Overview of CWA Section 316(a) Evaluations of Power Plants with Thermal Discharges in Maryland

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Abstract

As an EPA-delegated state, in the late 1970s Maryland developed and implemented regulations of thermal discharges and mixing zones in accordance with EPA guidance on implementation of Clean Water Act Section 316a provided at that time. Maryland regulations (Maryland Code of Maryland Regulations (COMAR) 26.08.03.03) established procedures for determining thermal impacts to biota in the receiving water relative to determination of necessary changes in facility processes or operations to minimize these impacts. Maryland has applied these regulations to all power plants in Maryland with thermal discharges, including facilities located on both freshwater and estuarine waters. Over the past 30 years, Maryland's Power Plant Research Program (PPRP) participated in and/or conducted studies of a wide range of thermal impacts in various habitats. These evaluations resulted in a range of determinations, from a decision that the existing discharges met the mixing zone limits to requiring further studies, e.g. long-term fishery studies at Chalk Point and Dickerson power plants. These studies, some lasting over 20 years, ultimately showed no long-term impact from the thermal discharges.

Introduction

Maryland facilities with thermal discharges are regulated by the Maryland Department of the Environment (MDE), the state agency with authority and responsibility for NPDES permitting. Maryland regulations relating to thermal discharges were developed based on EPA guidance on implementation of Clean Water Act Section 316a when that legislation was enacted, and are documented in Maryland Code of Maryland Regulations (COMAR) 26.08.03.03 (available online at http://www.dsd.state.md.us/comar/26/26.08.03.03.htm). These regulations address thermal impacts and mixing zone specifications for tidal and non-tidal waters of the state. While MDE is responsible for regulation of thermal discharges, a sister agency, the Maryland Department of Natural Resources (MdDNR), provides the technical support employed to address these issues at power plants through its Power Plant Research Program (PPRP).

PPRP was established in 1971 to ensure that Maryland meets its electricity demands at reasonable costs while protecting the State's valuable natural resources. It provides a continuing program for evaluating electric generation issues and recommending responsible, long-term solutions. The Maryland legislature created the Power Plant Siting Program, precursor to the current PPRP, in 1971 as a result of extensive public debate regarding the potential effects on the Chesapeake Bay from the Calvert Cliffs Nuclear Power Plant. Calvert Cliffs was a source of concern because the plant uses a once-through cooling system that withdraws over 3.5 billion gallons of water per day from the Bay and discharges the water back to the Bay with a temperature elevation of about 12ºF. The controversy over potential environmental impacts during the licensing of Calvert Cliffs prompted the creation of PPRP to ensure a comprehensive, technically based evaluation and resolution of environmental and economic issues before decisions were made regarding whether and where to build other generating facilities. Today, PPRP maintains this role by providing a comprehensive set of technically based licensing recommendations for proposed generating facilities. PPRP also conducts research on power plant impacts to the Chesapeake Bay, one of Maryland's greatest natural resources, and provides technical support to MDE regarding all power plant NPDES permits and variances associated with those permits. In addition to surface water concerns, PPRP's evaluations consider impacts to Maryland's ground water, air, land, and human resources. PPRP examines all of these areas in its review of effects on Maryland's natural resources, especially the Chesapeake Bay and its ecosystems.

PPRP operates with a small administrative and technical staff, supported by "integrator contractors" with special expertise in engineering, economics, biology/ecology, and atmospheric sciences. The program is funded from an Environmental Trust Fund that is maintained through a surcharge on users of electricity. The surcharge amounts to about 20 cents per month for average residential customers, but has provided a relatively stable source of funding to address the State's power plant assessment needs for nearly three decades. The manner in which PPRP carries out its responsibilities with regard to thermal discharge assessments are varied and customized to issues and circumstances specific to individual facilities and impacts. As a result of review of a permit or variance application from a given facility, PPRP may recommend studies be performed by the applicant. In such instances, PPRP's integrator contractor will be assigned responsibility for technical reviews of applicant's study plans and the findings of the studies. A final review of findings would be prepared for PPRP, and upon its review and concurrence would then be incorporated into recommendations from PPRP to MDE concerning disposition of the applicant's application. In cases where an issue may be relatively generic and findings may be relevant to broader statewide issues, PPRP may develop cooperative studies with an applicant, with PPRP contractors working with the applicant and their consultants to develop and implement studies. In cases where potential impacts are of concern, or where the efficacy of new technologies may be of interest, PPRP may conduct independent studies. Since inception of the program, PPRP has carried out all of these modes of study at all power plants in Maryland with regard to cooling water discharge impacts. Findings from a number of these studies are the basis for the remainder of this presentation and for the State's perspective on thermal impact assessment methodologies, significance and solutions.

Maryland Thermal Regulations

COMAR section 26.08.03.03 describes the factors, criteria, and standards for thermal effluent limitations, including definitions of regulatory mixing zones that apply to cooling water discharges from power plants and other large industrial facilities. Dischargers unable to meet mixing zone criteria can request alternative effluent limitations (AELs) which "assure the protection and propagation of a balanced, indigenous community [BIC] of shellfish, fish and wildlife in and on the body of water into which the discharge is made." In making such a request, dischargers are required to show that the thermal discharge limitations that would otherwise apply to them are more stringent than necessary to protect the BIC. The regulations also require AELs to consider: 1) cumulative impacts of the thermal discharge together with all other significant impacts on the species affected, including impingement and entrainment impacts; 2) a significant increase in abundance or distribution of any species considered to be nuisance species; 3) a significant change in biological productivity; 4) a significant elimination or impairment of economic or recreational resources; and 5) a significant reduction in the successful completion of the life cycle of Representative Important Species (RIS) (defined according to COMAR 26.08.03.04).

Existing dischargers at the time the regulations were issued (1974), were allowed to base their demonstration of AELs on the absence of prior appreciable harm instead of predictive studies. These demonstrations had to show that: 1) appreciable harm has not resulted from the thermal component of the discharge, taking into account the interaction of the thermal component with other pollutants and the additive effect of other thermal sources, to a BIC of shellfish, fish and wildlife in and on the body of water into which the discharge is made; or, 2) despite the occurrence of the previous harm, the desired AELs, or appropriate modifications to them, will nevertheless assure the protection and propagation of a BIC of shellfish, fish and wildlife in and on the body of water into which the discharge is made.

In determining whether prior appreciable harm has occurred, MDE is to consider the length of time an applicant has been discharging, and the nature of the discharge. If the discharger fails to demonstrate that existing facilities, or AELs together with all other impacts, will assure the protection and propagation of a BIC of shellfish, fish, other aquatic life, or wildlife in and on the receiving water, then the discharger is to make changes in the facility processes or operations, or both, sufficient to assure the protection and propagation of a balanced indigenous population of shellfish, fish, other aquatic life, or wildlife in and on the receiving water.

