stations were again sampled by beach seine following the same procedures as in 1999. To improve collection efficiency at some sites, an electroshocker was used inside the beach seine. All fish collected by beach seine were identified, counted, and measured to the nearest millimeter total length. When large collections were obtained a subsample of 30 to 50 fish was measured (Mirant Kendall, 2001).

8.1.1e Gill Net Sampling

To obtain information on fishes entering or residing in the Broad Canal for comparison with those impinged on the Kendall Square Station intake screens, gill net collections were made by the permittee. Beginning on July 9 and continuing biweekly through December 1999 two gill nets were set. Nets were strung in line at an oblique angle across the canal for approximately 24 to 30-hour periods on each occasion. In 1999 both nets were set with their top lines at the surface. In 2000, gill netting was conducted weekly from early-March through October, although one net was set at the surface, while the other was set near the bottom of the 12-feet deep canal. All fish obtained in the gill nets by the permittee were identified, counted, and measured to the nearest millimeter total length (Mirant Kendall, 2001).

The results of the seining and gill netting data submitted by the permittee provided information on the relative abundance and species composition of the lower Charles River Basin finfish populations. Seining in 1999, 2000, 2002 and 2003 occurred at five locations and gill netting occurred near the plant within Broad Canal. During field work for the project numerous other fishery observations were made, including a large striped bass that was observed feeding on fish (appeared to be river herring) on the surface of the Broad Canal. Largemouth bass (and sunfish) have also been observed within the Broad Canal exhibiting spawning behavior in the spring of 1999. Juvenile river herring were abundant in beach seine samples collected between Soldiers Field Road and the Longfellow Bridge throughout both summers into the fall. The locations of these collections and the other biological sampling locations of the permittee for the Mirant Kendall project can be found in the permit application (Mirant Kendall, 2001).

In the fall of 1999, the EPA conducted electro fishing collections of fish in the lower basin. The EPA staff responsible for the collections reported the greatest abundance of fish at the station located in the Kendall power facility discharge plume, with lesser numbers caught in areas further from the discharge (i.e., near the Museum of Science) (Personal Communication, H. Snook,1999).

8.1.1f Impingement Sampling

A screenwash monitoring and alert program was formalized by the permittee at Mirant Kendall on April 22, 1999. The purpose of the program was to provide an estimate of the number and species of finfish impinged on each of the three circulating water traveling screens at Kendall Station. As part of the standard operating procedure and throughout the program, at least three of the six circulating pumps were run on a continual basis and the screens were run once during each eight-hour shift. All debris washed off the screens was collected in a wire mesh basket and the finfish that were collected were placed in plastic bags with a label containing information relative to date, time of day, unit number, operator, and any general comments. Samples were frozen and picked up by a trained fisheries biologist on a weekly basis. Frozen samples were identified and the species, lifestage, and numbers of finfish impinged were recorded. Impingement rate per hour for each unit was calculated in addition to the monthly rate. A complete presentation of impingement sampling methodologies and results are provided in the permittee's NPDES application (Mirant Kendall, 2001)

8.1.1g Field Data Analysis To Assess Impingement Impacts

Seining and gill net sampling conducted by Mirant in 1999, 2000, 2002 and 2003 provided some information regarding the finfish populations and relative abundance of fish in the area of the CWIS. This data was compared with impingement data from Kendall Station for the same time period to gain insight on the full potential of CWIS impingement on fish residing in the lower basin.

Seining collected appreciable numbers of young-of-the year river herring (alewife and blueback herring) in both years. Other species common at all seining stations included sunfishes such as pumpkinseed and bluegill, and yellow perch. The majority of fish were collected in the summer months. In 1999, the largest number of blueback herring were collected at Feidler Station on August 30 (895 fish). The largest number of alewife were collected at Hyatt Station, on July 19 (284 fish). No alewife were collected by beach seining after August 30 in 1999. White perch peaked at Hyatt Station on August 16 (78 fish), but were absent later in the year. Yellow perch peaked at Hyatt Station on July 9, (152 fish), but were collected consistently throughout most of the sampling period. In all, 16 species were represented in the beach seine collection in 1999. A complete list of species and numbers of fish collected by seining can be found in the permittee's application (Mirant Kendall NPDES Permit Application, Volume II, Appendix 5-1, 2001). A map listing sampling stations is located in the permittee's application (Mirant Kendall NPDES Permit Application, Volume I, Section 5-1, 2001).

In the year 2000, seining collection again yielded the largest numbers of fish from the species blueback herring (up to a mean of 714 fish at Hyatt Station on August 3) , yellow perch (up to a mean of 54 fish at Storrow Station on July 19), and pumpkinseed, a resident species sunfish (up to a mean of 48 fish at Hyatt Station on July 27). This was not greatly different from the pattern seen in 1999. In all, 16 species were also represented in the beach seine collection in 2000, although they were not the exact same species seen the year before. Over the course of the two years, 20 different species were identified from beach seine samples.

Gill net sampling, designed to collect adult fish, yielded fish representing 10 species in 1999. Unlike beach seine sampling, gill net sampling was conducted directly in the Broad Canal, in close proximity to the CWIS. Adult fish numbers were relatively low, with white perch (45 fish) and yellow perch (8 fish) the most abundant.

In the year 2000, gill net sampling data was standardized to a mean collection rate of fish per 24 hours. Using this analysis, May and June had the overall highest number of fish collected. Blueback herring was the most abundant species caught (approximately 63 fish for all 24 hour periods). Yellow perch was second (approximately 21 fish for all 24 hour periods), and white perch was third (approximately 15 fish for all 24 hour periods). A total of 17 species were collected in 2000. Both the number of species and the raw numbers of fish were higher in 2000 when compared with 1999 gill net sampling data.

Impingement sampling was also conducted by the permittee in 1999 and 2000. In total, there were 356 fish, making up 16 species, impinged from April 22 through the end of December,

1999. River herring and white perch made up 53% of the impinged fish. Another 40% consisted of bluegill, goldfish and pumpkinseed. These five species made up 93% of the impingement. 72% of the fish were impinged in May and June 1999 and another 12% in July and August. Impingement rates were very low for other months of the year in 1999.

Impingement data for the year 2000 was markedly different from 1999 impingement results. In total, there were 2081 fish from 19 species impinged from January through November, 2000. Since only 50 fish from this total were impinged from January to April, 2000, the fact that sampling in the year 2000 took place during these extra months, compared to 1999 sampling, does not explain the reason for the large difference in impingement numbers over the two sampling years. The total number of fish impinged in 2000 was more than 5 times the numbers impinged in 1999. Blueback herring made up 86% of the impinged fish, which was a much higher percentage than seen in 1999. Alewife, bluegill, white perch and yellow perch made up another 12% of impingement results. These five species composed 98% of the impinged fish. Regarding the timing of impingement events, 97% of the fish impingement occurred in May and June of 2000. Impingement rates were very low for other months of the year in 2000. Impingement rate and relative abundance differences between the two years may be related to lower river flow seen in 1999 as compared to river flow recorded in 2000. The pronounced variability of magnitude in impingement rates seen between 1999 and 2000, possibly influenced by river flow, among other effects, is of concern. Without several years of impingement data sampled under a variety of river conditions, a "typical" impingement profile to be expected at Kendall Station cannot be constructed.

In general, the assemblage and numbers of fish impinged at the Kendall Station CWIS were a subset of the fish collected by beach seining and gill net sampling. Juvenile river herring, however, seen in beach seine samples, did not appear in great numbers in impingement samples in 1999, but did appear in larger numbers in 2000. The relatively limited amount of impingement data and large variability between years may be an indicator that much about impingement rates at Kendall Station is not fully known, including the potential for impingement of juvenile river herring in future years.

When reviewing what is currently known about fish impingement at the Kendall Station CWIS, EPA has identified several areas of concern. These issues include the total numbers of fish impinged each year, the number of fish species impinged in relatively large numbers that are present on the Kendall Station List of Finfish Priority Species (river herring, white perch, sunfish, yellow perch; Table 2.6-1; Mirant Kendall NPDES Permit Application, Volume I, Table 5-1, 2002), the concentration of impingement in the months of May, June, July and August, and the marked variability from one year of sampling to the next. EPA and MA DEP also note the special importance of protecting anadromous fish runs in the Charles River, which underscores concern over impingement of river herring during these months. These concerns are evaluated with the understanding that MKS has proposed to withdraw up to 80 MGD for longer periods during these months as compared to the Station operation prior to the upgrade. This proposed increased water withdrawal for extended periods has the potential to increase impingement rates and the total numbers of organisms entrained at the CWIS for a given year. For these reasons, BTA to minimize adverse environmental impacts must reduce or eliminate the potential for impingement mortality at Kendall Station.

8.1.2 Entrainment Impacts From Kendall Station

8.1.2a Introduction

Fish eggs and larvae, along with many other organisms, are entrained when cooling water is drawn into the facility and organisms small enough to fit through the openings of the intake screens pass through the plant cooling system with the cooling water flow. Organisms that transit the plant cooling system are typically exposed to high sheer stress as the water moves through the system, high quantities of heat as the water absorbs heat from the plant's condenser, and occasionally high concentrations of chlorine or biocides. These stresses are easily sufficient to kill the entrained organisms. Generally, the quantity of entrained organisms is a function of cooling water flow through the plant and the concentration of organisms in the source water that are small enough to pass through the intake structure's screening system. As explained above with respect to impingement, the location of the intake structure can have a major influence on entrainment. Different types of ecosystems may have greater or lesser concentrations of entrainable fish eggs and larvae.

