CHAPTER III

AIR IMPACT

This chapter discusses the effects on air quality of fuel combustion at power plants in Maryland. The various types of emissions from power plants are discussed, including components of recent interest such as fine particulate materials and trace elements. The contributions of power plant emissions to observed ambient pollutant concentrations in Maryland are assessed, and actual and proposed changes in regulatory requirements affecting power plants are also presented. Various tools for determining the effects of emissions on air quality--such as dispersion modeling and measurement networks--are discussed, as well as the latest development in pollution control technology and research efforts in air quality modeling and measurement programs in Maryland.

A. Emissions

Power plants emit pollutants that can affect ambient air quality and public health. Federal air pollution control regulations established under the Clean Air Act group pollutants into two classes: criteria pollutants, for which comprehensive health effects assessments have been performed and national ambient air quality standards (NAAQS) have been set, and noncriteria pollutants, which are regulated under the Clean Air Act but for which NAAQS have not been established.

Principal criteria pollutants emitted by fossil-fueled power plants are: 1) sulfur dioxide (SO_2) from the sulfur in fuels; 2) nitrogen oxides (NO_x) created by oxidation of nitrogen both in the fuel and in the combustion air; and 3) particulate matter (PM) primarily from ash, the noncombustible fraction of fuels. The fraction of emitted particles in the respirable size range (less than 10 μm and designated PM_{10}) depends on whether the plant burns solid or liquid fuel and on the type of emission control equipment used. Power plants also emit fluorides and metals (both trace constituents of fuels) and small amounts of organic compounds. Emissions from plants burning nonfossil fuels, particularly refuse-derived fuel, sometimes contain higher proportions of trace elements and organics than emissions from fossil-fueled plants because the concentrations of these materials are higher in these alternative fuels. Significant levels of particulate matter, known as fugitive dust, may also be emitted from coal and ash handling facilities of coal-fired plants.

Presented below are the most recent available estimates of Maryland power plant emissions of some criteria and noncriteria pollutants. Not enough is known about the size distributions of power plant particulate emissions to estimate PM_{10} emissions.

Emissions of Criteria Pollutants from Maryland Power Plants

The Maryland Air Management Administration (MAMA) compiles yearly inventories of statewide emissions of criteria pollutants from both mobile and stationary sources (1-8). Major stationary sources assessed by MAMA include power plants, industrial facilities, domestic and space heating, and refuse incineration. In general, mobile sources are responsible for the bulk of NO_x emissions, while fossil-fuel for power generation produces more than half of the SO_2 (Table III-1). The most recent year for which the inventory is complete is 1981. In that year, power plants appear to have contributed 62 percent of the SO_2, 34 percent of the NO_x, 11 percent of the total suspended particulates (TSP), and less than 1 percent of the carbon monoxide (CO) and hydrocarbons (HC) estimated to be emitted in Maryland.

Power plant emissions of all criteria pollutants decreased between 1977 and 1981 (Fig. III-1), reflecting both the decreased output of PEPCO's Chalk Point and Dickerson Power Plants during the installation of new particulate control equipment and the increased use of nuclear energy for generation in the State. However, in the years since 1981, the amount of SO_2 and NO_x emitted by Maryland power plants has increased, primarily because of the Chalk Point Power Plant's return to full service following major refurbishment (completed in late 1982), the coal conversion at the C.P. Crane Power Plant (completed in May 1983), and the start-up of the Brandon Shores Power Plant (May 1984). By 1995, emissions of SO_2 are expected to increase to levels comparable to those existing in the early 1970s as a result of coal conversions and increases in plant use and generating capacity at Maryland power plants (9). Power plant NOx emissions are expected to increase less rapidly because of the anticipated use of new, low-NO_x combustion processes (9). Particulate emission levels have decreased over time despite increased use of coal because of the introduction of new, highly efficient, particulate control equipment.

Reliability of Emissions Data for SO_2

Actual emissions from power plants may differ significantly from projected or permitted emissions. Many assessments of ambient air quality impact and measures required for control depend upon the accuracy of emission inventories. To assess their accuracy, we have compared the reported 1981-1984 SO_2 emissions in the MAMA inventory with inventories obtained from three other sources: the National Emissions Data System (NEDS); emission reports (10) of the four major utilities with generation facilities in Maryland [Baltimore Gas & Electric Company (BG&E), Potomac Electric Power Company (PEPCO), Potomac Edison Company (PECO), and Delmarva Power & Light (DP&L)]; and the Federal Energy Regulatory Commission (FERC) Form 1, which records actual utility fuel purchases (converted to emissions by assuming maximum permitted sulfur content of the fuel). Estimates of 1981-1984 emissions from these four data bases are compared in Figure III-2. Sulfur oxide inventories should be one of the most accurate because fuel sulfur content (upon which most calculations are based) is routinely measured by the utilities.

The utility-reported emissions were computed using actual fuel use and sulfur-in-fuel data. The MAMA emission inventory was derived from similar data reported by the utilities. The NEDS data are supplied to the U.S. Environmental Protection Agency (EPA) by MAMA and are expected to approximate the MAMA estimates. Since the FERC estimates were computed using sulfur-in-fuel permit limits for individual plants, they should serve as an upper limit estimate for the inventory. In general, the data from all four sources were in agreement to within a few percent. However, the MAMA and NEDS data appear to yield total statewide emission estimates that are about 8

Table III-1. Statewide total emission inventory for five criteria pollutants, 1975-1984 (data from Refs. 1-8)

	Total Emissions Reported (ton/yr)(a)									
Pollutant	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Particulate Matter (PM)										
Including mobile sources	85,000	73,500	103,233	95,290	103,898	63,169	56,168			
Excluding mobile sources	66,400	55,400	82,342	73,462	82,349	44,186	35,287			
Power plant totals	27,224	21,052	39,536	31,886	31,685	14,256	6,073	6,364	5,396	6,324
Power plant % of total (including mobile sources)	32	29	38	33	30	22	11			
Sulfur Oxides (SO_2)										
Including mobile sources	409,800	318,700	668,861	400,997	375,820	353,698	328,520			
Excluding mobile sources	383,300	274,100	615,740	346,736	319,756	297,588	271,442			
Power plant totals	283,642	180,906	332,361	228,099	200,031	227,199	202,503	210.7	215.3	247.6
Power plant % of total (including mobile sources)	69	57	50	57	53	64	62			
Hydrocarbons (HC)										
Including mobile sources	311,600	263,300	427,113	430,937	316,499	298,513	293,204			
Excluding mobile sources	76,200	56,100	68,139	185,571	80,897	88,383	79,360			
Power plant totals	3,048	1,683	1,525	2,011	1,422	1,243	1,142			
Power plant % of total (including mobile sources)	1.0	0.6	0.4	0.5	0.4	0.4	0.4			
Nitrogen Oxides (NO_x)										
Including mobile sources	359,000	288,200	502,200	355,913	317,737	301,610	251,114			
Excluding mobile sources	169,700	138,900	299,344	189,374	157,791	151,130	107,369			
Power plant totals	105,214	75,006	237,121	135,012	82,470	98,103	86,195	60,686	69,631	85,866
Power plant % of total (including mobile sources)	29	26	47	38	26	32	34			
Carbon Monoxide (CO)										
Including mobile sources	1,910,200	1,577,000	2,704,295	1,876,046	1, 759,044	1,985,165	1,461,876			
Excluding mobile sources	107,400	130,700	120,215	120,726	128,607	52,067	89,202			
Power plant totals	4,296	3,921	6,069	8,379	4,947	4,597	4,457			
Power plant % of total (including mobile sources)	0.2	0.2	0.2	0.4	0.3	0.2	0.3			

(a) Data for 1977-1981 have been revised by MAMA since the last CEIR.

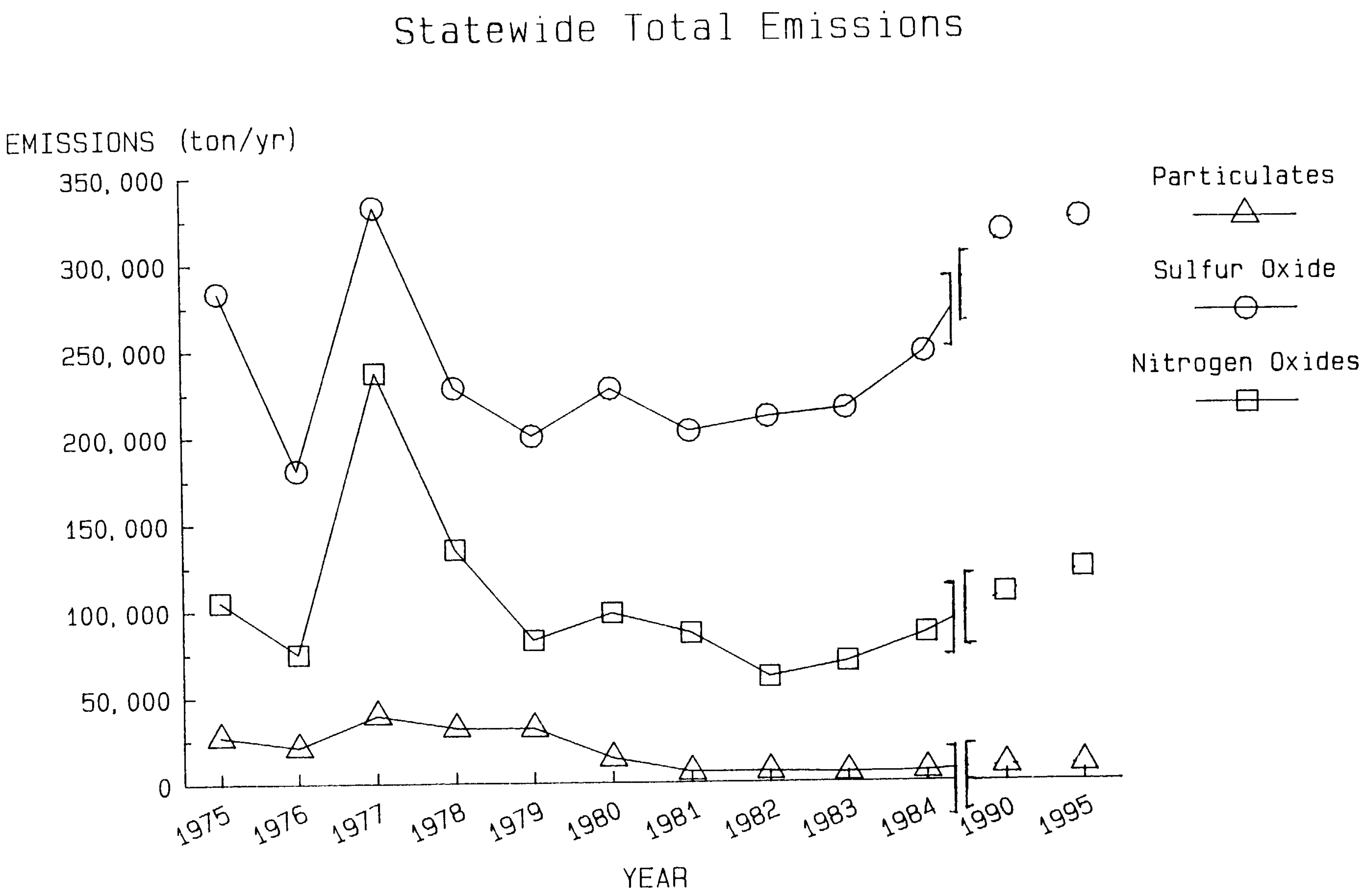
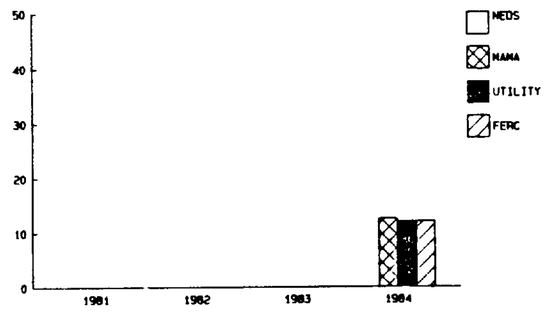
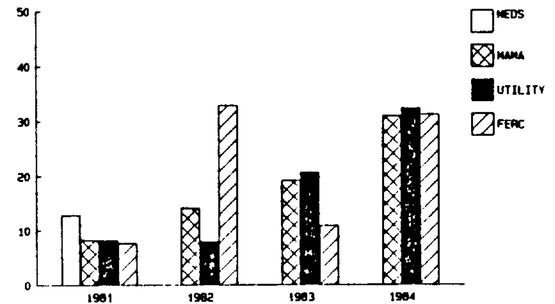


Figure III-1. Total Maryland power plant emissions of major pollutants. Reported emissions from Refs. 3-8; projections from Ref. 9.

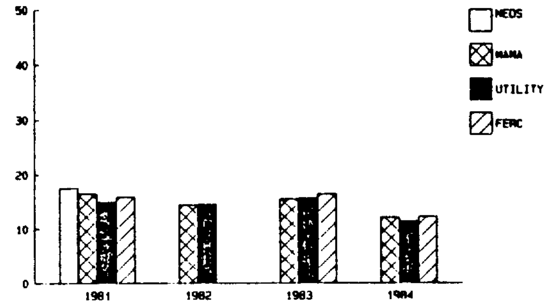
BRANDON SHORES(a)



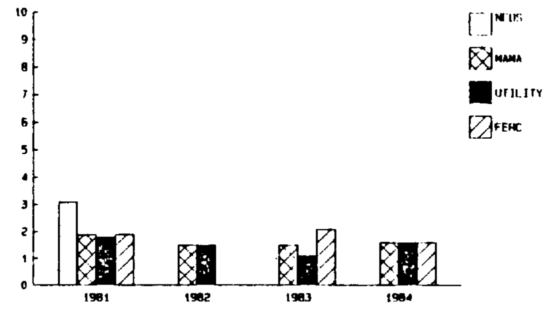
CRANE / RIVERSIDE(a)



WAGNER(a)

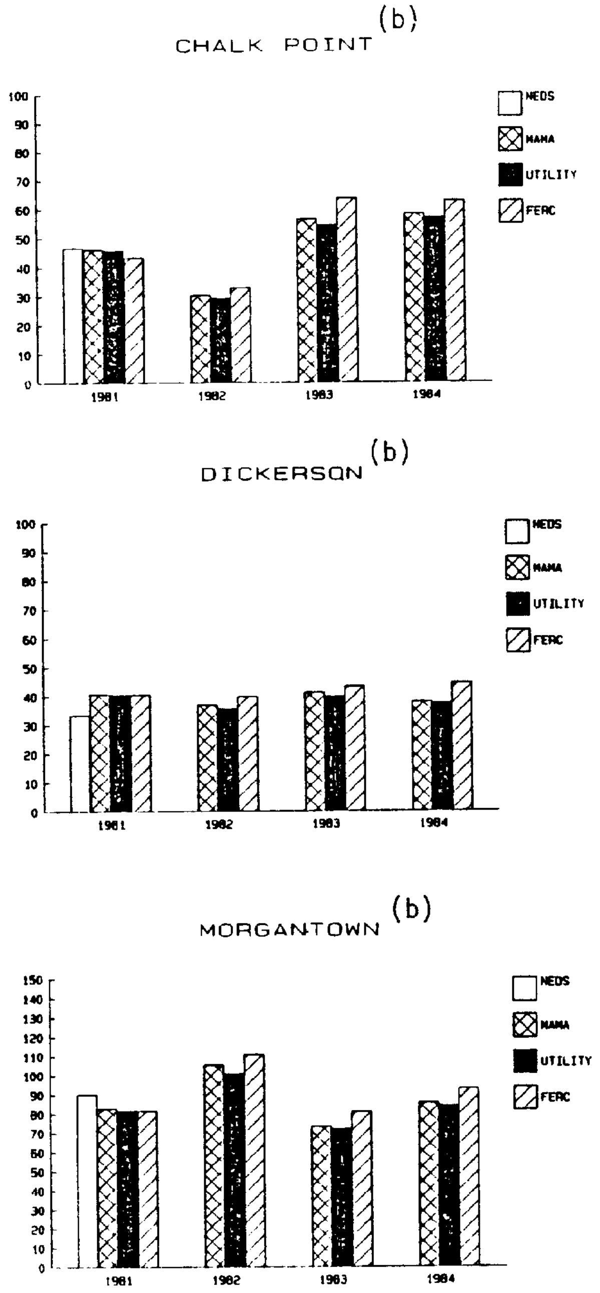


GOULD / WESTPORT(a)



(a)Owned by Baltimore Gas & Electric Company

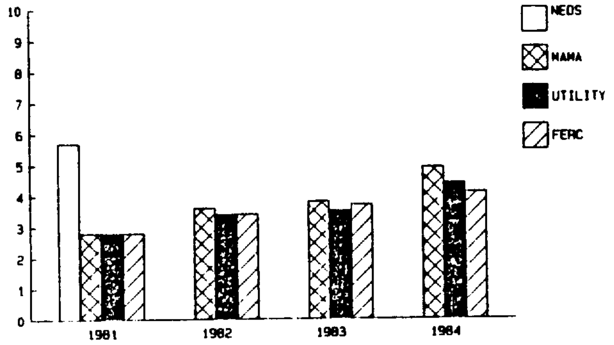
Figure III-2. Comparison of Maryland SO_2 inventories (emissions in thousands of tons per year)



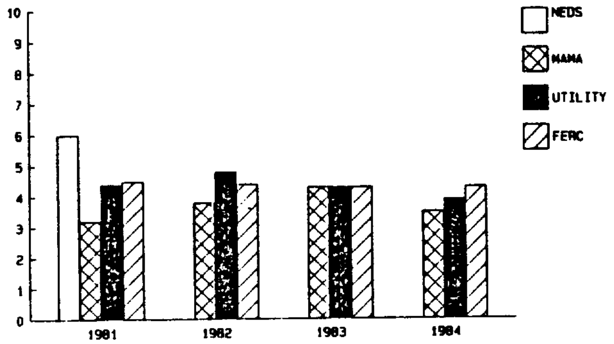
(b) Owned by Potomac Electric Power Company

Figure III-2. Continued

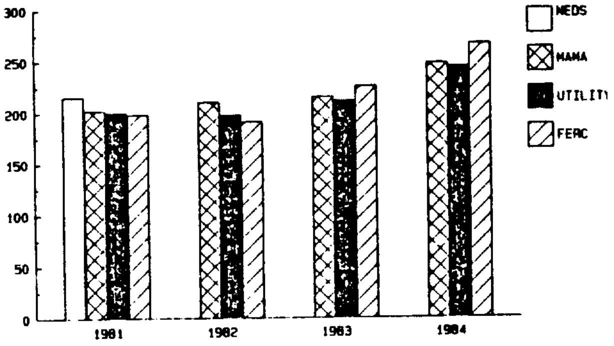
VIENNA(c)



SMITH(d)



COMBINED TOTALS



(c) Owned by Delmarva Power & Light Company

(d) Owned by Potomac Edison Company

Figure III-2. Continued

percent higher than emissions quoted by the utilities. This difference may be due to differing assumptions concerning sulfur retention in ash (up to 5% difference) or fuel sulfur content. Several differences (e.g., R.P. Smith in 1981 and 1982; Vienna in 1981; Crane/Riverside in 1982; Dickerson and Morgantown in 1981) are so large that they are difficult to explain.

The differences in statewide total reported emissions are sufficiently small to allow use of the data bases interchangeably for studies of aggregate emissions. For analyses of actual and projected impacts of individuals plants or for application to regulations that require an accurate inventory, it would be useful to know how accurately these inventory methods describe actual emissions. Current research linking sulfur dioxide and nitrogen oxide emissions to acidic deposition and recent interest in legislation to reduce these emissions for purposes of controlling acidic deposition has increased the interest in actual and accurate emissions inventories in all source categories.

All four utilities are now required to conduct continuous emission monitoring for SO_2 and opacity at their coal-burning power plants that have emission rates higher than 1.6 lb SO_2/MMBtu. In addition, BG&E has installed continuous monitoring equipment for NO_x at their Brandon Shores and C.P. Crane power plants. The SO_2 measurement equipment has been installed at all Maryland facilities and is, in general, now undergoing final testing and start-up (11). Opacity measurement equipment has been operating for a longer period of time.

At present, the utilities report only hours of exceedence, not actual emissions. (Often, the measurement equipment has not been set up to report actual emissions.) No comparison has been made by the utilities between the various methods of emission measurement and projection for any operating Maryland power plant. The present form (or expected form) of the data supplied to the state is useful only for official regulatory compliance purposes.

Emission of Noncriteria Pollutants

Fossil-fueled power plants emit metals and other pollutants, which are trace constituents of both oil and coal (12). Mercury is largely emitted as a gas; most other metals are likely to condense on the fine particulate matter emitted after combustion. Fluorides contained in the fuel undergo reactions during combustion to form both particulate and gaseous compounds that can be emitted in significant quantities from power plants. Fluorides accumulate in vegetation and can affect the bones and teeth of grazing cattle.

Emissions of some noncriteria pollutants (Table III-2) can be estimated by multiplying the concentration of the pollutant in the fuel by the fuel consumption rate and adjusting for emission controls, as they apply. For example, chromium is likely to be found in particulate matter and will thus be generally controlled with the same efficiency as particulate emissions. (See, however, Section E, Proposed PM_{10} National Ambient Air Quality Standard.) Several estimates of fuel trace element composition are available in the literature (see, for example, Refs. 14 and 15). However, elemental concentrations vary widely in both solid and liquid fuels. Estimating actual emissions for a particular plant requires a detailed analysis of the fuel being used, and emissions will change if a new source of fuel is selected.

Table III-2. Estimated trace element emissions for major Maryland power plants, based on 1984 SO_2 emissions as reported by the utility companies

Pollutant[a]	Emissions (ton/yr)											
	C.P. Crane	Brandon Shores	Wagner	Gould St.	Riverside	Westport	Morgan-town	Dickerson	Chalk Point	R.P. Smith	Vienna #8	Totals
SO_2												
Coal	30741	12125	7629	—	—	--	84300	37500	46700	3931	--	222926
Oil	--	—	3908	1070	1604	534	--	--	10200	—	4352	21668
Total	30741	12125	11537	1070	1604	534	84300	37500	56900	3931	4352	244594
Fluoride												
Coal	52.5	58.0	29.9	—	--	--	165.4	92.0	91.6	16.1	—	506
Oil[b]	—	—	—	—	—	--	--	--	--	--	--	--
Total	52.5	58.0	29.9	—	—	--	165.4	92.0	91.6	16.1	—	506
Mercury												
Coal	0.1	0.1	0.0534	--	--	--	0.3	0.2	0.1635	0.03	--	0.9017
Oil	—	—	0.0004	0.0001	0.0002	0.0001	—	—	0.0006	—	0.0003	0.0017
Total	0.1	0.1	0.0539	0.0001	0.0002	0.0001	0.3	0.2	0.1640	0.03	0.0003	0.9034
Beryllium												
Coal	0.002	0.002	0.0166	—	—	--	0.07	0.02	0.0068	0.004	—	0.122
Oil	—	—	0.0006	0.0002	0.0005	0.0001	--	--	0.0026	--	0.001	0.005
Total	0.002	0.002	0.0172	0.0002	0.0005	0.0001	0.07	0.02	0.0093	0.004	0.001	0.127
Arsenic												
Coal	0.004	0.005	0.037	—	--	--	0.15	0.1	0.02	0.008	--	0.27
Oil	—	—	0.006	0.002	0.004	0.001	—	—	0.02	—	0.01	0.05
Total	0.004	0.005	0.043	0.002	0.004	0.001	0.15	0.1	0.04	0.008	0.01	0.32
Lead												
Coal	0.03	0.03	0.223	—	—	—	0.90	0.32	0.09	0.05	—	1.641
Oil	—	—	0.002	0.001	0.002	0.0003	--	--	0.01	—	0.005	0.021
Total	0.03	0.03	0.226	0.001	0.002	0.0003	0.90	0.32	0.10	0.05	0.005	1.662
Cadmium												
Coal	0.0003	0.0004	0.0029	—	—	--	0.01	0.004	0.001	0.001	--	0.021
Oil	—	—	0.0003	0.0001	0.0002	0.00004	—	—	0.001	—	0.001	0.003
Total	0.0003	0.0004	0.0032	0.0001	0.0002	0.00004	0.01	0.004	0.002	0.001	0.001	0.024
Chromium												
Coal	0.02	0.02	0.157	--	—	--	0.6	0.2	0.064	0.034	--	1.16
Oil	—	—	0.005	0.002	0.004	0.001	--	--	0.023	--	0.01	0.05
Total	0.02	0.02	0.163	0.002	0.004	0.001	0.6	0.2	0.087	0.034	0.01	1.20
Fuel Sulfur Content (%)												
Coal	2.30(c)	0.82(c)	1.00(c)	—	--	--	2.00(c)	1.60(c)	2.00(c)	0.96(c)	--	
Oil	--	—	1.00(d)	1.00(d)	1.00(d)	1.00(d)	—	—	2.00(d)	—	1.82(c)	
Particulate Control Efficiency (%)												
Coal	99.9	99.9	98.5	—	--	--	98.9	99.3	99.8	99.4	--	
Oil	--	—	70	56.1	42.5	70	--	--	0	—	0	

(a) SO_2 emissions as reported in the Utility Submission to the Subcommittee on Acid Precipitation, 24 June 1985 (10). All trace pollutant emissions were calculated by ratio from the SO_2 emissions using the published concentration in fuels shown in Table III-3.