Mixing Zone Regulations

Maryland's thermal mixing zone regulations are diagrammed in summary form in Figure 1. There are 3 sets of mixing zone definitions laid out in the first part of the regulations (paragraph C, numbers 1,2,3): 1) a 50 foot mixing zone, meant to screen out small dischargers from further analysis; 2) a case-by-case mixing zone which may be requested when the detailed analysis required for tidal and non-tidal waters would not be applicable for some reason; and 3) compliance with maximum thermal limits and with specific mixing zone sizes depending on the type of receiving water. The maximum thermal limit criteria vary with the Use type definition as listed in COMAR 26.08.02.02B; however, all existing and proposed facilities in the state are located on waters defined as Use I or II, for which the thermal limit is 90ºF (32ºC). [The basis for selection of this value is not known to us; however, the 1974 draft EPA 316(a) technical guidance lists that value as a short-term maximum temperature for Bluegill survival for June through September, and 32.2ºC as an allowable summer maximum for tropical regions and for the east coast of the U.S. as far north as Cape Hatteras, NC.] If this criterion is not met, regardless of other aspects of the mixing zone criteria, AELs would have to be requested; to our knowledge, no discharger has applied for AELs based solely on this criterion.

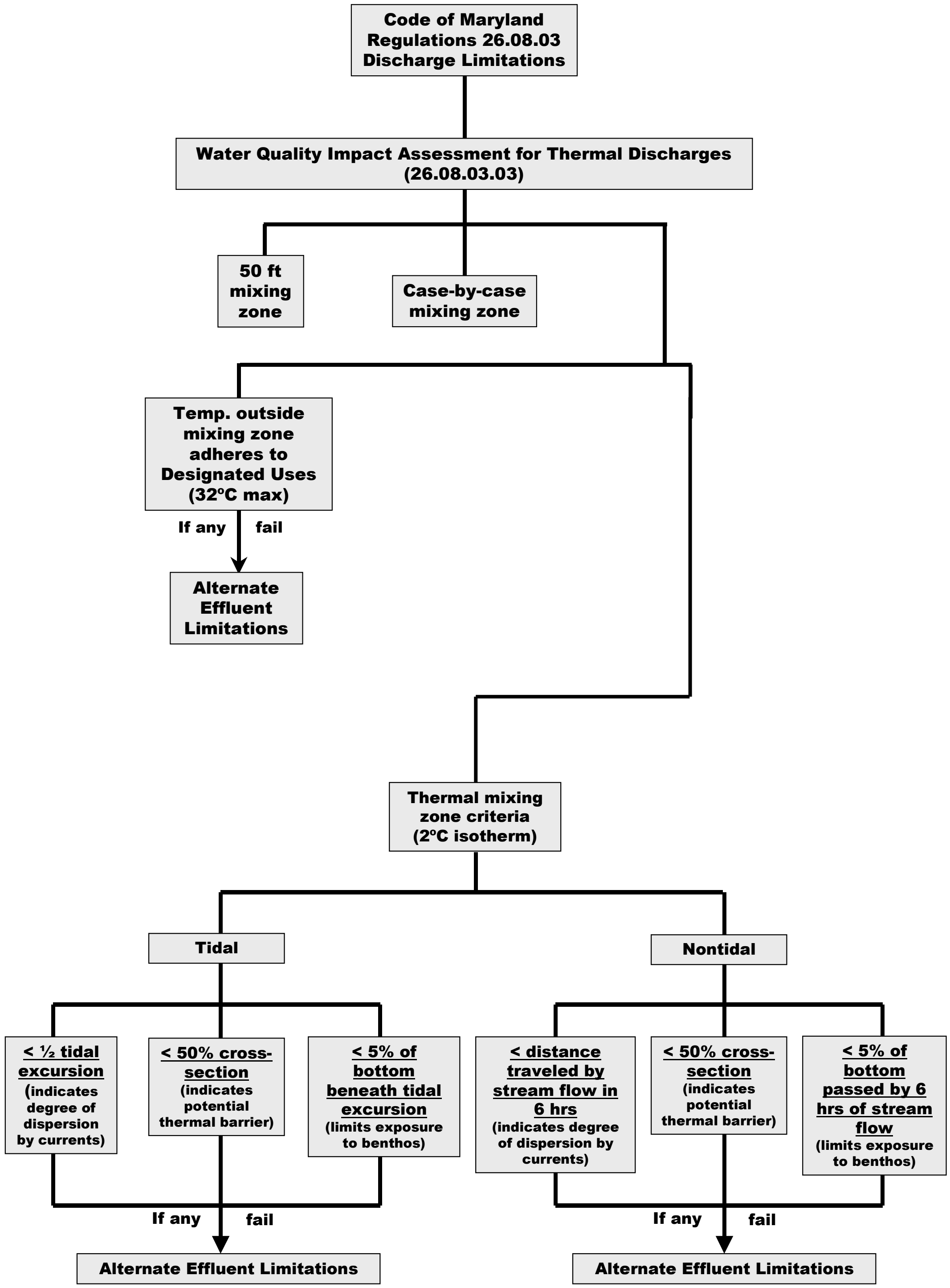

Figure 1
Diagram of Regulations for Thermal Discharges in the State of Maryland

Dischargers whose thermal plumes do not meet the 50-foot mixing zone limit are then required to evaluate their facility for compliance with specific regulatory size limits as summarized in the lower part of Figure 1. This part of the regulations (paragraph D) specifies size limits for tidal and nontidal waters of the state, specifically applicable to freshwater rivers such as the Potomac and estuarine waters such as the Chesapeake Bay and its tidal tributaries. These criteria are to be applied during critical periods, which are defined as 'that time of year during which sensitive life stages or densities of representative important species (RIS) are present in the plant intake or receiving waters.' They also apply as measured with the plant running at full capacity.

The first mixing zone limit depends on the degree of dispersion by flow past the point of discharge. For tidal waters this is one-half of the average ebb tidal excursion distance and the 24-hour average of the maximum radial dimension from the point of discharge cannot exceed this limit at the 2ºC above ambient isotherm. For non-tidal waters, this dispersion criterion is defined as the distance traveled in 6 hours by the receiving stream and the 24-hour average downstream distance from the point of discharge cannot exceed this limit at the 2ºC above ambient isotherm.

