

BAY SHORE POWER PLANT

INTAKE AND THERMAL DISCHARGE NPDES COMPLIANCE OPTION EVALUATION

1.0 INTRODUCTION

Under contract EP-C-05-046, Tetra Tech was tasked by USEPA's Office of Wastewater Management and EPA Region 5 to evaluate data and documentation submitted by FirstEnergy in support of Ohio EPA's ongoing efforts to develop appropriate NPDES permit conditions for FirstEnergy's Bay Shore Power Plant (BSPP) located near Oregon, OH. This effort focuses on impacts that may occur from cooling water withdrawal in the Maumee River estuary and elevated temperature waste discharges to Maumee Bay—two distinct, but related, aspects of the NPDES program.

Section 316(b) of the Clean Water Act (CWA) requires facilities to employ the best technology available (BTA) to minimize adverse environmental impact (AEI) from cooling water intakes. Ohio EPA is currently in the process of reviewing BSPP's current cooling water intake structure (CWIS) operation against the technology-based standard in the statute and will incorporate any necessary changes or improvements into a compliance schedule that will be part of the renewed NPDES permit for the facility.

The Ohio Administrative Code (OAC) establishes numeric water quality criteria for thermal discharges to state waters as well as narrative criteria that are designed to protect the designated uses of the receiving water (OAC Rule 3745-1-07). Mixing zones are permitted for thermal discharges but the discharger must demonstrate that certain conditions are met in order to ensure compliance with all applicable criteria are met (OAC Rule 3745-2-08). Through existing NPDES permit requirements, Ohio EPA has directed BSPP to conduct studies and collect additional data describing the facility's thermal discharge in order to determine if the mixing zone's size should be restricted or whether additional measures must be taken to ensure compliance with the appropriate water quality standards.

1.1 SCOPE OF WORK AND TASK ORDER SUMMARY

Tasks 1-4 direct Tetra Tech to review the facility's Proposal for Information Collection (PIC), all impingement mortality and entrainment (IM/E) sampling data and supporting documentation, and all data related to the thermal discharge, including the 2003 *Thermal Mixing Zone Study*.

Task 5 and its subtasks address Section 316(b) requirements and direct Tetra Tech to a) determine if IM/E estimates are reasonable and representative; b) determine if proposals (if available) for reducing IM/E are adequate and appropriate; c) recommend a level of IM/E reduction representing BTA for this facility; and d) recommend improvements and/or operational changes at the facility that will meet BTA.¹

Task 6 directs Tetra Tech to develop recommendations, conclusions, and/or suggestions regarding the possible impact of the thermal discharge and the need to and justification for restricting the size of the thermal mixing zone.

¹ BSPP did not submit detailed information regarding any proposed technologies or operational measures designed to reduce IM/E, except brief mentions of five technology categories proposed for further study in its Proposal for Information Collection (PIC). The PIC does not discuss the evaluation methods to be used or any data already collected or conclusions reached. As such, Tetra Tech did not conduct any determination under Task 5.b.

1.2 REPORT BASIS AND ORGANIZATION

Tetra Tech prepared this final report based on data collected and evaluated by BSPP and its contractors, as well as additional information gathered from other state resource agencies and provided by Ohio EPA. Tetra Tech did not collect any biological or temperature data as part of this effort nor was Tetra Tech involved in the process that evaluated BSPP's proposed study plans prior to those activities. All biological and temperature data specific to BSPP and discussed in this report were collected at the facility's direction with oversight by Ohio EPA and should be cited accordingly. Tetra Tech reviewed the adequacy of all available information and provided a summary to Ohio EPA by memoranda dated September 30, 2008 and December 12, 2008.

This final report evaluates the potential efficacy of several technology-based compliance options and their applicability at BSPP in the event Ohio EPA determines additional measures are necessary to comply with existing regulations. Options are reviewed according to accepted criteria used by Tetra Tech, US EPA and industry organizations such as EPRI when conducting the same type of evaluation at other facilities nationwide. Similar accepted practices are used in those instances where option cost estimates are also developed, although any estimate must be further refined with more detailed facility information if the option is selected for implementation.

The remainder of this report is organized as follows:

- Section 2 provides a brief overview of the BSPP facility, its operations and cooling water withdrawals.
- Section 3 discusses the various state and federal regulatory programs that address cooling water withdrawal and thermal discharge impacts.
- Section 4 summarizes data submitted by BSPP and describes how any identified deficiencies affect the final analysis.
- Section 5 presents the screening criteria used for this report and analysis results for several widely used technology-based options.
- Section 6 provides further detail and cost estimates for an evaporative cooling tower retrofit at BSPP.
- Appendix A contains a summary table of all options considered.
- Appendix B provides additional detail on the methods used to develop performance and cost estimates for an evaporative cooling tower retrofit.

2.0 FACILITY BACKGROUND AND DESCRIPTION

The Bay Shore Power Station is located on the south shore of Lake Erie near the confluence of the Maumee River and Maumee Bay near the city of Oregon (Figure 1). The facility operates four conventional steam boiler generating units with a combined nameplate rating of 631 MWe. Unit 1 has a circulating fluidized bed boiler while units 2-4 have either wall or vertical dry bottom boilers. Unit 1 was retrofitted in 2000 to consume petroleum coke generated at the nearby BP refinery. The remaining three units consume coal (Unit 1 is capable of burning coal if necessary) (EIA 2007). All four units are operated with once through cooling systems, wherein cooling water is withdrawn from a source, passed through a surface condenser to remove waste heat, and discharged to a receiving water.

BSPP operates as a baseload facility, which means it generates electricity for delivery to the grid more or less continuously for extended periods in order to meet minimum electrical demand. Baseload facilities may be inactive for normal maintenance periods or when electrical demand is low but generally operate year-round. Figure 2 shows the 3-year (2005-2007) monthly and cumulative average gross load for each unit expressed as a percentage of each unit's nameplate capacity. The facility-wide average gross load for the time period is 83% of BSPP's total capacity (USEPA 2007).

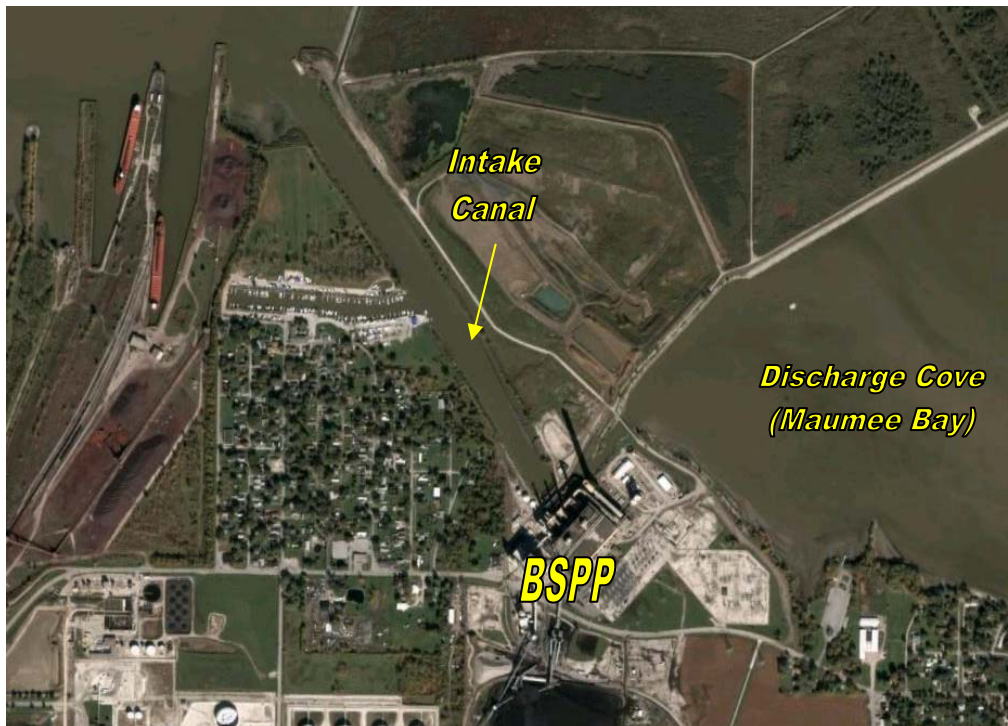


Figure 1. Facility Location

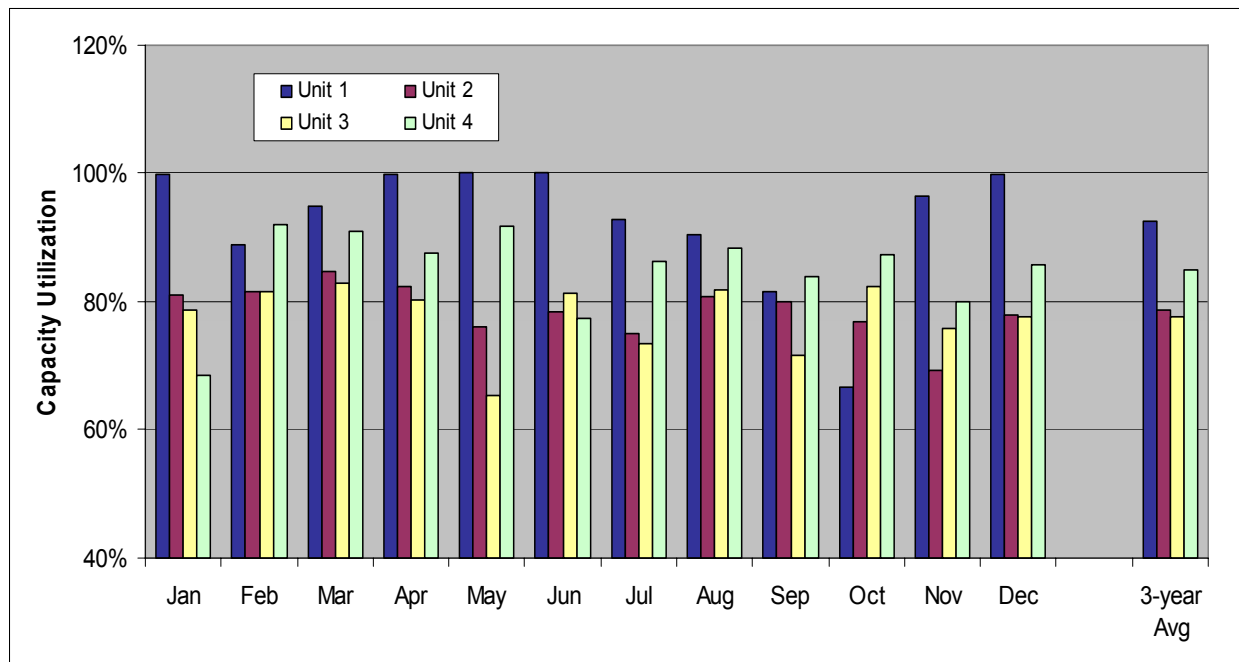


Figure 2. 2005-2007 Average Gross Load

BSPP operates one common CWIS to provide cooling water to each unit. Water is withdrawn from the Maumee River estuary via an intake canal extending 3,700 feet southeast to the facility, where the canal divides to nine individual intake bays. Each bay consists of bar racks that prevent larger debris from entering the cooling system and a vertical traveling screen fitted with 3/8-inch mesh panels to screen smaller debris. Screen #4 operates only 15 minutes per day while screen #7 operates for 30 minutes during each 12-hour shift (Kinetrics 2008). Operating information for the other screens is not available but presumed to include periodic rotations to remove accumulated items. Screens are washed during a rotation cycle with a high pressure (50 psi) spray that removes any impinged debris, including fish, which is then discharged to a common sluiceway that empties into Maumee Bay (Figure 3). The design through screen velocity is estimated at 2.58 fps (FirstEnergy 2004).

Each unit is served by two circulating water pumps, each with the capacity of 64,000 gpm, or 92 mgd, for a facility total of 512,000 gpm, or 737 mgd.^{2,3} Cooling water is drawn through a single pass surface condenser fitted with 90-10 copper-nickel tubes and combined with other in-plant wastes before final discharge to Maumee Bay through one of three permitted outfalls. This section of Maumee Bay is

² Information submitted in the PIC lists the combined intake capacity at 810 mgd while other reports identify maximum intake volumes of 745 mgd. The difference between the reported circulating pump capacity and actual withdrawal rates (see Kinetrics 2008, Table 4.1) may reflect additional volumes from service water or condensate pumps used for purposes indirectly related to steam condensation. Tetra Tech notes that the surface condenser capacity (128,000 gpm) is equal to each unit's total circulating pump capacity

³ Information provided by BSPP describing the surface condensers ("Knowledge Requirement Answers for Circulating Water Systems") does not specify the corresponding generating unit or whether all units share the same pump and condenser specifications. Without additional information, Tetra Tech assumed the specifications were applicable to all units.

currently designated for the following uses: exceptional warm water habitat (EWH), state resource water (SRW), agricultural supply water, public water supply, industrial water supply, and bathing waters.⁴



Figure 3. Intake and Discharge Locations

3.0 FEDERAL AND STATE REGULATORY REQUIREMENTS

3.1 COOLING WATER WITHDRAWALS

CWA Section 316(b) establishes a statutory requirement that CWIS location, design, capacity and construction reflect the best technology available for minimizing adverse environmental impact. Authority for implementing Section 316(b) resides with EPA and is addressed through the issuance of National Pollutant Discharge Elimination System (NPDES) permits. States may assume this responsibility if they implement an approved permitting program. Ohio was granted this authority in 1974.