The following sections discuss the methods employed by the permittee to characterize the fish community within the vicinity of the Kendall Station, including entrainment processes and the approaches used to quantify impacts to the fish community. In addition, impacts to benthic communities and primary producers (i.e., phytoplankton) will also be discussed as they pertain to the health of the aquatic environment and fish populations. The majority of this information was taken directly from the Mirant Kendall NPDES Permit Application, Section 5 (February, 2001). Further details of entrainment estimates and data analysis may be found in the application.

8.1.2b Factors Affecting Entrainment From Kendall Station

The permittee provided methods used to determine (1) the size of the local Charles River Basin fish population; (2) the mortality or cropping affect of the plant intakes; (3) Equivalent Adult Loss Analysis; and (4) other factors of mortality or impacts to fish species. Detailed discussions of the major assumptions underlying the population size estimates and the Equivalent Adult Loss Analysis are presented in Mirant's Permit Application (Appendix 5-6, February 2001).

8.1.2c Impact Assessment Methods

A review of existing reports and data pertaining to fisheries within the lower Charles River indicate that relatively few studies have been conducted in the recent past. The Massachusetts Division of Fisheries and Wildlife (MADFW) conducted a fish abundance survey within the lower Charles River in October 1975 (MADFW, 1975), and in the Fall of 1999 EPA performed electrofishing in the lower basin. However, to date, there is no indication of prior studies regarding ichthyoplankton within the Charles River. Information on the abundance, diversity, and distribution of fish species in the lower Charles River following construction of the New Charles River Dam and Locks in 1978, is largely lacking. In order to more accurately assess project impacts relative to existing conditions for its permit application, a number of data collection efforts were undertaken by the permittee during 1999 and 2000. For the purposes of entrainment assessment, these efforts included ichthyoplankton and phytoplankton sampling, entrainment sampling, and water quality sampling. A portion of the conditional mortality estimates generated by the permittee are referenced as part of this discussion. This information was fully presented in the permit application in Section 5.5 by species with estimation assumptions presented in the permit application Appendix 5-6 (Mirant Kendall, February 2001).

8.1.2d Ichthyoplankton Sampling

In the year 1999, ichthyoplankton populations were sampled by the permittee weekly from mid-May through August 1999. On each occasion from May 12 through May 31, 1999 duplicate samples were taken during daylight at two locations, one in the Broad Canal opposite the Kendall Station intakes (Intake) and one in the Charles River adjacent to the entrance to the Canal (River). From June 8 through July 12, 1999, sampling was expanded to collect additional information on the spatial distribution of larval river herring. Stations were added mid-way between the Longfellow and Harvard Bridges (MIT), between the Harvard and Boston University Bridges (Hyatt), further upriver above the Elliot Bridge (Soldiers Field), and adjacent to the Brighton public boat ramp (Marina) (Figure 5.7.3b-1 in this document; Mirant Kendall NPDES Permit Application; Figure 5-1, February 2001). From July 19 through August 30, 1999, when river herring larvae were no longer collected, four stations were sampled - Intake, River, MIT, and Hyatt. Beginning on June 8 and continuing through July 12, 1999, the River station was divided in half vertically, duplicate samples being taken separately in the upper and lower half of the water column.

In the year 2000, ichthyoplankton populations were sampled by the permittee weekly from mid-March through August 2000. Duplicate samples were collected at six locations - Marina, Soldiers Field, Hyatt, MIT, Charles River, and Old Channel. The Old Channel station was located near the western (Boston) shore in the relatively deep channel leading to the old locks. Due to shoal water and growth of aquatic vegetation, the Marina station was not sampled after June 12 . On a weekly basis beginning with May 23 and continuing through August 27, duplicate oblique samples were collected from two additional ichthyoplankton stations, one below the Museum Of Science and one below the New Dam (Figure 5.7.3b-1). These were sampled to obtain information on the advection of larval river herring out of the Charles River.

On five occasions in 2000 during the larval river herring season, ichthyoplankton samples were also collected by the permittee from the Charles River lakes district to determine the abundance and distribution of larvae above the Waltham Dam. These collections were completed at approximately two-week intervals beginning on 20 April and ending 30 June. (Figure 5.7.3b-1). Each ichthyoplankton sample was collected with "bongo" nets constructed of 0.333-mm nylon mesh. For a more complete discussion of sample methodology and results see Appendix 5-7 of the application.

8.1.2e Entrainment Sampling

In order to assess the potential entrainment losses, a program was carried out by the permittee in 1999 and 2000 to sample the entrainment of ichthyoplankton. Ichthyoplankton populations were sampled weekly from mid-May through August 1999. From May 12 through early July, 1999, samples were taken during daylight in the Broad Canal opposite the Kendall Station intakes (Intake). Beginning on July 9, 1999, and continuing weekly through August 1999, duplicate samples were collected from the Kendall Square Station discharge by streaming a 60-cm diameter; 0.333-mm. mesh plankton net in front of the outfall. These samples were intended to improve the assessment of numbers of fish eggs and larvae entrained. Samples were similarly collected from the Broad Canal and the discharge from mid-March through August 2000. In 2000, however, single discharge samples were collected three times per week. The three samples were collected on three different days, one sample in the morning, one sample in the afternoon, and one in the evening. Collections were approximately 10-minutes in length and utilized a General Oceanics 203OR2 flowmeter which is sensitive to low flow (Mirant Kendall, February 2001).

8.1.2f Equivalent Adult Analysis

In order to assess the existing condition impacts to finfish populations as a result of Kendall Station CWIS entrainment, the permittee undertook an equivalent adult analysis. A portion of this analysis is presented in Table 8.1.2-2. The entire analysis is presented in Appendix 5-6 of the permit application (Mirant Kendall, February 2001).

Reflecting a simple population model, the Equivalent Adult Loss approach utilized life stage specific survival rates to convert projected estimates of loss by life stage to an equivalent number lost at succeeding life stages. Stage specific survival values used for the equivalent adult analysis were applied for these calculations. Full details are presented in Appendix 5-6 of the permit application (Mirant Kendall, 2001). Equal numbers of males and females were assumed.

The basic approach for estimating equivalent adults followed the procedures discussed by Goodyear (1978). This method is based on the assumption that a given population of fishes is in equilibrium, i.e. deaths = births. Therefore, in its lifetime each adult female within the population can be expected to produce enough eggs to replace herself and one male.

8.1.2g Kendall Station Entrainment Sampling Results

Entrainment samples were collected by the permittee from the intake in 1999 and from the discharging wastewater in 2000 in order to determine which fish species pass through Kendall Station and at which times of the year. The complete sampling data can be found in Appendix 5-7 of the permit application (Mirant Kendall, February 2001).

In summary, the majority of entrainment seemed to occur in the months of May and June (especially June), during these two years, and was dominated by the two river herring species, white perch, and the two sunfish species. Yellow perch and rainbow smelt larvae were collected in much lower numbers and largemouth bass were essentially absent, despite observed nesting in the Broad Canal. Based on the sampling results, estimated annual entrainment is provided in Table 8.1.2-1. This table was presented in its entirety from the permit application (Table 5-4; Mirant Kendall, February 2001). The remaining 13 species from the Kendall Station List of Finfish Priority Species had no entrainment. As shown in the table, river herring, eggs and larvae combined made up 82.4% of all entrainment in 1999 and 97.7% in 2000.

TABLE 8.1.2-1
KENDALL STATION SUMMARY ENTRAINMENT INFORMATION

Species	**Eggs-1999**	**Larvae-1999**	**1999 Combined Percent of Total***	**Eggs-2000**	**Larvae-2000**	**2000 Combined Percent of Total***
River Herring	7,501,811	35,739,066	82.4%	86,677,022	29,317,019	97.7%
Sunfish	0	600,537	1.1%	0	427,223	0.4%
White Perch	87,903	8,569,809	16.5%	0	2,269,856	1.9%
Yellow Perch	0	9,387	0.02%	0	4,472	0.01%
Rainbow Smelt	0	0	0	0	39,581	0.03%

* The Combined Percent of Total value comprises the eggs and larvae of each species as a percentage of all organisms entrained for that particular year.

Results of the equivalent adult analyses prepared by the permittee used 1999 and 2000 entrainment data to capture existing conditions. As shown in Tables 8.1.2-1 and 8.1.2-2 (based on Table 5-4 and Appendix 5-11 of the permit application; Mirant Kendall, February 2001), entrainment occurred for four species in 1999 and five species in 2000. The tables also show that for sunfish, yellow perch and rainbow smelt, entrainment involved only larvae, which is consistent with the nest building characteristics of sunfish, the adhesive string egg mass of yellow perch, and the sparse densities of smelt in the basin, all of which would limit the presence of eggs in the intake water. Of note is the reversal in numbers of herring egg and larvae between 1999 and 2000 and the lack of white perch eggs in 2000. One possible explanation for more herring eggs reaching the Kendall Station CWIS in 2000 than in 1999 could be that they were advected from upstream by high flows throughout the season. The absence of white perch eggs in 2000 is not unusual, given their demersal nature and correspondingly patchy distribution.