The second mixing zone limit is intended to prevent the occurrence of a thermal barrier across the receiving water body. For tidal and non-tidal waters, the 24-hour average of the 2ºC above ambient isotherm may not exceed 50 percent of the accessible cross section of the receiving water body. The third mixing zone limit is intended to limit exposure of bottom dwelling organisms in the receiving water body. For tidal waters, the 24-hour average of the bottom touched by waters heated 2ºC or more above ambient isotherm may not exceed 5 percent of the bottom beneath the ebb tidal excursion multiplied by the width of the receiving water body. For nontidal waters, the same criterion applies except that the bottom area is defined by the stream bottom passed over by the stream flowing for 6 hours (as measured during critical periods).

Power Plants in Maryland

Figure 2 shows the locations of power plants in Maryland; those with once-through cooling are highlighted. Table 1 lists facilities in the state for which 316(a) studies were conducted and whether these facilities passed or failed the mixing zone criteria. (One of these, Westport, has subsequently retired the once-through cooling portion of the facility.) In summary, there were 5 facilities that passed all of the thermal mixing zone criteria, 4 facilities which failed, and 2 which failed under some flow conditions (both riverine facilities). One of the facilities (Wagner) which failed, subsequently applied for and ultimately received a case-by-case mixing zone, since there is an unusual flow pattern in its receiving water (Baltimore Harbor) which precludes easily calculating the standard mixing zone criteria.

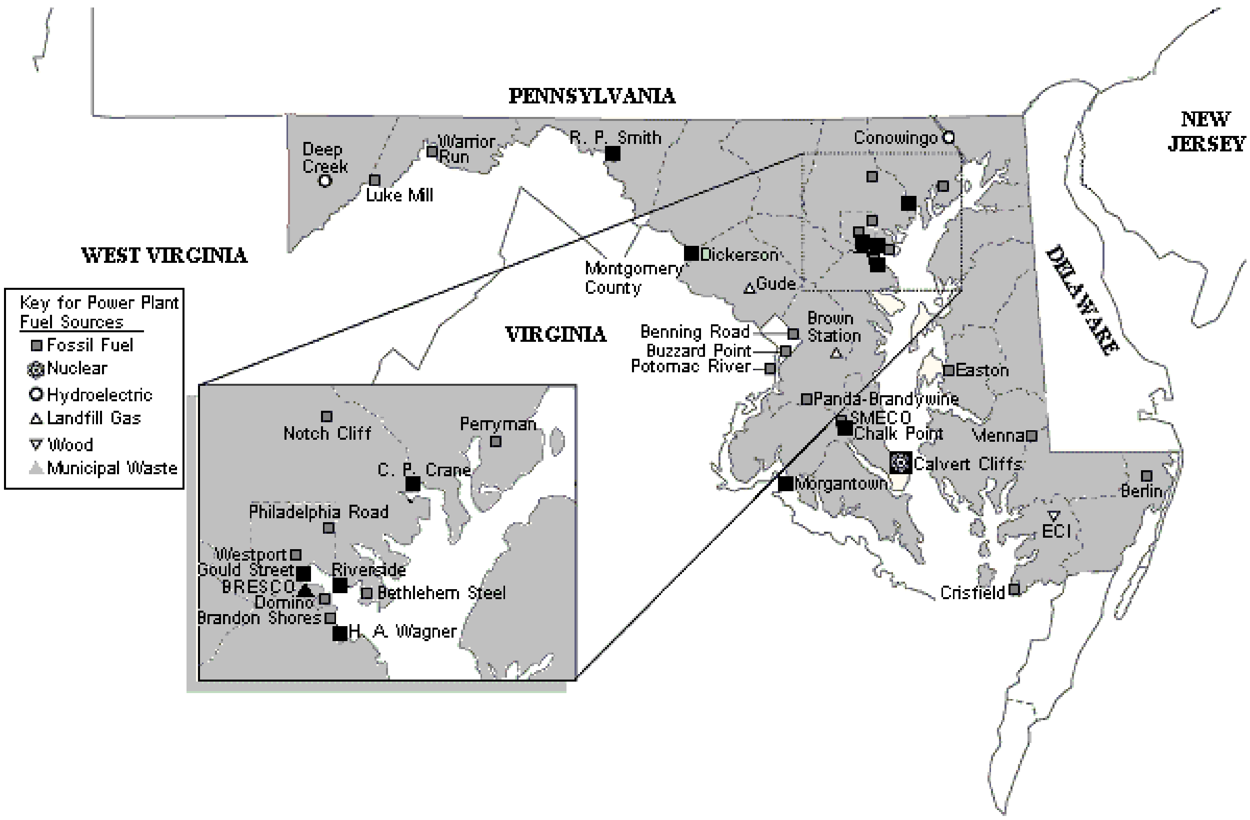

Figure 2
Locations of Power Plants in Maryland. Once-through Cooling Power Plants Indicated by Black Squares.

Table 1
Status of Power Plants Under Maryland Thermal Mixing Zone Criteria

Plant	Mixing Zone Regulatory Status	Water Body
BRESCO	Fails	Patapsco (Baltimore Harbor)
Calvert Cliffs	Passes	Chesapeake Bay mainstem
Chalk Point	Fails	Patuxent River estuary
Crane	Fails	Gunpowder River (tidal)
Dickerson	Fails*	Potomac River
Gould Street	Passes	Patapsco (Baltimore Harbor)
Morgantown	Passes	Potomac River estuary
Riverside	Passes	Patapsco (Baltimore Harbor)
R.P. Smith	Fails*	Potomac River
Wagner	Fails	Patapsco (Baltimore Harbor)
Westport	Passes	Patapsco (Baltimore Harbor)
* under some flow conditions		

Maryland Case Studies

In the remainder of this paper, we describe three mixing zone case studies of Maryland facilities in a variety of tidal and non-tidal waters and results of additional studies that were required to support alternate effluent limitations. These case studies were selected to illustrate a variety of facilities across the range of habitats in the state and how the mixing zone regulations applied to them. Calvert Cliffs was selected as a facility that passed the criteria and is located on the mainsteam of the Chesapeake Bay, a large estuarine water body. Chalk Point was chosen as an estuarine facility on a relative small waterbody, the Patuxent River estuary, and does not pass the mixing zone criteria. Dickerson was chosen as a freshwater riverine facility on the Potomac River and does not pass mixing zone criteria under some flow conditions.

Calvert Cliffs Nuclear Power Station

Calvert Cliffs is owned by Constellation Nuclear, a member of Constellation Power Source, Inc. (formerly BGE). Maryland's only nuclear power plant, it is located on the Chesapeake Bay mainstem in Calvert County. It has generating capacity of 1,675 MW, and employs a once-through cooling system utilizing 3600 million gallons per day (mgd). It has a shoreline intake embayment with curtain wall that extends 8.5 m below the surface, and a high velocity discharge orifice which is 4 meters high, 3 meters deep and extends 268 meters offshore in the main channel of the Bay. Units 1 and 2 began operating in May 1975 and April 1977, respectively.