(b) No concentration for fluoride in fuel oil was available.

(c) Fuel sulfur content as reported in (10).

(d) Maximum permitted oil sulfur content.

Noncriteria pollutant emissions have been projected for Maryland power plants using 1984 sulfur dioxide emissions and published general fuel compositions (see Table III-3). With the exception of fluorides, all of these pollutants are emitted in minute amounts, and the corresponding ambient concentrations are projected to be minimal (12). Several of these metals and other constitutents are regulated under the National Emission Standards for Hazardous Air Pollutants (NESHAP) (13).

B. Ambient Air Quality Standards

Ambient air quality standards are limits on the concentrations of selected pollutants in the ambient air. Both the EPA and the individual states have established such standards. Maryland's standards are identical to the Federal standards except that Maryland has a standard for fluorides, while EPA does not. The Federal and State ambient air quality standards are shown in Table III-4.

Federal Standards

The Federal National Ambient Air Quality Standards (NAAQS) were initially established in 1971 by the EPA in response to Sections 108 and 109 of the Clean Air Act. Section 108 required the EPA Administrator to establish a list of pollutants whose presence in the air could "reasonably be anticipated to endanger public health or welfare" and that resulted from "numerous or diverse mobile or stationary sources."

Section 109 of the Clean Air Act required the Administrator to establish ambient air quality standards for the listed pollutants based on the air quality criteria developed under Section 108. For each pollutant, two standards were required: (1) a primary standard set low enough to protect public health; and (2) a secondary standard set low enough to protect public welfare (e.g., livestock, vegetation, man-made materials, or the economic value of objects) from the adverse effects of pollution. The primary standard, because of its human health implications, must be met through the State Implementation Plan (discussed below) "as expeditiously as practical," while the secondary standard must be met within "a reasonable time."

The original NAAQS established under Section 109 applied to SO_2, NO_2, CO, HC, PM, and photochemical oxidants (ozone or O_3). In 1978, a NAAQS was added for lead (Pb). (Note from Table III-4, that the secondary annual level for TSP is not an enforceable limit, but a guideline to be used in assessing state plans for implementing measures to attain the 24-hr TSP standard.)

Review of National Ambient Air Quality Standards

Section 109 also requires the establishment of an independent scientific review committee to review the air quality criteria and ambient air quality standards once every 5 years in light of the current state of scientific knowledge about health effects. The committee will recommend revisions or new standards if they are warranted.

Table III-3. Typical trace element concentrations in fuels (ppm)

	Concentration (ppm)	
Element	Coal	Oil[a]
Fluoride	78.5[b]	--
Mercury	0.14[c]	0.0023
Beryllium	2.9[d]	0.01
Arsenic	6.5[c]	0.095
Lead	39.[c]	0.041
Cadmium	0.5[c]	0.005
Chromium	27.5[e]	0.09

[a] Values for oil concentrations from National Bureau of Standards, Standard Reference Material No. 1634 (16).
[b] U.S. Fish & Wildlife Service (14).
[c] Klein et al. (15).
[d] Ray & Parker (17).
[e] Gladney et al. (18).

Table III-4. National and Maryland Ambient Air Quality Standards (data from Refs. 21 and 22)

Pollutant	Primary	Secondary
Sulfur Oxides		
Annual arithmetic mean, $\mu g/m^3$	80 (0.03 ppm)	(c)
Maximum 24-hour concentration(a), $\mu g/m^3$	365 (0.14 ppm)	(c)
Maximum 3-hour concentration(a), $\mu g/m^3$		1,300 (0.50 ppm)
Suspended Particulate Matter		
Annual geometric mean, $\mu g/m^3$	75	60(b)
Maximum 24-hour concentration(a), $\mu g/m^3$	260	150
Lead		
Calendar quarter average, $\mu g/m^3$	1.5 (0.05 ppm)	(c)
Carbon Monoxide		
Maximum 8-hour concentration(a), mg/m^3	10 (9 ppm)	(f)
Maximum 1-hour concentration(a), mg/m^3	40 (35 ppm)	(f)
Nitrogen Dioxide		
Annual arithmetic mean, $\mu g/m^3$	100 (0.05 ppm)	(f)
Ozone		
1-hour average(d), $\mu g/m^3$	235 (0.12 ppm)	(f)
Gaseous Fluorides(e)		
24-hour average, $\mu g/m^3$	1.2	
72-hour average, $\mu g/m^3$	0.4	

(a) Not to be exceeded more than once per year.
(b) Federal guideline only.
(c) Not established.
(d) Attained when expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is less than or equal to one.
(e) Maryland standard only.
(f) Same as primary.

The review of the original NAAQS for CO, NO_2, and HC is complete. On June 19, 1985 (19), EPA decided to retain the existing identical primary and secondary annual standards for NO_2, and to defer the decision on the need for a short-term NO_2 standard pending the results of further research. On September 13, 1985 (20), EPA decided to retain the primary 1-hr and 8-hr standards for CO but to revoke all CO secondary standards.

The original NAAQS for HC was, like the present secondary annual TSP standard, only a guideline to be used in assessing state plans for implementing the O_3 standard. In 1983, after review by the Clean Air Scientific Advisory Committee, the HC standard was revoked on the grounds that there was no "consistent quantitative relationship" on a nationwide basis between ambient HC and O_3 levels (23).

For particulate matter, the committee's review of recent research and the original standards indicated that they did not adequately address the health effects of fine, inhalable particulate matter. Particulate matter has traditionally been represented by the TSP indicator, which includes all particulate material small enough to be airborne (less than a median diameter of 35μm). As a result of the committee's assessment, revisions to the existing standards have been proposed (24) that would establish a new fine particulate indicator, called PM_{10}, for particles less than or equal to 10μm in diameter. The proposed revision to the PM standards would replace the existing short- and long-term primary standards for TSP with new ones for PM_{10}, eliminate the short-term secondary standard for TSP, and establish a new secondary long-term standard for TSP (to replace the guideline now in effect). A discussion of the possible consequences of this change is contained in Section E.

Standards for SO_2, Pb, and O_3 are currently under review. According to EPA's latest semiannual regulatory agenda (25), a notice of proposed rule-making for possible revisions to the SO_2 standards was due in December 1985, while the preliminary review of the Pb and O_3 standards will be completed in July 1986 and February 1987, respectively. The review status of all the NAAQS is shown in Table III-5.

Maryland Standards

According to Section 2-302(c) of the Annotated Code of Maryland, the State must set its ambient air quality standards equal to the Federal NAAQS, unless some political subdivision requests a more restrictive standard. The State may also establish ambient air quality standards for additional pollutants not regulated by EPA.

The Maryland and Federal ambient air quality standards are identical, except that Maryland has a standard for fluorides in the ambient air (Table III-4). The State also originally had an HC standard, but it was revoked when the Federal NAAQS for HC was revoked.

Table III-5. Status of review of National Ambient Air Quality Standards

Pollutant	Type of Action	Schedule Actual & Proposed Dates			Results
		ANPRM[a]	NPRM[b]	Final	
SO_2	Projected Revision	10/2/79	12/85	1/87	-
PM	Projected Revision	10/2/79	3/20/84	9/86	-
CO	Completed Review	-	-	9/13/85	Standards Retained[c]
NO_2	Completed Review	-	-	6/19/85	Standards Retained[d]
HC	Completed Review	-	5/8/81	1/5/83	Standards Revoked[e]
		End Review Date			
Pb	Review in Progress	7/86			
O_3	Review in Progress	2/87			

(a) Advance notice of proposed rulemaking.
(b) Notice of proposed rulemaking.
(c) CO primary standards retained; identical secondary standards revoked (20).
(d) Existing NO_2 annual primary and secondary standards retained; decision on a separate short-term standard deferred pending additional research (19).
(e) See Ref. 23.

State Implementation Plan (SIP)

Section 110 of the Clean Air Act requires each state to prepare and submit to EPA a plan for implementing, attaining, and maintaining the national air quality standards--the so-called State Implementation Plan, or SIP. Maryland's SIP is a collection of documents establishing the regulatory limits on emissions that are necessary to ensure or attain compliance with ambient air quality standards throughout the State.

Since portions of Maryland are not currently in attainment of the O_3 and existing particulate matter standards ("nonattainment areas"), the SIP emphasizes plans and information necessary to bring areas into compliance, including information on: trends in ambient concentrations, inventories of principal emission sources, studies of control strategies and their relative effectiveness, plans for emission control, and proposed schedules for attainment.

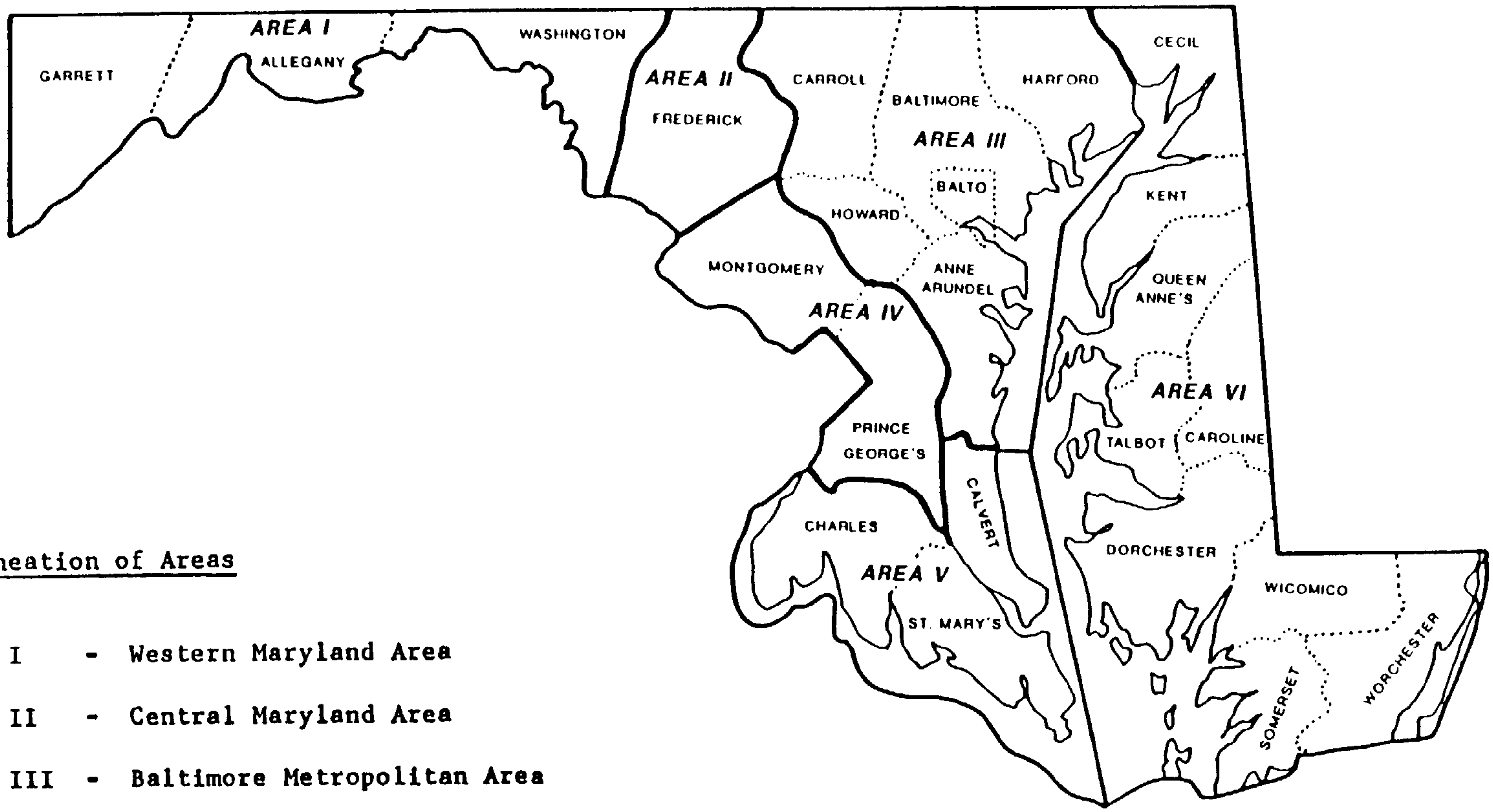
The SIP also includes the State's air pollution control regulations (Code of Maryland Regulations, or COMAR, 10.18.01. through 10.18.23) and plans for maintaining compliance with other ambient air quality standards. These provide the State with the authority to establish and enforce limits on emissions from individual pollution sources, to review plans for new sources before construction, and to collect data on emissions and ambient air quality for periodic submission to EPA. In addition, the SIP includes special emission limitations and compliance schedules for individual stationary sources, and plans for inspection and emission testing of mobile sources.

The SIP is revised whenever there is a change in state air regulations or in the Federal air regulations affecting the State (such as NAAQS), or when a new emission limit or compliance schedule is established for a specific emission source. The public has the opportunity to comment on all SIP revisions. EPA approval is required prior to incorporation by the State.

Attainment Status

For purposes of air quality designations, Maryland is divided into six air quality control areas .(see Fig. III-3): Western Maryland (Area I), Central Maryland (Area II), Baltimore Metropolitan (Area III), Washington Metropolitan (Area IV), Southern Maryland (Area V), and Eastern Shore (Area VI). The current attainment status of these areas is presented below for all criteria pollutants except Pb (for which EPA has not yet made designations).

The attainment status of air quality control regions may affect both existing and proposed new power plants. Existing plants located in or having a significant impact on a nonattainment area could, in the future, be required to reduce emissions of nonattainment pollutants to allow attainment of NAAQS or Maryland ambient air quality standards. Proposed new or modified plants in, or impacting, these areas could be required to undergo New Source Review (as described in Section E) and perhaps obtain emissions offsets (corresponding decrease in emissions elsewhere) to ensure that their emissions do not contribute to continuing violations of ambient air quality standards.



Delineation of Areas

AREA I - Western Maryland Area
AREA II - Central Maryland Area
AREA III - Baltimore Metropolitan Area
AREA IV - Washington Metropolitan Area
AREA V - Southern Maryland Area
AREA VI - Eastern Shore Area

Figure III-3. Maryland State air quality control areas

The entire state remains in compliance with both short-and long-term standards for SO_2. All of Maryland is in attainment of the annual standard for NO_x (26). However, Areas III and IV are considered nonattainment for ozone, a pollutant that is not emitted directly by power plants but that may be formed by atmospheric reactions involving HC and NO_x. Although both of these pollutants are emitted by power plants, they are principally emitted by mobile sources (26). The central business district of Baltimore, and certain census tracts in Montgomery and Prince Georges counties, have been designated nonattainment for CO (26). This pollutant is principally emitted by mobile sources and has been the target of recent automobile emission testing programs (26).

C. Ambient Air Quality

Air Quality Monitoring Programs

MAMA has been measuring ambient concentrations of all criteria pollutants and several noncriteria pollutants at various locations in Maryland since the early 1970s. In 1983, the agency measured ambient SO_2 levels at 9 locations in Maryland, 8 of which are near Baltimore or Washington; NO_x at 8 locations, 7 of which are near Baltimore or Washington; and TSP at 50 locations, 14 of which are in Baltimore City and the remainder of which are distributed around the State (22). In 1984, NO_x monitoring was discontinued at one location in Glen Burnie (27). Also, in the second quarter of 1984, the agency began operating two inhalable particulate (PM_{10}) monitors--one at Fairfield FMC and one at the Canton Recreational Center in southeastern Baltimore City. (Canton has historically been the location of the highest particulate concentrations in Maryland.)

The primary purpose of the MAMA monitoring program is to protect human health by ensuring that ambient pollutant levels are below the health-based federal and state air quality standards. Thus, the monitors are located in regions where concentrations or population exposures are expected to be high or a source impact is expected to be large (28). The impact of Maryland power plant emissions on all of the existing monitors (except, possibly, two Baltimore-area monitors) is most likely masked by the effects of other sources. Thus, in general, this monitoring information reflects little about the impact of power plants in the State.

Another purpose of monitoring ambient air quality, not served by the present network, is to determine background pollutant concentrations as needed for various regulatory and planning applications. The actual definition of "background" varies depending on the purpose to be served. For example, in evaluating the total impact of emissions from a large number of sources on air quality (for example, to compare with an ambient air quality standard), the background concentration might be defined as the concentration in the area before any of the sources were built. This background concentration could be determined instead from monitors sited in remote, rural locations relatively unaffected by anthropogenic activity. A similar type of background concentration might be useful in assessing cumulative effects of sources, such as power plants, on statewide or regional air quality. The urban location of the MAMA air quality monitoring sites for SO_2 and NO_x does not provide background concentrations suitable for this type of assessment of Maryland power plant operations.

To project the effect on air quality of a change in emissions at a new single source, the background concentration may in fact be taken to represent a "baseline" concentration: the concentration prevailing before the change occurs. In such a case, local air quality monitors can provide the desired information. For an isolated emission source, the background concentration for such an assessment could be determined simply by choosing measurements consistently taken upwind of the source. Where there is a complete lack of ambient measurements, air quality models may sometimes be used to project background concentrations. However, it is difficult to predict the impacts of emission changes at individual sources with accuracy. Ambient concentrations observed after emissions changes may be very different from the projections if the background is not accurately characterized.

The assessment of air quality changes around power plants is best accomplished by networks designed for that purpose. Two utilities, PEPCO and BG&E, currently conduct ambient air quality monitoring in the vicinity of their plants. PEPCO maintains networks around its Dickerson, Chalk Point, and Morgantown generating stations; BG&E monitors air quality near C.P. Crane and Brandon Shores. At the PEPCO plants, concentrations of SO_2, TSP, and NO_x are monitored; at C.P. Crane, TSP and SO_2 are measured, while at Brandon Shores, only TSP is measured. These programs are described in more detail below.

- <u>Potomac Electric Power Company</u>

Air quality monitoring networks have been maintained at the three PEPCO plants since 1967. The initial networks at all three plants were operated by TRW/Resources Research, Inc. At all three plants, the early networks (i.e., 1967 through 1973 or 1974) included 20-40 locations where sulfation and dustfall rates were measured. The purpose of measuring sulfation rates over a large area in each case was to determine the general spatial distribution of sulfur oxides around the plant so that continuous SO_2 monitors could be placed at the locations of highest impact. By 1975, the sulfation plate networks at Morgantown and Dickerson were replaced by three or four continuous SO_2 monitors.

Dustfall measurements continued through the end of 1976. Beginning in 1977, TERA Corporation took over the monitoring programs and redesigned the networks. They established five monitoring sites each at Dickerson and Morgantown. At each plant a key station was selected where continuous SO_2 and NO_x monitors and a TSP monitor were installed, as well as wind speed and direction sensors. At the four satellite stations at each plant, SO_2 and TSP monitors were installed. The dustfall measurements were discontinued. The change in particulate measurement systems was motivated by a revision of the Maryland air quality standards to a value based on TSP rather than dustfall.

In 1981 PEPCO personnel assumed responsibility for operation and maintenance of the networks. Since that time, some monitors have been relocated and others have been discontinued. The present configuration includes four monitoring stations each at the Dickerson and Chalk Point plants, and one at the Morgantown Power Plant.

- Baltimore Gas & Electric Company

The monitoring programs at C.P. Crane and Brandon Shores are conducted by BG&E in response to requirements established during the Public Service Commission (PSC) review of the 1983 coal conversion at C.P. Crane and the proposed construction of Brandon Shores as a coal-fired plant. The PSC Hearing Examiner required monitoring networks to provide information that could be used to evaluate the results of preconstruction fugitive dust modeling studies conducted for both plants. Most of the monitors are thus located very close to the plants, or on plant property, at sites that are expected to be heavily affected by fugitive dust sources (e.g., coal piles, coal handling, and truck traffic). At C.P. Crane and Brandon Shores, monitoring was required for 2 years preceding the coal conversion and at least 2 years following it. Monitoring began at the C.P. Crane site in January 1982; the conversion occurred in May 1983, and monitoring has continued as of the end of 1985. TSP is measured at five close-in monitoring sites; at a sixth station about 2 miles east of the plant, both TSP and SO_2 are measured. At Brandon Shores, TSP monitoring began in May 1982 at four locations ranging from one-quarter mile up to nearly 2 miles away from the plant.

- Other Monitoring

One-time air quality monitoring studies have been conducted at all of Maryland's major power plants, but no continuous body of data has been collected at any plants other than those discussed above. In 1982, ambient SO_2, NO_x, and TSP concentrations were measured for 6-9 months at the DP&L Vienna Power Station, although the data were never analyzed (29). In November 1974, monitoring for NO, NO_x, O_3 and SO_2 was done at the Easton Power Plant by personnel of the Johns Hopkins University Applied Physics Laboratory (30). Numerous short-term monitoring programs were conducted by EMI at several sites as part of the Power Plant Siting Program (PPSP) model validation program (e.g., Ref. 31).