Looking at the densities of the two years, which is detailed in the permit application (Mirant Kendall; Appendix 5-7 and 5-8, February 2001), herring peaked around the first week of June and white perch around-the end of May. Sunfish peaked around the end of the third week of June in 1999 and the first week of July in 2000. In general, entrainment densities tracked background river densities, suggesting the plant water withdrawal generally encounters densities similar to the river overall under the flow conditions seen in 1999 and 2000. The noted exception was when river flows dropped below 100 cfs (as in 1999). Larvae were possibly retained in localized portions of the river under these low flow conditions and became more vulnerable to entrainment.

8.1.2h Ichthyoplankton Sampling Results From The Charles River

Ichthyoplankton samples results were submitted by the permittee as part of the permit application (Mirant Kendall; Appendix 5-7, February, 2001). As discussed earlier, 1999 was a lower flow year while 2000 was a relatively wet year, resulting in different environmental conditions in the lower Charles River. Egg collection will be discussed separately from larval collection.

Sampling results from May 12 through June 28 1999 indicated that white perch and river herring eggs predominated in both the Broad Canal and the nearby Charles River sampling stations. Considering these eight sampling dates combined, river herring eggs accounted for 82% of the eggs taken at the River Station and 95% of the eggs taken in the Intake Station (based on density). In comparison, only river herring eggs were collected at the River Station in 2000. White perch accounted for an additional 1 % of the eggs taken at the Intake Station with unidentified eggs comprising the remainder. White perch and Atlantic mackerel accounted for 3 % each of the eggs collected at the River Station with unidentified eggs providing the remaining 12 %. The percentage contribution of river herring eggs to the catch increased dramatically in mid to late-May 1999 with very few eggs noted at either sampling location after early June (when flows dropped significantly). In 2000, river herring eggs were present in the River Station sample from the end of May to mid-June.

With respect to larval collection, in 1999 river herring larvae represented 92% of the larvae taken at the River Station and 76 % of the larvae in 2000. White perch contributed an additional 7 % to the Charles River catch in 1999 and 19 % in 2000 (based on density). The higher percent contribution of white perch larvae in both years relative to the percent contribution of white perch eggs may be attributed, at least in part, to the characteristics of white perch eggs. White perch eggs have been described in the literature as being more demersal and adhesive than river herring eggs (Smith, 1985). Highest observed densities for river herring larvae averaged over two replicates were 1,646 per 100 cubic meters of water in the Broad Canal and 1,680 per 100 cubic meters in the Charles River (both on the June 8 1999 sampling date). The corresponding highest densities for white perch were 459 larvae per 100 cubic meters in the Broad Canal and 290 larvae per 100 cubic meters in the Charles River (both on the May 18 1999 sampling date). In comparison, the 2000 data indicate that the highest observed river herring density at the River Station was 517 per 100 cubic meters of water and 231 for white perch. It is possible that with the lower river flows in 1999, more larvae were retained in the lower basin, resulting in higher densities at times than in 2000 (Mirant Kendall, February 2001).

River herring (i.e., alewife and blueback herring) and white perch larvae predominated in both the Broad Canal and the nearby Charles River sampling stations during the sampling conducted in 1999 and 2000.

During the July sampling events, the total number of plankton collected declined significantly as river flows dropped from the May and June sampling. River herring and sunfish larvae each comprised 50% of the plankton collected at the Intake Station in July 1999. River herring provided 79 % and white perch 2% of the larvae sampled at the River Station while sunfish represented 19 % of the total plankton collected in July 1999. In comparison, river herring and sunfish represented 71% and 29% of the larvae, respectively, collected at the River Station in 2000.

8.1.2i Mortality Estimates For Entrainment

The populations of various life stages of selected finfish were estimated by the permittee, using ichthyoplankton data collected in the lower Charles River Basin. While additional site-specific data must be collected to better estimate these population projections, they are included in this document for the sake of this discussion. Table 8.1.2-2 and 8.1.2-3 were based on tables assembled by the permittee. A full summary of this information was submitted as part of the permittee's permit application (Mirant Kendall; Section 5, Appendix 5-11, February, 2001).

Table 8.1.2-2 reports estimates of larval entrainment for the five species that were found in entrainment sampling conducted at Kendall Station. No site-specific information was available to explore the level of mortality experienced by these larval fish upon entrainment. In the absence of this information and in order to maintain a scientifically conservative and protective approach, entrainment mortality in this case was presumed to be 100%. Therefore, the estimate of the percent of larval fish entrained also represents the percent mortality, for the sake of this discussion. In addition, these figures do not include egg entrainment. The permittee reported the numbers of eggs entrained but did not report the percentage of eggs lost to entrainment as a percentage of the total eggs through the basin. Only river herring and white perch eggs were seen in the entrainment samples. The estimated number of eggs entrained is included in Table 8.1.2-1.

Table 8.1.2-2 Estimated Mortality Of Larval Fish From Kendall Station Entrainment

Species	Year	Estimate of Larvae Entrained	Estimate of Number of Larvae Produced in Basin	Estimate of Percent Larvae Entrained
River Herring	1999 2000	35,739,066 29,317,019	250,356,000 125,099,885	14.28 % 23.43 %
White Perch	1999 2000	8,569,809 2,269,856	29,528,131 28,258,771	29.02 % 8.03 %
Sunfish	1999 2000	600,537 427, 223	12,000,000 12,000,000	5.00 % 3.56 %
Yellow Perch	1999 2000	9,387 4,472	747,121 not available	1.26 % not available
Rainbow Smelt	1999 2000	0 39,581	not available not available	0 % not available

For the five species where larval entrainment was documented, the estimated percent mortality caused by Kendall Station entrainment ranged from a high of 29 % for white perch larvae in 1999 to a low of approximately 1.3 % for yellow perch larvae in 1999. The estimated percentage of river herring larvae mortality from entrainment was substantial, with approximately 14 % mortality in 1999 and 23% in 2000. In this specific case, EPA takes the position that where egg and larval fish productivity and entrainment mortality can be estimated with reasonable confidence, mortality percentages resulting from entrainment at these levels is a serious concern. Under this protocol, entrainment of river herring and white perch are of concern to EPA. Entrainment of sunfish larval fish barely reached a level of 5% estimated mortality in 1999, and was below that level in 2000. Because sunfish were documented spawning in the Broad Canal, in close proximity to the CWIS, however, the potential for elevated entrainment mortality of these fish is of concern to EPA, especially under lower river flow conditions. This concern is evaluated with the understanding that future station operation as a base load plant may include the withdrawal of the maximum flow of 80 MGD for more extended periods than was withdrawn in 1999 and 2000. This increased water withdrawal has the potential to increase entrainment rates at the CWIS and this impact should be addressed in the determination of BTA.

To further assess the environmental impacts of entrainment from Kendall Station, adult equivalent analysis was also submitted by the permittee as part of their permit application. Table 8.1.2-3 is based on the information submitted by Mirant Kendall. The entire adult equivalent analysis and protocol used can be found in Section 5 of the permit application (Mirant Kendall, February, 2001).

Based on the larval population analysis conducted by the permittee, potential loss of adult equivalent fish from Kendall Station entrainment ranged from almost 13% for white perch in 1999 to less than 1 % for all species with the exception of white perch in 1999 and sunfish and yellow perch in 2000. As mentioned previously, additional field data (including data for both eggs and larvae) will contribute to more refined estimates of adult fish populations in the lower basin. Based on this information, white perch and rainbow smelt adult equivalent losses are of concern and these impacts should be addressed in the determination of BTA.

In a preliminary survey of in-migrating adult river herring (alewife and blueback herring together) conducted in 2002, Mirant Kendall estimated the total river herring population that year to be 45,622 fish (Mirant Kendall Letter, July 28, 2003). The total river herring estimate for 2002 was only approximately 22% of the 203,393 adult river herring estimate listed in Table 8.1.2-3. If the lower estimate of river herring is substituted for the estimate in the table, the potential loss of river herring due to entrainment as a percent of population rises from 0.75% to 3.3% in 1999, and from 2.21% to 9.8% in 2000.

While the calculated increase in the percent of river herring population entrained, using the 2002 estimate, is of concern, it is understood that the 2002 estimate was based on a hydro acoustic pilot study sampling protocol that is undergoing revision and refinement. It was noted that anadromous fish potentially entering the river from two smaller boat locks at the dam were not included in the estimate (Mirant Kendall Letter, July 28, 2003). Also, information from anadromous fish in-migration counting programs from near-by rivers reflect a wide degree of variability in the number of returning adult fish from year to year. It may not be appropriate to use 2002 estimates when using adult equivalent fish numbers from other years. Further sampling of in-migrating river herring is necessary to determine a more reliable population estimate and a better evaluation of the loss due to entrainment of eggs and larvae from Kendall Station as a percent of population.