Because of its size and the extent of controversy surroundings its placement and construction, Calvert Cliffs was the subject of intense study. Utility contractors conducted a wide range of intense environmental studies to satisfy Nuclear Regulatory Commission license technical specifications. These utility studies were augmented by extensive PPRP-funded studies. All of these studies and their findings are described in detail in [1], which summarized PPRP's conclusions regarding biological impacts of Calvert Cliffs.

Figure 3 illustrates a plan view of the Calvert Cliffs discharge, showing an example of a thermal plume from one of the original studies as described in [2]and [3]. The figure also illustrates the surface dimensions of two of the mixing zone criteria in relation to the point of discharge and a sample discharge plume. These plume dimensions are based on estimates made in [4]. The figure shows that the discharge plume is well within the regulatory limits for the maximum radial extent and bottom area. Figure 4 illustrates a cross-section of the Chesapeake Bay in the vicinity of the Calvert Cliffs discharge, along with the allowable limit (50% of the cross-section) and the estimated maximum distance that the plume extended. This figure also shows that the discharge plume is well within regulatory limits, not an unexpected result since the discharge is located in a large open waterbody with plenty of room for dilution of the plume without impacting a large area. Table 2 summarizes the results illustrated in the figures, providing a list of allowed dimensions for each of the three mixing zone criteria, in comparison with estimated actual dimensions of the thermal plume. The ratios of actual to allowed dimensions are all well less than 100%, indicating that the mixing zone criteria are easily passed. Thus, no further 316(a) studies were required to be performed for this facility.

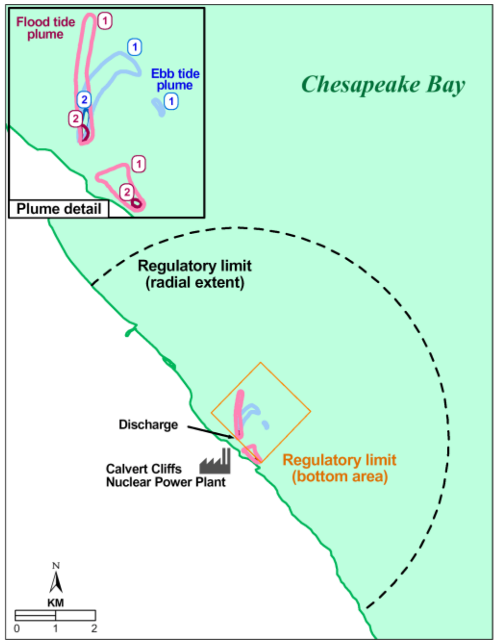

Figure 3
Limits of the Regulatory Mixing Zone (Radial Extent and Bottom Area) in the Vicinity of the Calvert Cliffs NPP Discharge in Comparison with Sample Flood Tide and Ebb Tide Thermal Plumes

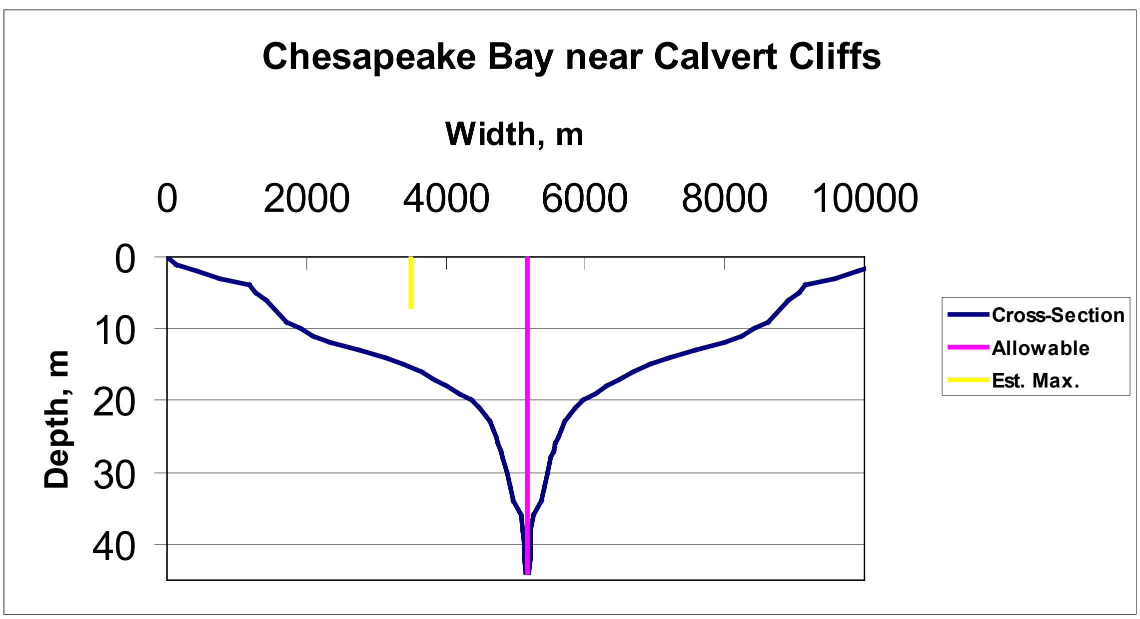

Figure 4
Limits of the Regulatory Mixing Zone (Cross-Sectional Area) in the Vicinity of the Calvert Cliffs NPP Discharge in Comparison with an Estimate of the Maximum Plume Extent

Table 2
Calvert Cliffs Nuclear Power Plant Mixing Zone Dimensions and Compliance with Maryland Regulations

Mixing zone specification	Allowed dimensions	Estimate of actual dimensions	Ratio of actual to allowed dimension
Maximum radial extent of 2EC-above ambient isotherm, 24-hour average (km)	5.3	1.8	34%
2EC-above ambient isotherm thermal barrier, 24-hr average (% of cross-section) (km)	9.1 - 14.3	3.5	25 – 38%
Area of bottom touched by waters heated 2EC or more above ambient (km^2)	3.1	.34	11%

Chalk Point Steam Electric Station

The Chalk Point Steam Electric Station, owned by Mirant Energy (formerly PEPCO), is located on the estuarine portion of the Patuxent River in Prince George's County. It is the largest generating facility in Maryland, with a total generation capacity of 2,415 MW provided by a mix of oil, coal and gas generating facilities. Units 1 and 2 utilize a once-through cooling system, withdrawing a maximum of 360 mgd per unit and discharging the heated water into the Patuxent River. Units 3 and 4 have closed-cycle cooling, using cooling towers and re-circulating water at a rate of 374 mgd per unit, with make-up and blow-down taken from and discharged into the intake and discharge streams of the once-through cooling system. Seven combustion turbine generators are also located on the site. The plant has dredged intake and discharge canals, as seen in Figure 5. One feature of the cooling water system to note in Figure 5 is the location of what are termed auxiliary cooling pumps. These pumps shunted water from the intake canal directly to the discharge canal as a means of ensuring compliance with a 100ºF maximum temperature of waters discharged to the Patuxent River.