Historical Air Quality Trends

According to the data published annually by MAMA (22,27, 32-42), general air quality in the State has remained relatively constant over the 12-year period 1972-1984 (Figs. III-4, III-5, and III-6). Ground-level concentrations of TSP and NO_2 were nearly constant from 1972 to 1982, while the statewide annual average SO_2 concentrations peaked in 1982. However, conclusions regarding air quality trends based on these figures should be viewed with caution. The shift in methodology and decrease in number and location of stations that occured in 1980-1983 for SO_2 and NO_2 introduces an unknown factor into the trend analysis. Most of the monitoring stations for these pollutants are now located in urban areas (28). In addition, it is unlikely that averages

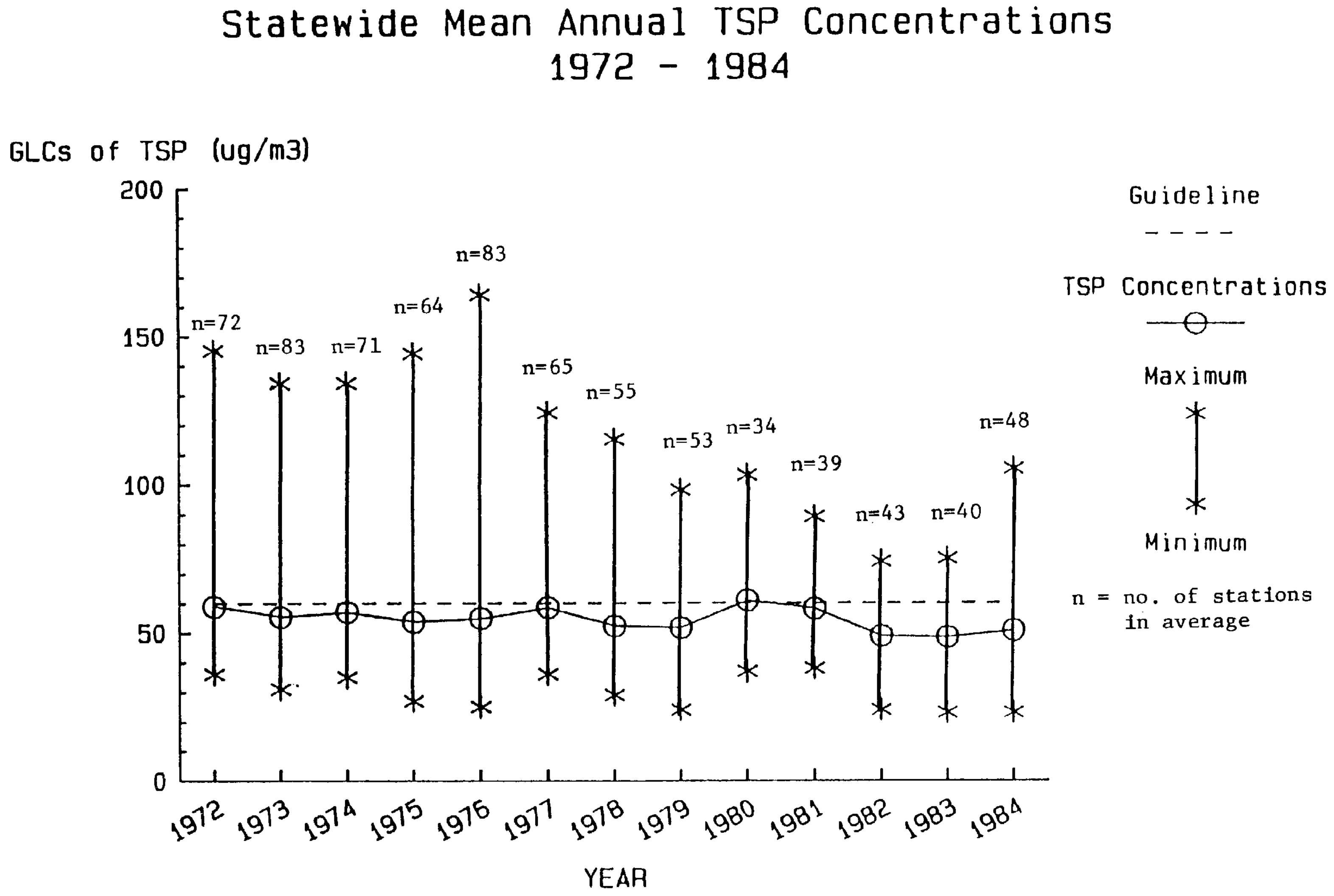


Figure III-4. Composite arithmetic mean of the annual geometric mean TSP ground-level concentrations for all Maryland stations with adequate data (at least 75% of the prescribed number of readings). Data from Refs. 22, 27, and 32-42.

Statewide Mean Annual SO2 Concentrations
1972 - 1984

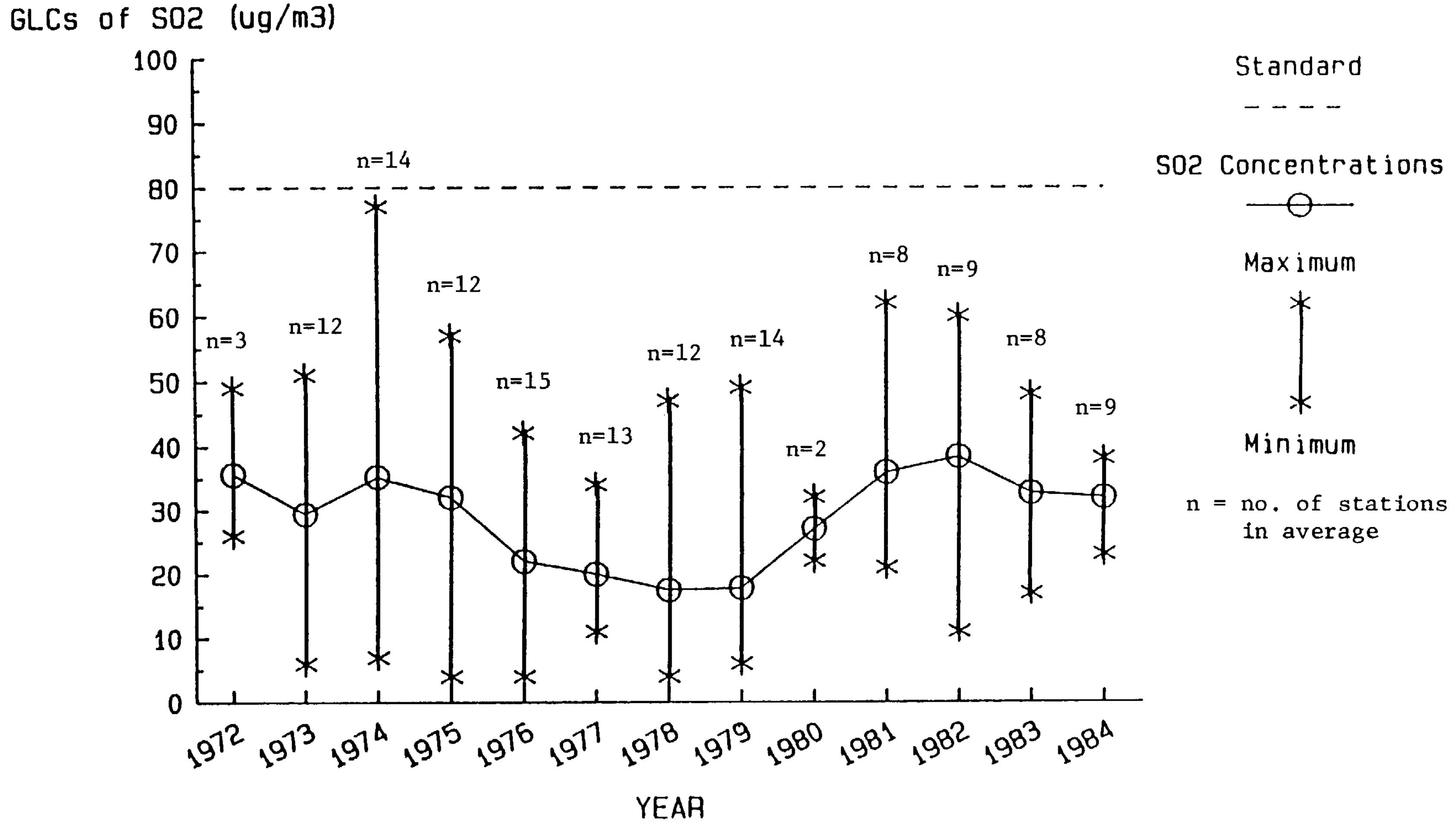


Figure III-5. Composite mean of annual average SO_2 ground-level concentrations for Maryland stations having data for the entire year. For informational purposes only; many stations have less than 75% of the prescribed number of readings. Measurements are by the flame photometric method (1972-1979) and by continuous/pulse fluorescence (1980-1984). Data from Refs. 22, 27, and 32-42.

Statewide Mean Annual NO2 Concentrations
1974 - 1984

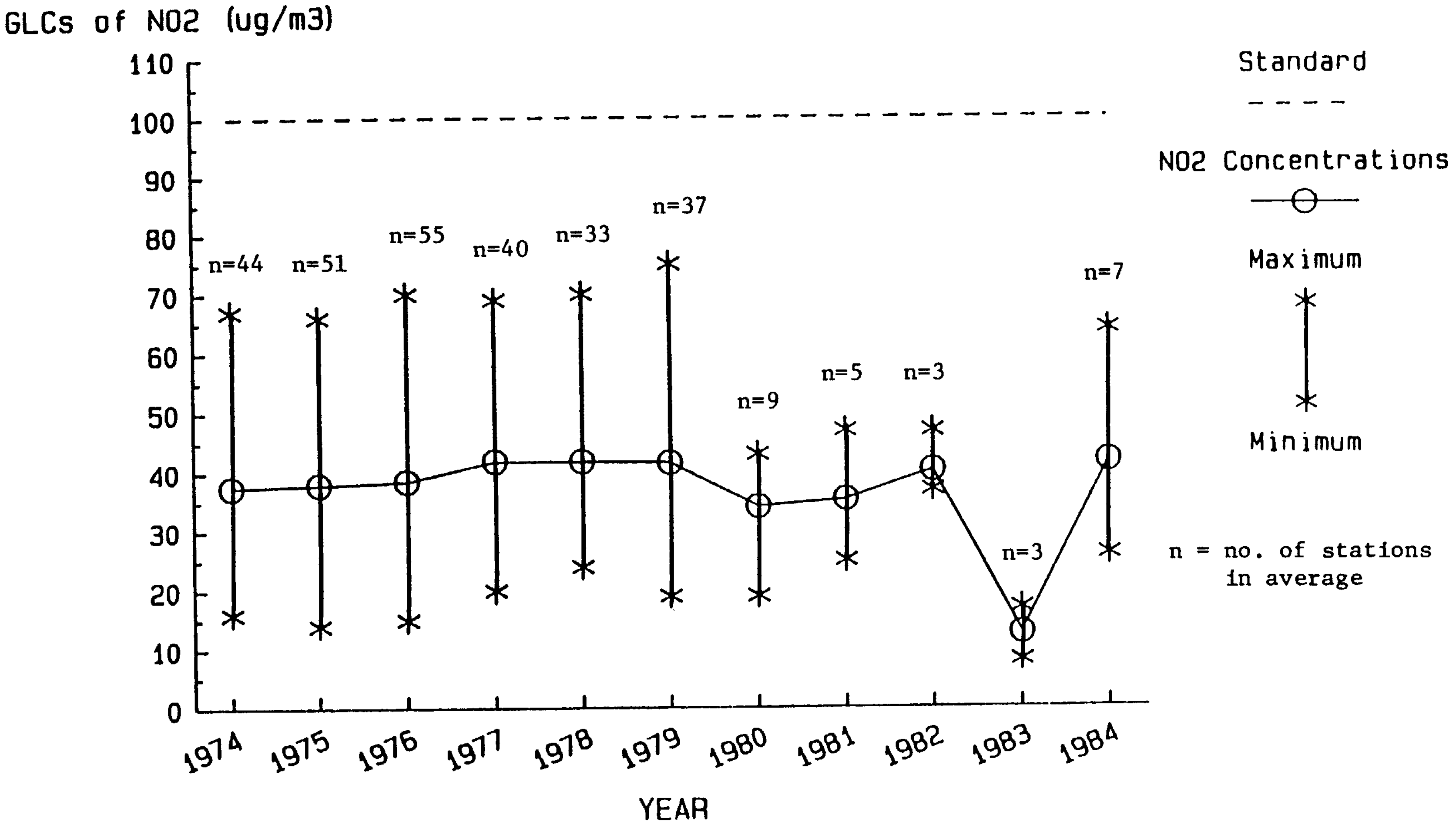


Figure III-6. Composite mean of annual average NO_2 ground-level concentrations for all Maryland stations with adequate data (at least 75% of the readings). Exception: in 1984 all stations were included in mean since no station had 75% or more of the readings. Data from Refs. 22, 27, and 32-42.

computed from three or fewer monitoring sites represent a true picture of statewide air quality, especially for the purpose of determining baseline air quality for computation of power plant impacts.

A list of the maximum measured ground-level concentrations from the utility monitoring programs during the period 1977-present is contained in Table III-6. Although these measurements represent the single highest concentrations during the seven years of record, only the TSP concentrations at the Brandon Shores Power Plant and the C.P. Crane Power Plants have been greater than the NAAQS. These plants are discussed in greater detail in Section G.

D. Modeling Results

The primary impetus for developing pollutant dispersion models is the need to predict the impacts of emissions on ambient air quality. These models are mathematical formulations that attempt to simulate pollutant dispersion in the atmosphere.

Dispersion models are routinely used, in a regulatory framework, to examine the air quality impact of power plants. For example, models are used in analyses concerned with:

- Impact assessment of existing, modified, or newly constructed power plant facilities (including assessment of fuel switching and emission control strategies)

- Evaluation of proposed power plant facilities

- Siting of ambient pollutant monitors near power plants.

The use of pollutant monitors would seem to be the logical choice for assessing the air quality impact of existing sources. However, due to the limitations in the spatial coverage of air quality measurements, it is considered unlikely that a typical monitoring program would detect the actual peak concentrations resulting from a power plant stack plume. Thus, EPA frequently requires that ambient monitoring data be supplemented with air quality modeling for demonstrating compliance of existing sources with ambient air quality standards.

For new sources, air quality models are the only method available for projecting future air quality. Typically, these models are run using plant design emissions and 1-5 years of meteorological data to project the highest or second-highest concentrations that would occur with the operation of a new facility. These projections are then used to develop licensing conditions which would ensure compliance with ambient air quality standards.

Table III-6. Comparison of ambient monitoring data and model predictions for four Maryland power plants

Plant and Pollutant	Maximum Concentration ($\mu g/m^3$)	
	Measured	Modeled
Brandon Shores		
TSP (24-hr)	278(a)	116(b)
C.P. Crane		
TSP (24-hr)	162(c)	148(d)
SO_2 (24-hr)	91(c)	209(e)
Dickerson		
SO_2 (24-hr)	240(f)	123(g)
SO_2 (3-hr)	889(h)	645(g)
Chalk Point		
TSP (24-hr)	115(i)	130(j)
SO_2 (24-hr)	147(k)	219(j)
SO_2 (annual)	26(l)	19(j)
SO_2 (3-hr)	328(l)	885(j)

(a) Data from Brandon Shores Fugitive Dust Survey report, 4th quarter 1984 (43). Only one unit operating.

(b) ISC model prediction from 1980 study by Enviroplan (44) assuming both units operating.

(c) Data from Crane Air Monitoring Results reports, 3rd quarter 1983, 4th quarter 1984 (45,46).

(d) ISC model prediction from 1980 study by Enviroplan (47).

(e) CRSTER model prediction from 1980 study by Martin Marietta (48).

(f) Data from Dickerson Area Atmospheric Survey report, 1st quarter 1978 (49). Flat terrain impact. Measurement results only from January 1977 through June 1979 (the on-line date of the tall stack) were reviewed.

(g) CRSTER model predictions from 1985 study by Martin Marietta (50) assuming 122-m stacks instead of actual 214-m stack. Flat terrain impact.

(h) Data from Dickerson Area Atmospheric Survey report, 2nd quarter 1977 (51). Measurement results only from January 1977 through June 1979 (the on-line date of the tall stack) were reviewed.

(i) Data from Chalk Point Air Quality Data report, 3rd quarter 1983 (52).

(j) CRSTER model predictions from 1977 study by Tera Corporation (53), modified for present sulfur content.

(k) Data from Chalk Point Atmospheric Survey Annual Summary, 1978 (54).

(l) Data from Chalk Point Atmospheric Survey Annual summary, 1980 (55).

Model Applicability and Accuracy

Accuracy and consistency in air quality modeling are necessary to provide air pollution control agencies, industry, and the public with a common basis for estimating air quality and assessing emission limitations. The EPA Office of Air Quality Planning and Standards (OAQPS) recognized this need and began devloping an air quality modeling guideline in late 1976. Based on opinions from EPA regional offices, the OAQPS prepared a draft which underwent scientific and public review and comment in mid-1977. The first Guideline on Air Quality Models was published in final form in April 1978 (56).

The EPA published proposed revisions to the Guideline on Air Quality Models in October 1980. Because of technical groups and user criticisms expressed at public hearings concerning the revisions, the guideline was never finalized. Based on public comments, internal EPA workshops, the cooperative agreement between EPA and the American Meteorological Society (AMS), model evaluations and peer reviews, and EPA research programs, the EPA once again published proposed revisions to the guideline in November 1984 (57). Until the 1984 guideline is finalized, the 1978 guideline (56) and the "Regional Workshops on Air Quality Modeling: A Summary Report" (58) will represent EPA policy concerning air quality modeling.

The proposed modeling guideline lists and describes the models that EPA currently considers acceptable for regulatory analyses. There are two levels of sophistication of regulatory dispersion models. The screening models are relatively simple estimation techniques that provide quick conservative estimates of "worst-case" air quality impact. If the screening technique indicates possible noncompliance with applicable air quality standards, a more detailed modeling analysis, using more refined modeling techniques, is required (57). The refined modeling techniques provide more detailed treatment of physical and chemical atmospheric processes, require more detailed input data (such as realistic meteorological data), and provide more specialized concentration estimates (57).

Specific models are appropriate for specific applications. For example, selection of the appropriate model for a source such as a power generating facility in Maryland generally depends on:

- Pollutant type
- Plant location (e.g., complex vs. simple terrain, proximity to land/water interface, urban vs. rural surroundings)
- Source configuration (e.g., multiple sources, controlled or uncontrolled emissions)
- Availability and representativeness of meteorological data used as input to the models.

Several refined modeling techniques are available. Table III-7 lists those EPA-approved models that are considered to be refined analytical techniques most likely to be used in air quality impact studies involving power plant sources. These models are strictly applicable to sources in relatively simple terrain. EPA has not formally proposed any refined analytical techniques for complex terrain applications (57).

Table III-7. EPA-approved models for simple terrain applications (58)

Power Plant Source	Land Use	Preferred Model for Simple Terrain (short-term/long-term)
Single source	rural	CRSTER/CRSTER[a]
	urban	RAM/RAM[b]
Multiple source	rural	MPTER/MPTER[c]
	urban	RAM/CDMQC[d]
Complicated sources[f]	rural	ISCST/ISCLT[e]
	urban	ISCST/ISCLT

[a] Single source (CRaSh TERrain) model.

[b] Gaussian-plume multiple source air quality algorithm (Real-time Air quality simulation Model).

[c] Multiple Point Gaussian dispersion algorithm with TERrain adjustment.

[d] Climatological Dispersion Model.

[e] Industrial Source Complex model.

[f] Controlled or uncontrolled point, area or volume sources that may be affected by building downwash or require estimates of particle settling, etc.

Based on the EPA evaluation of eight complex terrain models (59), EPA is planning to recommend that the Rough Terrain Dispersion Model (RTDM), developed by Environmental Research and Technology, Inc., be considered a third-level screening model for complex terrain situations (60). Currently, the EPA recommends the use of the Valley model and COMPLEX I model as first-level and second-level complex terrain screening models, respectively (60).

To evaluate the accuracy of air quality models for simple terrain applications, several studies have been conducted (61-65). These studies indicate that:

- Highest hourly model predictions exhibit little-to-no correlation with observed concentrations for the same time and location (paired in space and time) (66)
- Regulatory models show some ability to predict the maximum concentrations and the frequency of occurrence of the maxima, but they are unable to predict where or when these maxima will occur (66)
- A review of eight rural, simple terrain models revealed that 50 percent of the models indicate an average accuracy within a factor of 2 when the highest 1-hr observed and predicted concentrations, unpaired in space and time, are compared (67).
- Uncertainties in the knowledge of the precise location of the plume account for significant concentration prediction errors (57). Evaluations performed by PPSP (68) indicate that model predictions degrade when wind direction information is used to define the average plume axis. In fact, the correlation between simultaneous and coincident observed and predicted concentrations is near zero.

Figure III-7, taken from Tikvart and Cox (67), illustrates results from a typical model evaluation. For this evaluation, the 25 highest observed and predicted 1-hr concentrations, unpaired in space and time, were examined. The highest concentration grouping was selected since these values are of most interest from a regulatory perspective. The closer a model is to the center of the figure, the more closely it duplicates the observations. Values to the lower left of center imply model overprediction, while values to the top right imply underprediction. About half of the models are accurate to within a factor of 2.

Table III-6 presents a comparison of available model predictions of ground-level pollutant concentrations and measured concentrations around four Maryland power plants (Brandon Shores, Chalk Point, Crane, and Dickerson). The measurements are the maximum values observed during the period 1977-1985, thus approximating "worst-case" conditions near these plants. The predictions are the maximum projected ground-level concentrations obtained from various regulatory modeling studies. These studies often utilized off-site meteorological data from time periods different from the period of measurement, and assumed estimated background values which are not necessarily representative of current actual conditions at the monitoring stations. Thus, the predictions and measurements are not paired in either time or space. These

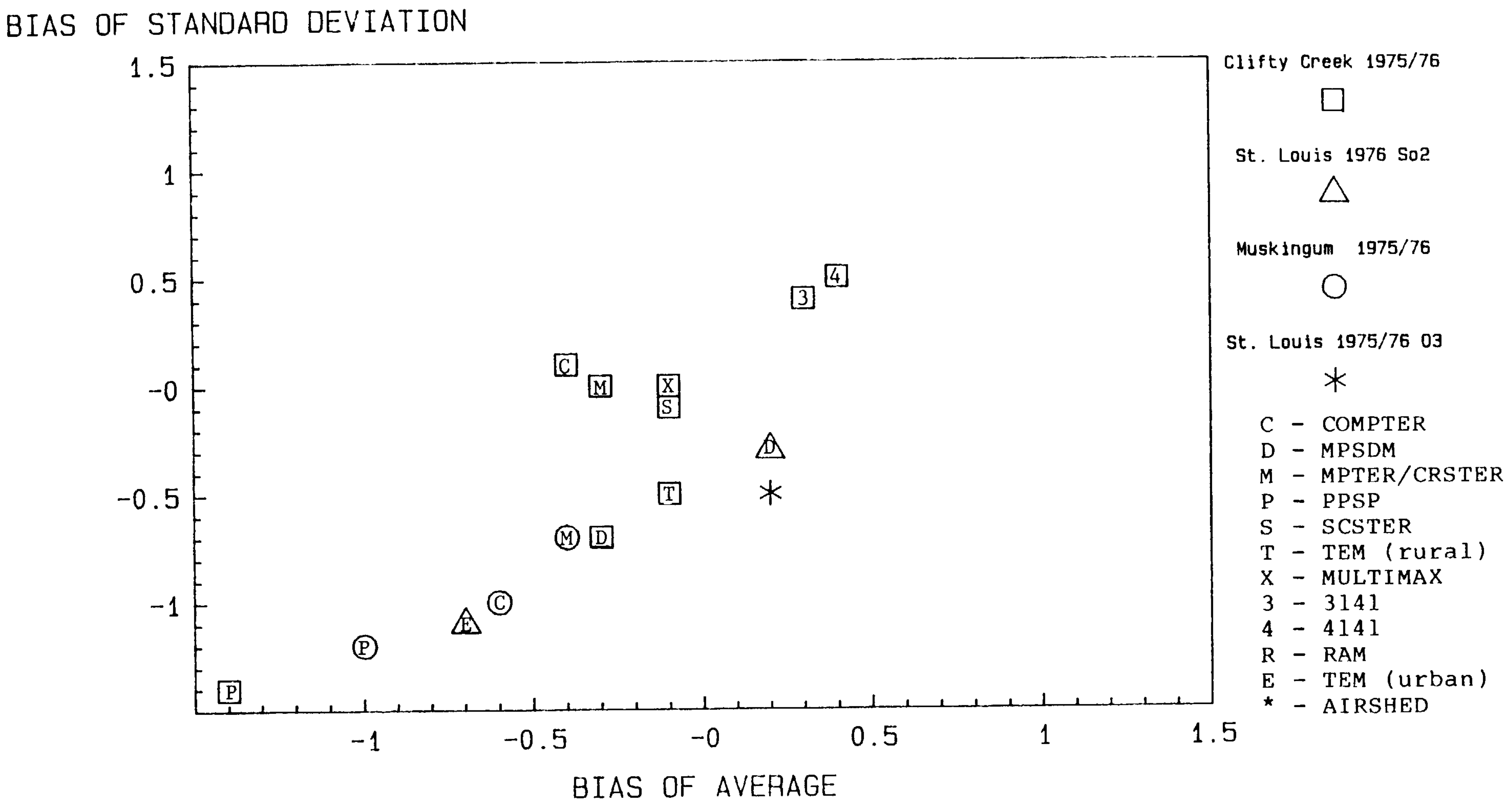


Figure III-7. Fractional biases for the 25 highest 1-hr observed and predicted concentrations (unpaired in space and time) results indicate that about two-thirds of these projections are within a factor of 2 of the measurements. Although this comparison is not meant to provide a rigorous evaluation of the models, it does provide an indication of their ability to project the future worst-case events used in developing licensing conditions.