In 1976 USEPA published a final rule implementing Section 316(b). Following a lawsuit filed by a group of utility companies, the Court of Appeals for the Fourth Circuit remanded the rule citing EPA's failure to comply with the Administrative Procedures Act by not properly publicizing the rule's supporting documentation. USEPA later withdrew most of the final rule, although a draft guidance document developed during the rulemaking—*Guidance for Evaluating the Adverse Impact of Cooling Water Intake Structures on the Aquatic Environment: Section 316(b)* ["1977 USEPA Guidance"]—was released and served as the basis for implementing Section 316(b) using best professional judgment (BPJ).

After entering into a consent decree with plaintiffs who challenged the lack of national technology-based standards, USEPA began developing section 316(b) implementing regulations in three phases. The Phase I rule, applicable to new steam electric facilities—was issued in 2001. The Phase II rule was adopted in

⁴ NPDES Fact Sheet OEPA Permit 21B00000*QD.

2004 and was to apply to most existing steam electric facilities, including BSPP. Following a court challenge, however, USEPA effectively suspended the Phase II rule on March 20, 2007 and directed permitting authorities to continue implementing section 316(b) statutory requirements on a BPJ basis (Grumbles 2007).

BSPP's previous permit was developed and issued during the interim period between the adoption of the Phase II rule in 2004 and its suspension in 2007. At the time, Phase II compliance was based on a multi-year process that involved the collection and submittal of various source water and biological characterization data, which might include new IM/E sampling efforts, as well as a plan of study for evaluating proposed compliance methods. The first step, the Proposal for Information Collection (PIC), would serve as an outline and study plan for any activities the facility would conduct prior to a final determination of BTA and the different methods it proposes to evaluate as possible compliance options.

The facility would then prepare a Comprehensive Demonstration Study (CDS) that evaluated the efficacy of any existing IM/E reduction measures and any additional measures that would be necessary to comply with the Phase II performance standards. BSPP submitted its PIC in 2004 and conducted impingement sampling, survival studies, and entrainment sampling over a 15-month period during 2005 and 2006. A final CDS was not prepared in light of USEPA's suspension of the Phase II rule.

3.1.1 DETERMINING ADVERSE ENVIRONMENTAL IMPACT

In 1978 Ohio EPA published *Guidelines for the Submittal of Demonstrations Pursuant to Sections 316(a) and 316(b) of the Clean Water Act and Chapter 3745-1 of the Ohio Administrative Code* ["Ohio 316 Guidelines"] that outlined policy procedures and objectives addressing both thermal and intake impacts. Specific to IM/E, the document states that the "primary objective of any 316(b) evaluation should be to determine if an existing or proposed cooling water intake structure minimizes adverse environmental impact" (OEPA 1978, p. 45).

Similar to the approach in the 1977 USEPA Guidance, Ohio EPA defines AEI as "damage that occurs whenever there is entrainment or impingement of aquatic organisms as a result of the operation of a CWIS" (OEPA 1978, p. 36) and provides guidance for determining whether the damage is acceptable by considering

1. the number of organisms entrained and impinged.
2. the percentage of each representative species lost due to entrainment and impingement damage.
3. the magnitude of damage to endangered species, or to commercially, recreationally, or ecologically valuable species.
4. whether the observed IM/E damage contributes to community unbalance.

Ultimately, IM/E impacts are considered unacceptable "if the maintenance of existing balanced communities or the recovery of perturbed or unbalanced communities are impaired or prohibited, or the magnitude of damage to endangered, commercial, sport, and/or ecologically valuable species interferes with an existing or planned use of the source water body" (OEPA 1978, p. 37).

3.1.2 QUALIFYING AND QUANTIFYING INTAKE DAMAGE

Furthermore, the Ohio 316 Guidelines provide instruction on what factors should be considered when attempting to quantify the level of impact that may be occurring and place it within the appropriate

context. Facilities that withdraw cooling water from surface waters are classified as either high risk or low risk based on several possible characteristics, including the source water designation and intake capacity. BSPP, which withdraws water from the Maumee River estuary, is automatically considered a “high risk” facility regardless of its intake capacity because it is located on a Lake Erie estuary (OEPA 1978, p. 38 no. 4).

A facility’s risk classification does not equate to more or less stringent criteria for determining BTA. Rather, the guidelines direct Ohio EPA and the facility to conduct all data collection and analyses using an increasing level of preciseness and sophistication that corresponds to a facility’s level of risk. Specifically, “the precision with which [intake damage] assessments and evaluations are made should increase proportionally with risk” (OEPA 1978, p. 47) and should

1. Estimate the numbers (with accompanying confidence limits) of fishes impinged and eggs and larvae entrained (by species) during each year of sampling.
2. Estimate the percent of each representative fish species population lost due to entrainment and impingement mortality (applicable to high risk intakes).
3. Evaluate the significance of the estimated losses to the representative fish species populations and existing fisheries in the source water body.

3.2 THERMAL DISCHARGES

BSPP is classified as point source discharge (and subject to NPDES permitting requirements) with a thermal component to its discharge. As such, BSPP is subject to both technology- and water quality-based effluent limitations pursuant to CWA Sections 301 and 306, including those established for temperature. OAC Rule 3745-1-07 contains water quality standards and numeric criteria for temperature applicable to discharges to Maumee Bay, while OAC Rule 3745-1-04 contains general narrative criteria prohibiting, to every extent practical and possible, discharges that cause nuisance conditions in surface waters, including mixing zones. OAC Rule 3745-2-08(c) lists various sizing and demonstration requirements for the purpose of establishing a mixing zone, subject to Ohio EPA’s review.

Ohio EPA’s *Section 316 Guidelines* provide further information for establishing the appropriate thermal effluent limitation and determining the mixing zone’s size. When a thermal mixing zone applies to a facility’s discharge, temperature limitations are expressed in terms of the net plant heat rejection rate (BTU/hr) rather than through an areal or volumetric description. For an existing thermal mixing zone, the review process evaluates the effects that the zone’s total size has on the populations and communities of the receiving water body (OEPA 1978, p.28) and is based on

1. Site-specific biological, chemical, and physical information provided by the applicant.
2. Temperature standards or other temperature criteria applicable to the receiving water body.
3. Demonstration that the mixing zone will assure protection and propagation of a balanced indigenous community.

The current permit for BSPP (21B00000*QD) was issued on June 29, 2007 and expired on January 31, 2009. Permit conditions require FirstEnergy to conduct a thermal mixing zone benthic survey to supplement information provided in the 2003 *Thermal Mixing Zone* study. The survey includes sampling for 2 years from 2008 through 2009. The most recent progress report, including a summary of the sampling results, was submitted to OEPA on December 31, 2008.

4.0 DATA SUMMARY, PERFORMANCE AND LIMITATIONS

The studies and data submitted by BSPP in support of thermal mixing zone and cooling water intake impacts reflect ongoing permit compliance efforts dating back several years, with study plans for IM/E sampling and thermal plume modeling having been previously approved by Ohio EPA. BSPP has submitted interim reports updating Ohio EPA staff on its activities and preliminary data thus allowing for continued input from staff on the direction of future activities.

Tetra Tech conducted an initial review of the information set and submitted its initial findings to Ohio EPA on 9/30/2008, which were then forwarded to FirstEnergy with a request to provide additional information. Tetra Tech reviewed FirstEnergy's response and additional data provided by Ohio EPA and submitted a follow up review on 12/18/2008. These memoranda provide a more detailed discussion of Tetra Tech's review.

Tetra Tech identified several critical missing elements to various reports, particularly the *2003 Thermal Mixing Zone Study*, and suggested additional data for collection to augment any final BAT/BTA determinations made for BSPP.⁵ A brief summary and a discussion of how any deficiencies affect the overall analysis is provided below.

4.1 IMPINGEMENT AND ENTRAINMENT

Tetra Tech reviewed data provided by BSPP from its 2005-2006 sampling effort. These data provide the basis for BSPP's estimates of the annual numbers of fish impinged on the facility's intake screens and the numbers of eggs and larvae entrained through the cooling system. The dataset is insufficient, however, to estimate the proportional losses that result from IM/E or discuss the impact to critical or important species in the proper context (see section 3.1.2). It is not clear if these deficiencies conflict with data collection requirements for "high risk" facilities (see section 3.1.1).

These concerns do not preclude Tetra Tech from conducting a detailed evaluation of different technology-based compliance options. Sufficient information is available to analyze the design and implementation constraints of multiple options against known logistical obstacles. Likewise, proportional IM/E reduction estimates for BSPP can be made based on performance data collected at other installations.

4.1.1 IMPINGEMENT

BSPP conducted 104 impingement sampling events between May 2005 and December 2006 to enumerate and classify impinged fish. Six survival studies were also conducted to evaluate mortality for fish removed from the screens and discharged through the debris sluiceway to Maumee Bay (see section 4.1.3). Data available from the 2005-2006 sampling event demonstrate BSPP impinges a high number of fish against its intake screens, both in terms of individuals (46,030,006 fish) and biomass (270,296 kg).

⁵ BSPP continues to collect benthic monitoring samples from the discharge area as part of the overall thermal impacts assessment. This effort, as required by the facility's current NPDES permit, had not concluded at the time this report was finalized.

Table 1 summarizes total impingement estimates for species with impingement values in excess of 50,000 during the sampling period. Fifty five species and/or species groups were observed in impingement samples collected during the 2005/2006 sampling period. Annual estimates of impingement values ranged from more than 24 million for emerald shiner to less than 100 rainbow trout.

To obtain its final estimate of 46,030,006 fish impinged on an annual basis, BSPP first averaged the numbers of impinged fish for months that were sampled during both 2005 and 2006 (May, October, November, and December), then summed these averages with the numbers of impinged fish for the months sampled only once, yielding an annual total (Kinetrics 2008). (Alternatively, a simple annual average based on 15 months of sampling data yields an annual impingement estimate of approximately 52 million fish.)

BSPP categorized impinged fish according to condition: alive and healthy; alive but stressed; recently dead; and long dead. Alive and healthy fish swam upright with good coordination and speed, avoided attempts to capture them, and struggled when handled. Alive but stressed fish swam poorly or were barely moving, but had a heartbeat upon internal examination. Recently dead fish had clear eyes, red gills, fresh mucous covering the skin, and firm flesh. Long dead fish had cloudy eyes, light pink or white gills, spotty or non-existent mucous covering the skin, pale body coloration, and might be in rigor mortis or some stage of decomposition. Long dead fish may have died of natural causes: the body could easily be transported by currents or the water intake flow, and become impinged. Additionally, longer-term impingement, especially during warmer weather, might also produce fish exhibiting “long dead” characteristics.

Reference data provided by BSPP describing general population estimates for emerald shiner, walleye and yellow perch are incomplete and are not directly relevant to calculating impingement losses as a proportion of the source water population. These data describe population statistics for the entirety of Lake Erie rather than the more appropriate localized population zone of Maumee Bay or, perhaps, the Western Erie Basin, without adequate justification. The scale of the Lake Erie basin, at nearly 10,000 square miles with 850 miles of shoreline, strongly suggests that habitat areas for the same species may be more or less independent from one another, and should be evaluated against a more realistic source population. Likewise, references to historic impingement rates from the 1977 study provide little context and, given the significant changes in reported species composition between the 1977 and 2005, seem only to underscore the inutility of any comparison.

Short of adequate source water sampling, other methods may be used to estimate source populations. One approach is to scale impacts by defining the habitat within the area of hydraulic influence and sampling within that area to estimate the population, although it is difficult to establish a level of confidence for the result without adequately characterizing the habitat and accounting for migratory/spawning patterns that may influence the number of individuals present at a given time. Another method would approximate the local habitat area as a percentage of the whole basin and use existing population estimates to quantify

Table 1. BSPP Estimated Annual Impingement

Species	# Impinged ^[a]
emerald shiner	24,080,877
gizzard shad	14,313,113
white perch	4,769,163
white bass	1,593,199
spottail shiner	313,326
freshwater drum	225,706
trout-perch	159,379
yellow perch	123,405
round goby	93,918
walleye	77,812
channel catfish	77,469
logperch	51,547

[a] Annual estimate based on 2005-2006 sampling effort for species with more than 50,000 individuals impinged. All data obtained from Kinetrics (2008).

impact. This method is likely to be less accurate since it assumes a random distribution of fish, which is not true.

Ultimately, the data as presented do not permit an easily quantifiable estimate of impingement losses with respect to source water populations in the Western Erie Basin or Maumee Bay, even for popular sport fish species such as walleye and yellow perch where additional data is available from annual harvest reports.