Figure 6 illustrates a plan view of the Patuxent River estuary in the vicinity of the Chalk Point discharge, showing an example of thermal plumes from one of the original studies as described in [2] and [5]. The figure also illustrates the surface dimensions of two of the mixing zone criteria in relation to the point of discharge and sample discharge plumes. These plume dimensions are based on estimates made in [6]. The figure shows that these sample discharge plumes are just within the regulatory limits for the maximum radial extent but well exceed the bottom area limit. (Note that the plumes shown here are not necessarily representative of the 24-hour average plume dimension but simply illustrate an example of a flood and ebb tide plume from one measurement). Figure 7 illustrates a cross-section of the Patuxent estuary in the vicinity of the Chalk Point discharge, along with the allowable limit (50% of the cross-section) and the estimated range that the plume extends. This figure also shows that the discharge plume always exceeded the regulatory limits, sometimes extending all the way to the opposite shore. Table 3 summarizes the results illustrated in the figures, providing a list of allowed dimensions for each of the three mixing zone criteria, in comparison with estimated actual dimensions of the thermal plume. The ratios of actual to allowed dimensions are usually all greater than 100%, indicating that the mixing zone criteria are not met for this facility.

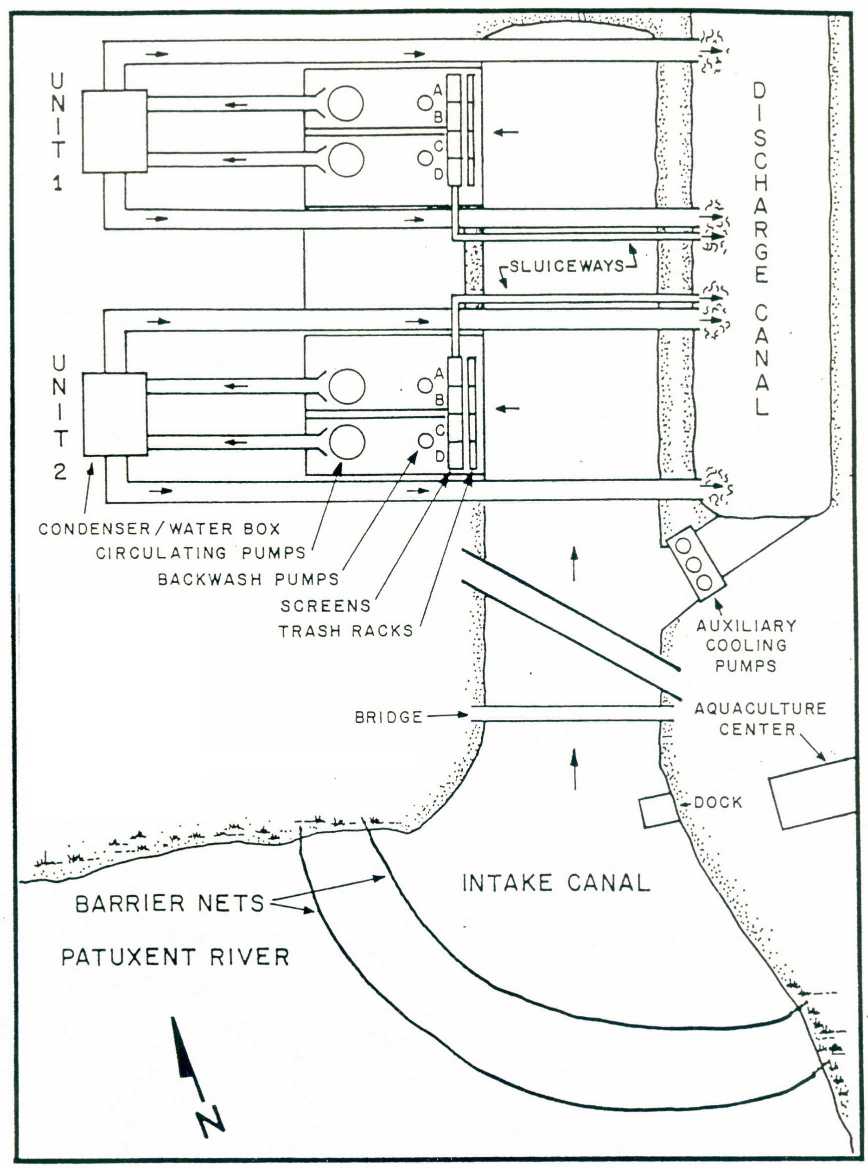

Figure 5
Chalk Point Steam Electric Station (SES) Intake and Discharge Canals Showing Points of Discharge from Units 1 and 2 and Auxiliary Cooling Pumps