Many air quality models now used to model elevated sources in rural, simple terrain do not reflect the current scientific understanding of the dispersion process. This concern was considered in the development of an air quality model for tall stack releases produced for the Power Plant Siting Program (PPSP) of the Maryland Department of Natural Resources (69,70). Since the 1970s, PPSP has sponsored the development of an air quality model that incorporates the latest in scientific understanding of the plume dispersion process. The model is intended for sources in flat or gently rolling terrain, and applies to tall stack plumes during convective (or unstable) atmospheric conditions, when such plumes usually yield their highest concentrations on flat terrain. The PPSP model uses methods that are in line with contemporary understanding of turbulence and diffusion in the planetary boundary layer for: estimating atmospheric stability and dispersion, predicting buoyant plume rise, and treating plume penetration (including partial penetration) of the elevated stable layer. Evaluation of the PPSP model with a set of ground-level SO_2 measurements downwind of Maryland power plant stacks showed that it performs much better than the CRSTER model under convective atmospheric conditions (70).

In April 1982, the PPSP model was submitted to EPA for review. The modeling support section of the Source-Receptor Analysis Branch of EPA evaluated the model using data from the Clifty Creek Power Plant in Indiana and the Muskingum River Power Plant in Ohio. The EPA evaluation revealed that the PPSP model performance was not superior to that of other newly submitted or standard models for these data sets (67). Comparisons between actual SO_2 measurements and model predictions revealed relatively poor agreement; the PPSP model consistently overpredicted by factors of 2-3.

At present, the PPSP model is not fully approved by the EPA. However, it is specified in the proposed EPA modeling guidelines as an alternative air quality model to be used on a case-by-case basis, subject to the approval of EPA. Efforts are continuing to evaluate and improve the PPSP model. These are briefly described in Section H, Research.

E. Regulatory Considerations

Air quality regulations are written by governmental bodies to control emissions and ambient air concentrations of pollutants that may adversely affect human health, crops, livestock, and other natural resources. Power plant owners and operators must conform to these regulatory requirements, both in the day-to-day operations of existing plants and in the design and obtaining permits to operate new plants. Thus, an understanding of regulations and associated issues is essential to the assessment of power plant operations and their impact on air quality.

Federal regulations under the Clean Air Act and Maryland state regulations that affect power plants fall into five categories: emission standards, ambient air quality standards (also discussed in Section B), visibility issues, Prevention of Significant Deterioration Regulations, and New Source Performance Standards (NSPS). The regulations governing ambient air quality apply equally to all sources, new and existing. The new source review programs apply to all proposed new sources and to certain modifications to existing sources. National Emission Standards for Hazardous Air Pollutants (NESHAP) have also been established, but they do not apply directly to power plant stack emissions. Under new source review provisions, power plants are required to conduct monitoring and BACT review for NESHAP pollutants emitted in amounts greater than the regulatory minimum. However, no emission standards for these pollutants have been specified for power plants. Finally, the NSPS program affects specific new sources, including fossil fuel fired utility boilers, diesel generators, and gas turbines. Basic provisions, recent changes, and proposed changes in these programs are described in the following sections.

Proposed PM_{10} National Ambient Air Quality Standard

The most significant regulatory development for power plants since the last CEIR is the proposed NAAQS for fine particulate matter (PM_{10}) (71,72). Concern about the health effects of fine particles prompted EPA's proposal of ambient air quality standards for PM_{10} in 1984 (71). Fine particles are more easily inhaled than large ones and have a longer residence time in the respiratory system. Also, fine particles, especially those less than 2μm in diameter, have been found to contain higher concentrations of toxic substances (especially metals) than coarser particles (e.g., 73).

The proposed revision to the NAAQS for particulate matter includes standards for both TSP and PM_{10}. The proposed ambient standards for PM_{10} and the associated new source review regulations (see below) will affect both existing and future power plants. Since the regulations have not been promulgated, and since the levels for the new standards are to be selected from proposed ranges, it is not possible at this time to determine the full impact of these regulations on power plants in Maryland.

It is likely, based upon the inhalable particulate data collected at the Canton and Fairfield monitors thus far, that existing air quality levels for PM_{10} at those sites do not exceed the low end of the proposed range of the PM_{10} standards. TSP levels elsewhere in Maryland are also low enough to indicate probable compliance with the revised PM_{10} and TSP standards. The Maryland Air Management Administration therefore plans to apply for redesignation of the affected areas to attainment once the PM_{10} standards are promulgated in final form (74). In most cases, power plant activities will probably not be further limited by the new NAAQS for PM_{10}.

Visibility Issues

The issue of visibility degradation or impairment has been a growing concern over the last several years throughout the United States, particularly in areas of important or unique scenic quality. Various environmental protection groups previously filed suit against EPA to force the agency to develop regulations designed to control visibility degradation. As a result, a settlement agreement was reached in 1984 which requires detailed visibility protection plans in 35 states across the country. Each targeted state is required to develop a State Implementation Plan (SIP) to control or reverse visibility degradation, mainly through tighter controls on new or newly modified emissions sources. Although Maryland is not listed among the 35 states and therefore is not required to submit a SIP for visibility, both Virginia and West Virginia are affected by the settlement agreement, and any effort they make to halt or reverse visibility degradation could have a positive impact on air quality in Maryland. The visibility requirements could also influence the issuing of permits for new or modified Maryland power plants that are close to the borders of affected states (for example, Dickerson).

New Source Review to Satisfy PDS Requirements

The most recently revised and updated Prevention of Significant Deterioration (PSD) regulations were promulgated in August 1980. These regulations limit increases in ground-level concentrations of TSP and SO_2 by establishing "increments" or maximum allowable increases above a baseline concentration (functionally the ambient air pollutant levels in 1977) for different areas throughout the United States. They also require review for all other pollutants regulated under the Clean Air Act if they are emitted in significant amounts. These regulations are one important means by which allowable operating conditions including maximum capacity, stack height, fuel sulfur content, and pollution control equipment are determined for power plants.

Any new source or modification located in an attainment area whose emission rate is large enough to qualify it as "major" must obtain a PSD permit prior to construction. Most Maryland power plants are large enough to be classified as major stationary sources, although current regulations apply only to construction and modifications occurring after 7 August 1977. The PSD review process requires three analyses:

- Best Available Control Technology (BACT) must be applied for all pollutants emitted in significant amounts (i.e., amounts in excess of EPA-specified "de minimis" values). BACT is determined on a case-by-case basis, taking into account economic and energy impacts as well as environmental benefits. The appropriate type of pollution control is selected based on these requirements--for example, a baghouse or a precipitator is used for particulate emissions and a scrubber or low-sulfur fuel is used for SO_2 emissions.

- Air quality modeling must be conducted to show that: 1) emissions from the new source or emissions increases from the modification will not result in exceedances of applicable PSD increments, 2) total allowable increases in ground-level pollutant concentrations occurring after the baseline date--the submittal date of the first complete PSD permit application after 7 August 1977--will not exceed the increment, and 3) total emissions from the affected facility will not cause or contribute to violations of ambient air quality standards.

Increments have been established only for SO_2 and TSP, but have been proposed for PM_{10}. The requirement that increments and ambient air quality standards be preserved may place limits on the maximum level of operation for a power plant.

- Up to a year of preconstruction ambient air quality monitoring is generally required for pollutants for which projected increases in ambient concentrations are greater than specified monitoring "de minimis" concentrations.

Two significant changes in the PSD review process have been proposed since 1982. These are: 1) changes in the use of a "Good Engineering Practice" (GEP) formula to determine the allowable stack height to be used in computing the PSD increment consumed by a project, and 2) the proposed addition of review requirements for PM_{10} emissions.

- Stack Height Regulations

  EPA is required by the Clean Air Act to set stack height regulations consistent with GEP (75). GEP stack height is the height needed to ensure that excessive pollutant concentrations near the source will not occur due to plume downwash caused by nearby buildings or terrain. In general, GEP height is defined as the greater of 65m or 2.5 times the height of nearby structures.

  EPA promulgated regulations in February 1982 that defined how GEP could be calculated and ways in which it could be adjusted depending on the effects of nearby terrain. Several provisions of these regulations were successfully challenged. Specifically, those provisions that allowed the use of stack heights in excess of GEP to facilitate dispersion and the location of sources in areas of complex terrain were remanded to EPA for revision by the U.S. Court of Appeals. The Court ruled that the 1977 Clean Air Act did not permit EPA to develop stack height regulations with such an allowance, and that plume impaction on elevated terrain downwind of the stack could not be used to justify stack heights in excess of GEP, although downwash effects due to elevated terrain could still be considered under some conditions.

  New regulations were proposed on November 9, 1984 (77) and promulgated in final form on July 8, 1985 (78). These restated the previous formulas for computing GEP but required physical modeling of some stacks taller than 65m. The regulations apply to all stacks constructed after 1970. The change in stack height regulations potentially affects several Maryland power plants, including Brandon Shores, Dickerson, and Chalk Point. Recently approved stacks in excess of 65m are exempt from the new GEP regulations if the source is proven to have relied on the July 1985 EPA-specified GEP stack height formula in determining stack design.

  As a result of the new stack height regulations, units at two existing power plants--Chalk Point Unit 3 and Brandon Shores (all units)--require modeling to ensure compliance with PSD or NAAQS regulations. The other power plants that could have been impacted are now exempt from review.

For example, the Dickerson plant is exempt, although having a stack taller than GEP and built after 1970. The emission limitations for Dickerson, as set in the Maryland SIP, were established by modeling emissions from the original 122m stack height. Chalk Point Units 1 and 2 are similarly exempt from GEP review because their emission limits were based on emissions modeled from the grandfathered 122m stack that originally served both units. The NSPS emission limitations applicable to Chalk Point Unit 4 were established without regard to stack height or other dispersion techniques and are also exempt from GEP review.

Although the Dickerson plant is currently exempt from GEP review, the new regulations may affect it in the future. Before the 1970s, when the 214m stack was installed, Units 1, 2, and 3 had been served by two 122m stacks, each of which exceeded the 93.6m GEP figure. These stacks were grandfatheredl because of their construction date. Their air streams were merged into a new single 214m stack, 120m in excess of GEP.

The current GEP regulations allow for merging air streams on successful demonstration that PEPCO had to do so for engineering or economic reasons. When Dickerson is next modeled in the context of any regulatory review or proceeding, PEPCO will probably need to provide such a demonstration.

- PM_{10} Review Requirements

Regulations proposed in 1985 (72) would implement new source review requirements for PM_{10} emissions from all new and modified sources. Although these regulations may be changed before promulgation, initial indications suggest the following implications of particular relevance to Maryland power plants:

- Power plant construction would be subject to PSD review for PM_{10} if increases in PM_{10} emissions resulting from the project are greater than 15 ton/year.

- Sources subject to PSD review for PM_{10} would be subject to BACT for PM_{10}.

- For sources emitting predominantly small particles, the PSD increment for PM_{10} would be more restrictive such as sources controlled by fabric filters and electrostatic precipitators, than the PSD increment for TSP. For other sources (such as dust from coal piles, flyash operations, or other on-site activities), the existing TSP increment would generally be more restrictive.

- Modeling required for PSD review of ground-level concentrations of PM_{10} would be difficult because emission factors are not well known, particularly for fugitive emissions.

- Preapplication monitoring of PM_{10} would be required for sources having a projected 24-hr average PM_{10} impact above or equal to 10 $\mu g/m^3$. The de minimis ambient air concentrations for preapplication monitoring of TSP would remain the same (10 $\mu g/m^3$, 24-hr average).

These conclusions assume that the regulations for TSP and PM_{10} are promulgated as proposed. Because these regulations may impose requirements on all proposed power plant construction, it will be important to analyze the regulations in detail once they are promulgated.

- Best Available Control Technology

In general, emission control systems are applied for two principal pollutants: SO_2 and particulates. The use of control systems for NO_x is a relatively new development.

Relatively minor changes have occurred since the last CEIR in the status of pollution controls at power plants in Maryland. The changes in Maryland, as well as across the country, include shifts from precipitators to baghouses because baghouse technology for use with coal boilers has advanced. For example, at the C.P. Crane plant in Baltimore County, baghouses were added when the steam units were converted from oil to coal firing.

Because of recent changes in the environmental regulations and the strict BACT review requirements, one might expect future trends toward pollution control at power plants to include increased emphasis on repair and maintenance of the control equipment, increased monitoring, and increased emphasis on control of fluorides and particulates below 10 m.

New Source Performance Standards

Development of New Source Performance Standards (NSPS) for various types of emitting sources was mandated by Section 111 of the Clean Air Act. These standards are intended to reduce emissions nationwide by ensuring that all new plants and industrial equipment are designed to meet certain minimal emission control standards. The applicability of NSPS is usually determined by date of construction and by a size or capacity criterion. For example, the SO_2 NSPS for electric utility steam generating units (80) apply only to equipment built or substantially modified after September 18, 1978 and having a heat input capacity greater than 250 MMBtu/hr. NSPS generally contain limits on emissions of NO_x, SO_2, and TSP from new and modified sources.

The sulfur dioxide NSPS for electric utility steam generating units larger than 250 MMBtu/hr heat input provide both a maximum emissions limitation and a percentage reduction requirement on potential SO_2 emissions that would otherwise escape if the plant operated without emission controls. Effectively this requires flue gas desulfurization systems on all new major emissions sources, with required removal efficiencies generally between 70 and 90 percent, depending on fuel sulfur content.

For solid fuels, the NSPS restricts SO_2 emissions to a maximum rate of 1.2 lb SO_2/MMBtu and requires 90% SO_2 removal from emissions stream down to a base rate of 0.6 lb SO_2/MMBtu. Below this rate, the percent removal requirement drops to 70%. This means that a new coal-fired power plant in Maryland, burning coal with a heating value of 12,000 Btu/lb and a sulfur content of about 3.6 percent, would require a 90% efficient scrubber and would have an emissions rate of about 0.6 lb SO_2/MMBtu.

For plants using extremely high-sulfur coal, reductions greater than 90% could be required to achieve the absolute emission limit of 1.2 lb SO_2/MMBtu. Additionally, for an intermediate range of sulfur coal, the scrubbing requirement can vary between 70 and 90 percent. For low sulfur coal, the base emissions control is 0.6 lb SO_2/MMBtu and 70% removal.

Standards have also been proposed for industrial-commercial-institutional steam generating units ranging in capacity from 100 to 250 MMBtu/hr (81). It is EPA's intent that these standards apply to both utility and non-utility sources. Although no Maryland utility has indicated plans to construct any steam units in this size range, auxiliary boilers (for heat, steam tracing, etc.) might be affected.

NSPS also exist for emissions of NO_x and SO_2 from stationary gas turbines with a heat input at peak load equal to or greater than 10.7 gigajoule/hr (about 3 MW) (82). NSPS have been proposed (83) for NO_x emissions from stationary large-bore diesel engines, which, like gas turbines, are used by some Maryland utilities as peaking units. The proposed limit of 600 ppm NO_x has raised many objections from diesel manufacturers. The standard has not yet been promulgated, nor has any date been set for final action (84).

F. Impacts of Coal Combustion

As discussed in the previous CEIR, virtually all Maryland power plants were coal-fired during the 1960s, but many were converted to oil in the early 1970s to comply with stringent new emission limitations and to take advantage of the lower cost of oil. When the oil supply shrank and prices rose in the mid-1970s, coal regained popularity, as evidenced by the construction of new coal-fired units, as well as the conversion of oil-fired units to coal and reduced usage or retirement of older oil-fired units.

There have been two major recent increases in coal use in Maryland. One is the 1983 conversion of the C.P. Crane plant (two boilers each having a capacity of 191 MW) from oil to coal firing; the other is the 1984 start-up of Unit 1 (620 MW) of the coal-fired Brandon Shores plant in Anne Arundel County. These changes have increased the total coal-fired boiler capacity from 2,795 MW (39% of 7,231 MW total capacity in Maryland) in 1983 to 3,797 MW (46% of 8,178 MW total capacity in Maryland) in mid-1985.

C.P. Crane Coal Conversion

In mid-1983, the C.P. Crane power plant was converted from oil to coal firing, as required by the Federal Energy Administration under the Federal Energy Supply and Environmental Coordination Act of 1974. Because it was mandatory, the conversion was exempt from review under the Federal PSD program. Preconversion modeling had indicated that there would be increases in ambient TSP concentrations at some locations. The Public Service Commission proceeding concerning the potential impacts of coal use on ambient air quality led to a requirement for both pre and post-construction monitoring for SO_2 and TSP in the vicinity of the plant (85).

The results of monitoring for SO_2 through 1984 have shown no exceedances of any applicable ambient air quality standard. Two TSP values slightly higher than the secondary 24-hr NAAQS of 150 $\mu g/m^3$ were observed on plant property during the first quarter following the coal conversion, but they may have resulted from construction and/or some other abnormal activities going on at the time (86). No exceedances have been observed since plant operation has stabilized. However, as expected, ambient levels appear somewhat higher in the postconversion period than they were in the preconversion period. At the four monitoring sites just inside the fenced portion of the property (note hat the NAAQS do not apply within fenced plant boundaries), the annual average TSP levels were between 4 and 7 $\mu g/m^3$ higher in 1984 than in 1982 (86). Modeling performed by Enviroplan (87) projected similar values for the maximum increase in annual average ambient air quality due to fugitive dust impacts from the coal handling facilities: between 4.1 and 5.7 $\mu g/m^3$ for the 5 years modeled. However, the annual average TSP level measured at a monitoring site distant from the plant boundaries, which would not be heavily impacted by fugitive dust from C.P. Crane, also increased by 7 $\mu g/m^3$, indicating that the agreement between the modeled and measured results may be only apparent and may be due to changes in non-power plant sources.

The Enviroplan report does not furnish maximum expected 24-hr TSP increment consumption for the coal conversion. The report indicates that the maximum impact of the fugitive dust sources is less than the maximum 24-hour PSD increment consumption allowed by regulations, i.e., less than 37$\mu g/m^3$ not to be exceeded more than once per year. In at least one case, the plant impact exceeded this amount considerably (88). Optical microscopy analysis of the TSP filter indicated that, on October 21, 1983, the C.P. Crane contribution to TSP at the settling basin site south of the plant was about twice that allowed. Further modeling and measurement analysis is underway to determine whether or not the exceedance was an isolated event that occurred during start-up of the coal facility, and whether the modeling approach used is appropriate for describing the short-term impacts of fugitive dust emissions at C.P. Crane.

Brandon Shores Start-up

Unit 1 of the new 620 MW coal-fired Brandon Shores plant was brought on-line in April 1984. Ambient monitoring at this plant is done for particulates only. Both preconstruction and post construction monitoring at locations on or near the plant site indicated air quality concentrations for TSP above the secondary 24-hr NAAQS of 150 $\mu g/m^3$ and primary standard of 260 $\mu g/m^3$ (89). TSP concentrations up to 484$\mu g/m^3$ were measured prior to plant operation. Since plant start-up, the highest measured value was 278 $\mu g/m^3$. Many of the high values measured on-site to date were related to blowing dust during plant construction of Unit 1 prior to operation and the continuing construction at Unit 2. The annual average concentrations of TSP measured on-site have decreased 3-7 $\mu g/m^3$ since the start of plant operations while off-site concentrations have increased by 3-9 $\mu g/m^3$. Monitoring is continuing at this site.

Emission Factors

Research is continuing to better define the emission factors and determine the impact of variables on emission factors. Topics of particular interest include emissions of trace metals and toxics, emissions of particles smaller than 10 m in diameter, fugitive emission factors, analytical methods used to quantify trace metals and toxics, and instrumentation to measure emissions.

As part of the PPSP program, studies (73) were conducted to summarize available information on emissions from the Maryland power plants of trace metals and toxics and emissions of particles less than 10 μm in diameter. Preliminary results of these studies indicate that: 1) emissions of toxic organics and trace elements (except for fluorides) are of negligible importance from a regulatory standpoint if ground-level concentrations are considered, and 2) the major emission sources of particles less than 10 μm are the boiler stacks.

A study was conducted to determine particulate emission factors from a rotary coal car dumper and from the shed in which the dumper was operating by measuring particle concentrations, wind speeds, and coal characteristics. Emission factors were determined to be much less than previously expected--0.01 lb emitted per ton dumped for the particles existing from the rotary car dumper shed and 0.03 lb/ton for the rotary car dumper itself--as compared to a typical literature value of 0.4 lb/ton as used in fugitive dust modeling for C.P. Crane (87). The difference between the two measured values represents the particles that settled in the shed without escaping through the shed doors. The emission factors at both places were found to vary significantly with coal moisture content (90).

Studies were initiated at the Morgantown SES to determine the ambient levels of fugitive dust sources at coal-burning facilities. Two of these show promise. The first (91) is the use of sophisticated statistical methods to determine the average contributions of potential sources to ambient particulate levels using existing meteorological and TSP data. Preliminary results obtained from 1 year of TSP data collected at four sites at the periphery of the plant indicate that the method could be used to ascertain whether or not sources were significant. The second (92) is the use of a continuous optical particle counter and wind sensor to simultaneously determine particulate concentrations and wind direction. The results of a 3-week study indicate that the method can be used for identifying periods of high ambient TSP and/or PM_{10} levels and determining the directions of the sources contributing to those levels. Preliminary results from these studies indicate that a number of power plant sources contribute to elevated ambient TSP levels at Morgantown. These sources include flyash loading and transporting activities, the coal pile, the bulldozer yard, and road traffic. Considerable dust was also observed to emanate from the direction of an off-plant truck stop. Further study, using statistical analysis of the existing TSP and meteorological data, is continuing in order to better account for dispersion of the dust, determine the limitations of the statistical methods, and obtain average source strengths for those sources contributing significantly to the TSP.

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CHAPTER IV

AQUATIC IMPACT

Generation of electricity is closely associated with rivers, lakes, and estuaries. They serve as sources of cooling water, receiving bodies for effluents, and sites for hydroelectric generation. Power generation activities can affect the aquatic environment in several ways.

A steam power plant using fossil fuel must reject about 4,400 Btu of excess heat via its condenser for each kilowatt-hour of electricity generated (for a nuclear power plant the figure is about 6,600 Btu/kWh). Most Maryland steam power plants use once-through cooling sysems to transport this excess heat from the condensers to the environment[1]. In these systems, "new" water is continuously drawn into the plant from a source water body, heated 5 to 17°C as it passes the condenser, and discharged into a receiving water body. Approximately one million gallons of water per minute (or 63 m^3/s) is required for each 1,000 MWe of generating capacity with once-through cooling. Closed-cycle cooling, which is used at a few Maryland power plants, "recycles" condenser cooling water through a cooling tower. Facilities with closed-cycle cooling use adjacent water bodies as a source of makeup water for evaporative losses and to clean internal parts of cooling tower structures. Water requirements for closed-cycle systems are 2 to 25 percent of those for once-through systems.