It should also be noted that the permittee submitted projections of benefits to the egg, larval fish, and adult fish survivability as a result of increased oxygen levels in the deeper waters of the lower basin. This predicted improvement in aquatic habitat is a by-product of the permittee's proposed operation of a deep water discharge diffuser. While EPA and DEP find these projected improvements to water quality that could, in turn, lead to increased fish production in the lower basin to be encouraging, the full impacts of diffuser operation, both positive and negative, are still under consideration. Therefore, EPA and DEP have decided not to permit the outfall diffuser at this time pending additional modeling to assure that the potential negative impacts of the diffuser operation do not outweigh the potential benefits. Consistent with this, and in order to maintain a conservative, protective approach to the permit renewal, the estimated increase of ichthyoplankton and adult fish equivalents in the lower basin proposed by the permittee will not be added to the analysis at this time. A more complete discussion of the potential environmental impacts of the discharge diffuser can be found in Section 2.5 of this document and Attachment A of the Fact Sheet. The complete submittal by the permittee related to increased fish populations as a result of projections of improved dissolved oxygen can be found in Section 5 of the NPDES permit application (Mirant Kendall; p 5-83, February, 2001).

Table 8.1.2-3 Estimated Mortality Of Adult Equivalents From Eggs And Larval Fish Entrained At Kendall Station

Species	Year	Equivalent Adult Entrainment Loss	Estimated Adult Lower Basin Population	Potential Loss As Percent Of Population
River Herring	1999 2000	1, 525 4,490	203,393 203,393	0.75 % 2.21 %
White Perch	1999 2000	1,716 454	13,318 13,318	12.88 % 3.41 %
Sunfish	1999 2000	318 226	95,400 95,400	0.33 % 0.24 %
Yellow Perch	1999 2000	1 2	30,800 30,800	0.00 % 0.01 %
Rainbow Smelt	1999 2000	0 55	1,000 1,000	0.00 % 5.50 %

8.1.3 Minimization Of Impingement and Entrainment Impacts

Losses from fish impingement and entrainment at Kendall Station must be considered in the context of all the additional stressors that eggs, larval fish, juvenile fish and adult fish are routinely subjected to in the lower Charles River Basin. Section 5.4 of this document details these stressors.

Fish impingement data from the Kendall Station CWIS, as reported by the permittee, has raised several areas of concern. These issues include the total numbers of fish impinged each year, the number of fish species that are present on the Kendall Station List of Finfish Priority Species (river herring, white perch, sunfish, yellow perch; Mirant Kendall NPDES Permit Application, Volume I, Table 5-1, 2002) impinged in relatively large numbers, the concentration of impingement in the months of May, June, July and August, and the marked variability in impingement numbers from one year to the next. These concerns are evaluated with the understanding that on individual days, future station operation as a base load plant may include the withdrawal of the maximum flow of 80 MGD for more extended periods than was withdrawn in 1999 and 2000. This increased water withdrawal has the potential to increase impingement rates at the CWIS.

Regarding entrainment impacts, estimated mortality from Kendall Station entrainment of river herring, white perch and sunfish larval fish are of concern. Entrainment of eggs is also a concern, though more information must be collected to more fully assess its significance. Also, when viewed through adult equivalent analysis, entrainment mortality of white perch and rainbow smelt are of concern, and preliminary data gathered in 2002 may indicate that entrainment of river herring is also of particular concern. Collecting additional data on river herring entrainment and populations estimates in the lower basin is essential. These concerns are evaluated with the understanding that on individual days, future station operation may consistently withdraw up to 10% more water than was withdrawn in 1999 and 2000, the two years studied in the entrainment sampling program. Assuming other factors remain the same, these increased water withdrawals would result in greater entrainment rates in the future. This will also be considered in the BTA determination.

For these reasons, various alternatives have been considered to ensure that the CWIS at MKS reflects the BTA for minimizing adverse environmental impacts from impingement and entrainment at the facility.

8.2 Available Cooling Water Intake Structure (CWIS) Technologies

8.2.1 Introduction

This section discusses potentially available, practicable technological alternatives for ensuring that the design, construction, location and capacity of the CWISs at Mirant Kendall Station (MKS) reflect the BTA for minimizing adverse environmental impacts, as required by CWA §316(b). This discussion considers engineering, environmental and economic issues related to these alternatives and is concluded with EPA's determination of BTA technology for this permit.

As part of its permit application, and in response to EPA information requests, the permittee has submitted information related to potential CWIS-related technologies. In evaluating alternative technologies, EPA has considered both the material submitted by the permittee and other materials, such as relevant guidance documents, information regarding experience at other power plants, and information from equipment manufacturers.

8.2.2 Technologies for Minimizing Adverse Environmental Impacts - General

The primary adverse environmental impacts of concern from the operation of CWISs at MKS are the entrainment of small organisms, such as fish eggs and larvae, and the impingement of larger aquatic organisms, such as fish. As described in this Section, viewed broadly, and as dictated by CWA §316(b), there are several major approaches to reducing adverse impacts from CWISs that must be considered. They include the following: 1) "capacity" (or flow) reduction measures which are considered to yield corresponding reductions in the numbers of organisms entrained and impinged by the CWIS; 2) "design" options to lessen impingement by reducing the velocity of the water drawn into the CWIS, and the use of barriers and fish return systems to try to reduce the number of organisms drawn into the CWIS where they are impinged or entrained and to try to return any impinged organisms to the source water body unharmed; and 3) "location" options, which for an existing plant would involve *re*-locating the CWIS to a new, less biologically productive or sensitive site or part of the water column that would reduce entrainment and/or impingement effects. With any of these options, the adverse environmental impacts of "construction" of the technology must also be considered along with alternatives for minimizing those impacts. For example, moving a cooling water intake to a new location might offer potential reductions in entrainment and impingement, but construction activities could have adverse environmental effects that would also need to be considered in deciding whether to require such a re-location under CWA § 316(b).

Within the broad categories described above, there are numerous specific technological options to consider. A variety of technologies exists for generating electricity with little or no withdrawal of water from natural water bodies for cooling (e.g., "dry" cooling towers; wet cooling towers; wet/dry cooling towers; or use of gray water for cooling). These technologies have been in use for many years, and they generally result in little or no adverse environmental impacts from CWISs. Many of these options are discussed in EPA's May 1977 Draft § 316(b) Guidance, the EPA 1976 Development Document, the 1994 EPA Background Paper No. 3, the 1996 EPA Supplement to Background Paper No. 3, and the various past regulatory preambles issued by EPA, including the preambles to the recent proposed and final CWA §316(b) regulations for new facilities. See, e.g., 41 Fed. Reg. 17388 (April 26, 1976); 39 Fed. Reg. 36189 (Oct. 8, 1974). Technologies are also discussed in records for the recent rulemakings for the Phase I and Phase II CWA 316(b) regulations.

8.2.3 Pertinent Submissions by the Permittee

In its February 2001 supplemental NPDES permit application (Volumes I and II), which also served as the plant upgrade document, the permittee included an evaluation of various technologies to minimize effects associated with CWIS's to support the next permit reissuance. Volume I, Section 6 evaluated various alternative technologies, which are summarized below.

8.2.4 Options for Ensuring that the Capacity of the MKS CWIS's Reflects the BTA for Minimizing Adverse Environmental Impacts

As discussed above, EPA has interpreted the term "capacity" in CWA §316(b) to refer to the volume of flow through the CWIS. As is also discussed above, EPA has indicated in relevant guidance and past decisions that flow reduction measures are in many cases the most significant steps that can be taken to reduce adverse environmental impacts from entrainment and impingement, especially if it is not possible to re-locate the CWIS to an area that is not biologically sensitive or productive. There are numerous ways for power plants to generate electricity while reducing the capacity of (or volume of flow through) their CWISs. Methods considered by EPA for possible application at MKS are discussed below.

(A) Closed-Cycle Cooling/Cooling Tower Options in General

Steam electric power plants can generate electricity while using substantially less water than is required for a once-through cooling system by instead using a "closed-cycle cooling" system. Generally, steam electric powerplants employ one of four basic types of circulating water systems to reject waste heat. These systems are (1) once-through cooling, (2) once-through cooling with supplemental cooling on the discharge, (3) entirely closed-cycle or recirculating cooling, and (4) combinations of these three systems. In a once-through (or non-recirculating) system, the entire amount of waste heat is discharged to the receiving water body. At MKS, the once through system is used in conjunction with a fin fan cooler, which rejects waste heat from the HRSG to the atmosphere and does not necessitate additional cooling water flows for this heat dissipation.

A once-through system with supplemental cooling (e.g. from "helper" cooling towers) removes a portion of the plant's waste heat from the effluent before discharging it to the receiving water and transfers this energy to the atmosphere. This type of system does not, however, offer a reduction in the volume of water used.

Closed-cycle or recirculating cooling water systems employ a cooling device that withdraws the plant's waste energy from the cooling water and releases it directly to the atmosphere. The facility is then able to recirculate and reuse the previously heated water for additional cooling. There are two basic methods of heat rejection for closed-cycle systems. The first is wet (or evaporative) cooling using cooling towers. See, e.g., 1994 EPA Background Paper No. 3, pp. 2-3 to 2-5 (general discussion of cooling towers); 66 Fed. Reg. 65282 (Dec. 18, 2001). The second uses cooling ponds or lakes. These two methods dramatically reduce cooling water use, though they do require a small amount of "makeup" water.