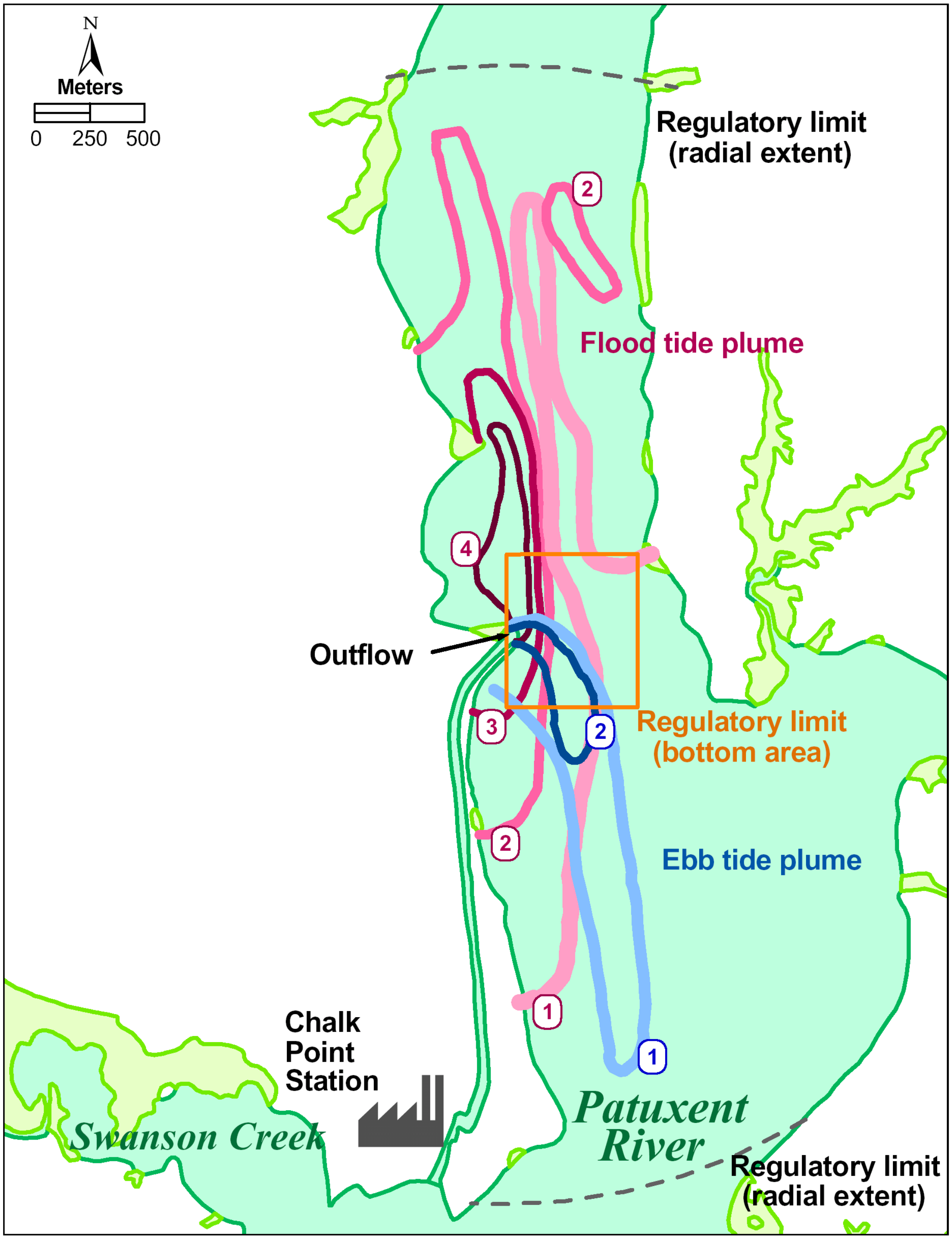

Figure 6
Limits of the Regulatory Mixing Zone (Radial Extent and Bottom Area) in the Vicinity of the Chalk Point SES Discharge in Comparison with Sample Flood Tide and Ebb Tide Thermal Plumes

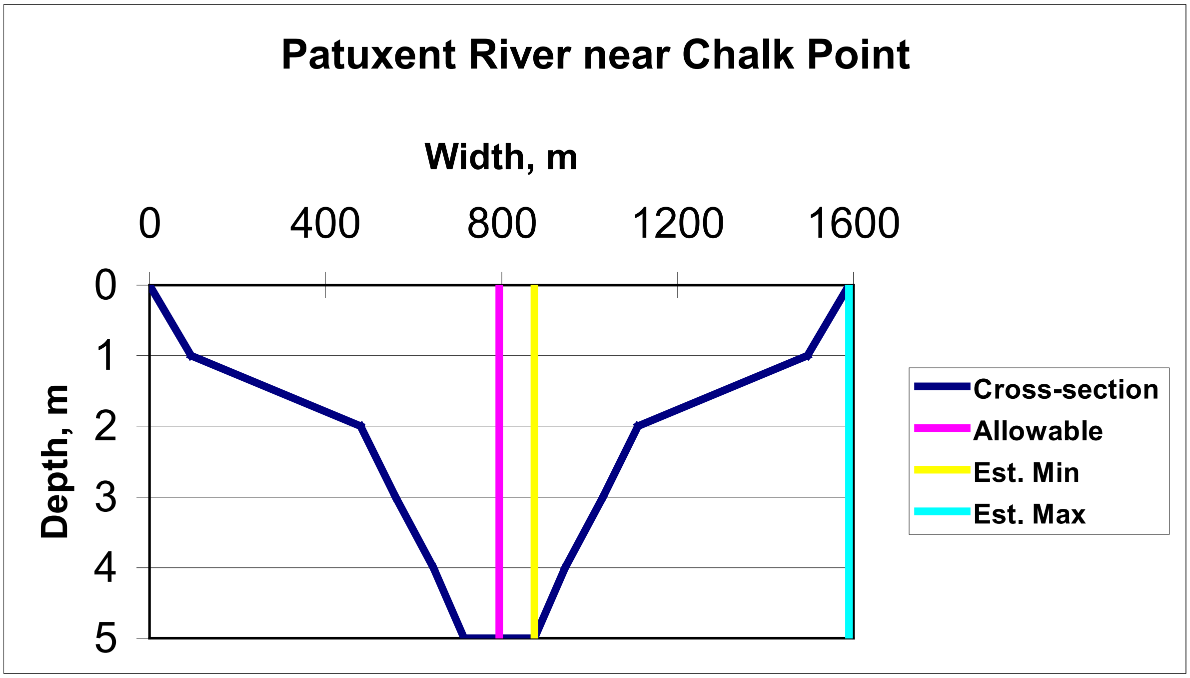

Figure 7
Limits of the Regulatory Mixing Zone (Cross-Sectional Area) in the Vicinity of the Chalk Point SES Discharge in Comparison with an Estimate of the Minimum and Maximum Plume Extent

Table 3
Chalk Point Steam Electric Station Mixing Zone Dimensions and Compliance with Maryland Regulations

Mixing zone specification	Allowed dimensions	Estimate of actual dimensions	Ratio of actual to allowed dimension
Maximum radial extent of 2EC-above ambient isotherm, 24-hour average (m)	2,500 - 2,650	2,500 - 4,600	94 - 184%
2EC-above ambient isotherm thermal barrier, 24-hr average (% of cross-section) (m)	50	55 - 100	110 - 200%
Area of bottom touched by waters heated 2EC or more above ambient (ha)	33 - 49	62 - 96	127 - 291%