4.1.2 ENTRAINMENT

In general, the sample collection methods and calculations used to estimate the number of eggs and larvae entrained annually appear adequate. BSPP estimates that 208,565,490 fish eggs, 2,247,249,020 fish larvae, and 13,824,022 juvenile fish (of sufficiently small size) are entrained on an annual basis. Table 2 summarizes the total larvae and juvenile entrainment for the 2005-2006 sampling event and BSPP's estimated population loss for larvae.

Table 2. Estimated Annual Larvae and Juvenile Entrainment

Species	Larvae ^[a]	Population loss ^[b] (% of total larvae)	Juveniles ^[a]
freshwater drum	977,426,912	10.1	155,542
rainbow smelt/Clupeidae	536,265,835	10.9	4,365,674
Unidentifiable ^[c]	465,945,050	10.2	—
Morone sp.	137,549,760	10.8	—
logperch	32,763,640	11.0	1,328,768
white sucker	29,196,575	11.3	—
emerald shiner	19,001,574	9.6	3,915,565
white bass	17,840,256	10.1	1,097,805
walleye	8,157,828	9.8	663,715
Cyprinidae	7,484,343	10.2	—
Notropis sp.	4,707,966	9.8	17,405
yellow perch	3,180,492	12.3	—
Percidae	2,300,638	10.8	—
common carp/goldfish	2,143,190	10.7	—
walleye/yellow perch	511,779	10.0	—

[a] Annual estimate based on 2005-2006 sampling effort for species with more than 100,000 larvae. All data obtained from Kinetrics (2008).

[b] Population loss calculated as a percentage of the estimated Maumee River population extrapolated from larval densities in the intake canal.

[c] Although the Kinetrics (2008) report does not discuss the unidentifiable portion of entrainment samples, this category typically includes intact larvae that cannot be identified to species with certainty as well as larvae that have been damaged beyond recognition as a result of either natural causes or sampling efforts. The Kinetrics report does not offer any conclusive explanation as to why so many larvae were unidentifiable, nor does it explain how this can be translated to a population loss estimate.

BSPP asserts that, although the raw numbers of egg and larvae entrainment are high and have increased since the 1976-1977 study, the total remains low as a percentage of the estimated Maumee River population. Background sampling to characterize the river population was not conducted during the 2005/2006 sampling events. Instead, BSPP assumed that egg and larval densities are roughly equivalent

(or perhaps higher) between the river and intake canal and extrapolated a flow-based population estimate that assumes a uniform distribution throughout the water body (Kinetrics 2008).

Several key issues affect the ability to quantify the entrainment-related impact with respect to the fish populations in the Maumee Bay and Maumee River. The assumption that larval densities in the Maumee River are the same or higher than the intake canal, and can thus be extrapolated from canal samples, discounts the potentially significant differences in ichthyoplankton spatial distribution that may reflect variations in bathymetry, temperature and flow between the river and canal. Likewise, normal temporal variations may not have been captured for certain species that spawn during part of the period in which entrainment samples were not collected (lake trout, northern pike and cisco).⁶

This extrapolation method may be even less accurate during low flow periods for the Maumee River, when stream flows entering the bay exert minimal influence over water turnover rates. During these periods, wind-drive tides or seiches play a greater role in determining water levels in Maumee Bay, which may introduce a different species distribution than might be present during periods of higher river flow.⁷

Finally, comparisons between 1977 and 2005/2006 entrainment estimates as a proportion of the estimated river population do not provide any usable context for the current analysis. Data in FirstEnergy's own report (Kinetrics 2008) shows the significant changes in both population densities and species makeup that have occurred in western Lake Erie in the intervening period and underscore the need for current data.

4.1.3 EXISTING IMPINGEMENT MORTALITY CONTROLS

BSPP does not employ any technologies that are typically considered effective for reducing impingement mortality, although FirstEnergy contends that the CWIS, as currently configured, partially reduces IM and does not result in 100 percent mortality for all impinged fish as had long been assumed. Rather, some impinged fish may survive screen impingement and removal and are returned alive to Maumee Bay. In support of this claim, BSPP conducted six impingement survival studies during the course of its 2005-2006 impingement sampling effort. The six studies evaluated the 48-hour survival rate for fish captured alive off the intake screens during sampling events. Reported rates varied significantly based on species and sampling event (Kinetrics 2008).

The sample methodology and collection procedures, however, raise questions about the accuracy of impingement survival estimates at BSPP, which cannot be considered representative of current performance. Stresses during the collection process, such as hand picking fish from buckets, might unduly stress fish and artificially reduce survival rates. More problematic, however, is the impingement sampling location near the traveling screens themselves. Samples collected at this location do not account for the potentially negative effects that impinged fish might also suffer during transit through the debris sluiceway or temperature shock encountered when released into the thermal plume. This plume extends several thousand feet east of the intake, and may make fish more susceptible to predation or restrict a fish's ability to recover from other stresses.

⁶ Excerpts from an untitled and undated document provided by BSPP show no observable relationship between river flows and entrainment. The table entitled "Maumee River Discharge Versus Larval Entrainment" is prefaced by the statement "No clear relationship was observed between entrainment and river flow."

⁷ BSPP's maximum intake flow (745 mgd) can exceed the river's discharge volume several times over, particularly during traditional low flow periods of late summer and early fall. This information alone, however, does not support the claim that BSPP necessarily withdraws the entire volume of the Maumee River under these conditions. Grassy Island (Island 18) divides the Maumee River as it enters the open bay and may divert a portion of the river flow away from the intake's influence.

The American Society of Civil Engineers' *Design of Water Intake Structures for Fish Protection* (ASCE 1982) considers numerous design criteria for fish return systems with the explicit goal of (a) minimizing the contact time between captured fish and any structural component (by continuously rotating screens), and (b) minimizing the stresses endured during capture, transport and release. These standards include the shape and size of collection buckets attached to screen panels, removal mechanism (low pressure spray [<20 psi]), construction materials that minimize turbulence and abrasive contact, flow channels without sharp turns or hydraulic jumps, and an intake location that approximates the source water conditions without subjecting fish to temperature shock or other stresses.

BSPP's collection and return system, as described, does not contain any components that specifically target IM, nor does the existing system conform to widely accepted design standards for a fish collection and return system. Intake screens at BSPP do not have modern Ristroph/Fletcher collection buckets, nor are they continuously rotated to minimize retention time. Fish are removed from the screens with a high pressure spray (50 psi) that also removes any impinged debris (trash, sticks, algae) to a common debris return trough. The return conduit is concrete and contains several sharp turns before a significant drop to the discharge sluiceway. Finally, the intake location is less than ideal considering the already significant stresses endured during collection and transport.

4.2 THERMAL DISCHARGE

Once through cooling water discharged to Maumee Bay contains a significant amount of waste heat discharged from each unit's surface condenser. The area of Maumee Bay to which this waste heat is discharged is partially enclosed cove bounded by BSPP, the south shore of Maumee Bay, and the Confined Disposal Facility (CDF) to the north (Figure 1). This area is approximately 500 acres with an average depth of 3 feet, although the thermal plume can extend well beyond this area at different times of the year and under different meteorological conditions. A plume measured in the summer of 2002 measured approximately 2,000 acres (LMS 2003).

The primary and overriding concern identified in the *2003 Thermal Mixing Zone Study* was how "delta T" was defined and how it was used to delineate the maximum extent of the thermal mixing zone. Generally, delta T refers to the difference between two temperature measurements, but when used to evaluate thermal discharges (and not to determine compliance), the term is defined as the difference between the discharge temperature at some point in the plume and at a point in the receiving water body outside the plume's influence. In this report, delta T was defined as the difference between the appropriate maximum water quality standard for temperature (which varied with date) and the temperature in the discharge or discharge plume.

Using this definition, the thermal mixing zone measured, modeled, and discussed in the 2003 study is the regulatory mixing zone rather than the physical mixing zone. Thus, the thermal plume described in this report is the area within which the temperature exceeds the OEPA temperature criterion and not the area within which the temperature exceeds some measure of background temperature. Because of the way delta T and the thermal plume were defined, the information provided in this report does not describe the areal extent of the thermal plume.

Figure 4 is an example of the facility's thermal plume and its influence on water temperatures relative to background measurements in Maumee Bay for a single day. Data provided by Ohio EPA for this date (August 21, 2002) show that BSPP was discharging wastewater at a rate of 745 mgd and at a temperature

of 79°F. This was 11.9°F higher than the measured intake temperature.⁸ A distinct temperature gradient extends more than 2 miles northeast from the discharge. Average and maximum discharge temperature differences for 2005-2008 are shown in Figure 5.

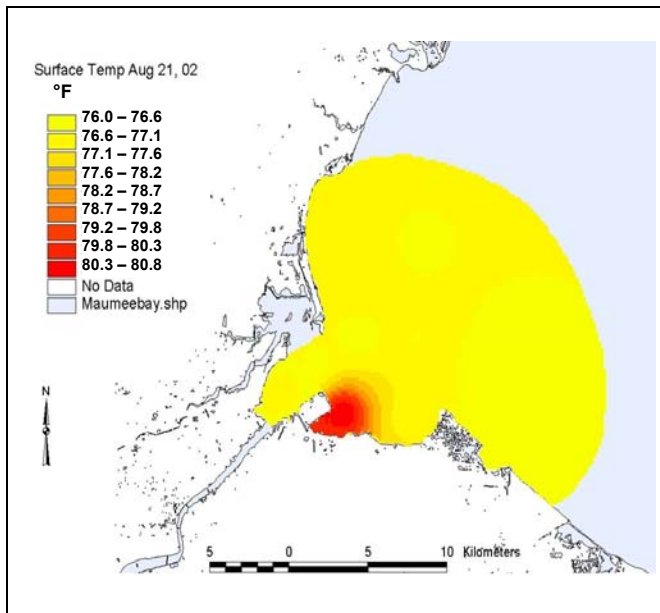


Figure 4. Thermal Plume—August 21, 2002

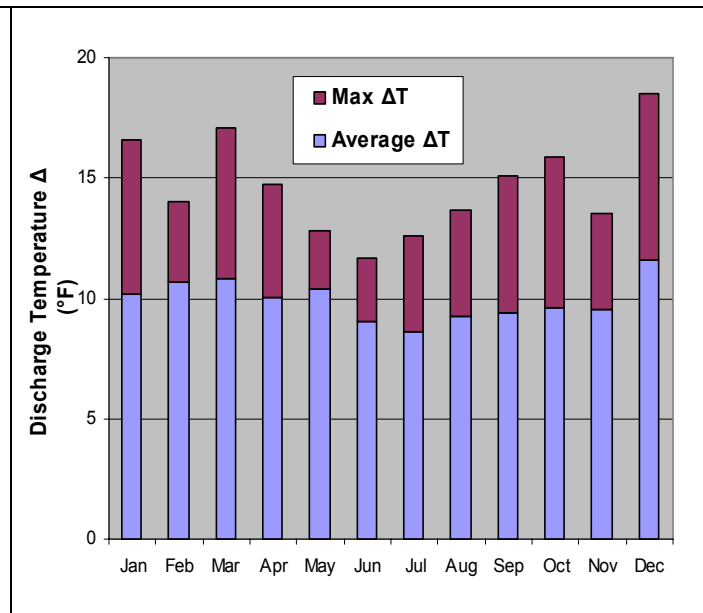


Figure 5. 2005-2008 Temperature Difference

4.3 LIMITS FOR TECHNOLOGY ANALYSIS

4.3.1 THERMAL DISCHARGE

The inability to accurately quantify the thermal mixing zone’s areal extent represents a fundamental deficiency that limits Tetra Tech’s ability to complete the objectives under Task 6 as originally directed. Without a clear understanding of the *physical* mixing zone (rather than one based on compliance standards) any estimate of the mixing zone’s impacts would be incomplete and fail to meet the decision criteria for evaluating alternative thermal effluent limitations (see section 3.1).

Additionally, no data or bases are provided that describe the thermal tolerances of species of concern that might reside within the thermal plume. The report does not include any discussion regarding portions of the receiving water that may potentially be areas of exclusion for those species as a result of the thermal discharge. Without such information it is not possible to evaluate potential thermal impacts to the biota of Maumee Bay.

Tetra Tech notes Ohio EPA’s concern that the existing thermal discharge may conflict with the narrative standards of OAC Rule 3745-1-04 by contributing to the algal blooms that have occurred repeatedly over the last several years.

⁸ It was not clear where the discharge temperature is measured. Condenser temperature rise estimates show the difference at 9.61°F.

Despite these limitations, this analysis includes a general discussion of potential technologies that can minimize thermal discharge impacts and have proven successful at other facilities. Some of these technologies address thermal impacts alone while others are effective at reducing both thermal and IM/E impacts and are discussed accordingly.

4.3.2 IMPINGEMENT AND ENTRAINMENT

Impingement and entrainment data are lacking in several key areas that limit Tetra Tech's ability to quantify the impact BSPP's CWIS is having on the source water populations. Cumulatively, however, the information is sufficient to reasonably support a determination by Ohio EPA that BSPP's current intake configuration does not meet the technology-based standard for minimizing AEI. Ohio EPA's *Section 316 Guidelines* give the agency discretion when evaluating BTA on a site-specific basis using BPJ and allow the agency to consider the relative importance of several factors, including:

- BSPP's lack of proven IM/E reduction technologies, design measures or operational practices that have been demonstrated effective for these purposes at BSPP or elsewhere.
- High rates of impingement mortality and entrainment.
- The location of the BSPP intake at the entrance to upstream spawning grounds in the Maumee River.
- Relative size of BSPP's intake capacity to the available source water volume, especially during low river flow periods.
- Commercial and recreational importance of local fisheries, particularly the renowned walleye runs of late winter and early spring.