A third type of cooling system does not use cooling water at all and, instead, employs "dry cooling towers" ("or air-cooled condensers"). This method eliminates the use of cooling water and rejects heat directly to the atmosphere from the surface of the condenser. No evaporation of water is involved. See, e.g., 66 Fed. Reg. 65282 (Dec. 18, 2001); EPA Office of Water, "Economic and Engineering Analysis of the Proposed § 316(b) New Facility Rule) (August 2000), Appendix A, p. 14 ("EPA Economic and Engineering Analysis"). Dry cooling systems are regarded to be substantially more expensive than wet cooling tower systems. See, e.g., 66 Fed. Reg. 65282-83 (Dec. 18, 2001).

Another type of closed system worthy of note is the "hybrid" (or "wet/dry") system which combines principles of both wet and dry tower operations. The advantage of this type of cooling system is that it can be used to reduce and /or eliminate any problematic water vapor plumes from mechanical draft cooling towers. See 65 Fed. Reg. 49081 (August 10, 2000) (discussion of wet/dry tower); 39 Fed. Reg. 36192 (October 8, 1974); EPA Economic and Engineering Analysis, App. A, p. 14. This technology would be less expensive than dry cooling but more expensive than a wet cooling tower system. See 65 Fed. Reg. 49081 (August 10, 2000) (discussion of wet/dry tower); Science Applications International Corporation (SAIC) Report (March 15, 2002), Table 5.

There is no question that *as a general matter* wet, dry and wet/dry cooling towers are all practicable, available technologies for power plants. Wet cooling towers have been widely used at power plants for many years. See, e.g., Id.; 65 Fed. Reg. 49080-81 (August 10, 2000); 1996 EPA Supplement to Background Paper No. 3, p. A-3; 41 Fed. Reg. 17388 (April 26, 1976); 1976 Draft EPA CWA § 316(b) Guidance, p. 13; EPA 1976 Development Document (April 1976), pp. 149-57, 191; 39 Fed. Reg. 36192 (October 8, 1974). Air cooling is also clearly a viable technology as air cooling systems have been installed or proposed for installation at a number of facilities in the United States, including new units at the Mystic Station and the Fore River Station in Massachusetts. See also 65 Fed. Reg. 49080-81 (August 10, 2000); November 6, 2000, Letter from Vernon Lang (US F&WS) to EPA Proposed Rule Comment Clerk, p. 3 (comments on EPA's proposed regulations under CWA § 316(b) for new power plants listing a number of facilities currently operating, under construction, or recently approved for dry cooling); EPA Economic and Engineering Analysis, App. A, p. 14. In addition, wet/dry cooling towers are also a practicable technology used at a number of plants. See, e.g., 65 Fed. Reg. 49080-81 (August 10, 2000); EPA Economic and Engineering Analysis, App. A, p. 14-15; 39 Fed. Reg. 36192 (October 8, 1974); Literature from Marley Cooling Tower Company; Public Service Commission of Wisconsin/Wisconsin Department of Natural Resources, Final Environmental Impact Statement, Badger Generating Company, LLC, Electric Generation and Transmission Facilities (June 2000, 9340-CE-100), Executive Summary.

Finally, it is also important to recognize that a single power plant could combine the use of both open-cycle and closed-cycle cooling technologies in order to reduce overall plant flows to some predetermined level or to prevent going above some specified cost threshold. See 1994 EPA Background Paper No. 3, p. 2-3. Such “combination options” should also be considered for existing plants which are evaluating possible retrofit of technology changes, because it will likely be easier and less expensive for an existing plant to retrofit to a partially closed-cycle cooling system rather than switching to a completely closed-cycle operation.

In the context of permitting for an existing facility, EPA must assess whether retrofitting the above cooling technologies at an existing plant is or may be practicable. EPA’s investigations have determined that there have been cases of existing power plants with open-cycle cooling systems changing to closed-cycle cooling by retrofitting wet mechanical draft cooling towers at the facilities. Some of these are discussed in the EPA Headquarters rulemaking records for the Phase I and II § 316(b) regulations. This establishes that such retrofits are practicable in general. EPA also sees no reason why a retrofit of natural draft cooling towers would not be practicable in general, though it may be less desirable for various reasons mentioned above. EPA did not, however, find a single example of an existing power plant converting from an open-cycle cooling system to a closed-cycle system by retrofitting a dry cooling system at the facility. While this does not definitively establish that such a conversion would be impracticable, the absence of an example of such a retrofit leaves EPA unable to determine based on current information whether such a conversion would be practicable in general, much less at a particular plant.

In addition to practicability, other issues also must be considered in determining whether the capacity reductions achievable from a particular closed-cycle cooling technology should be determined to be BTA at a specific plant. For example, cooling tower facilities could impose certain adverse environmental impacts on local property owners (e.g., noise, water vapor or mist emission plumes, aesthetic effects). Mechanical draft cooling tower facilities (wet or dry) have noise emissions. These noise emissions can be mitigated using various techniques and equipment, but such measures may add cost to the project. For wet cooling tower systems there may also be concerns related to emissions of plumes of mist or water vapor. Again, measures exist for controlling such emissions, but these steps may add cost. Finally, use of any closed-cycle cooling technology will also likely result in a marginal loss of electrical generation efficiency at the plant. This has an associated economic cost and could also affect the adequacy of local energy supplies and even potentially result in a plant burning more fossil fuel and emitting more air pollution in an effort to offset the efficiency losses. These kinds of issues are discussed further below.

Moving beyond this general discussion, it is also necessary to determine whether these technologies are available and practicable specifically for retrofitting *at MKS*.

(B) *"Air" or "Dry" Cooling Towers at MKS*

As discussed above, using air (or dry) cooling towers would yield the maximum reduction in flow of any cooling technology by essentially eliminating the use of water for cooling. Thus, this option would essentially eliminate the heat load to the Charles River and avoid the losses to aquatic life due to impingement and entrainment.

This option would, however, be substantially more expensive than using wet mechanical draft cooling towers. See 66 Fed. Reg. 65282-84, 65304-06 (Dec. 18, 2001). Various estimates put the costs of dry cooling from 1.75 to 3 times more than the cost of wet cooling. The permittee considered air cooled condensers for MKS and concluded that this option would not be practicable. The permittee determined that this would have significant economic impacts and reduce power output by about 2.5 MW, due to the power required to operate them. The permittee assumes that this lost power would be made up in the New England Power Pool (NEPOOL) by another plant which would likely result in greater emissions and at a greater cost, but specific evidence to back up this assertion was not provided. The permittee also cited significant capital costs associated with both the air cooling equipment and the acquisition of the additional real estate that would be needed to accommodate the equipment, as well as the noise impacts from their installation and operation, as additional reasons why this option was not feasible. MKS is located in an urban location closely bounded by businesses and residences. The permittee calculated total present worth costs associated with this option of about $43.7 million, which includes the cost of additional purchased land. This option would require an additional 4.3 acres of land added to MKS's property area of 5.8 acres due to buffer and setbacks requirements. This land is not currently available, as there is minimal space available adjacent to MKS's property.

EPA has decided based on current information to drop dry cooling towers from further consideration for retrofitting at MKS because it would be impracticable due to the absence of space at the plant. In addition, as discussed above, EPA has not identified a single existing power plant that has been retrofitted from a once-through to a dry-cooled facility. While this does not necessarily mean such a conversion would be impracticable at MKS, in the absence of further detailed, site-specific analysis demonstrating practicability at MKS, this factor contributes the present conclusion that such a conversion would be impracticable. With respect to noise emissions, it should also be noted that although noise can often be suitably mitigated, if this technology were being further considered for MKS, additional review of the noise issue would be warranted given the exceptionally close proximity to the plant of various commercial and residential properties. Since this technology has been deemed impracticable for MKS, however, there is no reason to further evaluate noise emissions from a dry cooling facility.

Although dry cooling towers is being rejected in this case, in order to offset any increase in cooling water flow associated with the new combustion turbine generator or HRSG, the permittee has installed a "fin fan cooler". This is a type of air cooling device which was installed on the roof above the new unit and will obviate the need for additional cooling water for the new HRSG by rejecting the unit's waste heat to the air.

Without the use of this cooler, the plant would have needed additional cooling water for the operation of the new generator.

(C) Wet Cooling Towers at MKS

Mechanical Draft versus Natural Draft Wet Cooling Towers. There are two principal types of wet cooling towers that are used in closed cycle systems: natural draft and mechanical draft towers. Natural draft towers have no mechanical device to create air flow through the tower and are usually applied in very small or very large applications. See 1994 EPA Background Paper No. 3, p. 2-4. Mechanical draft towers use fans in the cooling process. See Id.; EPA Economic and Engineering Analysis, p. 11-2 to 11-3; App. A, p. 14. The permittee also noted that there is a hybrid type of wet cooling tower called a fan assisted natural draft tower which it considered.

The permittee evaluated both natural draft and mechanical draft cooling towers and concluded that natural draft towers should be dropped, and further consideration should be given to mechanical draft applications, chiefly because the former would require 350-foot tall towers, which would stand more than 100 feet taller than the exhaust stack of the new unit. It is believed that natural draft towers are considerably more expensive as well.