Tempering pump entrainment - Auxiliary cooling water pumps, also called tempering pumps, were not screened. Thus, when operated, all ages and sizes of fish and crabs could be passed through the pumps and suffer physical damage from striking pump impellors and experiencing pressure changes. Large concentrations of fish and crabs were present in the intake canal, most likely because the intake flows and configuration of the canal were attractive to these organisms, which resulted in large numbers of organisms being entrained through the pumps. PPRP carried out a detailed assessment of the effectiveness of the tempering pumps for reducing plant-induced mortality of aquatic biota, using data collected by the facility owner and their contractors [7]. Several Representative Important Species (RIS) and dominant benthic and zooplankton species were used in the evaluation as indicators of overall system-wide responses. Expected mortality with and without auxiliary pump operation was estimated using thermal tolerance data available from the literature for blue crabs, white perch, striped bass, spot, Macoma balthica (a shellfish), and Acartia tonsa (a zooplanktor). PPRP concluded that the operation of the pumps increased plant-induced mortality of spot, white perch, striped bass, and zooplankton, but could reduce blue crab mortality slightly under some circumstances. Macoma mortality was largely unaffected by their operation. The overall conclusion was that cessation of use of the tempering pumps would result in a 50% decline in losses of fish and crabs from CWIS operations. A sensitivity analysis confirmed that the conclusions drawn were not significantly affected by uncertainties in the input data used. As a result of this evaluation, PPRP recommended to MDE that the Chalk Point NPDES permit be modified to eliminate the requirement for use of auxiliary pumps. Thermal criteria in the permit were later changed to a thermal loading cap rather than a specific discharge temperature cap.

As a result of failure to pass the thermal mixing zone criteria, Chalk Point was required to demonstrate that AELs should be granted and further studies were required on the thermal impacts from the discharge. Loos and Perry conducted a study to determine the abundance and species composition from 1991-2000 and compared results to a 1985-1990 study to indicate any thermal effects of discharges [8]. The study is based on a time series of fish abundance data by species from otter trawl samples, as well as data for chemical and physical parameters at fixed stations in the mainstem of the Patuxent estuary (n=22), the Chalk Point discharge canal (n=1), and in Swanson Creek (n=1). The sampling stations were generally allocated along transects across the estuary, and covered the shoal and the channel in control and nearfield regions. Trawling at each station was conducted with the tide. The abundances of 13 common species and the ratio of abundance by nearfield and control regions were summarized in tables, and compared through visual inspection of box and whisker plots. Spatial distribution was evaluated from box and whisker plots based on monthly data with annual variation being removed. The species composition in the 1991-2000 period was compared to results from earlier studies to evaluate whether the fish community had changed or been negatively impacted as compared to the previous study period (1985-1990). The study concluded that the species composition of the river has remained constant between the two study periods, with the exception for baywide changes for some species (e.g. an increase in striped bass abundance resulting from stocking). AELs have been granted at each 5-year permit cycle as these long-term studies continued.

Dickerson Steam Electric Station

The Dickerson SES, located on the freshwater portion of the Potomac River in Montgomery County, is owned by Mirant Energy (formerly PEPCO). It has total generating capacity of 556 MW, and utilizes a once-through cooling system with a capacity of 400 mgd. As with all other power plants in Maryland, Dickerson was the subject of intensive PPRP study and evaluation, as is summarized in [9].

Figure 8 illustrates a plan view of the Potomac River in the vicinity of the Dickerson discharge, showing an example of thermal plumes from one of the original studies as described in [2] and [10]. The figure also illustrates the surface dimensions of one of the mixing zone criteria in relation to the point of discharge and a sample discharge plume. These plume dimensions are based on estimates made in [9]. The figure shows that these sample discharge plumes exceed the regulatory limits for the maximum downstream extent. (Note that the plumes shown here are not necessarily representative of the 24-hour average plume dimension but simply illustrate an example of a plume from one measurement). Figure 9 illustrates a cross-section of the Potomac River in the vicinity of the Dickerson discharge, along with the allowable limit (50% of the cross-section) and the estimated range that the plume extends. This figure also shows that the discharge plume always exceeded the regulatory limits. Table 4 summarizes the results illustrated in the figures, providing a list of allowed dimensions for each of the three mixing zone criteria, in comparison with estimated actual dimensions of the thermal plume. The ratios of actual to allowed dimensions are often greater than 100%, indicating that the mixing zone criteria are not met for this facility.

As a result of failure to pass the thermal mixing zone criteria, Dickerson was also required to demonstrate that AELs should be granted and further studies were required on the thermal impacts from the discharge. Two studies were recently concluded, one on the overall fishery in the receiving water near the discharge [11] and the other focusing on smallmouth bass [12].

The general study was based on a time series of fish abundance data from electrofishing samples at fixed stations around and within the Dickerson Station thermal influence. Electrofishing collections were made at 43 stations from 1979 to 1989, and at a subset of 14 of the original stations, plus one additional station, from 1990 onwards. The electrofishing was conducted in each season, with repeat sampling of stations within season when logistically feasible. Only two electrofishing collections were made during winter from 1990 to 2000. The abundance (log-transformed) of fish by species or functional groups at impacted and control sites was compared through exploratory graphical analysis. Abundance patterns and species composition were also compared to expected results based on published studies of fish distributions. Results indicated that species in the sunfish and catfish family are neutral or attracted to the thermal plume, while minnows, suckers, and darters have the strongest avoidance reaction. These results are in agreement with the literature. The study concluded that the heated discharges have only a minor seasonal effect on fish distributions, and that no adverse long-term impacts have occurred.