In this case, the appropriate BTA standard may be guided by performance data collected for various technologies and measures that have been successfully deployed at other locations. This report, therefore, evaluates technology-based options that may be used to satisfy BTA requirements without defining a facility-specific threshold for AEI or quantifying specific rate reductions that would meet the applicable performance standard. All options are evaluated using BPJ.

5.0 OPTION SCREENING AND SUMMARY

This analysis follows a BPJ process in evaluating different technologies and operational measures for BSPP. BPJ is a sequential approach to determining BTA at a particular facility in lieu of national technology-based performance standards. The initial steps characterize the environmental setting and quantify AEI in the appropriate context. Subsequent steps identify the various technology-based options and assess their availability, performance and feasibility at a particular location while giving appropriate consideration to secondary environmental impacts and financial costs.

As discussed previously, Tetra Tech did not characterize AEI or establish a target IM/E reduction for BSPP. This report does not reach any qualitative assessment about the appropriateness or preference for any one technology at BSPP over another. Each technology is objectively evaluated using the criteria described below and weighed against the known information describing the BSPP facility.

5.1 SCREENING CRITERIA

Section 316(b)'s focus on minimizing adverse impacts before they occur makes it somewhat unique within the NPDES program. Technology-based options are evaluated by assessing their ability to minimize IM/E impacts to the local aquatic community, but these impacts, or the options to control them, can vary from one location to another. Thus, a technology's performance at one facility is not automatically transferrable to another. Modified Ristroph traveling screens, for example, have been shown to significantly reduce IM although the performance may range from 40 to 95 percent at one location versus another. The cause of this variation is often attributable to site-specific factors that must be addressed locally, particularly the target species the technology is intended to protect.

The influence of site specific factors such as species composition is less important for some options where IM/E performance can be estimated with a high degree of confidence based on objective physical properties. Reductions associated with flow reduction measures can be more readily quantified since the exact volume by which flow is reduced is knowable and predictable given adequate physical data.⁹ Likewise, cylindrical wedgewire screens have proven consistently effective at multiple locations because their performance is primarily driven by physical properties like ambient current velocities rather than fragility of the target species.

Technologies and operational measures evaluated as BTA options for BSPP are limited to those with a proven capability to achieve measurable and consistent IM and/or E reductions and have been evaluated by other agencies and organizations. Except as noted, performance estimates for BSPP are based on data compiled by USEPA for the Phase II Rule (USEPA 2004) and EPRI's *Fish Protection at Cooling Water Intakes: Status Report* (EPRI 1999).

Options were evaluated using the following general criteria:

1. *Is there documented evidence demonstrating the option has achieved satisfactory results at similar facilities or under rigorous laboratory conditions?*

In order to be a valid option in this analysis, a technology or operational measure must have a record that supports satisfactory performance results and allows for a reasonable assumption that similar performance would be achieved at BSPP.

Options that are experimental, too highly dependent on unique site-specific characteristics, or have limited supporting data are eliminated from further consideration.

2. *Is the option logistically feasible?*

The size and complexity of some options increases the possibility that they may encounter significant logistical obstacles that preclude their use at BSPP. Examples might include insufficient space for cooling towers or interference with waterborne navigation from intake screening technologies. Options are eliminated from further consideration if logistical obstacles are considered insurmountable.

3. *What factors might limit performance at BSPP and must be addressed prior to a final decision?*

⁹USEPA and industry organizations have accepted the general premise that impingement and entrainment rates are directly proportional to flow for the purposes of estimating performance for closed-cycle systems although other factors such as spawning/migratory periods and intake velocity also influence IM/E.

Option performance is not automatically transferrable from one facility to another. Site-specific obstacles might influence a logistically feasible option's performance and may require mitigation or redesign to ensure successful deployment. For example, modified Ristroph screens and a properly designed return system may significantly reduce impingement mortality, but the system's performance would be greatly enhanced by a lower through-screen velocity that would require expanding the intake's total area.

Options with limiting factors are not eliminated from the analysis. Limitations are discussed but quantified.

4. *Are there significant secondary costs/impacts that might require mitigation?*

In some cases options may cause their own environmental or performance impacts that require mitigation or consideration. The most prominent example of this is the expected energy penalty that would be incurred if BSPP retrofitted to a closed-cycle cooling system. An ongoing financial cost would be incurred from the reduced net generating capacity, which would have to be made up either on site or at other facilities. Depending on how the lost capacity is supplemented, air emissions may increase (on a per-kWh basis).

Options with secondary impacts are not eliminated from the analysis. Impacts are quantified to the degree possible.

5. *Is there another option that achieves the same or substantially similar performance but at a significantly lower cost?*

This step evaluates the cost-effectiveness of different feasible options only if performance is reasonably similar to another technology but at disproportionate cost. Cost-effectiveness compares technologies such as dry cooling and natural and mechanical draft wet cooling towers and eliminates dry cooling and natural draft wet cooling towers from consideration because the notably greater financial cost and additional impacts do not justify the marginal IM/E reductions they would achieve.

5.2 OPTION EVALUATION SUMMARY

Tetra Tech's evaluation of different technology-based options identified three feasible options (Ristroph screens, wet cooling towers, and intake velocity reductions) and one possible option (cylindrical wedgewire screens) that requires significant investigation to ascertain its feasibility, but it cannot be ruled out at this time. Cooling ponds may also be feasible when combined with additional measures such as a helper tower or spray ponds. A summary table of all technologies evaluated and the results of the screening process is available in Appendix A.

5.3 IMPINGEMENT AND ENTRAINMENT CONTROLS

5.3.1 BARRIER NETS

Fish barrier nets are constructed of wide-mesh fabric panels and configured to completely encircle the cooling water intake structure inlet from the bottom of the water column to the surface. The relatively large slot sizes (1/2 inch) combined with the larger overall area of the net reduce impingement mortality by preventing physical contact with the main intake structure and by maintaining a low through-net

velocity (0.2 fps or less). Other Great Lakes facilities have successfully deployed barrier nets, including the JR Whiting facility located approximately 7 miles north of BSPP in Erie, MI. Impingement rates have dropped by more than 90 percent compared to rates before the net was deployed (USEPA 2004).

Barrier nets are most effective when they are placed in relatively calm water and not subject to high debris loads, tides, or currents that might compromise the net's integrity. A large, unobstructed area is required in the source water in order to accommodate barrier net's relatively large size.

At an average through-net flow of 25 gpm/ft², a barrier net at BSPP would be approximately 20,500 ft² in total area. The intake canal's location and other local uses limit possible configurations. A net installed at the mouth of the canal (where the canal joins the Maumee River) would restrict access to the marina (see Figure 1). Installation in the canal downstream from the marina would require a wedge-shaped configuration with an approximate linear length of 2,500 feet (assuming a canal depth of 8 feet).

The facility notes that high debris loads are sometimes present during spring runoff and after storm events, which lead to large debris accumulating in front of the intake screens (see Figure 6 [date unknown]). Debris of this size and volume are likely to cause significant damage to any net installed in the intake canal.



Figure 6. Buildup of Large Debris at CWIS

Analysis Result: Infeasible. Lack of space and potential damage from large debris preclude barrier net installation at BSPP.

5.3.2 AQUATIC FILTRATION BARRIERS

Aquatic filtration barriers (AFBs) are fabric panels constructed of small-pore (< 20 microns) materials and deployed in front of an intake structure much like a barrier net. The small openings in the fabric allow water to pass through while screening out most organisms, including those that are susceptible to entrainment. Deployment considerations are similar to barrier nets, although a significantly larger area is required. At average flow of 10 gpm/ft², and AFB at BSPP would be approximately 51,000 ft² in total area and extend more than a mile in length (assuming an average depth of 8 feet).

Any limitations that preclude installing a barrier net are only more pronounced for an AFB.

Analysis Result: Infeasible. Lack of space and potential damage from large debris preclude AFB installation at BSPP.

5.3.3 CYLINDRICAL WEDGEWIRE SCREENS (FINE OR COARSE MESH)

Cylindrical wedgewire screens reduce impingement by maintaining a low through-screen velocity (0.5 fps), which allows larger organisms to avoid the intake current. Entrainment is reduced when the screen mesh slot size is small enough to prevent eggs and larvae from passing through.¹⁰ Hydrodynamics resulting from the cylindrical shape of the screen aids in the removal of small “entrainable” organisms that become caught against the screen. The low through-screen velocity is quickly dissipated and allows organisms to escape the system’s influence provided there is a sufficient ambient current present to carry freed objects away from the screen. Organisms that are impinged against the screens are released through the action of a periodic airburst cleaning system and carried away by the ambient current.

Wedgewire screen performance is driven by physical parameters describing the location where the screens are installed, while biological characteristics are less critical. As a passive technology, wedgewire screens rely on ambient currents to sweep any impinged organisms off the screen face and cannot be placed in slack or stagnant waters. The water depth must be sufficient to overtop the screens by several feet at all times. The Western Erie Basin is relatively shallow across its entire expanse (see Figure 7). Maumee Bay is even shallower with depths ranging from 3 to 15 feet in many areas. The Maumee River Toledo Shipping Channel is routinely dredged to 23 feet, although placement in the channel would likely interfere with ship navigation.

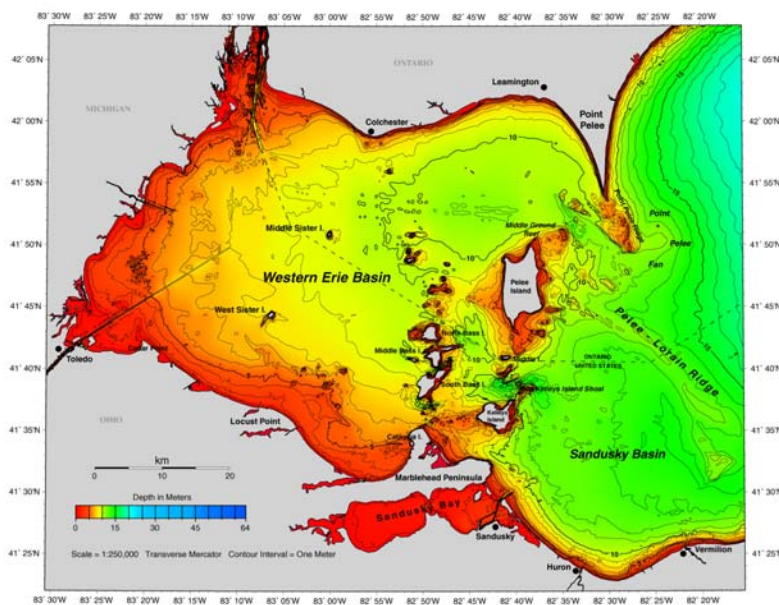


Figure 7. Western Erie Basin Bathymetry

¹⁰ Screens with slot sizes ranging from 1 to 2 mm are generally considered to be “fine mesh,” although the effective size in each installation must be determined based on the target species in the affected water body.

Placement in the discharge cove east of the facility is not feasible given the shallow depths (2-4 feet), the probable lack of sufficient ambient current, and likelihood that warm water from the discharge would be recirculated through the facility and impact turbine performance and exacerbate any thermal discharge effects. It is conceivable to place intake screens in the discharge cove if the discharge is relocated, but relocation is not considered feasible as discussed in section 5.4.1.

It is conceivable that a location northeast of the CDF could be dredged and maintained to a sufficient depth for the required number of wedgewire screens (see Figure 8). Ambient currents are more likely in this area but must be verified before proceeding. This location would avoid conflicts with shipping traffic in the main channel but may interfere with commercial and recreational boaters who frequent the area to access popular sport fisheries. Access to the CDF and use of any particular area is unknown at this time. Finally, the distance from the intake screens, at approximately 8,000 feet, would increase initial capital costs to account for the long pipe runs and additional pumping capacity required to deliver water to the facility.



Figure 8. Potential WW Screen Location

Estimated costs for different wedgewire screen installations at BSPP are shown in Table 3. Differences are dependent on the number of screens required and the total intake flow (512,000 gpm). Larger screens can be installed at less cost but may not be practical if water depths are limited. Screen installation and piping costs are based on estimates Tetra Tech developed for similar installations at two power plants in California, adjusted to reflect local considerations (Tetra Tech 2008). Cost estimates are based on limited information describing the bathymetry, uses, and ambient currents in the area.

Table 3. Estimated Wedgewire Screen Installation Cost

# Screens	Screen size (OD x L)	Screens ^[a] (\$)	Piping ^[b] (\$)	Contingency ^[c] (\$)	Total (\$)
8	84" x 300"	3,788,800	9,600,000	2,677,760	16,066,560
12-14	72" x 262"	4,300,800	9,600,000	2,780,160	16,680,960
19-22	60" x 220"	4,582,400	9,600,000	2,836,480	17,018,880

[a] Screen cost includes installation at the final location and airburst cleaning system for 1.2 mm slot screens. Screen cost decreases with larger slot sizes.