Mechanical draft towers at MKS would require about 1.7 MGD of make-up water and would discharge about 0.3 MGD of blowdown to the Charles River. The evaporative losses of about 1.4 MGD would not, however, be replaced in the Charles River, resulting in marginally lower river flows. Similar to the dry cooling tower option, this option would also substantially reduce intake flow, in this case by about 97%, but would have similar noise and visual impacts. The permittee has estimated that the total present worth costs of this option to be roughly $14 million, which includes the cost of additional purchased land. Again, the permittee concluded that this option is not available, however, due to the unavailability of the required amount of adjacent property.

EPA has also concluded that retrofitting the cooling system to use wet cooling tower technology is impracticable at MKS due to space constraints. As stated above, EPA has found examples of power plants converting from open-cycle to closed-cycle cooling using wet mechanical draft cooling towers, so this approach is generally practicable, but current information indicates that site conditions preclude this approach at MKS. As a result, there is also no reason to further investigate whether noise emissions and vapor and/or mist emissions could be suitably mitigated at the facility, or whether aesthetic effects would be significant (such effects would not appear to be severe given the visual context of the already existing power plant and generally urban environment).

(D) Wet "Helper" Cooling Towers at MKS

The permittee also evaluated "helper" mechanical draft cooling towers as another potential option for satisfying CWA § 316(b). With this option, the permittee estimates that about one half of the once through cooling water flow would be diverted from the discharge and sent through the helper tower. This water would be cooled and then mixed back in with the discharge water, resulting in a discharge temperature reduction of about 11° F. The permittee has estimated that this option would have present worth costs of about $5 million, including the cost of additional purchased land, and would impose similar noise, construction and visual impacts described above for the other tower options. Again, the permittee concluded that this option is not feasible due to the unavailability of the required amount of adjacent property. Based on current information EPA agrees with this conclusion. Moreover, since helper towers do not result in significant cooling water withdrawal reductions – they enable the facility to cool the water they have withdrawn – this technology would not result in significant further minimization of the adverse environmental effects of the CWIS's at MKS.

(E) Generation Curtailment & Timed Maintenance Outages at MKS

The permittee also looked at an operational shutdown or prescribed outage option to reduce flows through the plant. As currently operated, the plant services steam customers in Cambridge and Boston on a year-round basis. As such, one or more of the plant's steam turbines must remain online year-round as well. Backup steam capability can be produced by the onsite package boilers, but these are less efficient and only serve as an emergency backup when the steam turbines are out of service. The permittee contends that the nature of steam demand does not make the possibility of this option feasible.

EPA believes that the permittee should employ options to make reductions in electrical generation in a way that would not disrupt its obligations to its steam customers. In order to maintain sufficient steam generation capacity, the plant could discharge at a heat load of up to 10% of the maximum heat load discharge represented by a discharge of 80 MGD. In the case of MKS, EPA finds that flow reduction and generation curtailment are appropriate and available methods of meeting some short-term or seasonal heat reduction target. Regarding seasonal flow reductions, as a component of BTA, the permit will restrict the monthly average flow during the months of April, May and June to 70 MGD. These months coincide with the periods of maximum egg and larva entrainment and should help reduce these adverse effects.

Regarding flow reductions through generation curtailment, the permittee is required in this permit to reduce heat load to the river when particular temperature limits are being approached. It should be noted that Section 5.11.3 of this document presents for comment a BTU heat load proposal, which is an alternative means of enforcing instream temperature limits, and which could also produce flow reduction benefits.

8.2.5 Options for Ensuring that the Design of the MKS CWIS's Reflects the BTA for Minimizing Adverse Environmental Impacts

In general, the major options for ensuring that the "design" of a CWIS reflects the BTA for minimizing adverse environmental impacts involve technologies that attempt to reduce impingement and entrainment (I&E) of aquatic life by reducing intake velocities or by imposing some type of barrier to prevent organisms from entering the CWIS. In addition, technologies can be installed, such as fish return systems, to try to increase the survival rate of aquatic life that is impinged by any barrier mechanism.

(A) Velocity Reduction Measures

Design options for reducing the velocity of the water drawn into the CWIS help to reduce impingement by making it easier for fish to escape the influence of the CWIS. A commonly used guideline for intake flow velocity is that the flow should not be greater than 0.5 feet per second (fps) through the intake screens. See 65 Fed. Reg. 49087 (August 10, 2000) (discussion of literature regarding intake flow velocity). Other information points to similar velocity thresholds. See 1996 EPA Supplement to Background Paper No. 3, p. A-1. Finally, in EPA's recently signed, but not yet effective, Phase II § 316(b) rule, reducing the maximum through-screen velocity to 0.5 fps or less is considered BTA for minimizing adverse environmental impacts associated with impingement, unless any more stringent State requirements are applicable. See Pre-Publication Preliminary Draft (available on EPA website), 40 C.F.R. § 125.94(a)(1)(ii). The existing intake velocity at MKS' intake screens ranges from 0.57 to 0.76 fps. The permittee has proposed to install a new barrier net system, as described below, which it has predicted will reduce the approach velocity in front of the intakes to about 0.04 fps. Comprehensive testing to fully document this intake velocity has not been completed. If achieved, this would represent a substantial reduction in intake velocity from current levels and is expected to also result in a commensurate reduction in impinged juvenile and adult fish on the traveling screens. (This might also, to a lesser extent, reduce the entrained aquatic life which would otherwise be carried into the plant.) Therefore, it appears that the reduced approach velocities at the screens with the proposed barrier nets will contribute to the minimization of impingement (and, to a lesser extent, entrainment) at Kendall Station. Based on current information, EPA concludes that this reduction in velocity associated with a barrier net is one component of ensuring that the design of the CWIS at MKS reflects BTA. Further analysis may be required to verify actual through-screen and approach velocities resulting from installation of the barrier nets.

(B) Barrier Mechanisms

Barrier mechanisms can be divided into the general categories of Physical Barriers and Behavioral Deterrent Technologies.

i. Physical Barriers

There are many types of physical barrier technologies that can be considered for their potential to reduce entrainment and impingement impacts. These include screen systems (such as fine mesh screens), passive intake systems (such as perforated pipes, porous dikes, wedge-wire screens, and artificial filter beds), and diversion and/or avoidance systems. In addition, there are various fish return technologies that seek to maximize the survival of impinged organisms by returning them to the source water body with as little harm as possible. These include fish bypass systems, fish buckets and baskets, fish troughs, fish elevators, fish pumps, spray wash systems, and fish sills.

At present, MKS has three similarly operating intake structures. All three structures draw water from the Broad Canal through flush mounted trash racks which are followed by traveling screens. The screens are presently rotated three times per day and are backwashed daily with river water. Any debris is collected and disposed of properly. Although this intake system does not have a fish return system and the permittee is not currently required to return any fish caught in its screens to the receiving water, the draft permit directs the permittee to do so after collecting some of these fish for the impingement sampling requirement. After the proposed barrier nets are deployed, the permittee will only operate these traveling screens when the barrier nets are not in use. The draft permit also requires the permittee to report any above average impingement events and to account for the types and sizes of fish that are impinged as well as to conduct ongoing impingement monitoring.

In considering possible retrofits to the existing screening systems, the permittee has considered a number of possible options. Specifically, the permittee considered cylindrical wedge-wire screens and two types of barrier nets. The important features of all these options would be to decrease the intake velocity through these barriers and, as a result, to minimize the amount of aquatic life that is impinged or entrained by the CWIS.

It should be understood that if a net or screen successfully blocks an organism from being drawn into the cooling system, then that organism may be impinged on the screening material. The question then becomes whether or not the impinged organism survives the impingement (or the measures used to wash it off the screening material). This type of screening technology is most likely to be successful in a river environment where organisms that are blocked from entering the CWIS can then be washed downstream and away from the intake with the river current. It appears that acceptance of barrier net technology by resource agencies is growing for use at hydroelectric facilities. In addition, a geotextile mesh curtain (or boom) barrier system has been retrofitted on the pre-existing CWISs at the Lovett Station steam electric power plant on the Hudson River in New York. Nevertheless, the ability of a net or curtain to protect early stages of fish from entrainment depends on the size of the mesh of the proposed screening material, the nature of the screen wash or fish return system, and the individual conditions at the plant and water body in question.

a. Passive Fish and Ichthyoplankton Barrier Nets

The permittee has evaluated the option of retrofitting a barrier net system for the MKS CWISs. The proposed approach would involve installing a fine mesh curtain in front of each intake screen between February 15th and November 1st. This time period is believed to encompass the spawning seasons of all major indigenous fish species that may be present in the lower Charles River Basin. The curtain material proposed by the permittee is a woven filter fabric of 100% polypropylene, nonfilament yarns. These nets would have an overall open area of 30% of their total surface, with openings sized at 1/32 of an inch, and would be made to be simple to install and to take down for maintenance or replacement. These barrier nets would cost about $6200 for the 250 foot section required, and would be installed by a contracted diver at about $2000 per day. There have been some design changes made to the original barrier net plan which would not be expected to raise these estimates significantly.

Based on the permittee's proposal, the design approach velocity at these nets is expected to be about 0.04 feet per second (fps), which is less than one tenth of the current velocity at the intake screens. The permittee indicates, and EPA concurs based on current information, that such a reduction would be expected to yield substantial reductions in the impingement and entrainment (I&E) of fish and larger larvae as compared to current conditions. Larvae could, however, be impinged against the nets. These nets are also not believed to screen out eggs and smaller larvae due to the (relatively) large mesh size and the fact that these organisms essentially drift with the water. It should also be noted that there does not appear to be sufficient current available in the Broad Canal to allow for smaller, less mobile organisms to be directed back towards the Charles River were they to be blocked by a barrier or washed away from the barrier in some manner.