Hydroelectric power plants generally utilize the potential energy of impounded water to generate electricity. Water quality modifications to impoundments and downstream habitats may result from construction, filling, and operation of dams associated with hydroelectric power generation. Change to the physical characteristics of upstream and downstream habitats, and alterations to migration patterns of anadromous fish are other environmental alterations associated with hydroelectric generation.

The Chesapeake Bay and its tributaries serve as the major source of cooling water for electric generation in Maryland and are also receiving water bodies for power plant effluents. The Bay is one of the largest and most productive estuaries in the world, supporting a complex food web that produces large quantities of fish and shellfish (1,2). The Bay's food web consists of both direct and indirect pathways. In the direct pathway, microscopic algae, called phytoplankton, provide food for small animals, called zooplankton, which are in turn eaten by forage fish, such as anchovies and menhaden. Anchovies and menhaden are food for large fish, like white perch, striped bass, and bluefish. Dead and decaying organic matter (called detritus) derived from aquatic plants (marsh grasses, submerged aquatic vegetation, and phytoplankton) form the base at the food web in the indirect pathway. Detritus, and the micro- organisms that decompose it, are eaten by biota that live on the bottom (called benthic organisms). Benthic organisms, in turn, are eaten by fish and

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[1] The reader is directed to the Frontispiece (pg ii) for a map showing the location of plants in Maryland.

crabs. The existence of both direct and indirect food web pathways promote resilience of aquatic communities by allowing organisms to switch food sources as resources become more or less available. The Bay's complex circulation patterns result in the retention of suspended sediments, detritus, and nutrients (3,4). The nutrients that are trapped promote high levels of productivity. Retention of detritus increases its availability to animals which use it as a food source.

Maryland's rivers and streams also support complex assemblages of organisms, comprising both direct and indirect food webs comparable to those found in the Chesapeake Bay.

A major goal of the Power Plant Siting Program (PPSP) is to ensure that steam and hydroelectric generating facilities provide electricity at a reasonable cost, while not interfering with the maintenance of sustained yields of natural resources and the stability of Maryland's aquatic ecosystems, particularly the Chesapeake Bay. To achieve this goal, PPSP has established the following objectives:

- To determine the factors (e.g., engineering, and operational) that influence the types and magnitudes of aquatic impacts caused by power plants and hydroelectric facilities and to evaluate the mechanisms by which these impacts are produced.

- To evaluate existing aquatic impacts and recommend appropriate measures to minimize or mitigate these impacts.

- To minimize future power plant impacts through planned siting and construction procedures, including identification and recommendation of engineering features that enhance environmental protection.

- To resolve multiple and conflicting concerns relating to electric power generation (e.g., socio-economics, generation needs, natural resource conservation, regulatory concerns) by proposing technically sound alternatives and by providing technical support for regulatory proceedings.

- To ensure that steam and hydroelectric facility operations do not interfere with other uses of Maryland's water bodies and the biotic resources they support.

- To determine and report cumulative impacts of power generation to the public and the state government on a periodic basis.

This chapter is the cumulative impact assessment for the aquatic environment called for in the above list of objectives. In the following sections, present activities are discussed in detail. Studies covered in earlier CEIRs are presented in summary form. For details of these earlier studies, readers should refer to previous CEIRs (5-8) or the original sources cited.

A. Sources and Nature of Impact

As water is drawn through a steam or hydroelectric power plant and returned to the receiving water body, aquatic biota may suffer mortality or injury due to interaction with plant structures or due to plant-related environmental alterations (9-16).[1] The location and nature of these interactions and the ensuing stresses encountered by aquatic biota are briefly described in Figures IV-1a and IV-1b. A detailed description of these interactions, and the stresses to aquatic biota associated with them, was presented in previous CEIRs (5-8). Individual groups of organisms may be more susceptible to damage by one type of interaction than by another as shown in Table IV-1.

Modes of Interaction for Steam Electric Stations

Environmental concerns for steam electric stations can be classified into four major categories: entrainment, entrapment,impingement, and discharge (and discharge (canal) effects.

- Entrainment

  Entrainment is the transport of water borne substances through the plant cooling system and auxiliary pumps. Aquatic biota drawn in with entrained water interact with intake structures, cooling system structures, intake and discharge velocity fields, heated effluents, and chemicals used to prevent biofouling. These interactions cause damage and death.

- Entrapment

  Entrapment is the accumulation of fish and crabs (brought in with cooling water flows) in the intake region. Entrapped biota may be exposed to water of low dissolved oxygen content that is sometimes drawn in with intake flows, resulting in death. In addition, entrapped organisms may become weak from prolonged swimming against intake flows and eventually die or become impinged.

- Impingement

  Impingement, is trapping of larger organisms on barriers protecting internal plant structures (e.g, intake screens or barrier nets). Physically damaged organisms are more susceptible to disease and may be less able to compete when returned to the receiving water body. The

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[1] Radiological effects are discussed in Chapter V.

Table IV-1. Major types of aquatic effects of steam electric and hydroelectric power plant operations.

Source of Effects	Primary Susceptible Organisms	Type of Stress: Low DO	Mechanical	Thermal	Chemical	Habitat Alteration
		STEAM ELECTRIC POWER PLANTS				
Entrainment	Phytoplankton(a)		X	X	X	
	Zooplankton(b)		X	X	X	
	Ichthyoplankton(c)		X	X	X	
	Adult and juvenile fish		X	X	X	
Entrapment	Adult and juvenile fish and crabs	X				
Impingement	Adult and juvenile fish and crabs		X	X (d)	X (d)	
Discharge	Benthos(e) Shellfish(e) Adult and juvenile fish(f)	X		X	X	X
		HYDROELECTRIC FACILITIES				
Creation of Impoundment	All biota	X				X
Entrainment	Adult and juvenile fish		X			
Discharge	Benthos	X				X
	Adult and juvenile fish(e)	X				X
	Ichthyoplankton(f)	X				X

(a) Minute plants present in the water.
(b) Weak swimming animals in the water.
(c) Eggs and larvae of fish.
(d) Only applicable for power plants where impinged biota are returned to the receiving water with discharge waters.
(e) Organisms living in or on the bottom, including shellfish.
(f) Discharge effects on mobile taxa, such as fish, crabs, or plankton, whose behavior and distributions may be strongly influenced by hydrodynamic conditions are extremely difficult to detect.

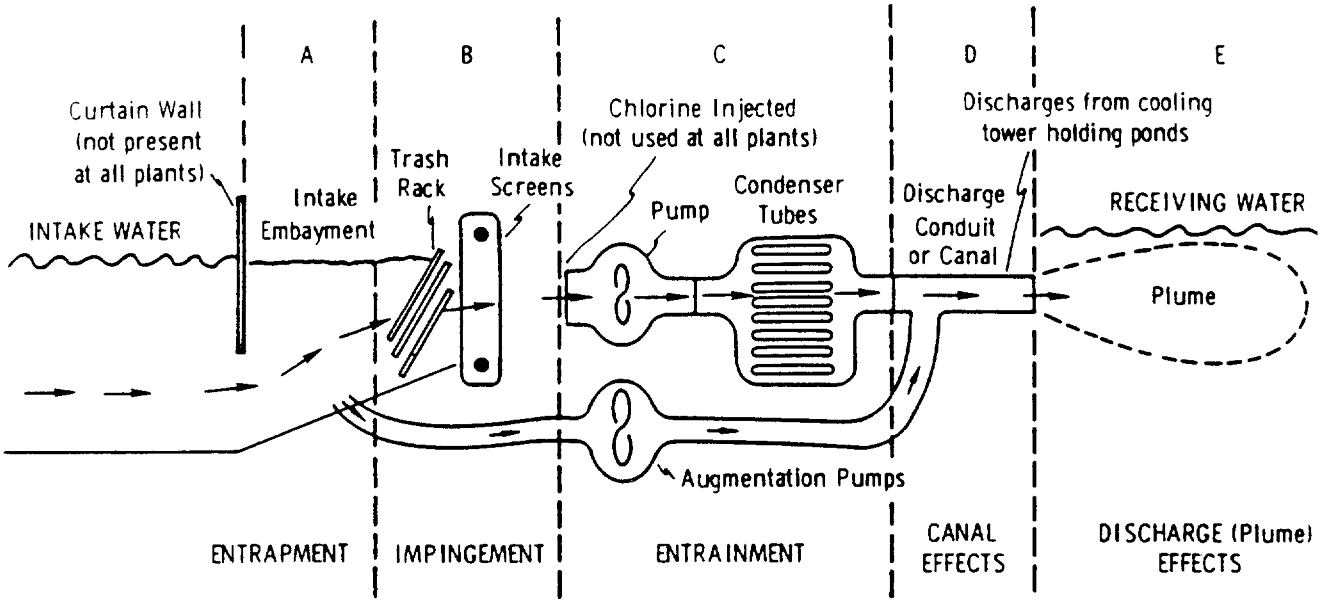

Figure IV-1a. Path of water flow through a power plant using once-through cooling and locations of plant-organism interactions.

A. Fish and crabs may accumulate and become entrapped in the intake embayment. During entrapment they may be exposed to water of low dissolved oxygen content that is sometimes drawn in with intake flows below a curtain wall (not present at all plants).

B. Organisms, mainly fish and crabs, too large to pass through intake screens may become trapped on them (i.e., are impinged). Intake screens are periodically rotated to wash off impinged organisms and return them to receiving water.

C. Organisms small enough to pass through intake screens (plankton) are drawn through the cooling system (i.e., are entrained). During entrainment, plankton experience a sudden temperature rise of from 5 to 17°C, shear and pressures forces, and many contact internal structures. At some plants entrained organisms are also exposed to lethal levels of chlorine and its residuals during warm months. Large organisms (fish and crabs) may also be entrained into unscreened augmentation pumps, which are present at one Maryland power plant. During auxiliary pump entrainment fish and crabs, experience mechanical damage from contact with internal pump structures.

D. Organisms surviving entrainment and impingement are exposed to continued excess temperatures and possibly to chlorine residuals during transit down the discharge conduit or canal enroute back to the receiving body.

E. Organisms in the receiving water may be exposed to elevated temperatures and potentially stressful chemical substances in the discharge plume. Currents associated with the discharge plume may cause habitat modifications through bottom scouring and changes in circulation patterns.

NOTE: Although fewer organisms are entrained by closed-cycle cooling systems, mortality is essentially 100 percent because residence time in cooling towers is high. Cooling towers discharge a portion of their cooling water on a regular basis; this water is known as blowdown. Blowdown may contain high levels of metals such as copper (from the cooling system pipes) and chemicals used to prevent fouling and scaling of internal structures. Fortunately, many of these pollutants are retained in sediments that accumulate in the bottom of tower structures. Concentrations of pollutants in blowdown may be from 5 to 200 times higher than those in effluents from a once-through cooling power plant. Due to evaporative losses, blowdown at estuarine plants have a much higher salinity than ambient water. Discharge effects of blowdown release are similar to those from a once-through cooling system, but because only small water volumes are involved, the affected area is small.

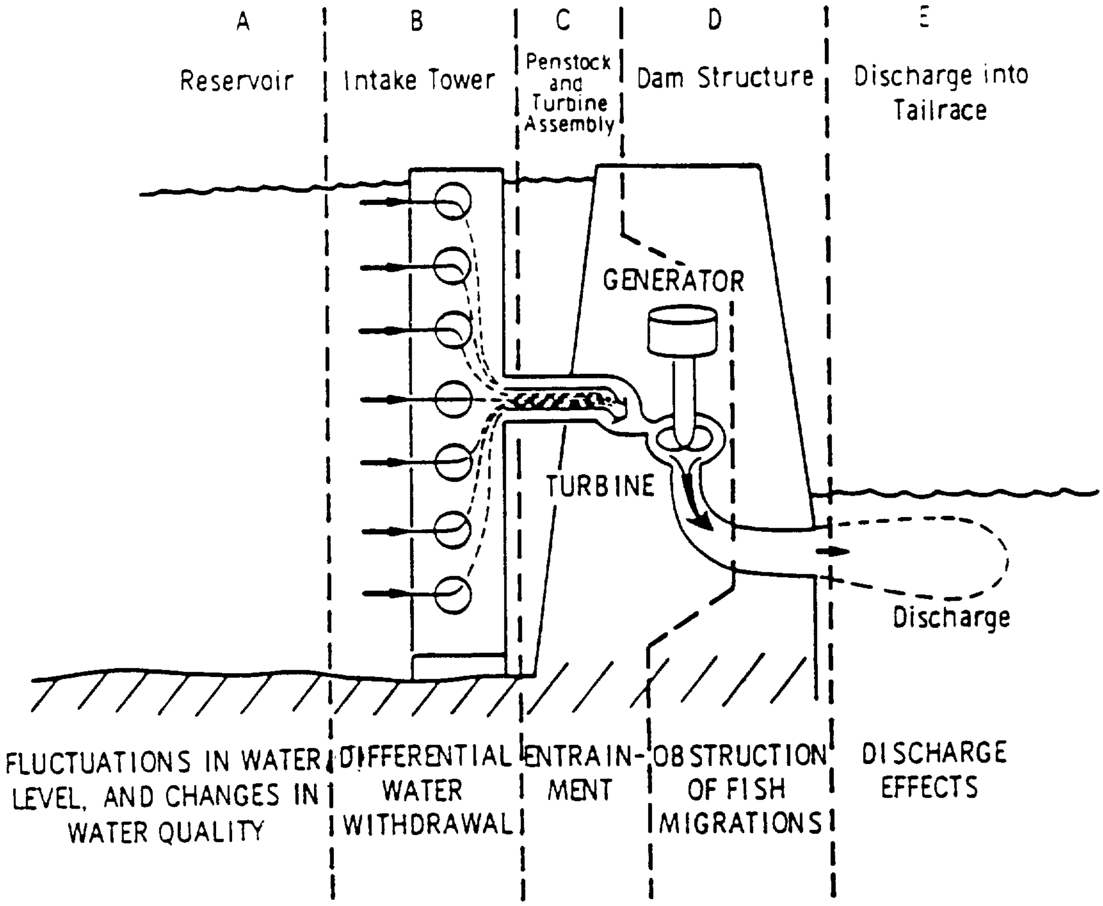

Figure IV-1b. Path of water flow through a hydroelectric power plant, and locations of plant-organism interactions.

A. Discontinuous (peaking) operation schedules cause fluctuations in water level and water quality within the reservoir.

B. The water quality (primarily dissolved oxygen levels and temperature) of both the reservoir and the water body downstream of the dam can be affected by differential water withdrawal through ports of a vertical intake tower (not present in all hydroelectric facilities).

C. Physical damage to biota may occur during entrainment. Downstream-migrating fish (both adults and juveniles) may be entrained through the penstock and turbine assembly.

D. The dam structure will block the upstream migration of anadromous fish if a fish passageway is not present.

E. A daily peaking-discharge schedule will cause fluctuations in water level, velocity, and water quality downstream of the dam. High-velocity releases may cause habitat modifications due to the scouring of sediments and erosion.

methods used to remove impinged organisms from barriers and return them to the receiving water body determine, to a large degree, the magnitude of impingement mortality.

- Discharge and Discharge Canal Effects

  Discharge effects consist of behavioral and physiological changes, as well as direct mortality resulting from exposure of aquatic biota to heated effluents, chemicals used to control biofouling (e.g., chlorine), and metals eroded from internal plant structures (e.g., copper). Discharges may also modify the overall physical and chemical properties of the receiving water body (e.g., salinity regime, sediment characteristics) resulting in changes in the kinds and abundance of organisms at the discharge site. Biological effects resulting from exposure to thermal effluents depend upon the magnitude of the temperature increase and the duration of exposure. Thermal mortality is generally a major concern when discharge temperature exceeds 35°C (95°F). Chlorine, toxic to most biota in the ppb to ppm range, is a major concern when the concentration in plant effluents is greater than 0.2 ppm. Copper eroded from condenser tubes accumulates in the tissues of some aquatic biota (e.g., oysters). High tissue copper levels (½100 ppm) may cause direct mortality or adversely affect growth and reproduction. When organisms containing high tissue levels of copper are eaten, copper may be passed up the food web and adversely affect higher trophic levels. Copper that accumulates in sediments is a potential long-term risk to the aquatic ecosystem.

Modes of Interactions for Hydroelectric Facilities

Environmental concerns associated with hydroelectric development can be classified into three categories: alterations of water quality, fluctuations in water level, and prevention of successful fish passage (Fig. IV-1b).

- Alterations of Water Quality

  The major water quality parameters of concern for hydroelectric generation are turbidity, dissolved oxygen concentration, nutrient concentrations and water temperature (11-17). Changes in turbidity are usually associated with construction-related activities such as dredging, and can frequently be minimized by proper construction practices. Turbidity is a special concern when sedimentation of the impoundment frequently recurs, requiring extensive and/or periodic dredging.

  Alterations to dissolved oxygen concentration, nutrient concentrations, and water temperature are more likely to arise in large, stratified impoundments. Stratification occurs during summer when the surface water of impoundments becomes warmer than bottom water, reducing vertical mixing between layers. Biological activity, mainly microbial decomposition of organic material, depletes the dissolved oxygen from bottom layers more rapidly than it can diffuse from surface layers. Bottom waters do not become reoxygenated until the fall when surface layers cool and the impoundment becomes well mixed. Nutrients, from decomposition of organic materials, also frequently build up in lower layers of stratified impoundments, especially if anoxic conditions develop. Depending upon the layer of the impoundment from which water entering the turbines is withdrawn, abnormal changes in down-stream water temperature, unacceptable concentrations of nutrients, and low dissolved oxygen concentration may occur in downstream aquatic habitats.

- Fluctuations in Water Level and Flow Reductions

  Unnatural water-level fluctuations occur in impoundments and in aquatic habitats downstream of dams when hydroelectric facilities are operated in a peaking/storage mode. In addition, a portion of streamflow is sometimes diverted away from the natural streambed for small-scale hydroelectric projects. Fluctuations in water level and flow are not aesthetically pleasing to recreational users of the water body, and may adversely affect aquatic biota (14,16). For example, some species of benthic invertebrates have stringent flow requirements and cannot tolerate sporadic flow fluctuations. Many fish, particularly those in impoundments, spawn along the littoral zone, and their eggs cannot tolerate the periodic dewatering.

- Prevention of Successful Fish Passage

  Hydroelectric development can prevent the movement of resident and anadromous fishes past the dam unless a fish ladder or fish lift is installed (11). Mortality associated with passage of fish through turbines as they move downstream also may be large, depending on the type of turbine employed, the proportion of the river flow that is diverted through the turbine, and the size of fish passing downstream (13).

Environmental Concerns

Mortalities resulting from interaction between biota and steam or hydroelectric power plants can cause population declines if they are not offset by compensating mechanisms such as increases in growth, fecundity, and/or survival (9,10,14). Losses of phytoplankton and zooplankton are generally recouped quickly because these biota have rapid growth and reproduction (generation times of hours to days). Organisms of higher taxonomic levels have much longer generation times, and power plant-related mortalities to these biota are much more likely to result in population declines. Fish, crabs, and many benthic organisms generally spawn once a year; however, some fish may not reproduce until several years of age.

Impacts from steam electric generation (i.e., entrainment, entrapment, impingement, and discharge effects) are of major concern when spawning and nursery areas of commercially or recreationally important species, particularly fish, occur near intake structures, resulting in large numbers of individuals in early life stages being entrained and impinged (9,10,15). Mortality to a large proportion of each year's spawn or nursery stock has the potential to adversely impact regional populations and harvests. Similarly, hydroelectric impacts on anadromous fish (i.e., blockage of spawning migrations, and destruction of a large percentage of juvenile populations due to turbine mortality) can eliminate populations of anadromous fish from a river system. Localized changes in biotic distributions or abundance from steam or hydroelectric power plants are of less concern in the case of ubiquitous species that have relatively broad spawning and nursery areas.

Although direct effects (e.g., entrainment and impingement losses to early life stages; changes in water quality downstream of dams) are the ones most likely to be measured, steam and and hydroelectric plant operations can also affect populations indirectly through a change in the composition or amount of food organisms (10,13,15). Indirect effects resulting from construction of impoundments for hydroelectric power plants can have profound effects on foodweb dynamics of rivers and streams because the kinds and abundances of biota in the impounded area differ completely from those existing prior to impoundment. Water level and flow fluctuations also affect the composition and abundance of biota in habitats downstream of hydroelectric facilities.

B. Aquatic Habitats

The central concept underlying the cumulative assessment of aquatic impacts of steam and hydroelectric power plants presented in this chapter is that the Chesapeake Bay, and the streams and rivers that flow into it, are composed of distinct and definable habitat types. Estuarine habitat types are defined by salinity, which is the environmental variable most important in controlling biotic distributions (2). Flow characteristics determine freshwater riverine habitat types (16). Each habitat has unique functions in producing or supporting important resource elements, although their biotic components overlap, and the areal extent of each habitat varies seasonally (with the exception of nontidal freshwaters). Cumulative impact is assessed in terms of significant effects on the biota over the entire extent of each habitat type within Maryland. The emphasis is placed on whether the long-term integrity and characteristic functions of the defined habitats are maintained. Localized plant-related changes to a portion of a habitat are, however, identified and discussed.

Aquatic habitat types can be defined using salinity and flow characteristics (2) as:

Habitat	Salinity Ranges
Marine	30.0 - 35.0 ppt (parts per thousand)
Polyhaline	18.0 - 30.0 ppt
Mesohaline	5.0 - 18.0 ppt
Oligohaline	0.5 - 5.0 ppt
Tidal fresh	0.0 - 0.5 ppt
Nontidal fresh (Rivers and Lakes)	0.0

The major ecological functions of each habitat are:

- <u>Polyhaline and Marine</u>

  These high-salinity waters are primary sites of blue crab spawning and development; they also support hard clam populations. Several fish species (e.g., spot, croaker, weakfish, and menhaden) spawn in marine waters the young of these species seasonally migrate into lower salinity zones and use them as nursery areas. Marine habitats do not exist in the Maryland portion of the Chesapeake Bay; however, polyhaline salinities are consistently found in the lower portions of the Maryland Chesapeake Bay up the mouth of the Potomac.

- <u>Mesohaline</u>

  These medium salinity habitats are the primary areas of shellfish production (soft-shell clams, blue crabs, and oysters), and benthic populations are frequently very productive here. Mesohaline habitats also produce most of the estuarine forage fish biomass (anchovies, menhaden, silversides), and serve as important feeding areas for large, predatory fish (e.g., white perch, bluefish, striped bass). The mesohaline salinity zone is sometime separated into two habitats: a high mesohaline habitat (10-18 ppt) and low mesohaline habitat (5-10 ppt). The high mesohaline habitat is important in nursery activities of shellfish, particularly oysters. The low mesohaline habitat is the primary nursery for juvenile blue crabs and many young-of-the-year fish (e.g., spot, bluefish).

- <u>Oligohaline</u>

  Much of the suspended sediment and detritus that are trapped by the Chesapeake Bay's complex circulation pattern is deposited in this low salinity zone. Nutrient concentrations are also high in the oligohaline zone as is primary productivity. These brackish water environments support resident fish populations and serve as spawning and nursery grounds for a few fish, including striped bass and white perch. Some forage fishes (e.g., silversides) use oligohaline areas as spawning and nursery grounds, and a few migratory species (e.g., menhaden) feed on its productive plankton populations.

- <u>Tidal Fresh</u>

  These segments of estuaries are under tidal influence but without significant salt intrusion. They provide spawning and nursery habitat for anadromous fishes and also support the larvae and juveniles of these species during early development. Striped bass and white perch are particularly important species that use tidal fresh habitats as spawning and nursery areas. Some resident fish (e.g., white catfish) spend their entire life cycles in this habitat zone. Large quantities of suspended sediment, detritus, and nutrients are also trapped in this low salinity zone by estuarine circulation patterns.