[b] Pipe costs are based on 8,000 feet of 120-inch concrete cylinder pipe with an installed cost estimate of \$1,200 per linear foot.

[c] Contingency cost is calculated at 20 percent of all capital costs and covers unforeseen expenditures and additional pump capacity.

Analysis Result: Possible, although additional information is necessary to make a final estimate. Physical attributes of Maumee Bay limit possible siting areas. Unclear if sufficient ambient currents are present

Distance from facility represents significant capital cost increase compared with an installation closer to the existing intake.

Estimated IM/E Reduction: Impingement: 90-95%; Entrainment: 85-90%. Performance is based on successful deployments in estuaries (Eddystone) and Lake Michigan (JH Campbell) as well as laboratory analyses that document performance under optimal conditions (USEPA 2004).

5.3.4 RISTROPH SCREENS WITH FISH RETURN

Section 4.1.3 discusses the existing CWIS configuration and the reasons why it does not conform to an acceptable design standard that seeks to minimize impingement mortality. Some fish do survive capture and removal from the traveling screens, but this is a secondary effect of the system's original intent: debris removal. This is evidenced by lack of fish collection buckets and a separate fish return trough.

It is feasible, however, to modify the existing coarse mesh traveling screens with elements designed specifically for fish protection. These modifications include low turbulence fish buckets attached to the screen baskets, upgrading screen motors to accommodate continuous screen rotation, a low pressure fish removal spray, a separate fish return trough, and a relocated return location.

Of these items, constructing a new fish return trough and return location presents the most significant cost component and logistical challenge. The existing return is a debris trough that subjects fish to numerous potential injuries. It is not clear to what extent the existing trough could be upgraded to acceptably mitigate these concerns; the more likely approach would be to construct a new, separate fish trough.

The exact point at which fish are returned to the discharge canal is not clear, but they are likely subjected to temperature shock that presents an additional stress and may compromise survival rates. Ideally, the return would be located in an area outside the influence of either the intake or thermal plume, but relocating the return to a point offshore in the discharge cove may avoid contact with the highest effluent temperatures and may be sufficient.

The estimated capital cost for the upgrades described above is shown in Table 4. This cost is calculated using cost models developed by USEPA during the Phase I rulemaking effort and updated to \$2008 (USEPA 2001).

Table 4. Estimated Ristroph Screen and Fish Return System Capital Cost

Element	Capital Cost (\$)
Upgrade traveling screens with fish protection technologies; new fish return system	13,037,000

Analysis Result: Feasible as IM control only. Requires evaluation of different return locations

Estimated IM/E Reduction: Impingement: 80-95%; Entrainment: 0%. Performance is based on numerous estuary and freshwater installations (USEPA 2004).

Additional Considerations: The design through-screen velocity is reported at 2.58 fps, although it is unclear if changes to the canal (sedimentation) or screen fouling have altered this value. The 1982 ASCE Guidance notes that reducing through screen velocity should be a primary consideration when designing this type of system. The Phase I rule recognizes the relationship between intake velocity and impingement

by setting a 0.5 fps through screen velocity as an impingement compliance option. Reducing intake velocity to this level would require substantially expanding the existing intake structure by installing new intake bays and screens, but even a 50 percent reduction would contribute to higher survival rates and less impingement overall.

The capital costs for an intake expansion cannot be quantified without additional information describing land availability in the area around the CWIS and a better understanding of any underground obstacles that may be present and the existing pipe/pump configurations.

5.3.5 FINE MESH TRAVELING SCREENS WITH FISH RETURNS

The basic feasibility considerations for fine mesh traveling screens are the same as for coarse mesh Ristroph screens (see section 5.3.4), but are more acutely limited by the screen mesh size and the need to accommodate entrainable organisms (eggs and larvae) in addition to larger juveniles and adults. Entrainment reductions can range as high as 90 percent or more when fine-mesh panels are used in conjunction with a return system. What is less understood, however, is the viability of eggs and larvae that are impinged against a fine-mesh screen and returned to the water body. Few studies have been conducted that evaluate viability, primarily because few facilities that have installed fine-mesh traveling screens.¹¹ Screened organisms, although they have been prevented from being entrained through a cooling water system, may suffer serious injury or mortality, which effectively results in the same adverse impact as if they had been entrained in the first place.

At BSPP this concern is further complicated by lack of acceptable return locations. Returning captured organisms to the Maumee River estuary, at a minimum distance of 4,500 feet, is likely to result in a significant portion being re-entrained, especially during periods when the intake volume exceeds the Maumee River flow and water is drawn from the bay as well. The current return location to the discharge cove subjects eggs and larvae to temperature shock and relocates them to an area of Maumee Bay that may not share the same characteristics as the intake location. Other locations, possibly northeast of the CDF, are not considered due to the long return distances.

Screen slot sizes typically need to be within the range of 1–2 mm, or perhaps smaller, in order to be effective as an entrainment reduction measure, although the size used at BSPP would be dependent on the target species. With a smaller open area per square foot than standard coarse mesh screens, fine-mesh screens require a larger overall intake structure in order to maintain desirable intake velocities. Simply replacing the existing panels with fine mesh would increase the through-screen velocity by 50 percent or more, resulting in fewer large organisms being able to escape and higher mortality rates for any organism captured against the screen.

Analysis Result: Infeasible. Egg and larvae survival rates are poorly documented. BSPP lacks an acceptable return location that could reasonably ensure survival.

5.3.6 VARIABLE SPEED DRIVES

A variable frequency drive (VFD) (similar to variable speed pumps [VSPs]) allows a facility to lower the cooling water withdrawal rate by reducing the electrical load to the pump motor. The pump speed can be tailored to suit the cooling water demands at a certain time or under certain conditions. VFDs can throttle

¹¹ Big Bend Power Plant in Tampa Bay conducted a viability analysis that showed that latent survival rates for eggs and larvae impinged against the fine-mesh screen and returned to the water were comparable to the control sample (EPRI 1999).

a pump's flow rate more precisely according to operating conditions, but must operate at a minimum flow rate in order to maintain sufficient head and prevent damage to the pump from cavitation.

Actual flow reductions with a VFD vary throughout the year depending on seasonal conditions and facility operations. At their maximum efficiency, VFDs enable a facility to withdraw the same volume of water as conventional circulating water pumps, thereby negating any potential benefit. Baseload units would not be ideal candidates for this technology, since they operate in the upper range of their load capacity for significant portions of the year. Units that are designated for peak or intermittent dispatch are more likely to accrue benefits from this method of flow reduction. In these situations, the use of VFDs must be evaluated against the operational profile of that facility and any seasonal variations in the makeup or abundance of affected species in the water body.

Analysis Result: Ineffective. BSPP's status as a baseload or load-following facility results in capacity utilization rates averaging 83% (see Figure 2). Operating profile indicates pumps would run at or near maximum capacity most of the year.

5.3.7 INTAKE VELOCITY REDUCTION

See "Additional Considerations" discussion for Ristroph screens (section 5.3.4).

Analysis Result: Feasible. The scope of any expansion is likely to be large in order to realize any significant benefit and may require the doubling or tripling of the existing intake, depending on the target through-screen velocity. Capital costs are not estimated because data describing the existing intake is insufficient but would be approximated using the same cost model for Ristroph screen modifications

5.4 THERMAL DISCHARGE CONTROLS

5.4.1 DISCHARGE RELOCATION

In some cases the discharge may be relocated to less sensitive areas with a greater capacity to dissipate waste heat quickly—essentially a larger heat sink. Typically, this involves constructing a discharge conduit that extends far off shore and terminates in deeper, colder waters. Maumee Bay is relatively shallow compared to other sections of Lake Erie and the Western Erie Basin (see Figure 7), with an average depth of approximately 5 feet outside of the 23-foot deep Maumee River Toledo Shipping Channel. Deeper waters begin at the 16.5 foot contour that is approximately 3 miles northeast of Cedar Point, nearly 8 miles northeast of BSPP.

The shallow depths of the rest Maumee Bay and size of BSPP discharge indicate that any thermal impacts would not be mitigated by discharging to other locations. Rather, the impacts would likely be relocated along with the discharge.

5.4.2 FLOW REVERSAL

Suggestions have been made that BSPP might be able to reduce its thermal impact, and possibly reduce some IM/E impacts, by exchanging the existing intake and discharge locations with one another. Reversing the flow configuration is not a complicated effort, especially at a facility like BSPP where intake and source waters locations are easily accessible. By making the source water the receiving water, and vice versa, it is conceivable that some technology-based options considered infeasible under the existing configuration might become feasible under a reversed flow regimen.

The only apparent advantage this option offers is the larger source water area that might accommodate technologies such as barrier nets and AFBs whereas the existing configuration does not support their deployment. Limitations would remain for fine mesh traveling screens, cylindrical wedgewire screens, and variable speed pumps.

In a scenario where flow is reversed and a barrier net or AFB is installed, the facility remains a once-through cooled system discharging up to 745 mgd of heated water to a receiving water (Maumee River) with a volume that is 50 percent less than the current discharge cove, with much of that volume contained in the shipping channel. The new discharge thermal plume would be more confined than in the existing discharge cove while still discharging the same amount of heat. This might result in more pronounced isotherms across the mouth of the Maumee River. Steeper temperature gradients in this area might create a blocking effect for migrating fish that spawn in the river and estuary.

BSPP's turbine and condenser performance are designed around 60° F cooling water. While temperatures naturally fluctuate throughout the year, the current discharge cove likely has higher ambient temperatures than the Maumee River, which is continually fed by cooler water from a large drainage basin. Reversing the cooling water flow would likely create an energy penalty similar one that would result from converting to closed-cycle cooling.

Lastly, IM/E impacts can not be immediately quantified because the new source water has likely been altered due to the existing thermal discharge. It is difficult to characterize the hypothetical indigenous population or aquatic community if the area were allowed to return to its unaffected condition, nor is it possible to predict how long a reclamation of this sort would take.

Reversing the intake flow offers no identifiable benefits over other options and might unnecessarily exacerbate or create other impacts.

5.4.3 MULTIPOINT DIFFUSERS

A multipoint diffuser consists of a submerged conduit extending into the receiving water with a large number of ports or jets extending from the main pipe at various angles. Heated water is discharged through these ports at high velocity, creating turbulence and inducing rapid mixing with the surrounding water. In shallow waters, such as Maumee Bay, thermal discharges through multipoint diffusers often result in complete mixing through the water column in the area around the diffuser. Diffusers do not reduce the net plant heat rejection rate since the "volume" of heat remains the same. Rather, diffusers encourage a more rapid dissipation of heat into the heat sink, which can have the effect of reducing the areal extent of the thermal plume. At BSPP, for example, a diffuser placed into the center of the discharge cove might reduce the plume's effects on the shoreline areas to the north and south.

Any estimate of a diffuser's effect on the thermal plume can only be calculated through advanced modeling that accounts for all necessary variables such as water volume, temperature, bathymetry, other sources, and meteorological conditions.

5.4.4 HELPER TOWERS

Helper towers are an evaporative cooling system that is designed to disperse waste heat from the effluent prior to discharge without recycling the water back for use in the cooling system. The design, structure, and function of these towers are fundamentally no different from wet cooling towers that would be part of a closed-cycle recirculating system, except that the overall tower size would be smaller because the same

cooling capacity is not necessary. The basic cost elements are also similar and are largely a function of the desired temperature reduction and the corresponding tower size.

Helper towers would reduce the thermal plume from BSPP and could be scaled to be larger or smaller depending on the target reduction. This type of system does not address IM/E impacts because the cooling water system essentially continues to function using once-through cooling water in the same volume as before.

5.5 COMBINED IMPINGEMENT/ENTRAINMENT AND THERMAL CONTROLS

5.5.1 SEASONAL OPERATION

Considerations for seasonal operation are similar to those for variable speed drives (see section 5.3.6).

Analysis Result: Ineffective. BSPP's status as a baseload or load-following facility results in capacity utilization rates averaging 83% (see Figure 2). Operating profile indicates water withdrawals occur throughout the year.

5.5.2 SURFACE COOLING PONDS

Cooling ponds function in a manner similar to evaporative cooling systems (see section 5.5.4) in that they dissipate heat to the atmosphere through evaporation, but at a less efficient rate. Cooling ponds are less expensive than mechanical or natural draft towers but require large amounts of stable land that can be excavated and converted to water storage.

Pond systems are infrequently used to provide large cooling water volumes because of the large land areas that they occupy. A rough approximation of the total required pond area can be made by assuming the pond's thermal capacity is 2 MWt per acre (Jirka et al. 1978). Assuming BSPP's efficiency is 35 percent, and allowing for a 10 to 15 percent stack loss, the facility would discharge approximately 1000 MWt through its surface condenser at maximum capacity and require a cooling pond system roughly 500 acres in total size.¹²

This is a low confidence estimate that does not account for local conditions that may place limits on individual pond sizes or depths. Furthermore, auxiliary systems like aerators and spray nozzles can increase the pond's thermal capacity and reduce the necessary size. A hybrid system may also be employed that increases the inflow of colder makeup water to the ponds or uses a helper tower to more efficiently reject heat.