Field trials of a barrier net were conducted in May, June, July and August of 2000 using a prototype of a fine mesh barrier net proposed to reduce fish impingement and entrainment losses at the water intakes for the upgraded plant. The prototype, with a mesh size of 1/32", was temporarily deployed around the Unit 3 intake from mid-May through early August 2000, at which time it was removed, cleaned and redeployed. The net remained sufficiently free of fouling to permit continued use without cleaning for more than two and one half months, until August.

Sampling of ichthyoplankton inside and outside of the net was performed on 13 separate occasions to evaluate exclusion effectiveness. Impingement sampling continued during the test to evaluate juvenile and adult exclusion effectiveness. Larvae/fish sampled from the outer net surface were included in mortality losses associated with the barrier net. Detailed results of this test are presented in Appendix 5-12 of the application.

In general, virtually all eggs appear to pass through the net. This is not surprising given that the net's mesh size is larger than the size of the eggs themselves. In addition, varying amounts of larvae were found on the inside of the barrier nets. In the pilot test, the permittee estimated that the barrier was over 80% effective in reducing I&E of *larger* larvae, but only minimally effective at screening out *smaller* organisms. The permittee projects that impingement of juvenile and adult fish will mostly be eliminated with the use of the barrier nets, as the fish should be able to swim away from the nets due to decreased velocity at the intake.

b. Wedgewire screens

Cylindrical wedgewire screens are another type of physical barrier that could reduce fish losses. EPA-New England has determined that several full-scale CWIS applications of this technology have performed satisfactorily, specifically with course bar spacings of 10 mm, or about 4/10 of an inch.

At MKS, such screens would likely be made of stainless steel and would need to be attached to new concrete walls which would be constructed in front of each intake structure. These screens would be air backwashed and could impact use of the adjacent walkway. The design through flow velocity would be expected to be about 0.25 fps. Installation of these screens is estimated by the permittee to be about $2 million. The wedgewire screens would be expected to reduce the rates of impingement and entrainment, but to a lesser degree than with the barrier nets discussed earlier because of the greater intake velocity and the larger openings in the screens.

c. Aquatic Filter Barrier with Boom

Another type of system investigated would be composed of a custom designed and sized filtration fabric installed in a boom-like configuration before the facility intakes to minimize or eliminate entrainment and impingement of fish eggs, larvae and larger organisms. One type of these systems, a Gunderboom Marine Life Exclusion System (MLES), has been used at a power plant on the Hudson River in New York (Lovett Station), and although there have been some problems anchoring the device, the system has been reported to significantly reduce entrainment at that plant. (E.P. Taft, "Fish Protection Technologies: A Status Report," Environmental Science and Policy (2000)).

This type of barrier system would be designed with a floatation, weighting and anchoring system. It would also include baffles to diffuse or rechannel the intake flow, and an air backwash system to periodically clear the filter fabric of accumulated sediment. The system would be installed halfway across Broad Canal. This may pose a problem to members of the public or station employees who enter the Broad Canal by boat. The cost of this system is estimated by the permittee to be between $1.2 to $1.6 million. The permittee indicated that the construction of the air backwash system would likely significantly disrupt the historic Broad Canal seawall at the locations of the existing intakes and its subsequent operation would potentially impact use of the adjacent walkway. Similar to the wedgewire screens, this barrier system would reduce the intake velocity, thereby reducing impingement and entrainment. Although the permittee did not provide an estimated intake velocity for this option, EPA would expect the design through screen velocity to be well below 0.5 fps.

ii. Behavioral Deterrent Technologies

Behavioral barriers which could be considered as possible steps to reduce *impingement* at MKS include sound barriers, light barriers, electrical barriers, air bubble barriers, and chain or cable barriers. These technologies are not, however, effective for reducing *entrainment* of floating or drifting organisms. Moreover, whether these technologies are capable of reducing impingement by repelling fish is uncertain. To determine their potential efficacy at a particular plant, a site-specific analysis of conditions at the plant and the likely behavior of the relevant species of aquatic life would be necessary. Thus, extensive testing would be required to determine whether one of these technologies might be effective at MKS. Although these options have not been evaluated, they may need to be considered in the future if proposed measures undertaken by MKS are not sufficient to satisfy Section 316 (b) requirements.

EPA agrees that at the present stage of development, behavioral deterrent systems do not constitute BTA for MKS. They are simply not clearly available or effective. In addition, even if effective at reducing impingement, they would not help with the problem of entrainment. EPA is aware that the Salem Nuclear Generating Station in New Jersey is actively investigating the feasibility of behavioral barriers as a technology to reduce impingement at the facility. Thus, it is possible that in the future such measures may be further developed and warrant consideration. At present, however, EPA believes that the permittee should direct expenditures for reducing impingement at MKS to measures whose efficacy is more certain, and that any major expenditures should be directed to measures that will also reduce the relatively more significant problems of entrainment and thermal discharge impacts.

8.2.6 Options for Ensuring that the Location of the MKS CWIS's Reflect the BTA for Minimizing Adverse Environmental Impacts

As a general matter, in the absence of closed-cycle cooling or dry cooling, one of the best ways to minimize the potential adverse impacts of a CWIS is to locate the intake in an area where impacts are more likely to be less severe, such as an off-shore, ocean location. It is always advisable in order to reduce adverse impacts from a CWIS to locate the intake in relatively less sensitive or less biologically productive areas as well as areas where low approach velocities can be attained. Of course, other steps may also be needed to ensure that the capacity, design and construction of the CWIS reflect BTA.

The permittee did not consider the option of relocating the CWIS to another location, such as the Boston Inner Harbor. However, its evaluation of extending the MKS discharge outfall to somewhere in the Boston Inner Harbor concluded that significant construction activity along the shoreline of the Charles River in areas out of the permittee's control would be required. Such construction could itself result in adverse environmental impacts to the river's environment. Moreover, moving the intake to the Inner Harbor would not be expected to significantly diminish the numbers of organisms that are impacted by the CWIS, as similar types and numbers of aquatic life are believed present throughout both the lower Charles Basin and the Boston Inner Harbor. EPA believes that the net effect on the watershed of moving the CWIS in this manner would not change significantly, and there could be difficulties with construction related to this change. Furthermore, relocating the CWIS past the New Charles River Dam and Locks, would introduce more salt water into the lower Charles basin, likely adding to the salt water wedge that is periodically documented in the basin. Additional saltwater could also degrade or completely eliminate the habitat of resident freshwater species that currently inhabit the lower basin. Relocating the CWIS to a low DO, deep, bottom area of the basin may result in a reduced potential for impingement or entrainment, but would likely result in other negative consequences, such as an anoxic discharge. Although there is evidence of minimal spawning activity occurring in the Broad Canal, this area appears to be of limited biological activity or production relative to the Charles River. Thus, EPA believes the CWIS in its current Broad Canal location is reflects BTA.

8.2.7 Economic Consideration of Technological Options

As discussed in Section 7, EPA has interpreted CWA § 316(b) to authorize it to consider the cost of the technological options for CWIS improvements when making case-by-case determinations of what constitutes BTA for minimizing adverse environmental impacts. First, cost is considered in terms of whether an option is economically "practicable." This can be understood as part of meeting the "availability" component of BTA. Second, under a case-by-case BPJ approach, the Agency also considers costs by determining whether or not the cost of the BTA requirements would be "wholly disproportionate to the environmental benefit to be gained." This comparison is not a cost/benefit analysis; rather, it is a particular type of consideration of costs that EPA has determined is consistent with Congressional intent under CWA § 316(b).

As discussed above, EPA has determined the adverse environmental impacts from entrainment and impingement by the MKS CWIS's to be serious, but not severe. A number of alternatives have been evaluated for determining permit limits under CWA § 316(b) that reflect BTA for minimizing adverse environmental impact from the MKS CWIS's. While major capacity reductions from converting the facility's cooling system to closed-cycle cooling using cooling towers might be the most effective approach to minimizing entrainment and impingement by the CWIS's, these alternatives have been determined to be impracticable due to space constraints at the plant site and the surrounding urban neighborhood. New location options did not offer clear improvements and raised certain environmental concerns. EPA has instead determined that a barrier net system which meets the proposed performance standards for reducing impingement and entrainment, in conjunction with the identified seasonal flow reductions, constitutes BTA for MKS based on information available to date. This design option was preferable to the other barrier/screening systems investigated for the reasons discussed above. The costs of this option have been determined to be practicable for the permittee – indeed, the permittee proposed the system – and given the nature of the reductions in impingement and entrainment that appear attainable, EPA finds that the costs associated with this option are not "wholly disproportionate" to the expected benefits.