- Nontidal Fresh (Rivers and Lakes)

  Nontidal riverine habitats in Maryland serve as the major spawning and nursery areas for many anadromous and semi-anadromous fish (shad, river herrings, and yellow perch). Rivers also support resident fish populations, many of which (e.g., trout and smallmouth bass) are actively pursued by sport fishermen. All large lakes in the state are artificial reservoirs that have been constructed and are managed for particular purposes. Uses of reservoirs in the state include flood control, augmentation of low river flows, municipal water supplies, hydroelectric power, and cooling of thermal effluents. Such uses can conflict with the maintenance of aquatic habitat for fish species of recreational importance.

The locations of the estuarine salinity zones change seasonally in response to rainfall and resulting changes in the amount of freshwater inflow (1,2). Table IV-2a indicates by season, the zones in which Maryland steam generating plants are located. Information on generating capacity is also provided. Two facilities (R.P. Smith and Dickerson) are located on the riverine portion of the Potomac. Three operational plants (Crane, Possum Point, and Vienna) and one that is in the planning stages (Perryman) are located in the tidal fresh-oligohaline zone. A 500 MWe unit, employing a cooling tower, is also licensed for proposed expansion at Vienna. Eight operational plants (BRESCO, Brandon Shores, Chalk Point, Gould Street, Morgantown, Riverside, Wagner, and Westport) are on oligohaline-mesohaline waters. One operational facility (Calvert Cliffs) is located in an area that is mesohaline in all seasons. There are no operational or planned steam generating plants in polyhaline habitats or in marine habitats along the Atlantic shoreline of Maryland.

The characteristics and locations of hydroelectric power plants in nontidal fresh waters are summarized in Table IV-2b. Water-use rates at peak power output, average river flows, and impoundment volumes permit comparisons of relative size. The Conowingo plant on the Susquehanna River is the only large-scale hydroelectric facility in Maryland. Eight small-scale hydroelectric facilities (i.e., less than 30 MWe capacity) are operational, and three more are presently under construction. Several more facilities have preliminary permits or have applied for permits.

C. Regulatory Considerations

Steam Generating Power Plants

The intake, use, and discharge of water by Maryland steam power plants is regulated through State Surface Water Appropriation and Use Permits and National Pollutant Discharge Elimination Systems (NPDES) permits. These permits reflect federal and state constraints on the amount of water and the type of intake used, as well as the chemical and physical characteristics of effluents.

Table IV-2a. Steam electric power plant locations in Maryland (by salinity regime and season).

	Net Capacity (MWe)	Winter/Spring				Summer/Fall			
		Riverine	Tidal-fresh	Oligohaline	Mesohaline	Riverine	Tidal-fresh	Oligohaline	Mesohaline
Brandon Shores	1,240(a)			X					X
BRESCO	50(b)			X					X
Calvert Cliffs	1,650				X				X
Chalk Point	1,955			X					X
Crane	376		X					X	
Dickerson	556(c)	X				X			
Gould Street	103			X					X
Morgantown	1,439			X					X
Perryman	600-800(d)		X					X	
Possum Point	1,108(e)		X					X	
Riverside	321			X					X
Smith	113	X				X			
Vienna	150(f)		X					X	
Wagner	988			X					X
Westport	177			X					X
Total Capacity by Zone		669	2,234-2,434	6,273	1,650	669	0	2,234-2,434	7,923

(a) Most of Brandon Shores is still under construction; one 620 MWe unit is in operation.

(b) BRESCO (Baltimore Southwest Resource Recovery Facility) began operations in 1985.

(c) As of March 1, 1984.

(d) Perryman is in the planning stages.

(e) Possum Point produces 322 MWe with once-through cooling and 786 MWe through a cooling tower system.

(f) Unit 9 at Vienna, a 500 MWe cooling tower unit, has been licensed and is scheduled to be operational by 1995.

Table IV-2b. Licensed and/or operational hydroelectric facilities in nontidal fresh waters in Maryland.

Facility	FERC Docket Number	Date Operational	River	Peak Capacity (kW)	Annual Generation (MWh)	Turbine Capacity At Peak Output (cfs)	Normal Impoundment Capacity (Acre-Feet)
Deep Creek	2370	1925	Deep Creek	20,000	29,000	N/A	93,000
Brighton	3633	Under Construction	Patuxent River	480	2,685	130	19,000
Rocky Gorge	6596	Under Construction	Patuxent River	125	1,090	16	17,000
Bloomington	4506	Under Construction	North Branch Potomac River	13,846	55,000	900	94,700
Potomac River #4	2516	Early 1900's	Potomac River	1,000	4,338	940	7,300
Parker Pond	Un-licensed	1950's	Beaverdam Creek	40	N/A	N/A	130
Conowingo	405	1926	Susquehanna River	512,000	1,738,000	75,800	310,000
Gilpin Falls	3705	1984	Northeast Creek	396	2,700	56	8
Potomac River #3	2515	1912	Potomac River	600	1,588	334	1,075
Potomac River #5	2517	1919	Potomac River	1,120	6,851	940	4,900
Gore's Mill	Un-licensed	1950's	Little Falls	10	N/A	N/A	4
Wilson Mill	Un-licensed	1983	Deer Creek	23	N/A	N/A	5

It is not possible or cost effective to assess power plant effects on all of the species inhabiting aquatic environments. State regulations governing thermal discharges thus provide for the evaluation of plant impacts on those biota which, because of their abundance, distribution, ecological roles (e.g., food web linkage), or economic importance (e.g., commercially exploited species), are essential to or representative of the maintenance of balanced indigenous populations of shellfish, fish, and wildlife. Because many of these species are near the top of estuarine food webs or are key links in food webs, changes in their abundance or distribution indicate system-wide alterations. These Represenative Important Species (RIS) are therefore considered to be indicators of system-wide responses.

The evaluation of once-through cooling systems on aquatic habitats is done in conjunction with the NPDES permit process and the Code of Maryland Regulations (COMAR) 10.50.01.13. Under these regulations, an initial evaluation of impact is based on the amount of water use and the size of the thermal plume with respect to physical characteristics of the receiving water body (i.e., mixing zone specifications) and the importance of the area as a spawning and nursery site. Mixing zone specifications are indicators of the potential for the receiving water body to dilute effluents, and failure to pass them indicates that the potential for discharge effects is large. The importance of the area as a spawning and nursery habitat is an indicator of the potential for entrainment and impingement impacts to have region-wide consequences. If the plant fails to pass these screening criteria, a more detailed evaluation of biological impacts is required. Alternate effluent limitations (i.e., a water use rate or a mixing zone that exceeds those defined by mixing zone specifications in COMAR 10.50.01.13) may be requested by the utility based upon the findings of the detailed biological studies.

Because impinged organisms generally represent losses to life stages that are the major reproductive units of populations, Maryland thermal regulations require impingement losses be estimated and actions (e.g., modifications to intake structures or operating practices) that minimize impingement impacts be evaluated. Estimates of the monetary value of impingement losses are used to evaluate the cost-effectiveness of actions required to reduce impingement. Actions required to mitigate entrainment losses do not have a specific dollar value limitation; rather, they are commensurate with the consequences of entrainment losses to regional RIS populations, ecosystem functioning, and economically important fishery resources. Management actions required to mitigate discharge impacts also do not have a specific dollar value limitation, and include any that may be required to preserve balanced indigenous populations in the receiving water body.

The status of regulatory proceedings for the various Maryland power plants that fall under COMAR 10.50.01.13 is summarized in Table IV-3.

Hydroelectric Power Plants

The State of Maryland does not license small-scale hydroelectric facilities. Licensing of small-scale hydroelectric facilities falls under federal jurisdiction; however, under provisions of the Fish and Wildlife Coordination Act, all comments and concerns of state and local resource

Table IV-3. Status of power plants under Maryland thermal discharge criteria.

Plant	Mixing Zone Criteria	Spawning and Nursery Area of Consequence	Alternate Effluent Limitations	Regulatory Status
BRESCO	Fails	PPSP recommended passage	PPSP recommended passage	Hydrothermal and impingement studies to be conducted
Calvert Cliffs	Passes	PPSP recommended passage	N/A	Approved 12/81
Chalk Point	Fails	Fails	Presently being evaluated	No determination has been made
Crane	Fails	PPSP recommended passage	PPSP recommended passage	Approved 9/84
Dickerson	Fails(under some flow conditions)	PPSP recommended passage	PPSP recommended passage	Approved 2/82
Gould Street	Passes	Passes	N/A	Approved 7/82
Morgantown	Passes	PPSP recommended passage	PPSP recommended passage	Approved 8/81
Riverside	Passes	Passes	N/A	Approved 7/82
R.P. Smith	Fails(under some flow conditions)	PPSP recommended passage	PPSP recommended passage	Approved 5/82
Wagner	Fails	Presently being evaluated	Presently being evaluated	Detailed biological studies presently being conducted
Westport	Passes	Passes	N/A	Approved 7/82

agencies must be incorporated into the federal licensing process. PPSP has been designated the lead agency within the Department of Natural Resources (DNR) for reviewing small-scale hydroelectric facility applications. The federal licensing agency, the Federal Energy Regulatory Commission (FERC), has adopted procedures for exempting certain projects (primarily small projects for which the applicant possesses property rights) from federal jurisdiction. In these cases, conditions to address environmental concerns of State and federal agencies are included in exemptions, and monitoring for compliance with these conditions is the responsibility of State and federal agencies, not the FERC.

Although there are presently no state licenses or permits specifically required for the operation of a hydroelectric power facility, Ch. 448 of COMAR requires that owners and operators of dams on State waters must cooperate with DNR to ensure sufficient water is released for maintenance of downstream water quality and aquatic habitat. Several state permits, such as the Water Appropriation and Use Permit and Waterway Construction Permit (both granted by the Water Resources Administration) are generally required. COMAR also calls for dam owners and operators to consult with other resource agencies, such as the Scenic River Review Board, the Maryland Geological Survey, and the Maryland Historical Trust. More details on the permits and consultations required for licensing and permitting of small-scale hydroelectric facilities are provided in the Inventory of Maryland Dams and Assessment of Hydropower Resources (17).

One of the first steps in PPSP's licensing review procedure for proposed small hydroelectric projects is preparation of a site description based on information submitted by the applicant. These site descriptions provide resource managers and regulators with information on the water quality, biological resources, and recreational activities near proposed projects as well as with engineering information on the type, size, and mode of operation of the proposed facility. Based on these site descriptions, potential environmental impacts are identified while proposed projects are in the planning stage. The developer then has the opportunity to modify the proposed project to minimize expected impacts or to conduct additional studies to precisely define potential impacts. This environmental review procedure has been applied to 10 projects over the last four years. They are: Bloomington, Savage River, Rocky Gorge, Brighton, Daniels, W.J. Dickey, Atkisson, Gilpin Falls, Dam No. 4, and Pine Grove.

D. Aquatic Impact Assessment for Steam Generating Power Plants

Relatively few new monitoring studies have been completed since the publication of CEIR-4 (8). Most of these were conducted in the vicinity of the Chalk Point plant. All data available through the end of 1984 have been incorporated into the following assessment of the impacts of steam generating and hydroelectric power plants on aquatic habitats in Maryland.

Mesohaline Power Plants

This medium salinity zone accounts for the greatest percentage of aquatic habitat in Maryland (1). The three largest plants using once-through cooling (Calvert Cliffs, Chalk Point, and Morgantown) are located in this zone. The Calvert Cliffs monitoring studies provide baseline information for the preoperation period as well as information that has been used to assess impacts for the first 10 years of operations (1975-1984). Detailed results for Calvert Cliffs assessment studies are reported in References 18 through 32, and were summarized in previous CEIRs (5-8). The Morgantown findings are summarized in References 33 and 34. They were also discussed in earlier CEIRs (5-8). The results of Chalk Point studies conducted in the 1960's are summarized in Reference 35. Results of recent studies for Chalk Point are summarized in References 36-38. Only major findings of Calvert Cliffs, Morgantown, and Chalk Point studies are summarized in this chapter.

Six plants (Gould Street, Riverside, Wagner, Westport, Brandon Shores, and BRESCO) are located in Baltimore Harbor, where salinities are generally in the oligohaline range in the spring and low mesohaline for the remainder of the year. Gould Street, Riverside, and Westport are all over 20 years old and are used for peaking and cycling service. BRESCO is a resource recovery facility which burns municipal solid waste to produce electricity and steam for commercial sale. Construction of BRESCO was completed in 1984. Brandon Shores is a closed-cycle fossil fuel facility for which one unit began operations in 1984. Make-up water for Brandon Shores is withdrawn from discharges of Wagner's unit 4 and blowdown discharges from Brandon Shores are returned to the Wagner discharge site. Wagner has a once-through cooling system with a 988 MWe baseload. Of the Baltimore Harbor facilities, only Wagner is required to conduct detailed assessment studies. Many of these studies were not complete at the writing of this CEIR; however, preliminary findings of completed study elements are presented here.

- Entrainment

  Phytoplankton and zooplankton entrainment effects at Calvert Cliffs and Morgantown were summarized in previous CEIRs (5-8). Losses were generally variable, with greatest reductions found in the summer, especially at Morgantown where chlorine is used as a biocide (33, 34)[1]. Entrainment losses did not result in nearfield depletions at either facility (29,34). This was probably because plankton populations recovered rapidly from power plant related stresses, and only a small proportion of the net flows available for dilution were withdrawn into the Morgantown and Calvert Cliffs facilities.

  Entrainment losses of phytoplankton and zooplankton have not been directly measured at Baltimore Harbor facilities; however, no nearfield depletions of plankton populations that can be attributed to power plant operations have been found (39). In addition, entrainment losses to phytoplankton and zooplankton from BRESCO and Brandon Shores are not projected to have adverse impact upon Harbor populations (40,41). Both of these facilities withdraw relatively small volumes of water.

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[1] See Section F. Biofouling.

The mesohaline power plant with the greatest potential for entrainment impacts to phytoplankton and zooplankton is Chalk Point. At Chalk Point, phytoplankton biomass declined between plant intake and discharge on most dates (36,38). These reductions averaged about 20%. There was no apparent relationship between cross-condenser declines in phytoplankton biomass, T, or chlorination status. Therefore, a large part of the declines appears to be due to mechanical damage. In summer and early fall, entrainment at Chalk Point depressed phytoplankton productivity when chlorine was applied (38,42-46). In cooler seasons when chlorine was not used, entrainment frequently (but not always) enhanced phytoplankton productivity (38,42,45). Phytoplankton entrainment effects at Chalk Point thus include thermal effects (positive and negative), chemical effects (negative), and mechanical damage (negative). Phytoplankton entrainment losses and gains, however, did not have consistent nearfield effects on algal productivity or biomass (38,46). Also, plant operations did not change phytoplankton species composition in the nearfield from entrainment stresses, usually by the time they reached the end of the discharge canal.

A special form of entrainment occurs during warmer months at Chalk Point when auxiliary pumps are used to temper thermal and chlorine stresses in the discharge canal and receiving body by dilution (36). These auxiliary pumps transport water directly from the intake region into the head of the discharge canal without passing through the plant's cooling system. Intakes to auxiliary pumps are not protected by screens. Large organisms, such as fish and crabs, as well as planktonic forms may be drawn into these pumps. Auxiliary pumps increase entrainment losses of phytoplankton, but do not increase or decrease the magnitude of nearfield effects on them (36). Dilution of thermal effluents by auxiliary pumps is therefore of little benefit to phytoplankton populations because thermal stress in the discharge canal is not a major source of phytoplankton mortality. Auxiliary tempering pumps actually increase the risk of phytoplankton losses due to mechanical damage and exposure to chlorine.

Zooplankton entrainment losses at Chalk Point have not been measured for full power operations; however, during partial power operation, zooplankton losses were generally largest during periods of chlorination, when reductions in density between the intake and the end of the discharge canal frequently were 30-80% (38,47). Without chlorination, through plant losses of zooplankton averaged 20-30%. Highest zooplankton entrainment losses were measured during periods of highest ambient densities (38). Zooplankton populations experienced additional mortality as they passed down the discharge canal, especially when chlorine was used (38). The discharge canal thus had the net effect of increasing exposure time, thereby increasing zooplankton mortalities due to stresses from high temperature and chlorine. Full-power generation is expected to result in zooplankton entrainment mortality rates of 90-100% during summer, when temperatures in the discharge canal are projected to exceed the upper thermal tolerance of dominant summer zooplankton (36, 38). Full power operation is not projected to result in increases in zooplankton entrainment mortality during winter, spring, and fall. During these seasons, discharge temperature is not projected to be in a range that is lethal to zooplankton (38). Nearfield zooplankton depletions have not been observed consistently at Chalk Point, probably because nearfield temperature and chlorine concentration do not approach levels that are lethal to these biota, and the effects of throughplant entrainment are rapidly diluted (36,38). Entrainment losses of zooplankton do not have regional consequences because zooplankton populations recover rapidly.

Planktonic life stages of benthic organisms, including oysters and soft-shell clams, are entrained at Calvert Cliffs (29). However, entrainment losses to these biota do not result in local population depletions (32, 48). Near-plant abundances of oysters and softshell clams, as well as most other benthic species with pelagic developmental stages, are generally similar to those found at nearby references areas (29, 32).

Salinities in the vicinity of Morgantown, Chalk Point, and Baltimore Harbor plants are marginal for the development and growth of planktonic life stages of oysters and soft-shell clams (32, 36, 40). Because these species seldom complete their life cycle near these power plants, entrainment losses to their planktonic life stages are not considered to be an important plant interaction. Abundances of other benthic organisms with entrainable life stages have not declined in the discharge regions of Morgantown, Chalk Point, or Baltimore Harbor facilities (32, 49, 50). However, the number of benthic species and the abundance of benthic biota colonizing bottom sediments in the discharge canal at Chalk Point was less than that found at nearby reference areas (49).

Potential losses to regional fish populations from ichthyoplankton entrainment were estimated at Calvert Cliffs, Morgantown, and Chalk Point to assess potential impacts of plant operations on spawning and nursery areas of Representative Important Species (RIS) (Tables IV-4 and IV-5). These estimates were made using information about hydrodynamics, life history, and stock size, and assuming entrainment mortality was 100 percent (51-55). These projections suggest that regional ichthyoplankton populations may be adversely affected at Chalk Point (53, 54). Forage species (e.g., naked goby, silversides, and bay anchovy) were determined to be particularly vulnerable. Only during rare periods of extremely high freshwater inflow are eggs and larvae of species that spawn in freshwater (e.g., yellow perch, herrings, white perch, and striped bass) transported into the vicinity of the intake or discharge of the Chalk Point plant (38,51). Atlantic croaker, bay anchovy, and possibly naked goby and winter flounder may be marginally affected at Calvert Cliffs (29). Naked goby populations were potentially affected at Morgantown (55). The projected economic effect of entrainment losses at all three facilities was low because entrainment losses of harvested species were projected to be small (Table IV-5). The projected change in net system productivity resulting from the calculated entrainment losses was low at Calvert Cliffs and Morgantown; however, projected losses to net system productivity at Chalk Point were relatively high (8.0%) (Table IV-5).

Table IV-4. Potential losses to adult fish populations in the regions adjacent to estuarine power plants due to entrainment losses of ichthyoplankton (Assuming 100% mortality). Values in percent of total population. Analysis adjusts for natural mortality but not for avoidance due to swimming

Species	Calvert Cliffs [(a)] (mesohaline)	Morgantown[(b)] (mesohaline-oligohaline	Chalk Point[(c)] (Low mesohaline-oligohaline)	Crane[(d)] (oligohaline-tidal freshwater)	Possum Pt (oligohaline-tidal freshwater)
Striped bass	0	0.13	3.34	<0.10 (<0.01)[(e)]	6.30
White perch	0	0	5.76	2.10 (0.04)	5.10
Spot	0.27	0.07	2.40	1.10 (<0.01)	0
Atlantic croaker	6.39	0.22	0	<0.10 (<0.01)	0.02
Atlantic menhaden	1.04	0.89	1.20	1.10 (0.02)	0.62
River herrings	0	0.02	4.38	<0.10 (<0.01)	6.00
Winter flounder	4.68	0	0	0 (0)	0
Yellow perch	0	0	5.14	0.80 (0.01)	0
Bay anchovy	4.99	2.30	19.16	2.50 (0.07)	0.11
Naked goby	4.13	4.40	62.40	4.90 (0.07)	0
Silversides	0.26	2.10	34.20	2.00 (0.10)	1.20

(a) Region of evaluation was the head of the bay to the mouth of the Patuxent (Ref. 29).
(b) Region of evaluation was the tidal Potomac (Ref. 55).
(c) Region of evaluation was the tidal Patuxent (Ref. 53).
(d) Region of evaluation was the Gunpowder estuary (Ref. 56).
(e) Number in parenthesis is an analysis using the entire upper Bay as the region of evaluation.

Table IV-5. Percentage of potential economic and ecological effects due to entrainment losses of ichthyoplankton

	Economic Losses to the Regional Fishery		Loss of Ecological Productivity in the Regional Ecosystem
Site	($)	(%)	(%)
Calvert Cliffs[a] (mesohaline)	200	0.12	0.73
Morgantown[b] (mesohaline-oligohaline)	5,200	0.10	0.35
Chalk Point[c] (low mesohaline oligohaline)	3,000	4.10	8.10
Crane[d] (oligohaline-tidal freshwater)	202 (100)[e]	0.33 (0.004)[e]	0.95 (0.0238)[e]
Possum Point[b] (tidal freshwater)	167,310	3.20	0.44

[a] Region of evaluation was the head of the bay to the mouth of the Patuxent (Ref. 29).

[b] Region of evaluation was the tidal Potomac (Ref. 55).

[c] Region of evaluation was the tidal Patuxent (Ref. 53).

[d] Region of evaluation was the Gunpowder estuary (Ref. 86).

[e] Number in parenthesis is an analysis using the entire upper Bay as the region of evaluation.

Field survey data support the findings of entrainment modeling. Ichthyoplankton entrainment losses at Calvert Cliffs and Morgantown did not result in nearfield depletions in ichthyoplankton populations (29, 34). However, forage species were consistently less abundant in the discharge region of the Chalk Point SES than in the intake region (38). Entrainment losses to forage populations at Chalk Point also have a potential adverse impact on spawning and nursery areas and successful completion of the life cycles of these species (36).

The Baltimore Harbor power plants are not located in a spawning area for harvested fish species (57-61). Major fish species spawning in Baltimore Harbor are forage organisms, including bay anchovy, Atlantic silversides, tidewater silversides, rough silversides, naked goby and hogchoker (40, 41, 57-61). Ichthyoplankton entrainment losses at the Gould Street plant were low; ichthyoplankton entrainment losses at the Riverside and Wagner plants were higher (58-60). Entrainment losses at Brandon Shores and the BRESCO facility are projected to be low (40, 41). Estimates of the potential regional impacts of entrainment losses at Baltimore Harbor facilities have not been made because of insufficient baseline information on RIS ichthyoplankton that use the Harbor area as spawning and nursery grounds. Baltimore Gas and Electric Company (BG&E) is currently collecting the baseline data required to assess the potential impacts of ichthyoplankton entrainment on spawning and nursery areas of RIS in Baltimore Harbor.

The number of adult and juvenile fish and crabs entrained through Chalk Point's unscreened auxiliary pumps was estimated to be equal to or larger than the number impinged on intake screens (62). About 42 percent of the crabs and 76 to 95 percent of the fish passing through auxiliary pumps die immediately.

Organisms that survive passage through auxiliary pumps are exposed to high temperatures and chlorine residuals when they are released in the discharge canal. Delayed mortality for auxiliary pump entrainment has not been measured but is expected to be high (62).

- Impingement

Impingement at mesohaline facilities was summarized and discussed in previous CEIRs (5-8). This information, along with 1982-1983 data for Chalk Point, is summarized below.