Costs for a surface cooling pond system at BSPP were not developed for this report because of the lack of sufficient information describing several factors, such as land availability and soil conditions, as well as the numerous potential configurations that might be used at BSPP. Costs for this technology are driven by land acquisition (if necessary), excavation, additional engineering to ensure pond integrity, and piping runs that may extend several thousand feet in total. Incorporating a helper tower would increase initial capital costs depending on how many tower cells were installed.

¹² Condenser specifications provided by BSPP report a steam duty of 614,500,000 BTU/hr, which translates to 180 MWt per unit, or 720 MWt for the entire facility. At 33 percent efficiency, this would correspond to a stack loss of 28 percent, which is outside the normal range for a coal-fired facility.

Analysis Result: Feasible (partially). The BSPP parcel has large undeveloped sections that could be used for cooling ponds, but does not have access to 500 acres. Some form of a hybrid system as described above would have to be employed to achieve the desired result.

Estimated IM/E Reduction: Impingement: 80-95%; Entrainment: 80-95%.

Additional Considerations: A cooling pond system would exact an energy penalty on the facility because of higher condensing temperatures. The penalty's value would be calculated in the same manner as for evaporative cooling towers (see section 5.5.4).

5.5.3 DRY COOLING

Dry cooling systems are so named because the removal of heat from the steam cycle is accomplished through sensible heat transfer (convection and radiation) rather than through latent heat transfer (evaporation) that is characteristic of wet cooling systems. By relying solely on sensible heat transfer, dry cooling systems eliminate the need for a continuous supply of cooling water to the condenser, thus reducing many of the environmental concerns associated with once-through or wet cooling systems—such as adverse impact on aquatic ecosystems, consumptive use of water resources, and plume or drift emissions.

Dry cooling systems can be broadly categorized as either direct or indirect. Direct systems, also known as air-cooled condensers (ACC), feed the turbine exhaust steam through sealed ducts directly to a fin tube array where air is drawn across and heat is rejected to the surrounding atmosphere, much like a radiator in a car. Indirect dry cooled systems incorporate a surface condenser as an intermediate step between the turbine exhaust and cooling tower. Heat is transferred from the turbine exhaust to the circulating water in the condenser and dispersed to the atmosphere through a fin tube array in a tower, much like the operation of a wet cooling tower. The difference is that, like the ACC, the condenser circulating water is not exposed to the outside air and instead runs in a continuous loop from the turbine to the tower.

Indirect dry cooling is the most likely option for retrofitting a once-through cooled system with dry cooling since the surface condenser is already present and can be more readily modified to a closed-loop heat exchanger. This configuration, however, is the principal disadvantage of an indirect dry cooling system that uses a two-step process to reject heat. The added thermal resistance from the surface condenser reduces the overall heat transfer efficiency of the system. In order to achieve a comparable level of cooling, an indirect system will require a much larger cooling surface area, at increased capital and operational cost, than would be expected for a similar ACC system.

Dry cooling systems do not reject heat as efficiently as evaporative cooling towers, especially in a retrofit scenario. This reduced efficiency translates to higher condensing temperatures and increased turbine backpressure, which reduces the turbine's overall efficiency. Comparatively, a dry system retrofit will always have a higher energy penalty than an evaporative cooling retrofit for the same facility, and at a much higher cost.

Retrofitting to dry cooling at BSPP is technically feasible but impractical when weighed against the higher initial capital cost and higher energy penalty compared to evaporative cooling, especially considering the IM/E reductions are substantially similar (>99% for dry cooling; 97-99% for evaporative cooling).

Analysis Result: Feasible, but impractical. Dry cooling's marginally better IM/E reduction is more than offset by higher capital costs and greater efficiency loss compared to evaporative cooling.

5.5.4 EVAPORATIVE COOLING

Evaporative cooling systems, more often referred to as “wet cooling towers”, function by transferring waste heat to the surrounding air through the evaporation of water, thus enabling the reuse of a smaller volume of water several times to achieve the desired cooling effect. Compared to a once-through cooling system, wet cooling towers may reduce the volume of water withdrawn from a particular source by as much as 98 percent depending on various site-specific characteristics and design specifications.

Wet cooling towers are classified into two broad categories depending on the mechanism used to induce draft—the flow of cooler, drier air through the tower. Natural draft towers rely on ambient atmospheric conditions while mechanical draft towers use fans to create the necessary air flow.

Natural draft towers (the classic hyperbolic cooling tower) rely on the chimney effect that results from the temperature difference between warm, moist air exiting the top of the tower and cooler outside air drawn in near ground level. These towers must be fairly tall to achieve the desired temperature differential, typically reaching heights of 500 feet or more, and can result in a significant visual impact for any nearby communities.

Mechanical draft cooling towers rely on motorized fans to draw air through the tower structure and into contact with the water. Without the same need for height as natural draft towers, the mechanical draft design presents a much lower visual profile against the surrounding area with typical heights ranging from 30 to 75 feet. The overall area devoted to cooling towers, however, may be comparable to natural draft units since one mechanical draft unit, or “cell”, has a smaller cooling capacity. Mechanical systems are arranged into multi-cell units, which are collectively referred to as the cooling tower, and can be placed in a single row (inline) or back to back. Although often more feasible, and in some cases more practical, than natural draft towers, mechanical systems place an added draw on the facility’s net generating output in order to operate the fans that induce the draft.

Natural draft cooling towers have higher initial capital costs due to their scale and complexity and are more economically competitive with mechanical draft towers when selected for high volume, baseload facilities with utilization rates greater than 90%. Operating costs are lower for natural draft towers over the long term because they do not draw electricity to power fans; mechanical draft towers can consume as much as 1 percent of a facility’s generating capacity to operate the fans.

The principal advantages of mechanical draft cooling towers are their significantly lower cost compared to natural draft towers and the greater number of design and configuration options based on a simpler, multi-cell configuration. The capital cost for a natural draft tower can be 2 to 4 times greater than a comparable mechanical draft tower while not adding any significant benefit in terms of impingement or entrainment reductions. Both systems would achieve similar performance with respect to IM/E and thermal discharges, but mechanical draft towers are significantly less expensive.

This report does not evaluate natural draft towers because, on a cost-effectiveness basis, they offer no notable advantages over mechanical draft towers that would justify their higher costs. Wet cooling towers are evaluated in detail as a retrofit option for BSPP in the following section.

6.0 BSPP EVAPORATIVE COOLING TOWER RETROFIT

This section evaluates the overall costs and considerations that would be incurred if BSPP retrofitted its existing once-through cooling system with a mechanical draft, closed-cycle wet cooling tower system. Existing system information provided by FirstEnergy is supplemented with assumptions and models developed for other analyses to develop a conceptual model of a wet cooling tower configuration. This configuration is then used to calculate initial capital costs and long term costs, including the energy penalty, and annual costs.

6.1 DESIGN CONDITIONS

The wet cooling tower conceptual design selected for BSPP is based on the assumption that the condenser flow rate and thermal load to each will remain unchanged from the current system. Condenser modifications can reduce the thermal efficiency penalty but are expensive and can require a facility to shut down for extended periods. Parameters used in the development of the cooling tower design are summarized in Table 5 and Table 6.

Table 5. Condenser and Turbine Design Conditions

	Units 1-4 ^[a]
Thermal load (MMBTU/hr)	614.5
Surface area (ft ²)	85,000
Condenser flow rate (gpm)	128,000
Tube material	CuNi 90-10
Heat transfer coefficient (U _d)	511
Cleanliness factor	0.85
Inlet temperature (°F)	60
Temperature rise (°F)	9.61
Steam condensate temperature (°F)	78.4
Turbine exhaust pressure (in. HgA)	0.98
Turbine Inlet Temp (°F) ^[b]	850
Turbine Inlet Pressure (psia) ^[b]	1,000
Full load heat rate (BTU/kWh) ^[b]	9,800

[a] Condenser information provided by FirstEnergy did not specify which unit. Tetra Tech assumed all units share same characteristics.

[b] Facility specific data not available. Values represent averages for subcritical coal facilities.

Table 6. Surface Water and Ambient Wet Bulb Temperatures

	Surface (°F)	Ambient Wet Bulb (°F)
January	40.1	24.5
February	39.0	26.9
March	43.0	35.4
April	50.8	47.4
May	60.4	61.8
June	70.0	73.5
July	79.7	77.6
August	73.8	76.3
September	68.8	65.8
October	57.7	51.6
November	48.4	39.6
December	40.7	29.3

6.1.1 CONCEPTUAL DESIGN

Based on the design conditions discussed above, a three-tower conceptual design was developed for BSPP. The design reflects the similar dispatch profiles for units 2 and 3 by combining their cooling towers into a single complex, which allows for small cost savings.

Table 7. Wet Cooling Tower Conceptual Design

	Tower 1 Unit 1	Tower 2 Units 2 & 3	Tower 3 Unit 4
Thermal load (MMBTU/hr)	614.5	1,229	614.5
Circulating flow (gpm)	128,000	256,000	128,000
# Cells	11	22	11
Tower type	Mechanical Draft	Mechanical Draft	Mechanical Draft
Flow orientation	Counterflow	Counterflow	Counterflow
Fill type	Modular splash	Modular splash	Modular splash
Arrangement	Inline	Inline	Inline
Primary tower material	FRP	FRP	FRP
Tower dimensions (L x W x H) (ft)	506 x 55 x 50	1012 x 55 x 50	506 x 55 x 50

6.1.2 COOLING TOWER LOCATION

BSPP is located on a 329 acre parcel north of City of Oregon WWTP and east of the BP refinery. Toledo Edison owns the switchyard area immediately north and east of the generating units. The northernmost section of the parcel is shown in Figure 9.



Figure 9. Bay Shore Power Plant Location

The most practical location for the three cooling towers would be south of the current coal pile storage area and north of the City of Oregon WWTP. Sufficient area exists to place three inline mechanical draft cooling towers without significant disruption to facility operations or local activities. These towers would be located at an approximate distance of 2,500 feet from the existing CWIS. An approximate layout of the three towers and supply/return piping is shown in Figure 10.

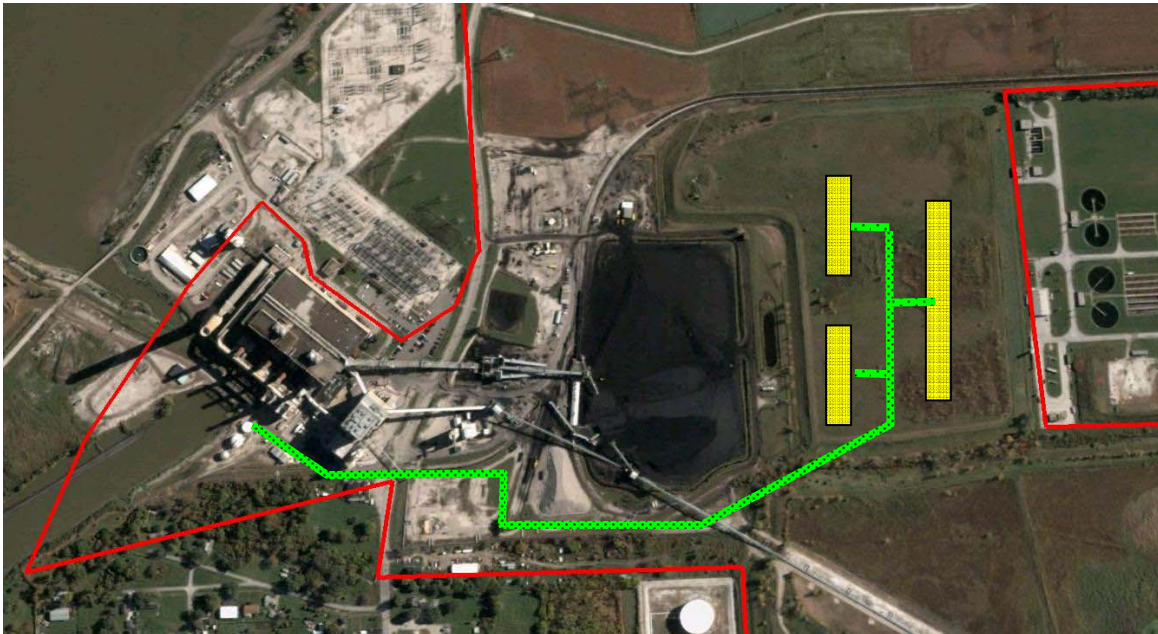


Figure 10. Conceptual Wet Cooling Tower Layout

6.2 COST ESTIMATE

6.2.1 INITIAL CAPITAL

Capital cost estimates may be developed using one of two methods. The facility-specific approach (“bottom-up”) calculates the total cost based on as much specific information as is readily available. The model approach (“top down”) aggregates different cost evaluations that have been conducted for many different facilities and attempts to develop a correlation that can be applied to most facilities based on a shared characteristic.