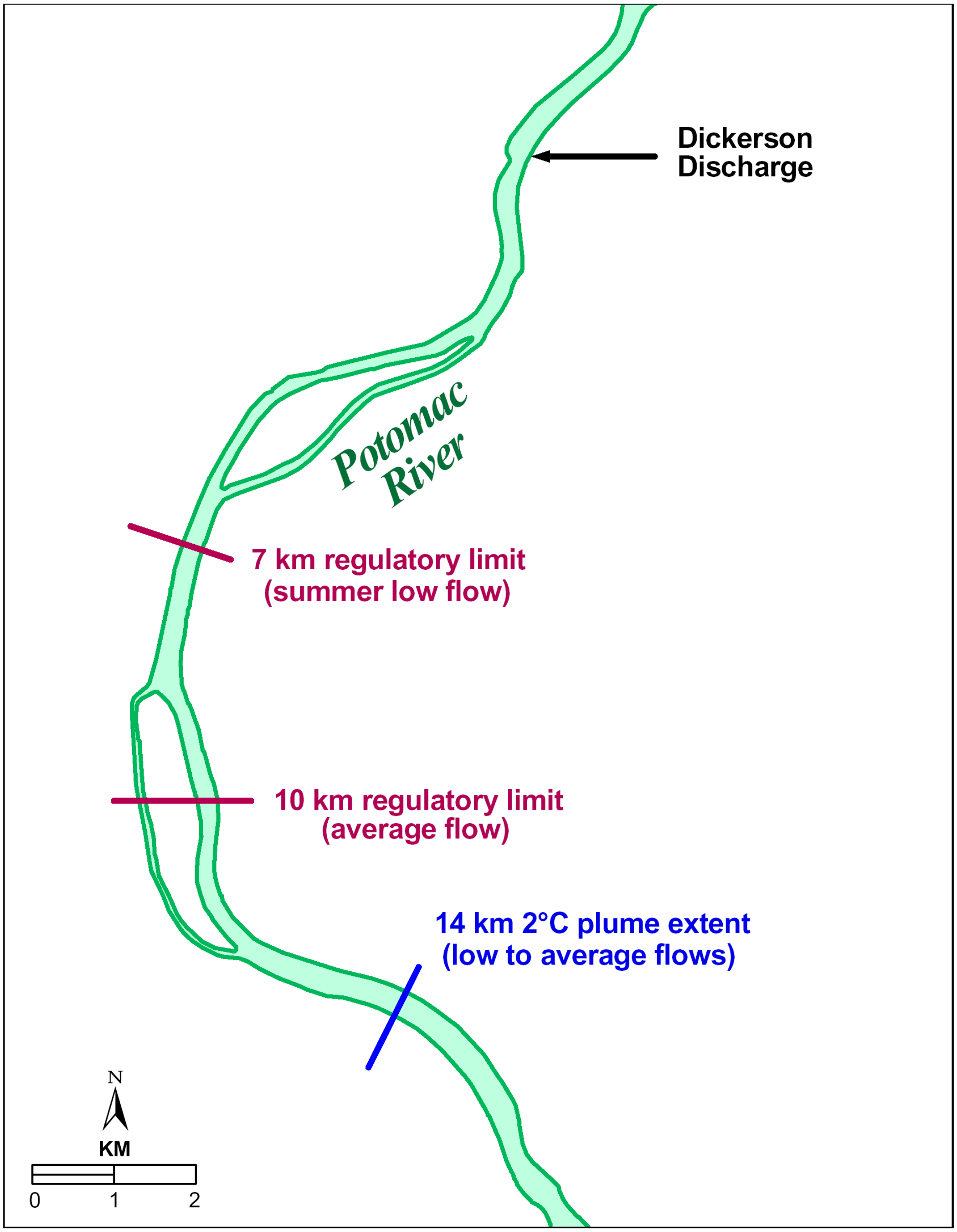

Figure 8
Limits of the Regulatory Mixing Zone (Downstream Extent) in the Vicinity of the Dickerson SES Discharge in Comparison with Sample Thermal Plumes for the Summer Low Flow and Average Flow Conditions

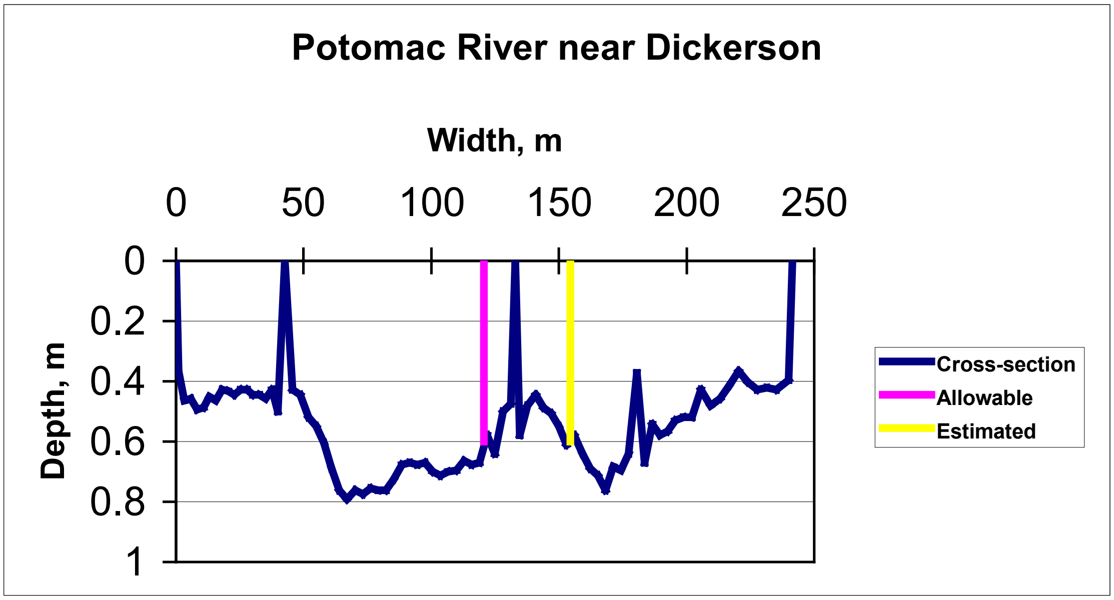

Figure 9
Limits of the Regulatory Mixing Zone (Cross-Sectional Area) in the Vicinity of the Dickerson SES Discharge in Comparison with an Estimate of the Maximum Plume Extent. River Islands are Present at Two Locations as Shown Where the Bottom Profile Reaches the Surface.

Table 4
Dickerson Steam Electric Station Mixing Zone Dimensions and Compliance with Maryland Regulations (low to high summer flows)

Mixing zone specification	Allowed dimensions	Estimate of actual dimensions	Ratio of actual to allowed dimension
Maximum downstream extent of 2EC-above ambient isotherm, 6-hour travel time (km)	7.3 - 19.6	2.5 - 14	34 – 192%
2EC-above ambient isotherm thermal barrier, average low-flow (% of cross-section) (m)	140 - 155	192 (maximum extent)	123 – 137%
Area of bottom touched by waters heated 2EC or more above ambient, 6-hour travel time (10^3 m^2)	110 - 295	45 - 1400	41 - 1,273%

The smallmouth bass study was based on length and scale/otolith samples collected from the Dickerson discharge and Point of Rocks (control site) in 1998 and 1999. A SAS clustering procedure was used to group the individuals into age classes based on scale/otolith readings. Analysis of variance was conducted to test for differences in mean length at age and overall mean length between the control and impacted areas.

Smallmouth bass near the discharge was found to have significantly larger mean length across age groups than bass collected at Point of Rocks. The comparison of mean length by age group was inconclusive. The study concluded that the discharge does not have an adverse impact on the growth of smallmouth bass.

Conclusions

This brief overview provides several diverse examples of the process employed by Maryland in making power plant thermal mixing zone and impact determinations under Maryland's thermal regulations. Based on 30 years of PPRP experience, the major points we wish to convey include:

- All studies confirmed that thermal mixing zone criteria are protective of the biotic community in the vicinity of power plant thermal discharges, since these thermal criteria have been used in identifying facilities with a potential for impacts

- Detailed assessments that were required to demonstrate AELs then served as a foundation for technically-based regulatory decisions

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