At mesohaline facilities, a few species (menhaden, spot, bay anchovy, hogchoker, and blue crabs) dominate impingement counts. The Calvert Cliffs impingement data suggest that the species composition of impingement is relatively similar from year to year. Year-to-year fluctuations in impingement catch generally reflected year-to-year fluctuations in fish and crab abundance in the nearfield area. Highest impingement generally occurred in late summer and fall, and lowest values occurred in winter and spring (29, 33, 36, 58, 59). Juveniles dominated impingement catches, and the number of fish impinged usually was greatest at night (29, 38).

A barrier net, placed across cooling water intake flows at Chalk Point in 1982, effectively reduced impingement for blue crabs (by 80%) and total finfish (by 60%) (Table IV-6). However, impingement increased for some RIS fish (e.g., white perch and striped bass) after the barrier net was installed. In many cases, these increases were large (700-4000%) (38).

According to one hypothesis, the increased impingement of white perch (and possibly other species) after installation of the barrier net resulted from fish getting trapped behind the barrier net during its installation in early spring (32). The impingement of a large number of white perch in April 1982 shortly after deployment of the barrier net supports this hypothesis. However, many small white perch less than 10 cm long, were impinged in late summer and fall, months after the barrier net was installed (63). These were mostly young-of-the-year fish and were not yet spawned when the barrier net was deployed. A possible explanation for the increase in impingement for these fish following barrier net installation is that they were attracted to the net (and its associated structures) and passed through or under it, eventually becoming impinged. A notable episode of white perch impingement also occurred in March 1982, before the barrier net was installed. This episode was probably a result of accumulation of white perch in the intake region during their spring spawning run (63). The increase in white perch impingement following deployment of the barrier net was therefore probably due to many factors, including entrapment and attraction. A detailed evaluation of barrier net operations, including a determination of the effectiveness of a two-net system, is being done.

Mortality rates of impinged fish varied from species to species and from facility to facility. Impinged organisms at Chalk Point are returned to the receiving body via the discharge canal, and summer discharge canal temperatures frequently exceed the upper thermal tolerance of finfish and crabs (38). The canal also contains toxic chlorine residuals. Post-impingement mortality rates at the Chalk Point plant were estimated to be unacceptably high during summer (45). During other seasons and at other Maryland power plants, about 90 percent of the hardy species (e.g., spot and hogchoker) survive impingement, whereas only about 25 percent of the sensitive species (e.g., menhaden and other clupeids) survive (25, 34, 38). Blue crabs had essentially no post-impingement mortality at facilities other than Chalk Point (29, 38, 64).

High impingement episodes account for a large proportion of annual impingement estimates at meshoaline facilities (29, 34, 38). At Chalk Point, high impingement episodes are related to seasonal migration (38). At Calvert Cliffs and Morgantown, high impingement episodes were related to the occurrence of low dissolved oxygen concentrations in the intake embayment (29, 65). Removal of panels from curtain walls at Calvert Cliffs reduced the frequency of high impingement episodes, presumably by providing entrapped fish with an escape route. Recent increases in the volume of Bay water with low dissolved oxygen levels suggest that the frequency, and possibly the severity, of high impingement episodes may increase in the future at Calvert Cliffs and Morgantown (32).

Table IV-6. Estimated annual impingement (number of individuals at the Chalk Point power plant), comparing impingement before and after installation of barrier net

Species	1976-1977 Before Barrier net[a]		1982-1983 With Barrier Net[b]	
	Number	Percent	Number	Percent
Atlantic menhaden	1,347,490	31	233,656	25
Spot	647,016	15	33,796	4
Hogchoker	191,926	5	94,764	10
White perch	41,910	1	344,676	37
Other fish species	139,982	2	25,358	3
Total fish	2,368,324	55	944,132	71
Blue crabs	1,948,132	45	380,760	29
TOTAL IMPINGED ORGANISMS	4,316,456	100	1,324,892	100

[a] Data from Ref. 38.
[b] Data from Ref. 63.

Impingement losses to dominant species at all mesohaline plants are small compared to commercial landings and are only a small percentage of the forage required for major predatory fish populations (29, 34, 38). Thus, impingement losses, including those projected for the BRESCO and Brandon Shores facilities, are not expected to impact commercial or recreational landings of fish and crabs from mesohaline habitats.

- Discharge Effects and Habitat Modification

Thermal plume dimensions for power plants in the mesohaline zone were discussed in previous CEIRs (5-8). In all cases, the distribution and size of these thermal plumes varied with season, with tidal stage, with wind velocity and direction, and with plant operating level (29, 34, 38, 58-60).

Of the mesohaline power plants, Chalk Point has the greatest potential for causing discharge effects (36, 66). This is because the receiving water body at Chalk Point is shallow, and plant water use exceeds the amount of flow available for dilution. Thus, a relatively large region of the Patuxent River is affected by the plant's thermal discharge (38, 66). In addition, the plant discharge is located approximately 4 km upstream of the intake, resulting in changes to natural salinity patterns. Chalk Point failed to comply with any of the mixing zone specifications in state thermal regulations (38, 66).

Nearfield changes in biotic distributions resulting from the thermal effluents of the Chalk Point plant, however, were localized and included increases in the abundance of heat-tolerant benthic species, mainly small segmented worms called oligochaetes, and mortalities to heat-sensitive benthic species and zooplankton (38, 49,). Fish and crabs were attracted to or excluded from the Chalk Point discharge region depending upon season (67). Attraction of sport fish to the Chalk Point discharge canal during winter created a cold period fishery there (68,69). Fish migration routes were not blocked (36, 67), and thermal effluents did not adversely affect the growth and reproduction of fish or other biota (38,70-75).

Copper released from the copper-nickel condenser tubes at Chalk Point was bioconcentrated by oysters in the discharge region (38, 76-78). Bioconcentration of copper, however, did not adversely affect oyster growth or survival (76). The affected region is not prime oyster habitat, and oysters are not commercially harvested there (36). High tissue burdens of copper have rarely been reported in oysters from commercial oyster beds located downstream (36, 38).

No consistent discharge effects on phytoplankton, zooplankton, or fish were measured at Morgantown or Calvert Cliffs (29, 33). However, high-velocity discharge systems modified habitat characteristics at both sites, scouring away natural sands and muds in the immediate vicinity of discharges (29, 32). These habitat modifications affected the abundance and makeup of benthic biota in a localized portion of the nearfield area. Plant-related increases and decreases in benthic abundance, growth, and productivity away from the scoured areas were also measured (32). Increases far outweighed decreases, and appeared to be related to organic additions to bottom habitats resulting from entrainment mortality of plankton (32). Many of the species that increased in abundance were heat tolerant organisms. Oysters in the vicinity of Calvert Cliffs and Morgantown bioaccumulated copper; however, oyster densities in the affected areas were low and did not support a fishery (29, 79). Copper uptake by other benthic biota in the nearfield areas of these plants was not observed (29, 32, 34).

From the available data (50), it is not possible to separate the effects of the Wagner plant on benthic populations from those of a variety of other industries located in the Harbor. Although spot and white perch were attracted to the Wagner thermal plume, this phenomenon did not occur consistently (50). Zooplankton depletions were not observed in the discharge region of Wagner (39). The addition of the Brandon Shores and BRESCO facilities in the Harbor area is not likely to result in additional adverse environmental impact on mesohaline habitats (40, 41).

• Conclusions for Mesohaline Power Plants

When the results of studies at all mesohaline plants are considered collectively, a picture emerges that indicates a low probability of cumulative impact on mesohaline habitats. Although large phytoplankton and zooplankton entrainment losses have been frequently measured, consistent nearfield depletions have not been found. This is probably due to the rapid recovery of most plankton from entrainment stress. No important commercial or recreational species spawn in the mesohaline zone; therefore, entrainment losses of their ichthyoplankton have little economic significance. Forage fish species spawn in this zone, and large numbers of their ichthyoplankton are entrained. The only mesohaline facility where riverwide spawning and nursery areas of forage species are potentially impacted is Chalk Point. The consequences of long-term cumulative entrainment losses of forage fish are poorly understood and are currently under evaluation. Large numbers of juvenile fish and crabs are impinged at mesohaline power plants; however, impingement losses do not result in measurable nearfield population depletions. Discharge effects in mesohaline habitats are generally localized. Fish and crabs are attracted to and repelled from plant discharges, but fish migration, spawning activity, or growth are not adversely affected. Benthic abundance and productivity are generally higher in thermally affected areas; however, increases in secondary productivity do not impact local or regional food web dynamics.

Tidal Fresh-Oligohaline Power Plants

Of the seven plants that are located in waters which are oligohaline in the spring (Table IV-2a), several (Chalk Point, Morgantown, and Baltimore Harbor area plants) are on waters which are mesohaline during most of the year. Impacts associated with these plants were discussed in the preceding section.

The remaining tidal fresh-oligohaline plants are Possum Point, Vienna, and Crane. Possum Point, on the Potomac River, and Vienna, on the Nanticoke River, are both in major striped bass spawning areas. Crane, though located on tidal fresh oligohaline waters, does not impact a striped bass spawning area. Delmarva Power and Light Company has been granted a license for a 500 MWe unit with a cooling-tower at Vienna. Issues and impacts relative to this proposed Perryman facility are discussed later in this section.

- Entrainment

  At Crane, entrainment enhanced phytoplankton productivity at low temperatures and inhibited it at high temperatures (56, 81-84). Zooplankton entrainment generally did not result in nearfield depletions except during summer (56, 81, 84, 85). Although ichthyoplankton entrainment losses were large in the receiving water body adjacent to Crane, the potential for regional impact from these losses was small (56).

  Entrainment of phytoplankton and zooplankton at Vienna was estimated to be low (86). Although the Vienna facility is located in a striped bass spawning area, ichthyoplankton entrainment of RIS is also probably low (87). Only unit 8, which has a cooling tower with intake flows of 0.12 m3/s for make-up water, is operational (87). When the proposed 500-MWe expansion (unit 9, 1995 completion date) becomes operational, ichthyoplankton entrainment at Vienna is predicted to average 2 percent of the Nanticoke River larval striped bass population (88).

  Entrainment studies have not been conducted at Possum Point. However, no nearfield depletions of phytoplankton or zooplankton were found during nearfield surveys suggesting that entrainment losses, if they occurred, did not have nearfield consequences (89). Entrainment losses to spawning populations of striped bass (6.3%), white perch (5.1%), and river herrings (6.0%) are high at Possum Point relative to other Maryland power plants (Table IV-4) (55). This corresponds to a monetary value of about 3.3 percent of the annual value of the Potomac fishery, and to a change in net ecosystem productivity of 0.44 percent (55).

- Impingement

  Impingement of juvenile and adult fish at Vienna is negligible (87, 88). Impingement at Possum Point is also suspected to be small since water use is not large. At Crane, a significant number of menhaden, white perch, and blue crabs are impinged (90, 91); however, impingement rates are generally lower than for mesohaline facilities.

  Increasing the intake screen wash cycle from once every 8 hours to once an hour increased the impingement rate at Crane (90). However, 8-hour screen wash cycles may be optimal to minimize impingement losses. Factors contributing to the loss of fish from intake screens using an 8-hour wash cycle are discussed in Section G (Best Available Technology and Operating

Practices). Although impingement rates at Crane were irregular and fluctuated considerably from one sampling date to another, the general trend was for impingement to be highest in summer and fall, and lowest in late winter (90).

Post-impingement mortalities at Crane varied from species to species (91). Mortality rates were high for menhaden and gizzard shad (70-100%). Spot, hogchoker, white perch, and yellow perch had post-impingement mortality rates of 10 to 50 percent. Post-impingement mortality rates were size-dependent, with largest mortalities generally associated with smaller individuals (91). Essentially all blue crabs that were impinged survived (91).

- Discharge Effects and Habitat Modification

The thermal plume at Vienna was small and discharge effects were negligible (92). No discharge effects from Possum Point were found in the Potomac River, probably because the point of discharge release is located on Quantico Creek (89). In Quantico Creek, only small changes in biotic distributions were attributed to effluents from Possum Point (89). Fish avoided the thermal effluents during summer and were attracted to them during winter. However, fish migration and spawning and nursery activities of RIS were not adversely affected.

The thermal plume at Crane affected about 40 percent of the volume of the receiving creek system(93). Crane effluents also resulted in a slight increase in nearfield salinity, but did not affect nearfield dissolved oxygen (94, 95, 96). No above-ambient levels of copper were found in sediments or biota near Crane or any other tidal fresh-oligohaline zone power plant (87, 89, 97). Thermal effluents from Crane inhibited nearfield phytoplankton productivity during summer, but not during other seasons (81, 82, 96). Submerged aquatic vegetation (SAV) grew marginally better at reference areas near Crane than in the thermally affected area (98, 99). Compared with normal seasonal trends and natural year-to-year variation, plant effects on zooplankton community composition and abundance, were small (83-85, 94). Thermal effluents at Crane affected benthic populations by reducing winter mortality of cold sensitive forms, increasing summer mortalities of heat sensitive species, and enhancing growth and development of heat-tolerant species (100-103).

As was true of mesohaline power plants, fish were attracted to or avoided the Crane discharge region depending upon season (104, 105). However, fish migration routes were not impeded, and discharge effects on local fish movements did not adversely impact regional populations (80, 81). The tributaries near Crane are not important spawning areas for striped bass and shad. White perch and yellow perch spawn in the area and use the region as nursery grounds (80, 81); however, power plant operations did not adversely impact these nursery or spawning activities.

BG&E established an experimental waste heat aquaculture facility at Crane in 1983. Striped bass are cultured at this facility using the heated effluents. Fish reared at the Crane aquaculture facility are stocked into the Chesapeake Bay and its tributaries in a cooperative program with the Maryland Department of Natural Resources.

- Conclusions for Tidal Fresh-Oligohaline Power Plants

Entrainment losses at Crane do not affect regional RIS populations. At Possum Point and Vienna, entrainment losses affect striped bass and other harvested fish populations; however, these effects are small (only a few percent of baywide catches). The consequences of impingement at oligohaline plants are similar to those at mesohaline plants: many organisms survive impingement and the major species impinged are ubiquitous and abundant throughout Maryland's tidal waters.

Impingement losses appear too small to have a detectable effect on regional stock sizes or fisheries. Power plant operations at Crane play a role in defining the salinity and temperature regimes of the receiving water body, especially during summer when high temperatures, low freshwater flows, and high generating loads occur. Local plant-related thermal effects were frequently detected under these conditions. Discharge effects at Possum Point apparently are similar to those at Crane, but do not have an impact on Maryland waters. Discharge effects at Vienna are negligible. The operations of power plants in the tidal fresh-oligohaline zone therefore do not significantly affect biotic resources in this habitat zone.

Nontidal Freshwater Power Plants

Two steam electric stations are located on riverine waters. These are R.P. Smith and Dickerson, both on the Potomac River (Table IV-2a). Each facility uses, at times, a substantial portion of river flow for cooling purposes. These plants are relatively old, of low to medium generating capacity, and located in areas inhabited by typical, warm water, riverine biota (106-108).

- Entrainment

Entrainment of phytoplankton and zooplankton are not major concerns at steam generating stations located on Maryland's nontidal freshwater habitats because of the minor role of these biota in biological productivity and system dynamics of this habitat (106-108). Ichthyoplankton entrained at R.P. Smith and Dickerson were mostly forage species. Economic and ecological losses due to this entrainment were projected to be small and not likely to have regional consequences (106, 107).

- Impingement

  Impingement at R.P. Smith was projected to have negligible effects on regional fish populations, and the monetary value of the impinged fish was estimated to be less than $500 annually (108, 109). Impingement at Dickerson was negligible except in March and May when sporadic high impingement episodes impinged up to 8,000 spottail shiners over a 24-hr period. These losses, however, have little economic consequence (107).

- Discharge Effects and Habitat Modification

  Plant-related changes in the number of benthic taxa, in density and biomass of some invertebrates, and in the life history characteristics (growth rate, timing of emergence) of some insects have been measured within thermally affected regions of R.P. Smith and Dickerson (107, 108, 110). Fish were attracted to or excluded from the thermal plumes of Dickerson and R.P. Smith, depending upon season (107, 108, 111, 112). Feeding habits and the physiological condition of fish collected in thermally influenced areas also differed slightly from those collected from nearby reference areas (112). These differences were not large enough to suggest that plant-related changes had occurred in the structure of the Potomac food web. Changes in biota from the long-term degradation of water quality of the Potomac far exceeded the power plant effects measured (107).

- Conclusions for Nontidal Freshwater Power Plants

  In general, entrainment and impingement impacts are small at freshwater facilities, and discharge effects are localized. No long-term cumulative impacts have been identified from operation of these facilities.

E. Aquatic Impact Assessment for Hydroelectric Facilities

Status of License Renewal and Assessment Studies for Conowingo Dam

Conowingo Dam on the Susquehanna River is the largest hydroelectric generating station in Maryland. Significant stocks of resident and anadromous fish species (e.g., channel catfish, white perch, striped bass, river herring) occur downstream of the dam, and historically, large spawning runs of anadromous species were found upstream of it (126). Sport fishermen regularly visit the region, and recent surveys suggest that the area is one of the most intensively fished locations in Maryland (127).

In 1976, the Conowingo hydroelectric facility came up before FERC for license renewal. At that time, a number of interested parties' (U.S. Fish and Wildlife Service, Pennsylvania Fish Commission, Pennsylvania Department of Environmental Resources, Susquehanna River Basin Commission, Pennsylvania Federation of Sportsmen's Clubs, Upper Chesapeake Bay Watershed Association, and the State of Maryland) became involved in the licensing procedure as intervenors. The groups wanted the Philadelphia Electric Company (PECO), operator of the facility, to restore anadromous fish runs upstream of the dam, and to implement actions which would alleviate environmental problems downstream of the dam. The major environmental problems downstream of the dam were associated with water level fluctuations resulting from peaking operations. They included the occurrence of low dissolved oxygen concentrations in dam discharges and the reduction and degradation of aquatic habitat during periods of turbine shutdown (128, 129). Low dissolved oxygen concentrations may have deleterious effects on a wide variety of aquatic biota (128), and flow fluctuations may directly affect the abundances of food organisms important to fish growth and survival (16, 129). Loss of freshwater spawning and nursery habitat of anadromous fish due to blockage of migration routes is frequently cited as a major factor contributing to recent population declines of these biota (130).

Until 1982, Conowingo Dam operated in a peaking mode throughout the year. The intervenors requested a continuous minimum release of water to alleviate habitat modifications downstream of the dam. In response to this request, FERC ordered that beginning in 1982 a minimum flow of 5000 cfs must be maintained from 15 April through 15 September, while field studies that were designed to aid in the selection of a permanent minimum flow, were completed. A study evaluating the responses of benthic invertebrates and fish to the interim minimum flows found that benthic abundance increased dramatically under the interim minimum flow and declined rapidly when it was terminated (129). Fish feeding rates and condition were also greater during the interim minimum flow period than during the period of sporatic water release (129). Disputes between PECO and the intervenors over the appropriate study type resulted in additional FERC hearings. A decision on the study type to use for determining the effectiveness of continuous water release is expected in late 1985. Establishment of a permanent minimum flow must await determination of whether the interim minimum flow, or some other minimum flow will enhance fish populations below Conowingo Dam.

Modeling and field studies to identify factors affecting water quality in aquatic habitats downstream of Conowingo Dam and in Conowingo Pond were funded by PECO and PPSP. A simulation model of the dissolved oxygen dynamics for aquatic habitats downstream of Conowingo Dam indicated dissolved oxygen concentration in these habitats was controlled by the dissolved oxygen concentration in the water released through the turbines (131). Processes in the river had little influence on dissolved oxygen levels. Because dissolved oxygen concentration in surface water of Conowingo Pond was higher than that in bottom water during the summer (i.e., the impoundment was vertically stratified), the relative proportions of surface and bottom water withdrawn through the turbines determined dissolved oxygen concentration in water downstream of the dam. A simulation model of the oxygen dynamics in Conowingo Pond was developed to determine factors controlling oxygen concentration in the impoundment (132). An empirical model of the pattern of water withdrawal from the impoundment was also constructed to predict vertical withdrawal patterns under differing dam operating conditions (133). The reservoir and withdrawal models were linked and used to predict the dissolved oxygen concentration in water passing through the turbines for a range of alternative minimum flow release schedules (134). Results indicated that, due to the strong vertical stratification and near anoxic bottom water in Conowingo Pond during summer, the dissolved oxygen concentration in discharge flows (and thus downstream) could not be increased substantially by continuous minimum flow release schedules (132). The only feasible methods identified to increase the dissolved oxygen concentration of water passing the turbines during minimum flow releases were: adding oxygen to the water (either in the impoundment or in the turbines); or reducing (or otherwise controlling) the amount of oxygen-consuming material entering the impoundment from upstream sources (133). Findings from these studies will be used to determine the most feasible means of alleviating low dissolved oxygen problems downstream of Conowingo Dam. Resolution of this issue will result in a direct settlement between the intervenors and PECO, but may also require an additional FERC hearing.

FERC hearings on a separate docket related to restoration of anadromous fish runs upstream of Conowingo Dam took place over a two-year period concluding with final briefs being submitted in early 1983. A settlement on restoration of fish runs was arrived at between the intervenors and the three utilities which operate dams upstream of Conowingo. Settlement discussions on restoration of anadromous fish runs for Conowingo are still proceeding. A fish lift is currently operating at Conowingo Dam; however, relatively few fish (¼1000 annually) are transported to upstream habitats. The effectiveness of fish lifts is strongly influenced by river conditions and dam operations (135).

Status of Assessments for Small-Scale Facilities

As mentioned previously, 10 small-scale projects have been reviewed by the State thus far. Five of these facilities are now in operation or under construction (17). A number of environmental-related issues have been repeatedly raised in the review of these projects.

Modification of river flow, which can be subdivided into flow fluctuation and minimum flow, is a difficult issue because of its importance to developers and resource agencies. Without alterations in river flow, some projects will be economically infeasible. However, numerous studies (12, 14, 17) have shown that the potential negative effects of flow alteration on biota are large. As a result of concerns about the effects of flow alterations, the turbine configurations in the Gilpin Falls and Brighton Dam projects were modified from equally sized turbines to unequally sized turbines to minimize water level and flow fluctuations downstream of the proposed projects (136). A field study is underway to assess the effects of the Brighton dam project on downstream biota. The study includes collection of preoperational and postoperational data. The minimum flow issue has arisen at the Gilpin falls and W.J. Dickey projects. Both projects, as originally proposed, included diversion of a large fraction of streamflow from behind a dam to a generating facility some distance downstream. Under the proposed operational regimes, the diverted stream reaches would have been partially dewatered, leading to possible biotic impacts. This issue was successfully resolved at Gilpin Falls; the W.J. Dickey project is still under FERC review. A field study is being conducted at the later project to provide the baseline information that will be used to project the environmental impacts of these fluctuations on downstream biota. This study will also provide baseline information for preoperational conditions which can be compared to the findings of similar studies conducted if the dam is granted an operating license.

The requirement for fish passage is a major issue at a number of projects, principally those located in areas which might support migratory (e.g., anadromous) fish populations. This is a particularly troublesome requirement or developers due to the high cost of construction of fish passage facilities. A requirement that "fish passage facilities will be established if anadromous fish are restored to the base of the dam" has been repeatedly included as a license condition in the State's comments to FERC on proposed projects.

Several court cases have recently led FERC to consider cumulative impacts of multiple hydropower projects in the same watershed as part of the environmental review process. FERC has developed a procedure a procedure for conducting such a review for proposed projects in the northern Rocky Mountain States and the Pacific Northwest. Two rivers in Maryland (Patuxent and Potomac) have more than one licensed project (17) and several other river or stream systems in the existing the Pacific Northwest. Two rivers in Maryland (Patuxent and Potomac) have more than one licensed project (17) and several other river or stream systems in the state (Patapsco, Antietam, Monocacy, Gunpowder, Deer) have more than one existing dam which has been identified as having potential for hydroelectric development (17). Cumulative impacts would be of greatest concern on streams supporting migratory fish populations (where the amount of impact to the population is directly related to the number of hydro projects with which the fish come in contact) or where projects may affect water quality (i.e., where a series of projects on the same river each add to the degradation of water quality).