USEPA and EPRI have used the model based approach to estimate initial capital costs for cooling tower retrofits. The EPRI cost model divides facilities into three separate categories based on the relative difficulty expected for the project (see Figure 11) (EPRI 2007). BSPP has a large section of available land and no obvious mitigating circumstances that would indicate the retrofit capital cost estimate should be based on a “difficult” facility model. Based on the information available for this analysis, Tetra Tech assumed the facility would fall somewhere between the easy and average models and selected a capital cost multiplier of \$190/gpm, or \$97,000,000.

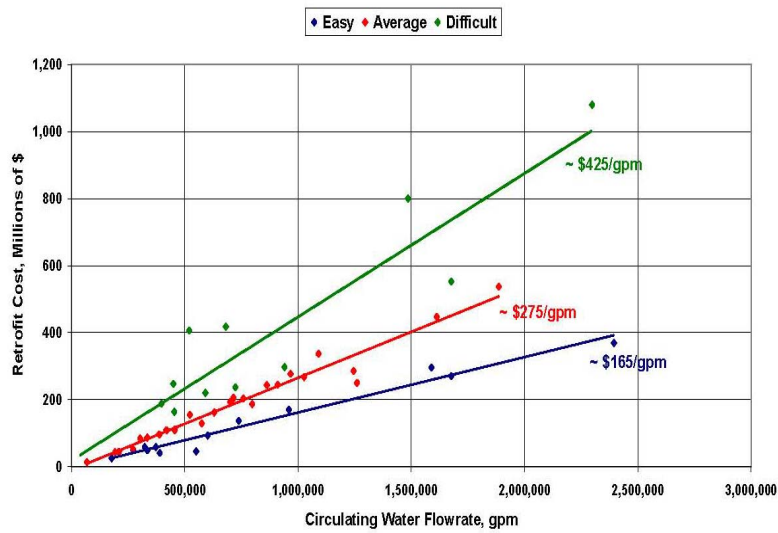


Figure 11. Retrofit Cost Models

6.2.2 ENERGY PENALTY COMPONENTS

The energy penalty is divided into two components: increased parasitic use resulting from the additional electrical demand of cooling tower fans and pumps; and the decrease in thermal efficiency resulting from elevated turbine backpressure values. Figure 12 shows the monthly efficiency loss calculated for BSPP.¹³

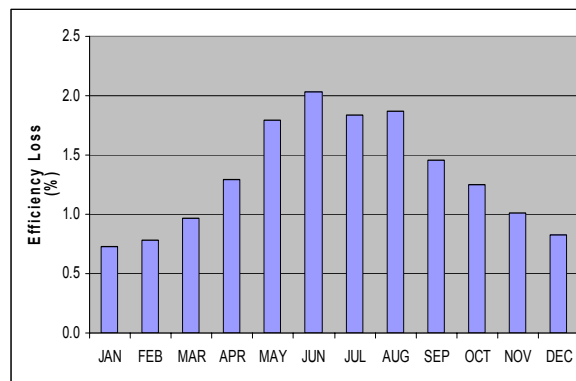


Figure 12. Average Monthly Energy Penalty

¹³ Notable difference between July and June/August values in Figure 12 is likely the result of insufficient or inaccurate climate or water temperature data. More facility-specific information will be necessary to properly size each cooling tower and calculate the precise loss in efficiency.

Table 8 and Table 9 show the estimated parasitic use for fans and pumps.

Table 8. Fan Parasitic Use

	Tower 1	Tower 2	Tower 3	BSPP Total
Units served	Unit 1	Units 2 & 3	Unit 4	--
Generating capacity (MW)	136	280	215	631
# Fans (one per cell)	11	22	11	44
Motor power per fan (hp)	211	211	211	--
Total motor power (hp)	2,316	4,632	2,316	9,263
MW total	1.73	3.45	1.73	6.91
Fan Parasitic Use (% of Capacity)	1.27%	1.23%	0.80%	1.09%

Table 9. Pump Parasitic Use

	Tower 1	Tower 2	Tower 3	BSPP Total
Units served	Unit 1	Units 2 & 3	Unit 4	--
Generating capacity (MW)	136	280	215	631
Existing pump configuration (hp)	816	1,632	816	3,264
New pump Configuration (hp)	3,055	6,009	3,055	12,118
Difference (hp)	2,239	4,377	2,239	8,854
Difference (MW)	1.7	3.3	1.7	6.6
Net Pump Parasitic Use (% of Capacity)	1.23%	1.17%	0.78%	1.05%

6.2.3 ENERGY PENALTY COST

Monetizing the energy penalty at BSPP requires some assumption as to how the facility will choose to alter its operations to compensate for the loss in marketable generating capacity, if at all. One option would be to accept the reduced amount of revenue-generating electricity available for sale and absorb the economic loss ("Option 1"). A second option would be to increase the firing rate to the turbine (i.e., consume more fuel) and produce the same amount of revenue-generating electricity as had been obtained with the once-through cooling system ("Option 2"). The degree to which a facility is able, or prefers, to operate at a higher firing rate, however, produces the more likely scenario—some combination of the two.

Ultimately, the decision to alter operations to address efficiency changes is driven by considerations unknown to this study (e.g., corporate strategy, contractual obligations, and turbine pressure tolerances). For simplicity, the monetized value of the energy penalty assumes the facility will increase the firing rate to the turbine to compensate for reduced efficiency and generate the amount of electricity equivalent to the once-through system. In general, the increased fuel option is less costly, in nominal dollars, than the production loss option, but may not reflect long-term costs, such as increased maintenance, that may result from the continued high firing of the turbine.

Table 10 summarizes the cumulative energy penalty cost assuming BSPP would not increase the thermal input to the boiler and instead absorb the loss directly (Option 1). Using this approach the energy penalty cost is \$10 million. By comparison, the energy penalty cost using Option 2 would be \$1.7 million.¹⁴

Table 10. Cumulative Energy Penalty Cost—Option 1

Month	Wholesale Price (\$/MWh) ^[a]	Net Gen (MWh)	Energy Penalty (%)				MWh Equivalent	Net Cost (\$)
			Efficiency Loss	Fan	Pump	Total		
JAN	45.17	376,950	0.73	1.09	1.05	2.87	10,824	488,898
FEB	78.00	367,468	0.78	1.09	1.05	2.92	10,736	837,387
MAR	67.67	415,878	0.97	1.09	1.05	3.11	12,923	874,452
APR	75.13	397,301	1.30	1.09	1.05	3.44	13,652	1,025,631
MAY	62.17	395,410	1.79	1.09	1.05	3.94	15,561	967,361
JUN	54.00	378,706	2.03	1.09	1.05	4.18	15,814	853,978
JUL	90.93	386,543	1.84	1.09	1.05	3.99	15,407	1,400,914
AUG	64.00	402,201	1.87	1.09	1.05	4.01	16,113	1,031,257
SEP	55.00	362,490	1.45	1.09	1.05	3.60	13,032	716,752
OCT	49.25	372,960	1.25	1.09	1.05	3.39	12,638	622,401
NOV	48.25	364,708	1.02	1.09	1.05	3.16	11,514	555,552
DEC	55.25	400,325	0.83	1.09	1.05	2.97	11,877	656,228
BSPP Total								10,030,811

[a] Based on 2008 weighted wholesale electricity prices reported at the Cinergy trading hub.

6.2.4 NET PRESENT VALUE

The net present value (NPV) reflects the cumulative cost of all yearly expenses over the projects lifespan (20 years). These expenses are discounted according to the year in which they were incurred and the selected discount rate. Facility-specific financial data were not available for FirstEnergy; therefore, the appropriate discount rate cannot be determined. The discount rate used in this study (7 percent) is based on federal government guidelines for developing economic analyses of proposed regulations and is a conservative estimate of the average pre-tax rate of return for private investment (OMB 2007). USEPA used the same rate in developing its cost analysis for the Phase II rule (USEPA 2002). Table 11 shows the 20-year NPV calculation for a wet cooling tower retrofit at BSPP using the production loss option described above (Option 1). The NPV using the increased fuel option (Option 2) is \$153 million.

¹⁴ Fuel costs based on the 2008 average monthly delivery price of coal for independent power producers expressed as \$/MMBTU (US EIA 2008). Unit 1 uses petroleum coke cost as its primary fuel but costs were not publicly available. Average coal prices were used instead.

Table 11. Net Present Value Calculation—Option 1

Project Year	Capital / Startup (\$)	O & M (\$)	Energy Penalty (\$)	Total (\$)	Annual Discount Factor	Present Value (\$)
0	97,000,000	--	--	97,000,000	1	97,000,000
1	--	2,048,000	10,020,363	12,068,363	0.9346	11,279,092
2	--	2,088,960	10,604,551	12,693,511	0.8734	11,086,512
3	--	2,130,739	11,222,796	13,353,535	0.8163	10,900,491
4	--	2,173,354	11,877,085	14,050,439	0.7629	10,719,080
5	--	2,216,821	12,569,519	14,786,340	0.7130	10,542,660
6	--	2,261,157	13,302,322	15,563,479	0.6663	10,369,946
7	--	2,306,381	14,077,847	16,384,228	0.6227	10,202,459
8	--	2,352,508	14,898,586	17,251,094	0.5820	10,040,137
9	--	2,399,558	15,767,173	18,166,732	0.5439	9,880,885
10	--	2,447,550	16,686,399	19,133,949	0.5083	9,725,786
11	--	2,496,501	17,659,216	20,155,717	0.4751	9,575,981
12	--	3,028,992	18,688,749	21,717,741	0.4440	9,642,677
13	--	3,089,572	19,778,303	22,867,875	0.4150	9,490,168
14	--	3,151,363	20,931,378	24,082,741	0.3878	9,339,287
15	--	3,214,391	22,151,677	25,366,068	0.3624	9,192,663
16	--	3,278,678	23,443,120	26,721,798	0.3387	9,050,673
17	--	3,344,252	24,809,854	28,154,106	0.3166	8,913,590
18	--	3,411,137	26,256,268	29,667,405	0.2959	8,778,585
19	--	3,479,360	27,787,009	31,266,369	0.2765	8,645,151
20	--	3,548,947	29,406,991	32,955,938	0.2584	8,515,814
Total						292,891,638

6.2.5 ANNUALIZED COST

An annualized cost estimates the constant annual value of financial expenditures and revenue losses due to a particular project over time; this can also be considered a facility's annual cost of compliance. It presents the annual economic impact a facility can expect to sustain due to amortized capital costs, O&M, and the energy penalty.

Operations and maintenance (O&M) costs for a wet cooling tower system at BSPP include routine maintenance activities; chemicals and treatment systems to control fouling and corrosion in the towers; management and labor; and an allowance for spare parts and replacement. Annual costs are calculated based on the combined tower flow rate using a base cost of \$4.00/gpm in Year 1 and \$5.80/gpm in Year 12, with an annual escalator of 2 percent (USEPA 2001). Year 12 costs increase based on the assumption that maintenance needs, particularly for spare parts and replacements, will be greater for years 12–20. The annual cost for a wet cooling tower retrofit is the sum of annual amortized capital costs plus the annual average of O&M and energy penalty expenditures. Capital costs are amortized at a 7 percent discount rate over 20 years.

Table 12 and Table 13 Table 1 show the range of estimated annualized costs under Option 1 (production loss) or Option 2 (increased fuel consumption).

Table 12. Option 1 Annualized Cost

Estimated Gross Annual Revenue ^[a] (\$)	Initial Capital		O&M		Energy Penalty		Total Annual Cost	
	Cost (\$)	% of Gross	Cost (\$)	% of Gross	Cost (\$)	% of Gross	Cost (\$)	% of Gross
287,600,000	9,200,000	3.2	2,700,000	0.9	18,100,000	6.3	30,000,000	10.4

[a] Based on 2008 weighted wholesale electricity prices reported at the Cinergy trading hub and average generating output.

Table 13. Option 2 Annualized Cost

Estimated Gross Annual Revenue ^[a] (\$)	Initial Capital		O&M		Energy Penalty		Total Annual Cost	
	Cost (\$)	% of Gross	Cost (\$)	% of Gross	Cost (\$)	% of Gross	Cost (\$)	% of Gross
287,600,000	9,200,000	3.2	2,700,000	0.9	3,500,000	1.2	15,400,000	5.4

[a] Based on 2008 weighted wholesale electricity prices reported at the Cinergy trading hub and average generating output.

6.2.6 ESTIMATED RATEPAYER COST

Annualized costs can be presented in terms of the average rate increase that would be expected if all costs were passed through to the rate payer. Table 14 shows the average increases for capital costs only and the high and low options. Increases range from 3.3 percent to 6.5 percent depending on the selected option.