8.3 § 316(b) Determination

CWA § 316(b) requires that the design, capacity, location and construction of cooling water intake structures reflect the Best Technology Available (BTA) for minimizing adverse environmental impacts. Entrainment and impingement of aquatic life are two of the key adverse environmental impacts associated with cooling water intake structure operations. Based on information available at this time, EPA regards the adverse environmental impacts of the cooling water intakes at MKS to be serious, but not severe, in light of the number of organisms being entrained and impinged and the apparent degree of effect on the populations and the overall community of organisms in the ecosystem. It should be noted that information is lacking on certain parameters of interest, as discussed above, and new information could lead to new conclusions in the future.

While adverse impacts from the CWISs at MKS could be minimized to the greatest degree by converting the open-cycle cooling system to a closed-cycle system using cooling towers, these options are not available due to space constraints on and around the site. However, EPA also notes that the permittee's use of the fin fan (air) cooling equipment in conjunction with the new HRSG will limit the amount of additional flow that would otherwise be associated with the new unit. In addition, EPA finds two other flow reduction methods to be available and appropriate components of BTA in this site specific circumstance and is proposing CWIS capacity limits that reflect these two steps. First, flow reductions are anticipated with generation curtailments associated with the temperature conditions in this permit. Second, the permittee is required to limit its discharge flow during the months of April, May and June to 70 MGD, as a monthly average. Spawning activity takes place primarily during this three month period and limiting the discharge flow during this time will lead to lower rates of I&E of aquatic organisms as compared to the plant's permitted daily maximum discharge of 80 MGD. Yet, the permittee should be able to comply with this limit as 70 MGD is the yearly average design flow proposed by the permittee and April through June are not typically the highest demand months of the year.

Re-locating the CWIS did not appear to offer any clear environmental advantage, and appeared to pose several possible disadvantages, over the current intake location. Therefore, no changes in location are proposed.

EPA has determined that for the design of the CWIS to reflect BTA at Kendall Station, the facility should install and operate intake barrier nets that meet the performance standards proposed by EPA for this permit. This design technology follows the proposal by the permittee. The design proposed by the permittee has an effective mesh size of less than 1/32" that serves as a physical barrier to fish and larger larvae. Also, the permittee estimates that an intake barrier net will reduce intake velocity to about 0.04 fps. The barrier net will be attached to the outside of the new boardwalk to be installed in the Broad Canal and will terminate at the Broad Canal wall in a manner to preclude the bypass of intake water around the net. The barrier is comprised of removable screen sections. This will allow the screens to be cleaned periodically during operation and prior to their deployment each season.

For impingement, the permit's goal is a minimum of 80% impingement mortality reduction as compared to the baseline condition. For entrainment, the permit's goal is a minimum of 60% entrainment reduction as compared to the baseline condition. The baseline condition assumes that there is no barrier net. The draft permit also contains other performance standards to ensure the barrier net is BTA. These include an intake through-screen velocity not to exceed 0.5 fps; attachments of the net to fixed structures to preclude any passage of waters around, over or under the net; and measures to allow for impinged eggs and larvae to be freed in a manner to maximize their survival. EPA has set these permit limits based on a BPJ, case-by-case analysis, but in setting the performance standards in this permit EPA has also considered the performance standards described in the newly signed, but not yet effective, Phase II 316(b) regulations. The impingement mortality standard in the new rule is to reduce such mortality for all life stages of fish and shellfish by 80 to 95% from the calculation baseline. The entrainment performance standard in the new rule is to reduce entrainment of all life stages of fish and shellfish by 60 to 90% from the calculation baseline. EPA believes that the information presented to date suggests that a barrier net system at MKS seems likely to be able to meet the proposed performance standards (though there is some uncertainty regarding entrainment). EPA welcomes comments regarding the proposed performance standards or alternative standards that might be imposed.

If the barrier nets are installed and found not to meet the I&E reduction goals, or other performance standards set forth in the permit, the permittee will be required to implement an adaptive management approach for revising design and construction technologies, operational measures, operation and maintenance requirements, and/or monitoring requirements to determine how to improve performance. Based on this approach, the permittee would propose and implement barrier net design changes, or alternative screening devices, to improve I&E reduction levels, meet the I&E reduction goals, and achieve the other performance standards described in the permit. The permit also requires monitoring of the nets' effectiveness during the life of the permit to assess the degree to which the I&E of aquatic organisms is being achieved. If the use of these nets does not demonstrate the ability to meet the I&E goals of the permit, there may be separate or additional requirements which the permittee will have to implement to assure BTA is satisfied.

In summary, EPA has considered the nature and magnitude of the adverse environmental impacts from MKS' CWIS (primarily the impingement and entrainment of aquatic organisms), and has evaluated the technological options for minimizing these impacts. EPA has determined that the site-specific BTA for this facility consists of the following measures: (1) installation of barrier nets which achieve the required performance standards in front of each of the three intake structures; (2) restriction of non-contact cooling water flow to a monthly average rate of 70 MGD during each of the primary spawning months of April, May and June; and (3) maintaining location of the intake structures in the Broad Canal.

8.4 References

Mirant Kendall, L.L.C. February 2001. NPDES Permit # MA0004898 Kendall Square Station Equipment Upgrade Project, Cambridge, MA, Volumes I and II. Prepared by TRC for Mirant Corporation.

Taft, E.P. 2000. Fish protection technologies: A status report. Environmental Science & Policy: 3(Supplement 1): S349-S359.

9.0 Final Permit Requirements for Thermal Discharge and Cooling Water Intake

Each time a permit is reissued, EPA revisits its latest determinations under §§ 316(a) and (b) of the Clean Water Act. CWA § 316(a) allows for variance-based limitations for thermal discharges if certain conditions are met, while CWA § 316(b) governs cooling water intake requirements. EPA's determinations and supporting evaluations for setting thermal discharge and cooling water intake structure limits under CWA §§ 301, 316(a) and (b) for the Mirant Kendall Station NPDES permit are contained in this document. A brief summary of the conclusions of EPA's analyses and the resulting permit limitations are presented below.

In developing effluent limitations, EPA is required to determine technology-based and water quality-based requirements, and whichever of these is more stringent would govern the permit requirements. For thermal discharges, however, EPA may also consider granting a variance under Section 316(a) from either or both the technology-based and water quality-based effluent limitations if less stringent variance-based limitations will nevertheless be sufficient to "assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife" (BIP) in and on the water body receiving the discharge. As a practical matter, EPA has for some permits simply developed permit limitations under a Section 316(a) variance – without first determining technology-based and water quality-based limits – if these limits were determined to be sufficient to assure protection and propagation of the BIP. In such cases, determining the technology-based and water quality-based limitations would serve no practical purpose, because the less stringent variance-based limits would ultimately be granted. Similarly, in some cases, EPA has determined water quality-based conditions without determining the technology-based requirements, when EPA had reason to believe that it was clear that the water quality-based requirements would be more stringent than the technology-based standards and, therefore, would govern the permit whether or not technology-based limits were determined.

In this case, the permittee has requested a variance pursuant to Section 316(a) and has proposed specific thermal discharge limitations that would apply under such a variance. In reviewing this variance request, maximum instream temperatures were established for the receiving basin to meet the desired goal of protection and propagation of the balanced indigenous fish populations. The approach focused on setting temperatures to protect the fish species, or the life stage of the fish species, that is most sensitive to elevated temperature. This is a recognized way to ensure that other species found in a water body receiving thermal discharge are also adequately protected.

Based on the analysis summarized in Section 5 of this document, EPA does not approve of the § 316(a) variance proposed by the permittee. However, based on the analysis in Section 5, EPA has determined that a § 316(a) variance from certain aspects of the Massachusetts Water Quality Standards (WQS) is appropriate and adequately protective of the BIP. The key aspect of the Massachusetts WQS subject to this variance is the state's mixing zone policy, which calls for no lethal affects in the Zone of Initial Dilution (ZID). EPA assumes that the proposed variance-based effluent limits, which must maintain the instream temperatures described in permit Attachment A, are less stringent than either water quality-based or technology-based permit limits would be, albeit without EPA having undertaken a comprehensive or complete derivation of such water quality-based or technology-based limits.

It should be noted that the variance-based thermal limits in this permit are consistent with several aspects of the Massachusetts WQS, so that no § 316(a) variance is actually required with respect to these provisions. These provisions are as follows:

- Site specific temperature limits for spring and winter periods;

- Maintenance of a Zone of Passage of at least 50% of the cross sectional area of the Charles River;

- A maximum ΔT of no more than 5^oF between a background station and six different points in the vicinity of the discharge, including within the Zone of Passage and Habitat (ZPH);

- A minimum dissolved oxygen level of 5.0 mg/l at any point in the ZPH; and

- A maximum summer temperature of 83^oF in the ZPH.

To assure protection of the BIP with this variance, the permit mandates continuous instream monitoring to ensure compliance with temperature, delta T and other requirements necessary to assure the protection and propagation of the BIP. The results of this monitoring will be used during the future reissuance(s) of the permit or any permit modifications.

Regarding the application of § 316(b), EPA has determined that the site-specific BTA for this facility consists of the following measures: (1) installation of barrier nets which achieve the required performance standards in front of each of the three intake structures; (2) restriction of non-contact cooling water flow to a monthly average rate of 70 MGD during each of the primary spawning months of April, May and June;

and (3) maintaining location of the intake structures in the Broad Canal. The permit also requires monitoring of the nets' effectiveness during the life of the permit to assess the reductions in the I&E of aquatic organisms that are being achieved.