A final issue which has arisen is turbine-related fish mortality. As an example, an increase in generating capacity was proposed for Potomac Dam No. 4. During the relicensing process, the possibility of increased turbine entrainment mortality was identified as a potential adverse impact on recreationally important fish populations near the dam. Allegheny Power System, the operator of the facility, is presently conducting extensive field studies, as required by its FERC license, to determine the potential for such mortality. An assessment of turbiine mortality was also required at the Brighton project; field studies are anticipated to be conducted in 1986.

Conclusions for Hydroelectric Facilities

Dam operations at the Conowingo hydroelectric facility control water level and flow in downstream aquatic habitats thereby directly affecting the abundance and type of food organisms important for fish growth and survival. Low dissolved oxygen concentrations in the discharge water during summer also results in poor water quality downstream of the dam. Anadromous fish are denied access to spawning areas upstream of Conowingo Dam. Negotiations presently underway with PECO should result in an agreement which will restore some anadromous fish runs to the Susquehanna River upstream of Conowingo Dam and improve dissolved oxygen concentrations downstream of the dam.

Few assessment studies have been conducted at small-scale hydroelectric facilities in Maryland. Field work is being performed at the Brighton, W.J. Dickey and Dam No. 4 projects. Conclusions cannot yet be drawn concerning the actual impacts of the individual facilities since the Brighton project has only recently become operational (December 1985); results are not yet available for the Dam No. 4 turbine mortality studies. Based on existing literature and the results of previous studies conducted elsewhere, it is anticipated that the impacts of small-scale hydro projects will be smaller then those from large facilities such as Conowingo (137). However the relative magnitude of the impacts may be large, since SSH projects are generally located on smaller rivers and streams in Maryland. In addition, the potential cumulative effects of multiple facilities on the same river or stream, which may be substantial, has not yet been evaluated.

F. Biofouling

Nature of the Problem

The buildup of living organisms on intake structures (e.g., traveling screens, the walls of water boxes) and in the condenser is a major engineering problem at most estuarine power plants (138). These growths can slough off and clog condenser tubes, reducing condenser cooling water flows and causing plant shutdowns. Relatively few species of invertebrates make up the majority of biofouling growth in Chesapeake Bay (29, 38, 139, 140). Colonial species, mainly bryozoans and hydroids, which are characterized by rapid growth, are the major species that adversely affect power plant operations. However, species of tube building worms, crustaceans, and barnacles are also of concern. Tube structures clog fine-mesh intake screens (139). In addition, tube builders are frequently initial colonizers of clean surfaces and may be precursors for colonial forms (139). The abundance and kinds of biofouling organisms vary along the salinity gradient (139, 141). Different groups are of concern in the different salinity zones. Biofouling growth mainly occurs from early spring to late fall; however, it is most rapid from June to September (139).

Biofouling growth has historically not been a problem at power plants located on Maryland freshwater habitats (107, 142). However, the Asiatic clam, Corbicula fluminea, has recently invaded freshwater habitats throughout the U.S., including Maryland, and has characteristics (e.g., rapid growth, high fecundity, planktonic developmental stages) which can severely impede freshwater power plant and hydroelectric facility operations (142). This clam is a potential threat to operations of steam and hydroelectric power plants in Maryland freshwater habitats.

Current Practices Used to Control Biofouling

Maryland power plants inject chlorine (a strong oxidizing agent that is widely used as a disinfectant at wastewater treatment facilities) into condenser cooling water to control biofouling (42). Chlorine is generally injected during the entire growing season. Because chlorine is injected into cooling water just after plant entry, it adds a chemical stress to entrainment (143, 144).

Biotic Effects of Chlorine Use

Studies at Morgantown and Chalk Point indicate that entrainment mortality was higher during periods of chlorination than when chlorine was not used (33, 36, 38, 42). Laboratory biotoxicity studies further demonstrate that early life stages of fish and shellfish are adversely affected by chlorine and its decay residuals at very low concentrations (ppb ranges) (145, 146).

Factors Influencing Chlorine Use

The chemistry of chlorine decay and factors that determine the amount of chlorine required to prevent biofouling have been thoroughly studied for Chesapeake Bay (147-149). The amount of organic material in water is the single most important factor affecting chlorine decay (144, 147-149). Other factors are adsorption on colloidal substances, catalytic decomposition of chlorine by condensers, materials nitrogen concentration, temperature, light, and reducing agents in the water, (e.g., sulphides) (147). The decay of chlorine in natural water is a two-phase process (148). The first phase is very rapid, accounting for the loss of about 90 percent of active oxidant, and takes 4 to 5 minutes (144, 147, 148). The second phase of chlorine decay generally takes 1 to 2 hours. Chlorine decay is faster in estuarine water than in freshwater, with maximum rates of decay occurring at about 10 to 15 ppt salinity (mesohaline) (148).

Chemical removal of chlorine from effluents (dechlorination) reduces the levels of active oxidant in discharge waters thereby decreasing its toxicity in the receiving water body (151). Dechlorination does not, however, reduce entrainment mortality because many entrained biota are exposed to toxic doses of chlorine and killed before declorination occurs. At present, the amounts of active chlorine oxidant discharged to Maryland receiving waters from power plants is low; therefore, dechlorination of power plant discharges is not necessary and would not be cost effective (147).

Alternatives to Chlorine

Economically feasible alternatives to chlorine for power plant application include bromine chloride and ozone (147). Both are strong oxidizing agents, and both have environmental consequences similar to chlorine (144, 150).

Discontinuing the use of chlorine and replacing it with mechanical cleaning methods (i.e., Amertap) would be expensive. In addition, most mechanical cleaning methods are designed to control biomass buildup on condenser tubes. They do not control biomass buildup on the walls of water boxes and intake and discharge conduits, which are the site of the most serious biofouling problems affecting long-term power plant operations (142).

Ultrasound has been shown to control fouling on glass slides in laboratory tests, but this technology has not been developed for implementation at operational power plants (152). Although ultraviolet light is a suitable alternative to chlorine for wastewater treatment. The large volumes of water required for condenser cooling, however, render this technology unsuitable for power plant applications (147). Backwashing with heated water has been used at power plants in other states to control biofouling (153). This technology has not been seriously considered for Maryland applications because fouling organisms in Chesapeake Bay can tolerate short-exposures to temperatures in excess of 40°C (154), and retrofitting of thermal backwash systems into exisiting facilities would also be prohibitively expensive.

A promising new technology for the control of biofouling, especially on water boxes, is the use of antifouling coatings, particularly organotin-based paints (155-159). Organotin paints are licensed and extensively used to control biofouling growth on boats. Organotin coatings are not licensed for use on power plant structures, but EPA is allowing a few utilities to field test them on a trial basis in Florida and New York (159). Preliminary data indicate these coatings are effective for power plant applications; however, their long- and short-term environmental consequences are suspected to be adverse. Toxic decay products are known to adversely affect the growth and reproduction of oysters and other biota at very low concentrations (ppb range) (157, 158). Considerable information is available on leach rates of commonly used organotin paints. These rates are easily controlled and varied by binders added to the paint. A first order question that must be addressed in Maryland is what are the environmental concentrations of toxic forms of tin (in the water and in the sediments) likely to be for various painting scenerios at Maryland power plants. Although organotin paints breakdown to nontoxic forms when exposed to sunlight and microbial action, little information exists for degradation rates and chemical speciation associated with the breakdown process. This information is needed before organotin paints can be registered for power plant use.

Conclusions for Biofouling Control

Chlorine injection will continue to be used to control biofouling of internal power plant structures in Maryland, at least for the next decade. Other chemical alternatives have environmental consequences similar to those of chlorine, and most other biofouling control technologies are either expensive or are not sufficiently developed for implementation. The allowable chlorine discharge limit at Maryland power plants is 0.2 ppm or less. Spawning and nursery habitats of RIS should be protected and ecosystem integrity preserved as long as these discharge limits are maintained.

Biofouling will continue to be a major problem facing Maryland utilities over the next decade, and alternatives to chlorination may be required in the future. Research is needed to determine if use of organotin based paints by power plants is likely to pose a serious to threat to aquatic biota. In addition, non-toxic means of controlling biofouling should be evaluated and developed for power plant applications. One recently developed approach is a non-toxic coating which controls biofouling by retarding attachment of fouling organisms (159).

G. Best Available Technology and Operating Practices

Previous discussions indicate that entrainment and impingement mortalities are the primary mechanisms through which power plant operations adversely impact Maryland's aquatic habitats (36). Numerous technologies have been developed for reducing entrainment and impingement impacts (36, 124, 160). The technologies can be classified into three categories:

- Physical barriers, such as intake screens or nets, which prevent withdrawal of organisms.
- Behavioral barriers which cause fish to actively avoid intake flows.
- Technologies that collect fish after contact with intake structures and return them to the receiving water body with minimal harm.

Entrainment and impingement losses can also be reduced by modifying plant operations (e.g., periods of reduced or no power production during the spawning season of biota of concern).

Intake Control Technologies

Physical barriers are very effective in preventing entrainment of early life stages of fish and in preventing impingement of adults and juveniles. However, biofouling is generally a problem when the mesh size of physical barriers is sufficiently small to exclude fish eggs and larvae (124). Behavioral barriers (e.g., air bubble curtains and sound) are sometimes partially effective at reducing impingement of some schooling fish, but are ineffective at reducing entrainment and impingement of early life stages and most older fish (160). Early life stages generally lack sufficient swimming ability to overcome intake flows. Most fish simply do not respond to the stimuli provided. Collection of organisms after impingement is only partially effective at reducing impingement losses. Some of the organisms collected, particularly early life stages and juveniles, are sensitive to handling and abrasion and suffer high post-impingement mortality (161).

Two promising intake control technologies for Maryland applications are barrier nets and wedgewire screens (36, 63, 124, 162-165). Barrier nets reduce impingement levels by denying fish access to intake areas. They generally are economical to install and maintain, and they effectively reduce impingement levels in both estuarine and freshwater habitats (36, 163). Wedge-wire screens are cylindrical wire drums that are constructed of various materials and wire spacings. They are usually placed with their axis perpendicular to the natural currents. In this way, intake velocities through the screen are low relative to natural currents around them (164, 165). Impingement on the face of the screens is low because intake velocities are weak relative to the swimming ability of most fish and crabs. Natural currents rapidly wash away organisms that accumulate near or on wedge-wire screens into by-pass flows (165). Because wedge-wire screens are generally constructed with fine mesh spacings (1-3 mm), entrainment of early life stages through them is low.

As previously discussed (Section D of this chapter), a barrier net (3 cm mesh) has been tested at Chalk Point since 1982. Initial results indicated a significantly reduced total finfish and blue crab impingement. However, impingement of some fish (e.g., white perch and striped bass) increased after barrier net installation. Several actions were taken to overcome this problem. They included: increasing the period of net deployment from April to December to year round; and improving net operations (i.e., securing the net bottom to the sediment, frequent replacement of damaged panels, and frequent cleaning and inspection). A second finer mesh (1.5 cm) barrier net was installed behind the first one in 1984. The larger-mesh outer net is designed to exclude ctenophores and jellyfish as well as adult fish and crabs, and the finermesh inner net is designed to exclude smaller organisms, particularly young-of-the-year fish and juvenile crabs. A detailed evaluation of the effectiveness of the double barier net system is being conducted. Preliminary results are favorable.

Barrier net operations, including modifications necessary to maximize their effectiveness, are much more economical for retrofitting into older power plants than most other impingement reducing technologies (e.g., construction of by-pass systems, reductions in intake flows, installation of wedge-wire screens) (36). Barrier nets are not, however, applicable to all Maryland power plants (166). Their applications will depend upon the design of existing intake structures and the abundance of ctenophores and jellyfish in the adjacent water body. Management decisions about installation of barrier nets must therefore be made on a case-by-case basis.

Field and laboratory tests of wedge-wire screens were conducted for a variety of organisms, including striped bass, white perch, bay anchovy, naked goby, isopods, mysid shrimp, and small crustaceans (124, 164, 165). Results of these tests indicated that these screens reduced entrainment of ichthyoplankton and large invertebrates by 50 to 100 percent (124). However, the number of zooplankton entrained was not reduced (124). The effectiveness of wedge-wire screens was strongly dependent upon fish size. Fish larvae below 5 mm in length were not excluded; however, almost total exclusion was found for larvae above 10 mm in length. Screen slot size (1, 2, or 3 mm), through-screen intake velocity (9.5, 20, or 40 cm/s), and screen diameter had measurable, but small, effects on the number of fish entrained (124). Essentially no fish or crabs were impinged on wedge-wire screens during the field tests (124). Some fish larvae may avoid the complex flow patterns that exist near the surface of wedgewire screens; however, most appear to be physically excluded by the fine mesh wire spacing (124).

Biofouling of wedge-wire screens has previously been identified as the major problem affecting their long-term operations at many Maryland power plants (124, 139). At Vienna, the most suitable method to control biofouling was mechanical cleaning and backflushing with air (87). Thirty-day field tests, conducted using operational-size screens at Chalk Point, also demonstrated that backflushing with air was a cost-effective way for controlling biofouling (139). Painting wedgewire screens with organotin antifouling paint was also identified as an effective method for controlling the buildup of biofouling biomass. The environmental fates and effects of organstim compounds, however, are not well understood.

Wedge-wire screens are moderately expensive to retrofit into operational power plants or install into new plants. However, they are much less expensive and are equally as effective as alternatives that require flow reductions (e.g., closed-cycle cooling or periods of reduced power production and intake flows) (36).

Operating Practices

It is frequently possible to reduce power plant entrainment and impingement losses by modifying plant operating practices. Because the capital costs associated with this minimization approach are small compared with the costs associated with modification of intake structures, it is frequently cost-effective and desirable to both utilities and regulators. Three power plant operating practices that are currently being evaluated at Maryland power plants to determine if they should be changed are: intake screen wash cycles, use of auxiliary tempering pumps, and continuous chlorination.

• Intake Screen Wash Cycles

Most Maryland power plants rotate intake screens once per 8 hours to clean them of impinged organisms and debris (29, 33, 36, 81). When intake screens are rotated more frequently (e.g., once per hour), impingement counts increase as does the survival rate of impinged organisms (36, 81, 90, 91). Estimation of annual impingement loss has generally led to the conclusion that the 8-hour wash cycle minimizes impingement impacts on the receiving water body. That is, the total number of organisms that die with an 8-hour screen wash cycle was estimated to be less than the total number that die with shorter screen wash cycles. However, numerous factors contribute to the disappearance of organisms from intake screens including predation by crabs and large fish, decomposition and simply falling off (168). The greater the length of time between screen rotations, the higher the probability that organisms will disappear. Before screen wash cycles can be optimized for Maryland power plants, estimates of the magnitudes of loss from intake screen due to decay, falling off, and predation must be made.

PPSP is currently evaluating the bias associated with various screen wash cycles and impingement sampling protocols. Results of these evaluations will be used to determine the influence of screen wash schedules on impingement estimates. Based on the conclusions of this evaluation, a recommendation of the most appropriate screen wash cycle and impingement sampling protocol will be developed.

- Auxiliary Tempering Pumps

  As previously discussed, auxiliary tempering pumps are used at Chalk Point to temper thermal and chemical power plant effects in the discharge canal and nearfield area (61). Auxiliary tempering pumps were also used at Morgantown in the past (33, 34). In recent times, the effectiveness of auxiliary pumping has been shown to be minimal, mainly because their intakes were not protected by intake screens, and many of the fish and crabs that are entrained through them die (61, 45). Entrainment losses associated with the increased flows resulting from auxiliary pump use far exceeds any protection they offer (45). Based on these findings, PPSP has recommended that the use of auxiliary tempering pumps be discontinued at Chalk Point. Discontinuing the use of auxiliary tempering pumps would not only benefit the aquatic biota, it would also result in a cost savings to the utility ($200,000 annually).

- Continuous Chlorination

  As previously discussed, many Maryland power plants use continuous chlorination to control biofouling of internal plant structures (33, 36). However, biofouling growth at some power plants can be controlled by periodic chlorine application resulting in reductions in the amount of chlorine discharged to the environment and minimization of the cost of chlorine applications. Maryland utilities are therefore required to conduct studies that demonstrate the need for continuous chlorination.

Conclusions for Intake Control Technologies and Operating Practices

Minimization of impingement and entrainment losses by identification and development of cost-effective intake control technologies and operating practices has always been a major objective of PPSP. Two intake control technologies that are applicable to Maryland (i.e., barrier nets and wedge-wire screens) have been identified and field tested. Both are effective and appear to be applicable throughout Maryland. PPSP has recommended that an operational barrier net be a part of the operating permit for the Chalk Point SES. Future PPSP research for reducing impingement will be directed toward optimization of barrier net deployment, evaluation of the effectiveness of intake screen wash cycles, and evaluation of the applicability of new devices (e.g., devices that direct that direct or divert fish away from intake screens for minimizing impingement losses. No future work is planned by PPSP for wedge-wire screens. These screens are one of the most appropriate methods for reducing entrainment losses for oncethrough cooling units in Maryland and are also recommended for use with makeup flows for closed-cycle cooling. Several New York utilities are conducting an evaluation of the effectiveness of periods of no power production for reducing entrainment losses in the Hudson River (167). Findings of these studies will be evaluated to determine their applicability to Maryland entrainment and impingement problems. PPSP will continue its evaluation of the effectiveness of auxiliary pump operations and intake screen wash cycles as a means of reducing environmental impacts at operational power plants. A recommendation on both is expected in 1986.

H. Long-term Effects of Power Generation on Maryland's Benthic Resources

Long-term operations of power plants in Maryland may have cumulative effects on the biota of the receiving water bodies. For example, the continual entrainment of large numbers of early life stages may result in long-term adverse population changes, or the continual low level release of copper may eventually build up to toxic levels in certain organisms. Because of the potential long-term consequences of power plant operations, PPSP has initiated long-term benthic monitoring programs in both estuarine and freshwater habitats.

Benthic organisms were selected as a representative fauna to use as an indicator of long-term power plant effects because they are known to be good indicators of water quality and system "health" (169). In addition, most benthos have limited mobility and cannot avoid changes in conditions resulting from power plant related changes to the environment. Limited mobility also means the benthos can be quantitatively sampled relatively easily. Benthic organisms are also major secondary producers in the Bay and in Maryland's rivers and streams, forming key linkages between primary producers and higher trophic levels. The basic approach of PPSP's long-term benthic monitoring programs is to measure natural spatial and temporal variation due to location, season, and year and separate it from changes due to power plant operations. PPSP's long-term benthic monitoring programs thus provide quantitative information on regionwide long-term trends of benthos in addition to assessing cumulative long-term power plant effects on these biota (170). Long-term monitoring efforts in estuarine habitats have been developed in conjunction with the Department of Health and Mental Hygiene's monitoring programs for evaluating the effectiveness of ongoing Baywide cleanup activities. The long-term monitoring program for freshwater habitats is limited to the Potomac River near the R.P. Smith and Dickerson power plants.

Long-term Power Plant Effects for Estuarine Habitats

Results of long-term and site-specific monitoring studies at estuarine sites have indicated that thermal effluents are rapidly dispersed at these power plants, and thermal tolerances of estuarine benthos are exceeded only in the discharge canals of Chalk Point, Morgantown, and Crane (36, 102, 170). Heat sensitive species have not been excluded from nearfield regions of any Maryland power plants. However, a few heat tolerant species are consistently more abundant and have higher biomass in the thermally affected areas (170). These power plant effects do not affect regional food web dynamics. Reproduction of a few species is initiated earlier in the season at thermally affected stations (102, 170). However, total reproductive output of these species is not affected.

Intake water at both Calvert Cliffs and Morgantown is withdrawn from deep offshore layers. As a result, it has higher salinity and lower dissolved oxygen concentration than ambient water in the discharge region of these facilities (170). Small nearfield declines in dissolved oxygen concentration resulting from plant operations at Calvert Cliffs and Morgantown have little impact on nearfield benthic organisms. Dissolved oxygen tolerance limits of dominant species are not exceeded. Plant related salinity changes at these locations are also not of a magnitude that affects benthic distributions. In general, plant effluents from estuarine power plants in Maryland are rapidly mixed with ambient water, and plant-related changes in nearfield salinity and dissolved oxygen concentrations are not detectable beyond the immediate discharge region (29, 33, 36, 102).

The high velocity discharge system at Morgantown and Calvert Cliffs washed away soft sediments from the immediate discharge region (170). As a result, a portion of the nearfield area at these power plants is now a marginal habitat for burrowing organisms. Fouling organisms are, however, more abundant in scoured areas than they are in adjacent soft bottom habitats (29). Since fouling organisms have approximately equivalent resource value as burrowing organisms, there has been no net loss in the amount of food available to higher trophic levels. Power plants with low velocity discharge systems (e.g., Crane, Chalk Point) do not strongly influence sediment characteristics (36, 81).

Measurable amounts of copper are released by corrosion of condenser tubes of several Maryland power plants (i.e., Calvert Cliffs, Morgantown, Chalk Point) (29, 33, 36). This copper is bioaccumulated by oysters, and possibly a few other biota, in the immediate discharge regions. Sediments, however, do not accumulate the released copper in significant quantities (29, 36). Copper released by power plants is apparently not passed up the food web and does not affect the growth or abundance of biota that accumulate it (36). The net impact of power plant copper releases is thus minimal. (See Chapter V for additional information).

The benthos of the Chesapeake Bay have experienced long-term changes in abundance over the last 14 years in response to an overall degradation in water quality (169, 170). Although the same species are numerically as abundant now as during the early 1970's, their relative abundance has changed. Year-to-year variation in salinity and long-term trends in dissolved oxygen concentration are the major factors affecting long-term Baywide trends in biotic abundance. Power plant operations have not altered the direction of long-term trends for most species. Relative to long-term Baywide trends power plant effects are small (170).

Long-term Power Plant Effects for Freshwater Habitats

Long-term benthic monitoring studies at Dickerson and R.P. Smith power plants on the freshwater Potomac were started in 1983 (102, 112). Insufficient data exist to partition power plant effects from variations associated with long-term trends in water quality or climate. Preliminary data, however, suggest that power plant effects are measurable and localized near discharge sites (102, 112). In addition, long-term changes in benthos due to long-term water quality trends appear to be large relative to power plant effects. Detailed analysis of the long-term benthic data for the Potomac will be conducted in the future when a more comprehensive and complete database is available.

Conclusions For Long-term Monitoring Programs

Long-term power plant effects on benthic organisms in Chesapeake Bay are small. This is probably because plant-related alterations to the estuarine environment are small and do not change the water quality or exceed tolerances of most organisms. The power plant alteration to the environment most likely to have long-term cumulative effects on the Chesapeake Bay is the addition of organic detritus to bottom habitats from mortalities to entrained organisms. Such organic additions are rapidly used by benthic biota and result in increases in benthic stocks, particularly for short-lived species with high productivity. Power plant operations also appear to have long-term effects on the benthos of the freshwater Potomac. Quantification of these effects must await additional data, but also appear to be small relative to natural long-term trends. Findings of PPSP long-term benthic monitoring programs provide a perspective for findings of short-term assessment studies and are evidence that long-term trends in the vicinity of most Maryland power plants are more related to regional water quality changes than to long-term power plant operations.

Recent increases in the volume of Bay water having low-dissolved oxygen concentrations may increase impingement losses and discharge effects for power plants with deepwater intake systems (i.e., Calvert Cliffs and Morgantown). This potential problem will be evaluated in the future.

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