Table 14. Estimated Ratepayer Increases

Base Rate ^[a] ¢/kWh	Capital Only Increase		Option 1 Increase		Option 2 Increase	
	¢/kWh	%	¢/kWh	%	¢/kWh	%
8.39	0.17	2.0	0.54	6.5	0.28	3.3

[a] Base rate obtained from 2008 EIA market data for average retail price of electricity for all sectors (residential, commercial, industrial, and transportation) for Ohio. Residential rates are higher (10.13 ¢/kWh). http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_b.html

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Appendix A—Option Summary

Option Group	Technology or Operational Change	Logistically Feasible?	Satisfactory Performance?	Major Secondary Effects?	316(a) and (b)?	Disqualifying Limitations?	Cost Effective?	Estimated BSPP IM/E Reduction	Result	Notes
Closed-Cycle Recirculating Cooling	Natural draft wet cooling towers	YES	YES	Energy penalty; aesthetics	(a) and (b)	None	NO	IM: 95-98% E: 95-98%	Eliminated	Natural draft towers more expensive; mechanical draft towers achieve same result at lower cost
	Mechanical draft wet cooling towers	YES	YES	Energy penalty; aesthetics	(a) and (b)	None	YES	IM: 95-98% E: 95-98%	FEASIBLE	Sufficient land available; requires better information to calculate energy penalty cost
	Dry cooling	YES	YES	Energy penalty; aesthetics	(a) and (b)	Excessive efficiency loss;	NO	IM: >99% E: >99%	Eliminated	Energy penalty and high cost not justified; mechanical draft towers achieve similar result at lower cost
	Surface cooling ponds	POSSIBLE	YES	Energy penalty	(a) and (b)	Available land	n/a	IM: 80-95% E: 80-95%	FEASIBLE (partial)	Requires large area; unlikely to achieve same result as towers, possible combination system
Physical Barriers	Ristroph screen with fish handling and return system	YES	YES	None	(b) only	None	n/a	IM: 80-90%	FEASIBLE	Upgrade to acceptable design could increase IM survival significantly
	Fine mesh traveling screens	YES	YES	None	(b) only	Lack of suitable discharge location; intake velocity	n/a	n/a	Eliminated	Unlikely to have enough room to maintain intake velocity; return location in thermal plume
	Cylindrical wedgewire screens	POSSIBLE	YES	None	(b) only	Possible navigation interference	n/a	IM: 90-95% E: 85-90%	POSSIBLE	Canal placement infeasible; shipping channel placement unlikely; dredged areas in Maumee Bay possible
	Barrier net	NO							Eliminated	Insufficient area in the intake canal; cannot place at the canal entrance due to boat traffic
	Aquatic filter barrier	NO							Eliminated	Insufficient area in the intake canal; cannot place at the canal entrance due to boat traffic
Diversion or Avoidance Technologies	Velocity cap	NO							Eliminated	Insufficient depth in Maumee Bay

Appendix A—Option Summary

Option Group	Technology or Operational Change	Logistically Feasible?	Satisfactory Performance?	Major Secondary Effects?	316(a) and (b)?	Disqualifying Limitations?	Cost Effective?	Estimated BSPP IM/E Reduction	Result	Notes
	Louvers	YES	NO						Eliminated	Species specific; lack of data
	Behavioral barriers (physical, electrical, light, sound)	YES	NO						Eliminated	Species specific; lack of data
Operational Measures and Structural Changes	Seasonal or other flow reductions	YES	YES	None	(a) and (b)	CUR and dispatch profile			Eliminated	Facility operates at 80% with no seasonal downtime
	Variable speed pumps	YES	YES	None	(a) and (b)	CUR and dispatch profile			Eliminated	Facility operates at 80% with no seasonal downtime
	Intake velocity reduction	YES	YES	None	(b) only	None	n/a	IM: 80-90%	FEASIBLE	Expansion dependent on available space; Reduction based on sufficient size increase
	Swap Intake and discharge locations	YES	NA	Thermal impact to Maumee River	(a) and (b)	Impact to river likely higher than to cove			n/a	Smaller discharge area to Maumee River
	Discharge relocation	YES	YES	unknown	(a) only	unknown			n/a	Shallowness of Maumee Bay suggests impacts would be similar
	Multi-port diffusers	YES	YES	None	(a) only	unknown			n/a	Thermal plume would be smaller with shallow jets; reduction unknown
	Helper towers	YES	YES	None	(a) only	None	NO		n/a	Unable to calculate necessary size; costs are significant and difficult to justify compared with recirculating system and added benefits

1.0 THERMAL EFFICIENCY PENALTY

A wet cooling system will invariably increase the condenser inlet water temperature compared to a once-through system. This increase in temperature affects the condenser's ability to reject waste heat from the system and raises the backpressure at the turbine exhaust point. Adjustments to the turbine backpressure are a function of the change in steam condensate pressure, which is directly related to the increased circulating water temperature. To obtain the steam condensate pressure, the temperature of the saturated steam condensate must first be calculated using the following equation:

$$Q = (U_o \times F_w \times F_m \times F_c) \times A \times \left[\frac{(T_s - T_i) - (T_s - T_o)}{\ln\left(\frac{(T_s - T_i)}{(T_s - T_o)}\right)} \right]$$

where:

- Q = condenser thermal load, in BTU/hr
- U_o = base heat transfer coefficient, in BTU/hr-ft²-°F
- F_w = temperature correction factor
- F_m = tube material factor
- F_c = cleanliness factor
- A = surface area of condenser, in ft²
- T_s = steam condensate (saturated) temperature, in °F
- T_i = condenser inlet temperature, in °F
- T_o = condenser outlet temperature, in °F

The effect the change in backpressure has on overall performance is reflected in changes to the unit's operating heat rate. Heat rate adjustments were calculated by comparing the theoretical change in available energy that occurs at different turbine exhaust backpressures, assuming the thermal load and turbine inlet pressure remain constant, i.e., at the maximum load rating. The relative change at different backpressures was compared to the value calculated for the design conditions (i.e., at design turbine inlet and exhaust backpressures) and plotted as a percentage of the maximum operating heat rate to develop estimated correction curves. A comparison was then made between the relative heat rates of the once-through and wet cooling systems for a given month. The difference between these two values represents the net increase in heat rate that would be expected in a converted system.

2.0 INCREASED PARASITIC USE (FANS)

Depending on ambient conditions or the operating load at a given time, a facility may be able to take one or more cooling tower cells offline and still obtain the required level of cooling. This would also reduce the cumulative electrical demand from the fans. For the purposes of this study, however, operations are evaluated at the design conditions, i.e., maximum load; no allowance is made for seasonal changes.

The fan penalty is expressed as a percentage of the total generating capacity and is calculated using the following equation:

$$F_p = \left(\frac{F_{hp} \times 0.0007457 \text{ MW/hp}}{G} \right) \times 100$$

where:

- F_p = energy penalty from fan power demand, in %
- F_{hp} = motor power, in hp
- G = generating capacity, in MW

3.0 INCREASED PARASITIC USE (PUMPS)

Wet cooling towers require substantial pumping capacity to circulate the large volumes of water through the towers and condensers. The wet cooling system will demand more electrical power than the once-through system it replaces because the configuration and demands are somewhat different. For example, static head values will likely increase due to the height required to reach the top of the tower risers (50 feet or more for many facilities), while friction head loss may increase if the cooling towers must be located far from the condensers they serve, thereby requiring long stretches of supply and return piping.

In most cases, the change in operating demand will require new pumps with different design specifications. Where feasible, some of the existing once-through circulating water pumps will be retained to provide makeup water to the towers. The net pump penalty estimates the power demand of the new configuration versus the existing demand relative to the facility's overall generating capacity.

The pump penalty is expressed as a percentage of the total generating capacity and is calculated using the following equation:

$$P_p = \left(\frac{(P_1 - P_2 + P_3) \times 0.0007457 \text{ MW/hp}}{G} \right) \times 100$$

where:

- P_p = energy penalty from net pump power demand
- P_1 = total motor power for cooling tower pumps, in hp
- P_2 = total motor power for existing circulating water pumps, in hp
- P_3 = total motor power retained from existing circulating water pumps, in hp
- G = generating capacity, in MW

4.0 MONETIZED ENERGY PENALTY – PRODUCTION LOSS (OPTION 1)

The shortfall amount, per month, is summed, and multiplied by the average annual procurement cost to determine an annual estimate calculated using the following equation:

$$R = \sum_{n=1}^{12} \left(\frac{HR_{cc} - HR_{ot}}{HR_{ot}} \right) \times MWh \times P_w$$

where:

R = annual revenue loss, in \$

HR_{cc} = heat rate with closed-cycle cooling for month n , in BTU/kWh

HR_{ot} = heat rate with once-through cooling for month n , in BTU/kWh

MWh = net generating output for month n , in MWh

P_w = wholesale electricity price for month n , in \$/MWh¹⁵

5.0 MONETIZED ENERGY PENALTY – INCREASED FUEL (OPTION 2)

Adjustments to the heat rate were calculated based on the ambient conditions for each month and reflect the estimated difference between operations with once-through and wet cooling tower systems. Using the increased fuel option, the cumulative value of the energy penalty is obtained by first calculating the relative costs of generation (\$/MWh) for the once-through and wet cooling systems. The cost of generation is based on the relative changes in heat rates and the average monthly wholesale natural gas cost (\$/MMBTU) (ICE 2006b). The difference between these two values represents the increased cost, per MWh, that results from a wet cooling tower retrofit. The difference in cost, per month, is applied to the net MWh generated for the particular month, and summed to determine an annual estimate, using the following equation:

$$R = \sum_{n=1}^{12} \left[\left(\frac{HR_{cc} \times F}{1000} \right) - \left(\frac{HR_{ot} \times F}{1000} \right) \right] \times MWh$$

where:

R = annual revenue loss, in \$

HR_{cc} = heat rate with closed-cycle cooling for month n , in BTU/kWh

HR_{ot} = heat rate with once-through cooling for month n , in BTU/kWh

F = fuel cost for month n , in \$/MMBTU

MWh = net generating output for month n , in MWh

6.0 NET PRESENT VALUE

The net present value (NPV) is an economic valuation tool to estimate the potential for profit or loss associated with a large capital investment over a certain time period. The NPV takes into account all expected annual cash flows, both positive and negative, over the life of the project, applies a discount rate, and sums them to a single value presented in current dollars. It does not represent a cash outlay at the beginning of the project. Ordinarily, the NPV is used to measure the potential for profit, i.e., if the NPV is positive, the investment will earn money over the long term.

¹⁵ Weighted average monthly wholesale price, 2008, Intercontinental Exchange for Cinergy trading hub.

For this study, it is assumed there is no potential to realize any discernible profit from the investment, so all cash flows will be negative and can be expressed as costs.

The discount rate used in this study (7 percent) is based on federal government guidelines used in developing economic analyses of proposed regulations and is a conservative estimate of the average pre-tax rate of return for private investment (OMB 2007). EPA used the same rate in developing its cost analysis for the Phase II rule (USEPA 2002 EBA). Higher or lower discount rates may be more appropriate for individual facilities but sufficient economic data were not available to conduct the appropriate sensitivity analysis.

This study selected a 20-year amortization period for the NPV based on the expectation that a 20-year lifespan for cooling towers is a reasonable period before degradation of the original structure becomes significant and incurs higher replacement and repair costs. The 20-year period is not based on a particular unit's projected or anticipated life span.

The NPV is calculated using the following equation:

$$NPV_{20} = \sum_{t=0}^{20} \frac{C_t}{(1+r)^t}$$

where:

NPV_{20} = net present value of all costs incurred over project life span (20 years)

t = project year beginning at $t = 0$

C_t = cost incurred in year t

r = discount rate (7.00 %)

7.0 ANNUAL COST

An annualized cost estimates the constant annual value of financial expenditures and revenue losses due to a particular project over time; this can also be considered a facility's annual cost of compliance. It presents the annual economic impact a facility can expect to sustain due to amortized capital costs, O&M, and the energy penalty.

Annualized capital costs (C_a) are developed according to the following equation:

$$C_a = \left[C_t \times \left(\frac{r \times (1+r)^n}{(1+r)^n - 1} \right) \right] + R + OM_a$$

where:

C_a = annualized cost

C_t = total capital cost (direct, indirect, contingency)

r = discount rate (7.00 %)

n = amortization period (20 years)

R = monetized energy penalty (Option 1 or Option 2)

OM_a = annual operations and maintenance cost

Assumptions made for discount rate and amortization period are the same as for the NPC calculation.

8.0 COST-TO-GROSS REVENUE COMPARISON

An annualized cost-to-gross revenue comparison further illuminates the financial impact that a cooling system retrofit will have on a particular facility. Ideally, facility-level economic data are used to accurately account for company finances, contractual obligations, and generating costs. These data were not available for this study. Instead, a gross annual revenue estimate is developed based on generating output and weighted average monthly wholesale prices for electricity at the Cinergy trading hub.

This estimate represents the proportional annual cost to gross, not net, revenues. It does not account for contractual obligations, revenues received from other activities, fixed revenue requirements, operational costs, or any tax savings.

For merchant generators, the ratio is calculated by the following equation:

$$G_r = \frac{C_a}{\left(\sum_{n=1}^{12} (P_w \times MWh) \right)}$$

where:

G_r = gross revenue ratio

C_a = annualized cost (Option 1 or Option 2)

P_w = wholesale electricity price for month n , in \$/MWh

MWh = net generating output for month n , in MWh

9.0 RATEPAYER COST INCREASE

A wet cooling tower retrofit's overall cost is often best expressed as a unit-level value that places large numbers in the proper context and allows for easier comparison between facilities of different sizes and different technology options. The ratepayer increase is calculated based on the annualized costs for Option 1 and Option 2 and the average retail price for electricity in Ohio for all user types.